Springer Proceedings in Business and Economics

Kesra Nermend
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Neuroeconomic and Behavioral Aspects of Decision Making

Proceedings of the 2016 Computational Methods in Experimental Economics (CMEE) Conference

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Editors

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ISSN 2198-7246 ISSN 2198-7254 (electronic)
Springer Proceedings in Business and Economics
ISBN 978-3-319-62937-7 ISBN 978-3-319-62938-4 (eBook)
DOI 10.1007/978-3-319-62938-4

Library of Congress Control Number: 2017952334

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Neuroeconomics is a fairly new domain of knowledge that emerged in the 1990s. It is an interdisciplinary field that combines insights from neuroscience, psychology, and economics to build a comprehensive decision-making theory. The essence of neuroeconomics is to analyze the decision-making process not only in terms of external conditions or psychological aspect but also from the neuronal point of view by examining the cerebral conditions of decision making. Examining the decision-making process from these three perspectives leads to its more complete understanding.

Neuroeconomics was preceded by numerous young fields—behavioral economics, experimental economics, and cognitive neuroscience. Ever since, these fields have been witnessing a dramatic development—although independently. They are, however, bound by common interest areas based primarily on experiments whose results are used to test and to better understand theories in economics.

This book includes papers from researchers who are immersed in this subject with a certain level of experience in the field. Its main objective is to exemplify the links between various domains of knowledge which are part of neuroeconomics, behavioral economics and experimental economics. The book is divided into three parts:

- Theoretical Basis of Decision Making—Interdisciplinary Approach
- Behavioral Aspects of Economic Decision Making
- Practical Issues—Case Studies

The first part of the book presents the theoretical aspects of decision-making process from the point of view of various scientific disciplines. It frames the historical background of applying neurobiology and psychological determinants to measure and monitor emotions in the decision-making process during the economic experiments, as well as several other issues referring to the neuroeconomic and behavioral aspects of the decision-making process.

The second part of the book contains a broad outline of behavioral aspects of economic decision making along with instruments and tools that support the

decision-making process in various phases of study. Thus, it contains a wide overview of the applications of different methods that support the analysis of the impact of behavioral factors on the process of decision making in various areas. In sum, the aim of this part is to present the importance of the scientific toolkit of decision making in economics research.

The last part presents examples of broadly understood experiments in economics in the context of decision making. It refers to different areas and utilizes various methods, which are described in the methodological chapters of the book. However, it presents only selected experiments and approaches in neuroeconomics, behavioral economics, and experimental economics. It nonetheless outlines a wide range of topics and methods that can be used in this field of study. Recent advancements in technology pave the way for shaping increasingly advanced and interesting economic experiments related to decision making. Therefore, it can be assumed that this field of science will develop dynamically in the future.

The issues addressed in this book do not exhaust the subject of neuroeconomic and behavioral aspects of decision making. Yet, in the opinion of the editors, the book shows the diversity of areas, problems, methods, techniques, and domains concerning this subject.

Szczecin, Poland

Kesra Nermend
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Part I
Theoretical Basis of Decision Making: Interdisciplinary Approach

Chapter 1
Neurobiology of Decision Making: Methodology in Decision-Making Research. Neuroanatomical and Neurobiochemical Fundamentals

Andrzej Potemkowski

Abstract The research into decision making relies on psychology, neurobiology, pathology as well as economics and it encompasses factors that play a leading role in the process of making decisions on the neural level, regardless of the fact if they are made consciously or subconsciously. From the psychological point of view decision making is a process where cognitive, emotional and motivational aspects play a vital role. Studies on the brain magnetic nuclear resonance imaging reveal that decision-making processes begin before an individual is able to realize it. Neurochemistry has identified several neurotransmitters that are differently associated with decision-making processes, the most important ones being dopamine, serotonin, cortisol, oxytocin and prolactin. Due to a complicated nature of neurotransmitters, the mechanisms that implicate their production are to fully understood yet and it is still not quite known how they work. From the neurochemical perspective, the control of decision-making processes is determined by good communication among different parts of the brain that is regulated by the levels of serotonin. Decision making is a complex process which is possible due to processes taking place in many parts of our brain. However, neuroanatomically speaking, it is the prefrontal cortex that plays a pivotal role in coordinating these processes. To some extent decision making is based on an assumption that people are able to predict other people's behavior and step into their shoes. This capability results from individual preferences and beliefs. Social neuroscience allows us to see neural mechanisms underlying the human ability to represent our intentions. Neurobiology, in turn, strives to explain how relevant moral decisions appear in our brains and how they can modify our emotions. Studies on neurobiological background of our decision-making processes give us better insight into the presumably bounded human rationality as well as into the role of emotions, morality and empathy. Also,

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_1

these studies contribute to our knowledge about the course of decision-making processes and their adaptive value.

Keywords Experimental economics • Definition • Good experiment • Features

1.1 Introduction

Making decisions is a vital, but, at the same time, a trivial part of human lives. Decisions about even the simplest of choices can sometimes get difficult, thus forcing us to analyze gains and losses.

The study into decision-making processes is a field of science which, on the one hand, integrates the knowledge of psychology, medicine, neurobiology, physiology or pathology, while on the other hand—of economics, ethics, philosophy or law. Continuously progressing neurobiological research into decision making is a significant part of the neuroeconomic theories which deal with such problems as how much human behavior, including the economic one, is influenced by emotions, and how much it is ruled by rationality. These theories address factors that play a leading role in decision making on the neural level, regardless of the fact if decisions are made consciously or subconsciously. From the adaptive point of view, good decision making requires integration of many relevant data, motivations with the knowledge concerning potential consequences of the resulting action (Bayer 2008). In order to gain an insight to these processes neurosciences have turned to methods of neuroimaging, especially the functional one.

From the psychological point of view, decision making is a complicated and multi-stage process determined by cognitive, emotional and motivational aspects. In the pre-decisional phase a problem is defined and information about available options is collected; in the consecutive phase the preferred options are identified and the right decision is made, while in the post decisional phase the decision-making process is assessed and evaluated (Svenson 2003).

Neurobiology perceives the human brain as an organ which, as a result of evolution, stores and processes information. It is an organized system where the extensive number of operations, prepared and conducted by the brain itself, is taking place. Decisions associated with the undertaken actions arise out of the neuronal processes of self-organization as well as of a massive number of sensory data coming from the external and internal environment as well as from the knowledge stored in the functional brain architecture.

Complicated physical and chemical neural processes have brought the neurobiologists to the conclusion that decisions are determined by the pre-conditions influencing specific neural networks. The concept of the neural origin of decisions is in strong opposition to the view accepting the presence of free will and puts in question the importance of the decision making 'I' that could act as the free will which singlehandedly is able to induce the brain to initiate a series of processes. According to neurobiologists, a human being is able to make their decisions

consciously and rationally as a result of neural processes taking part in their brain that is subject to physical and chemical processes, similarly to any other function of the brain. However, the information processing in the brain which leads to conscious decision making involves neural systems that are completely different from the ones involved in unconscious events, thus bringing entirely different results (Merkel and Roth 2008). We still have insufficient knowledge as to how these processes differ (Singer et al. 2004).

1.2 Methods of Research into Decision Making

In order to understand and assess the role of individual brain structures and occurring there functional, bioelectrical and neurochemical processes which underlie and accompany decision making, specific studies need to be conducted. Non-invasive and constantly improved imaging methods make it possible to observe the activity changes in particular brain structures during initiating the decision, preference assessment, risk-taking or the execution of other tasks. What is more, the analysis of measurements obtained at rest and in experimental conditions enabled the researchers to recognize the parts of the brain that are activated in the course of performing different tasks.

The available monitoring methods can be divided into the ones that provide images of the brain structures (computed tomography—CT, nuclear magnetic resonance—NMR, anatomopathological tests) and the ones that monitor its functions (functional NMR—fNMR, electroencephalography—EEG, positron emission tomography—PET). Additionally, the researchers have at their disposal other, more technically challenging methods that create new opportunities for monitoring the neurochemical or neurophysiologic brain activity.

Today, the elementary method of brain imaging used in experimental studies and in pathology diagnostics is the nuclear magnetic resonance (NMR). Technological advancement has brought even more precise high-field imaging devices (7 T). The functional nuclear magnetic resonance (fNMR) is a brain imaging method monitoring changes in the magnetic field. It assesses the amount of oxygen transported to various parts of the brain, thus visualizing which parts of the brain become active when making specific decisions. The effect of structural changes (such as the focal lesions or the lesions in cerebral cortex) on decision making, e.g. in brain-aging processes, can be monitored by means of conventional neuro-imaging methods, such as computed tomography or magnetic resonance imaging.

The resonance technology facilitates the assessment of morphological lesions in the brain tissue. Metabolic irregularities are detected by means of proton magnetic resonance spectroscopy (1H-MRS) which allows for a quantitative viability measure of brain metabolites and for an insight into its chemical composition (Demaerel 1997). Another, relatively new technique of imaging is the diffusion NMR that resolves the diffusion water movement in the inter- and intra-cellular fluids within the brain (Thijs et al. 2001). The diffusion of water molecules within

the brain is anisotropic, therefore in a way of mathematic transformations we can obtain the so called Apparent Diffusion Coefficient (ADC) maps in the brain. Due to this neuroimaging technique the changes in the brain can be detected within minutes, in contrast to conventional tests such as KT and NMR that take hours. There are the following diffusion techniques: Diffusion Tensor Imaging (DTI) that can be used in diagnosing lesions in white matter tracts and Diffusion-Weighted Imaging (DWI) which is highly effective in resolving various forms of the brain pathology. The above methods have been recently applied in the neuroeconomic research.

Before the introduction of DTI specific tracts within the brain could be traced only by means of neuropathological tests. Apart from the analysis of lesions in some parts of the brain, DTI allows neuroscientists to focus their interests on the networks that link these lesions. Thus emerged the opportunities to study various networks within the brain, as well as their parts (Chiang et al. 2009). The diffusion tensor and a new technique called tractography, which also visualizes white matter tracts, have become the methods that can be used not only in the clinical practice, but also in behavioral psychology or in neuroeconomic research (Johansen-Berg and Behrens 2006).

PET is a very accurate scanning technique where a radioactive tracer is transported to the parts of the increased neuronal brain activity, thus allowing detection of the structures that are most activated during the performance of an individual task. The practical disadvantage of this method is the procedure of the tracer preparation, its stability and cost.

Other brain imaging methods use a laser beam with near-infrared wavelength, which allows to track the blood flow that absorbs light of different wavelength depending on its oxygenation. What is registered is the light reflected by the brain. Such methods include: NIRS (near-infrared spectroscopy), DOT (diffuse optical tomography) that enable researchers to build brain activation maps, and EROS (event-related optical signal) that shows changes taking place in activated neurons. Unfortunately, this method can only be used to examine cerebral cortex and its disadvantage is its poor spatial resolution.

EEG, that monitors solely the bioelectric brain activity, is a relatively cheap method whose accuracy was not initially appreciated but, along with the technological advancement and the introduction of multichannel devices, has become more and more popular.

There are also brain stimulation methods such as transcranial magnetic stimulation (TMS) where after transcranial stimulation the maps of brain activity typical of a given task are made.

Extremely interesting opportunities are created by methods of neurobiological observation due to which we can monitor processes in single neurons or in their groups. After placing an ultra-thin microelectrode in the cell body, the changes in neural stimulation can be monitored. These method are used in experiments on animal brains. In one of the first neuroeconomic studies the researchers analyzed how single neurons in a monkey's brain respond to the changes in value and to a reward (Glimcher 2003). It is also possible to map single neurons by means of

single neuron imaging (SNI) where electrodes are implanted in specific neurons, which can be done due to genetic engineering and imaging techniques (Kawasaki et al. 2007). Unfortunately, it is an invasive method that cannot be applied in studies on humans. Nevertheless, it creates the opportunity to measure directly the activity of neurons.

Other, interesting solutions are offered by optogenetics chosen "the Method of the Year" by the journal *Nature* in 2012. In a technologically complicated way genes of light-sensitive proteins are injected into specific animal brain neurons and then the secretion of neurotransmitters is monitored by means of light (Deisseroth 2011).

Psycho-physiological methods correlate various psycho-physical functions with physiologic responses, thus testing, e.g., what effect positive and negative emotions have on heart rate, ventilation rate, blood pressure or skin conductivity. One of the most common methods in this group is galvanic skin response (GSR). The method is used, for instance, to assess the reactions of anxiety associated with risky decisions (Bechara et al. 2000). Another interesting method is eye-tracking (ET). These methods have long been known, the observations are easy to record and interpret, which explains their popularity.

Vital information can be obtained by correlating the findings of examinations of anatomo-pathological brain structures associated with the decision-making related activity. This method is applied in diagnosing neurological patients with impaired decision-making skills and poor evaluation of the consequences of the decisions they have made. The example is a study where healthy individual's ethical opinions were compared with the opinions of patients with damaged ventral-medial part of prefrontal cortex (Koenigs et al. 2007). It was observed that the patients' choices were much more rational and ethical than those made by healthy individuals in the control group.

When analyzing methodology of neuroeconomic research it is clear that the majority of researchers use one or two methods. It seems to result from the cost of individual tests or from other kind of difficulties.

1.3 Brain Activity and Decision Making

The first answers to the question how human brain works in terms of volitional processes were suggested by the outcomes of B. Libet's experiments in the 1980s (Libet 1985). He observed the electrical activity of the brain during a simple task of voluntary flexing the wrist and discovered the so called readiness potential that occurred about a second before the motor act, while the very awareness of the will to flick the hand preceded the movement by about one fourth of a second. That meant that the brain had made the decision before the individual became aware of it.

The fact that the decision-making processes begin before the individual becomes aware of them has been confirmed by studies using the functional nuclear magnetic

resonance (fNMR). Subjects examined by the NMR scanner were asked to decide whether they wished to add or subtract two figures. It was observed that the neural activity allowing to predict if the subject intended to add or subtract emerged app. Four seconds before they actually became aware of that decision (Haynes et al. 2007).

The results of that study caused some controversy, primarily leading to a conclusion that there was no free will. Williams wrote in New Scientist: "Unconscious processes result in making a decision long before conscious thinking begins" and "the brain probably makes decisions before its owner does" (Williams 2013). Coyne, the evolutionary biologist, said in his column "So it is with all of our other choices: not one of them results from a free and conscious decision on our part." (Coyne 2012). The above concepts that our decisions associated with conscious acts and their planning are made solely in our subconsciousness should be approached with caution as it is still highlighted that free will plays an important role in decision making.

Studies on humans and apes found that principally two neural systems were involved in financial decision making (McClure et al. 2004). The first system, consisting of the structures of the limbic and paralimbic systems embracing the ventral part of striatum, prefrontal and orbitofrontal cortex and a part of hippocampus, became active when the option of immediate benefit or loss was available. But when the decision concerned the delayed option, the second system, composed of posterior parietal and lateral prefrontal cortex, took over. However, that hypothesis was not confirmed in subsequent studies. Instead, it has been revealed that the limbic system is not particularly involved in decisions concerning immediate options (Bayer et al. 2007). In subjects making decisions associated with obtaining most immediate benefits the highest activity was observed in the ventral striatum and the posterior and anterior cingulate cortex (Kable and Glimcher 2007). Those structures were also engaged in the delayed benefit decision making but their activity was much weaker than in the case of the decisions concerning immediate benefits.

1.4 Neurobiochemistry of Decision Making

Neurobiochemistry has defined several compounds—neurotransmitters—that are related with decision-making processes. The most important are dopamine, serotonin (Rogers 2010), cortisol, oxytocin and prolactin which are chemical substances controlling the transmission of electric impulses between neurons. Their role is to mobilize the brain to undertaking specific tasks (Bayer et al. 2007).

In order to assess the relationship of dopamine with various economic factors, such as risk or benefit delay, the studies were conducted on single neurons in monkeys. It has been found out that the dopamine midbrain neurons influence the decisions concerning consumption of fluids and foods (Schultz 2006) as well as

error prediction (Schultz et al. 1997). The studies suggest that the delayed benefit decisions are also connected with the dopamine neurons (Kobayashi 2008).

The studies on relations of serotonin with economic behavior were based on pharmacological interventions in humans. The researchers applied rapid tryptophan depletion (RTD), the technique of temporary reducing brain serotonin by ingestion of an excess of neutral amino acids in the reduced presence of serotonin precursor, i.e. tryptophan. The studies compared the economic behavior of the treatment and the control group. It was found that RTD considerably altered decision-making processes in gambling tasks and made the treatment group choose the more likely of the two possible outcomes more often than the control group (Talbot et al. 2006). On the other hand the subjects who followed RTD had poorer ability to distinguish the volume of the expected rewards attributed to specific choices (Rogers et al. 2003).

The findings of the research into the relationship between brain serotonin and the approach to risk are inconclusive. Some studies do not confirm the correlation between risk taking and the levels of serotonin (Rogers et al. 2003; Talbot et al. 2006), while the others provide evidence that there is a dependency between serotonin levels and neuroticism, loss avoidance or aversion which are individual attributes closely related with risk avoidance (Gonda 2008, Murphy et al. 2008). Another scientific project investigated the impact of two neurotransmitters, serotonin and dopamine, on risk taking and confirmed their mutual vital role (Kuhnen and Chiao 2009). It is generally assumed that serotonin interacts with dopamine in triggering the signals of prediction processes (Denk et al. 2005, Tanaka 2007). It has been observed that the importance of delayed rewards is ignored when serotonin levels are low (Schweighofer et al. 2008). The brain activity of both the dopaminergic and and serotonergic decrease with aging, which aggravates cognitive disorders. This explains specific changes in economic behavior occurring that are age-related or accompany neurodegenerative conditions such as Alzheimer's disease or other dementia syndromes (Mohr et al. 2010).

Also, the location of numerous subcortical nuclei in brainstem and hypothalamus that control the production and transport of neurotransmitters to various parts of brain as well as to specific parts of body apart from the brain. Due to complicated character of these chemical compounds it has not been fully explained yet what mechanisms implicate their production and what their effect is. In neurochemical terms, what conditions the control of decision-making processes is good communication among different parts of brain which is regulated by serotonin concentration. Its level rises at the moment of getting satisfaction from making an important decision, while its deficit can cause lowered self-control capacity. There are different levels of neurotransmitters in each cerebral hemisphere. In the right-brain the concentration of noradrenalin and serotonin, playing fundamental roles in activating and suppressing emotions, is higher. The left hemisphere is richer in dopamine that is responsible for concentration and attention, which are vital in decision making. It also controls the right-brain inhibiting the actions that are regarded improper from the social point of view. The more the right hemisphere controls one's personality, the individual will be vulnerable to their own impulses

and emotions in decision making (Denk et al. 2005; Rogers 2011). The influence on decision-making processes of other chemical substances present in the central nervous system, such as norepinephrine is increasingly being recognized (Eckhoff et al. 2009).

What is essential for the proper neurochemical functioning of the brain is the right concentration of glucose, the deficit of which can lead to anxiety, agitation and aggressive behavior.

It needs to be remembered that in decision making the functional state of the brain is important, but also the condition of the whole body. Fatigue, exhaustion, dehydration, misbalance of homeostasis contribute to making wrong choices.

1.5 Neuroanatomy of Decision Making

Decision making is a complex process that is possible only due to the processes taking place in many parts of the brain (Lee et al. 2007). From the neuroanatomical point of view, however, it is prefrontal cortex that plays a crucial role in their coordination (Krawczyk 2002). Neuropsychological studies, particularly the neuroimaging ones, have defined the areas of prefrontal cortex that are pivotal for decision making. Also, the research into the relationships of anatomopathological lesions with changes in the patient's functioning allowed for evaluating the importance in decision making of specific cortex areas such as orbitofrontal cortex (Volz and von Cramon 2009), dorsolateral prefrontal cortex (Lee and Seo 2007) and anterior cingulate cortex (Rushworth and Behrens 2008).

1.5.1 Orbitofrontal Cortex

Orbitofrontal cortex has extensive connections with sensory analysis structures—olfactory, gustatory, visual and somatosensory cortices, as well as with corpus striatum being a part of the reward system. Such neuroanatomic conditionality allows orbitofrontal cortex to participate in perception and generation of responses to stimuli of the primary reward value. It results in decisions associated with need satisfaction (Rolls 2004). Additionally, this part of the cortex is responsible for the analysis of the individual stimuli value. The example is a patient with damaged orbitofrontal cortex who, despite preserved high level of declarative knowledge and problem-solving skills, was experiencing difficulty in making decisions in simple, everyday situations as well as in adapting to the environment (Eslinger and Damasio 1985). It was observed that patients with lesions of orbitofrontal cortex performed tasks disregarding their high costs, expected immediate and big profits

and were not able to accept a long-term perspective (Bechara et al. 2000). That allowed to make the somatic marker hypothesis, according to which the emotional response related to the options to choose is possible due to the connections between orbitofrontal cortex with amygdaloid nuclei and with hippocampus (Bechara et al. 1994).

It has been proven that orbitofrontal cortex also participates in generating responses to abstract cues, such as the financial ones, and that it is where value is attributed to individual objects (Plassmann et al. 2007). The fNMR tests have clearly shown in which parts of orbitofrontal cortex are activated in response to financial benefits and losses (O'Doherty et al. 2001). Particularly strong activation of this brain area occurs when decisions are made in the circumstances of uncertainty (Hsu et al. 2005).

Particularly strong activation of orbitofrontal cortex with connections to the reward system facilitates active recognition and sustenance of profit-generating behavior and suppresses behavior resulting in financial loss. It occurs when the decisions are associated with substantial financial rewards or penalties (Elliott et al. 2000).

The sensitivity of the neurons in orbitofrontal cortex to a reward stimulus triggers subjective stimulus value on the continuous scale and dissociates the options to be chosen (Grabenhorst and Rolls 2009). What also takes place in this cortex is the adaptation to environmental changes, long-term monitoring of their effects and extinguishing the response to stimuli whose reward value is decreasing (Krawczyk 2002).

The activation of orbitofrontal cortex subside when the stimulus is delayed. Therefore it has been observed that in human decision making the value of delayed stimuli tends to decline (Green and Myerson 2004).

1.5.2 Dorsolateral Prefrontal Cortex

It is the dorsolateral prefrontal cortex where the decision-making process is recognized and where thus obtained information is used to control the decisions (Krawczyk 2002). What is essential for decision making, this cortex stores information about the decision maker's environment in the short-term memory and then processes this information (Lee and Seo 2007). The dynamics of human decision-making processes depends on intellectual evaluation and adaptation to the environment where the decisions are made (Gigerenzer 2007).

In the dorsolateral prefrontal cortex other relevant operational memory-related tasks are performed, such as storing information, including the affective ones, out of which the decision goals and options are chosen (Krawczyk 2002; Goldman-Rakic 1996). Other vital functions of the dorsolateral prefrontal cortex include:

- shaping the rules of proper decision making and referring them to new situations on the basis of previous experience (Wallis and Miller 2003),

- simultaneous processing of information about environmental conditions and about the reward value of environmental stimuli (Kobayashi et al. 2007),
- integrating information about physical and abstract attributes of individual decision options and their motivational importance (Sakagami and Watanabe 2007),
- distinguishing and categorizing newly perceived stimuli and, on that account, making choices out of options with similar attributes and similar subjective usability (Krawczyk 2002),
- categorizing new stimuli and attributing them with reward values (Pan et al. 2008),
- planning, controlling and adapting behavior to temporarily and prospectively important rules and consequences (Sakagami and Niki 1994),
- selecting responses adequate to the present stimulus, predicting its reward value and planning the response accordingly (Wallis et al. 2001),
- modifying behavior on the basis of previous decisions (Hare et al. 2009).

1.5.3 Anterior Cingulate Cortex

Anterior cingulate cortex plays a specific role in making decisions in the conditions of uncertainty as it is responsible for choosing between responses to two or more competing stimuli. The level of activity of this cortex is directly proportional to the intensity of the conflict. Basing on the observation of increased activity in cingulate cortex after having made wrong decisions it has been found that due to this mechanism a human being is able to continuously monitor the correctness of their behavior (Carter et al. 1998).

Other vital functions of the anterior cingulate cortex include:

- altering the chosen activity after the wrong decision has been recognized; predicting the potential value of the selected choices and evaluating their costs and pay-off (Walton et al. 2007),
- choosing between an available small reward and the substantial but effort-based one (Walton et al. 2002),
- decreasing the decision-making uncertainty (Yoshida and Ishii 2006),
- initiating the choice of the decision which is the most accurate in given circumstance (Rushworth et al. 2007),
- observing and collecting information about other people's behavior that leads to making interpersonal or broad-range social decisions (Rilling et al. 2002),
- predicting negative consequences of decisions that have been made and analyzing the uncertainty of the consequence assessment (Rilling et al. 2002),
- integrating cognitive aspects of the decision uncertainty with the autonomic arousal that accompany negative consequences of decision making; creating conditions for decision verification and correction (Critchley et al. 2005).

1.6 Brain Processes: People's Behavior Prediction and Empathy vs. Decision Making

Decision making is to some extent based on the assumption that people are able to predict the behavior of others and empathize with them. This ability results from individual preferences and beliefs. Social neuroscience provides insight into neural mechanisms underlying our capacity to represent intentions, beliefs and desires of other people and to share other people's feelings, e.g. to empathize. Empathy makes people less selfish, allows them to share emotions and feelings with others, thus motivating them to make decisions oriented at other people. Studies on empathy indicate that the same affective brain neural circuits are automatically activated when we are feeling pain as well as when we see others in pain. Therefore, while making decisions, empathy often directs our emotions at other people.

Developmental and social psychology as well as cognitive neuroscience focus on human ability to assess and predict various states, such as desires, opinions, intentions, of other people. A study was conducted on the brain activity during the choice- and belief-related tasks (Bhatt and Camerer 2005). It revealed the involvement of the medial part of prefrontal cortex, i.e. the anterior cingulate cortex. This part of the brain takes part not only in reading other people's thoughts, intentions and beliefs, but also helps refer to one's own states of mind. It assists in creating decoupled representations of our beliefs about the state of the world (Frith and Frith 2003).

Similar research concentrated on searching for neural mechanisms being a basis for human ability to represent other people's goals and intentions solely by observing their motor acts. Such an approach stemmed from the observation that neurons in premotor cortex in macaques' brains activate both when the monkey makes a hand movement and when it observes another monkey or a human making the same hand movement. It was a remarkable discovery of the fact that the so called mirror neurons reflect the neural origins of imitation which is vital in the decision-making context (Rizzolatti et al. 1996). The system of mirror neurons may be the basis for our ability to empathize with mental states of other people, ensuring that we automatically simulate their acts, goals and intentions and adapt our decisions to this.

Apart from the ability to understand other people's state of mind, people are also able to empathize, i.e. to share other people's feelings in the absence of any emotional arousal. What is more, humans can feel empathy toward others in many different emotional situations, both elementary such as anger, fear, sadness, joy, pain or desire, and more complex, such as the sense of guilt, embarrassment or love. Relying on the perception models explaining behavior and imitation, the researchers proposed a neuroscientific model of empathy, implying that the mere observation or image of a person in a given emotional state automatically activates the representation of this state in the observer together with the related responses of their autonomic and somatic systems, thus strongly influencing their decision-making (Preston and de Waal 2002).

The research by Singer has proved that both strong stimuli (pain) and the awareness that someone important to us feels pain activate the same pain neural circuits. That finding implies that if a person dear to us suffers from pain, suffering will also appear in our brain (Singer et al. 2004). It seems that the ability to emphasize could have developed from the same system which creates the representations of human inner states and it helps predict and understand other people's feelings associated with some event, e.g. with a decision that has been made.

The results of Singer's study suggest as well that empathic response is automatic and does not require active assessment of other people feelings. Volunteers subjected to neuroimaging did not know that the experiment examined empathy. The analysis confirmed that the ability to emphasize is individually diversified.

What is important for understanding decision-making processes is the fact that emphatic responses appear also when individuals who undergo brain imaging tests do not know the person who receives the pain stimulus. The findings of studies on empathy can contribute to better understanding of social preferences, especially of behavior considered honest and dishonest. These findings show that many people have a positive opinion about those who behaved honestly in their decision making and are regard negatively those who behaved dishonestly. Such a pattern of preferences suggests that people prefer to collaborate with honest partners, advocating penalties for dishonest competitors (Fehr and Gächter 2000).

1.7 Neurobiology of Moral Dilemmas vs. Decision Making

From Aristotle to I. Kant to J.S. Mill, moral philosophy theories say that the primary role in making moral decisions is played by brain. In the light of modern developmental psychology, rationality is perceived as the foundation of moral choices. On the other hand, sentimentalists contended that emotions play the primary role in moral decision making. A. Smith wrote in 1759 that morality comes from understanding other people and the feeling of sympathy toward them. His view finds its appreciation in the concepts of modern sentimentalists, such as (Haidt 2006).

Neurobiology attempts to find out how moral decisions appear in the brain and how these decisions van by modified by emotions. It is the doctors who face particularly controversial moral dilemmas in their everyday practice, having to choose between two bad solutions, e.g. which accident victim they are to help first, being aware that their decision reduces the other victim's survival odds. The economists also have to decide which poorly performing company or bank should be given access to funding.

The studies of lesser-evil decisions are based on M.D. Hauser's Moral Sense Test (MST). It is a series of hypothetical situations where subjects choose one of several difficult solutions (Hauser 2007). What is interesting, fNMR tests show that time of response is longer when the decisions are associated with the choice of a utilitarian solution than when they require violating personal moral standards (Hauser 2007).

In the famous Thomson's Trolley Dilemma where the decision has to be made whether to redirect the runaway trolley from the its current course and save five people standing on the track and kill one person standing on the alternative track. The question is: is it morally acceptable to hit the switch to turn the trolley to save five people at the expense of the one? (Thomson 1978). The majority of tested subjects decide to hit the switch, regarding such a choice as the utilitarian solution, thus following J.S. Mill's view that moral acts are the ones that make people happier.

The decision of another type has to be made in the Footbridge Dilemma where a trolley heading for a group of several people can be stopped by pushing a stranger off the bridge and onto the tracks. Unlike to the previous moral dilemma, most subjects do not decide to push off the stranger, which may result from the fear of violating the moral standard: Do not kill.

There is an interesting explanation of the above decisions based on the double effect doctrine credited to Thomas Aquinas which says "An act which causes a certain ethically negative effect and which would be morally unacceptable if performed intentionally can be morally justified when performed with the intent to cause another, morally justified effect and only becomes its unintentional, although predictable, effect" (Galewicz 2001).

Hence, the act which is an effect of specific decisions will be acceptable when: its effect is good, brings at least as much good as its abandonment, will not be performed in bad faith and will be an effect of the action rather than the bad outcome. According to such approach, saving people in the Footbridge Dilemma does not satisfy the last criterion (people have been saved as a result of killing one person), this is why most subjects do not make this decision. In the Trolley Dilemma the death of one person was caused by hitting the switch (the death was 'just' induced).

Modern moral psychologists J. D. Greene and J. Haidt maintain that although decisions concerning the above moral dilemmas are connected with violating moral standards, they still have ethical character. In the Trolley Dilemma the decisions are of non-personal nature, while in the Footbridge Dilemma, they are definitely personal decisions. When facing decisions that may lead to hard consequences, most people accept non-personal violation of moral standards, while rejecting personal violation of these rules.

1.8 Conclusions

Decision making is closely connected with neurobiological, neurostructural, neurochemical and psychological mechanisms. They take place in specific parts of the brain, particularly in the prefrontal cortex, an area integrating connections with individual decision options. This process prepares relevant preferences with reference to current needs of a decision maker. Studies on neurobiological background of decision making give better insight into the human implied bounded rationality

and into the role of emotions, morality and empathy. Moreover, these studies contribute to the knowledge about the course of decision-making processes and their adaptive value.

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Chapter 2
Psychological Determinants of Decision Making

Ernest Tyburski

Abstract Decision making has been a subject of study in many scientific fields. It is psychological studies, however, that have brought significant contribution to understanding mechanisms that underlie making choices by individuals. The purpose of this chapter is first of all the description of mental processes, also referred to as decision-making activities, that are involved in various stages of decision-making. The second purpose is to present two systems of information processing which are engaged in varying degrees in the process. Moreover, the chapter describes the strategy of decision making, i.e. the heuristics allowing for prompt and economical actions. It also defines the role of free will and self-control in the decision-making processes. What is of key importance is the explanation from the psychological perspective of the process of decision making under uncertainty as well as the discussion of potential negative consequences of complex decisions made by individuals, groups and communities.

Keywords Decision making • Cognitive functions • Cognitive dualism • Consequences of decision making

2.1 Introduction

The decision-making mechanisms have been in popular interest for a long time and the related research has been conducted at the interface of many scientific fields. Psychology has made substantial contribution to understanding the decision-making phenomenon. Thanks to theories developed on its basis it has become possible to explain how individuals make their choices in real-life situations. First of all, a distinction should be made between two notions, i.e. between a decision itself and decision making. The simplest definition of the decision states that it is a purposeful and non-random choice of one out of at least two alternatives, while

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_2

decision making is a process that involves various mental functions, both the elementary ones, such as working memory and long-term memory, and the complex ones, such as thinking, reasoning or problem-solving, as well as executive functions lying in the middle, between cognition and action (Hastie and Dawes 2010; Toplak et al. 2010). Moreover, in the process a vital role is played by emotional and motivational functions because while making decisions individuals formulate their cognitive judgments basing on their own emotional experience (Lerner et al. 2015). Also, modern reference literature often discusses conscious and unconscious influences on decision making, including the power of impact of explicit and tacit processes on individual choices and the correlations between these processes (Newell and Shanks 2014). The above mental functions are subordinated to a specific goal, i.e. the choice. Hence, it can be assumed that they are decision-making activities (Falkowski et al. 2008).

The decision-making activities lead to the choice of one of two or more alternatives as well as to the so called alternative choice. For example, when planning their shopping, people do not have to choose the product in advance. If it turns out that product A is fresh, they can buy it, if it is not—they decide on product B as an alternative. In complex decision-making situations, mainly when facing crucial life dilemmas, the choice among a limited number of possibilities is usually preceded by long considerations aimed at reducing the complexity of the dilemma, which consequently leads to an "either-or" choice. For instance, theoretically speaking, a fresh high school graduate can choose among thousands of university courses basing their decision on such aspects as the reputation of the university, their own interests, financial conditions or career prospects. Therefore, the young graduate reduces this excessively complex dilemma to just several options to be considered.

This chapter presents the characteristics of mental processes that are activated at individual stages of decision making followed by the description of two systems of information processing that are responsible for human decision making. Additionally, the purpose of this review is to describe the decision-making strategies, i.e. the heuristics that facilitate prompt and efficient actions and to define the role of free will and self-control in the decision-making processes. What is of key importance is the explanation from the psychological perspective of the process of decision making under uncertainty as well as the discussion of potential negative consequences of complex decisions made by individuals, groups and communities.

2.2 Stages of Decision Making

In the psychological approach decision making is divided into three phases: the pre-decision phase (problem formulation and information gathering), the decision phase (the choice among previously defined options) and the post-decision phase (the evaluation of the decision made) (Svenson 1992). The basic activity in the pre-decision phase is identification of a problem, or in other words—defining the

discrepancy between the present state (no decision has been made yet) and the desired state (the decision has been made). The dilemma situations faced by individuals when making a choice can be categorized according to diverse criteria, such as (a) convergence, when the desired state is relatively well defined and just one solution is possible (Sloane and MacHale 1997), (b) complexity, when more complex problems require processing a considerable amount of data and generating their mental representation in a form of a mental model (Nęcka and Orzechowski 2005) and finally (c) definiteness, when the problem is well defined, which means that it has all the information about the goal, circumstances, the terms of acceptability of future solutions, limitations and other data necessary to find a solution (Reitman 1965). The settlement of a dilemma situation can be achieved by reducing the gap between a hardly satisfying starting point and a desired target point. A crucial element of the problem-solving situation is planning, i.e. examining the problem area in a systematic way and defining the directions of searching for solutions which require a certain budget of attention (Morris and Ward 2004). There are two major methods of planning: modeling (arranging steps of action in the mental space) and analogizing (using the correlations in one area to solve problems in another one). Creating a plan is conditioned by three elementary factors: (a) the complexity of a problem that determine the involvement of the cognitive system (e.g. simple problems engage primarily the working memory while more complicated ones occupy abstract thinking), (b) the impact of situational and environmental context (e.g. the capacity to verbalize the task, which facilitates its realisation) (c) individual preferences (e.g. strategies that help specialists to better cope with certain problems than laypeople, Davies 2004). When defining a problem, the decision makers are basing on boundary conditions understood as some kind of limitations imposed on future choices. They also mark out the level of risk that is acceptable in a given situation. The above restrictions may not be complied with at every stage of decision making. What is more, individuals may but need not rationally assume that the fewer consequences of the decision, the higher the acceptable risk. Therefore, people tend to accept a higher risk when buying less valuable goods, and lower risk when the goods to be purchased are expensive.

Another important activity in the pre-decision phase is to collect information about the problem, especially about potential solution options. The decision makers search for information in various sources, e.g. external (Internet sites or friends) or internal (semantic or episodic memory). When they are going to buy a computer, they look for technical specification on-line or consult a computer geek they know. When they are actually buying a computer, they mine in their semantic memory for general data for, say, specific components, while the episodic memory provides information about, for instance, a range of brands to choose from. It is worth remembering, however, that the more complex the problem, the more information is required but harder to find. In addition to this, the search for information is biased and made at random, which may lead to a wrong choice. Some research has shown that the relation between the amount of information gathered by an individual and their competences is non-linear. The least information is collected by incompetent

people because they do not know where to look for and are not able to tell which data are useful and which are not. The most data is obtained by those relatively competent as they know where the sources of information are and can distinguish between the relevant and irrelevant data. Interestingly, highly competent decision-makers find the optimum amount of data, looking only for the necessary ones or they recall the ones they have learned about before (Falkowski and Tyszka 2001).

In the decision phase, the choice is made out of the options previously defined as available (Svenson 2003). It is a step-by-step process and it allows for the choice of one option that is more and more favored in comparison to others, i.e. it is increasingly better justified as logical and subjectively regarded as reliable. Nevertheless, if the decision makers do not restrict themselves to the previously defined options, they can build completely new ones. To this end they change their interpretation of known facts. In the situation when create a new option on their own, they can single it out and justify it by making a decision, simultaneously considerably changing the structure of their knowledge. Such a mode of operation is typical of experts who make decisions using the knowledge, the quality of which differs from the knowledge of laypeople because the former often make decisions that are non-typical for their field of expertise (Shanteau 2012).

In the above phase the collected information is evaluated, which means that relevant data are separated from the irrelevant ones. This particular process is determined by several factors, the most important being cognitive processes, experience and context. When evaluating the information, people derive from their long-term memory as well as employ effective thinking, reasoning and well-operating working memory (Hinson et al. 2003; Zagorsky 2007). Moreover, superior mental functions of cognitive control, termed executive functions, are activated, especially the attentional switch and cued response inhibition (Tranel et al. 1994; Del Missier et al. 2010). The cognitive sphere is also subject to other factors, such as emotions that accompany decisions whose effect can be consistent or inconsistent with cognitive functions employed in decision making (Schwarz 2000; Andrade and Ariely 2009). Additionally, the cognitive processes are modified through anticipating and imagining the consequences of the choice made, through the capability to benefit from feedback as well as through the general decision-making policy (Wood and Bandura 1989; Bandura and Jourden 1991). Another relevant function is the ability to assess risk connected with individual options. No matter what kind of risk the individual can accept, they need to be able to assess that risk and envision the alternative courses of action after the decision has been made. Yet, human imagination is usually not creative enough, therefore people make their choices bearing in mind not what might happen after the decision but what they believe will happen inevitably (Falkowski et al. 2008).

The evaluation of data collected in the pre-decision phase also relies on individual experience which in turn is determined by individual differences in personality, temper and expertise. Certain role is attributed to neuroticism which is associated with the aversion to risk and the propensity to choose the most systematic strategy of information search that helps define the decision-making problem (Falkowski et al. 2008). Additionally, conscientiousness, integrity and openness are

involved in decision making because they are traits that reflect availability in terms of cognitive and behavioral control (Djeriouat and Trémolière 2014). Some authors suggest that in comparison to laypeople, experts are able to tell relevant information from the irrelevant one thanks to their previously obtained knowledge, reasoning schemes and easy access to information stored in their long-term memory (Shanteau 1992; Randel et al. 1996; Zsambok and Klein 2014). Hence, a highly experienced person is able to focus their attention on relevant information, while ignoring the irrelevant one. Yet, in particularly difficult situations (e.g. on the battlefield) experts make mistakes as well because they are not able to extract the most essential information from the noise of data that are irrelevant or even misleading.

Another group of factors that determine the evaluation of information validity is context. It can be problem-related or general, i.e. referring to a specific problem or to environmental conditions (Rohrbaugh and Shanteau 1999). The example of the general context is an overall economic or political situation that must be taken into account when making investment or military decisions. The problem-related context reveals itself depending on the wording used when describing the problem or on the associations evoked in the decision maker's brain. The example of an environmental factor that has a considerable effect on the judgment of the collected data is the pressure of time. In important areas of life, when people have to act under tight time pressure and it is not possible to follow a carefully devised strategy, it is recommendable to use automatic action schemes or to refer to one's intuition (Ordonez and Benson 1997).

In the last phase of decision making the post-decision processes set off that can take a form of doubt if the made choice was the best possible. Individuals can then attempt to convince themselves that they have chosen well by increasing the attractiveness of the selected option and simultaneous depreciation of the remaining alternatives. The mechanism is referred to as the reduction of post-decision dissonance or as the discrepancy between the option and the goal which they have been pursuing (Liang 2016). The strategies of reducing the above dissonance can take various forms, e.g. seeking confirmation of one's decision with other people by comparing oneself with people who made a worse decision in an identical situation or cognitive manipulating the value of information after the choice has been made, i.e. giving value to disadvantages and depreciating the advantages. Despite such efforts the decision maker can experience the so called post-decision regret. The more difficult the decision, the stronger the regret. In such situation individuals take measures to alleviate the emotional repercussions of that regret, thus preventing themselves from changing the decision they have made. This is an example of the decision makers' limited rationality when making critical life choices.

2.3 Dualism of Mental Systems in Decision Making

The way how individuals make decisions has been the subject of interest of researchers representing the range of scientific disciplines. The concepts originating from economics, termed normative theories, assume that decision makers have unlimited capacity, i.e. they are able to gather important information about various decision options, flawlessly analyze the data, correctly calculate the probability and eventually make a right choice. In other words, they always make rational decisions (Neumann and Morgenstern 2007). Psychological theories, defined as descriptive, presume that individuals do not always act in a reflective and logical way and they often make decisions that are satisfying but not optimal (Simon 1956; Zsambok and Klein 2014). Moreover, the cognitive psychology studies confirm that decision-making based on the analysis of all available data and following complex rules of behavior is accurate when performed in laboratory conditions rather than in natural circumstances (Payne et al. 1993; Ranyard et al. 1997; Juslin and Montgomery 2007).

Decision making is associated with a varying level of effort. People often make choices automatically, e.g. they go shopping to stores that are generally considered cheap. But decisions sometimes require conscious involvement and a thorough analysis of information, for instance, when a decision maker is buying a car. It is psychologists who search for an explanation how individuals make decisions, both the simple and the complex ones. In their deliberations they frequently refer to the division into two modes of reasoning proposed by James (1950/1980): intuitive/associative (recreative, based on comparisons) and logical/analytical (creative, based on the analysis of new data). Kahneman and Frederick (2002) claim that decision making depends on two competing systems of information processing. System 1 is called the intuitive system. Information is processed automatically, almost effortlessly, associatively, fast, parallel, unconsciously and often emotionally. This mode of operation is hard to control or to modify. System 2 is referred to as the reflective system. Information is processed in a controllable way, with substantial effort, deductively, slowly, sequentially and consciously. In this system the mode of operation is flexible and governed by general rules. In order to find out if a given mental process runs according to System 1 or System 2, we should observe the resistance to interruption caused by performing two tasks at the same time. In System 1 the operations are resistant to interruption, while in System 2 they can be disturbed (Kahneman 2003). The example is a situation where the subjects are asked to keep in mind several signs and simultaneously they are given another task. They usually respond automatically, following the first association (Kahneman and Frederick 2005). The differences between these two systems also lie in the content of the processed data. In System 1 the data content includes observations, temporary cues and their impressions that are non-voluntary and non-verbalized, based on emotions and specific. They are referred to as prototypes. Whereas in System 2 the data content represent ideas in a form of consciously generated judgments that are abstract and not affective. They create a set. The decision-

making process takes place according to the following scheme: first, System 1 is activated and proposes a solution, then System 2 joins and monitors the quality of mental operations. If the monitoring is disturbed and System 2 does not successfully intervene, what prevails are the judgments generated by System 1 on the basis of primary impressions.

Similar findings were published by Epstein (1994) according to whom individuals make choices relying on two systems that operate in parallel. Epstein calls the first one experiental as it is based on experience, He claims that it not only fast and automatic, but also that its operating manner is holistic, concrete, primarily non-verbal and minimally demanding of cognitive resources. It is highly dependent on emotions and on learning from affective experience, the effect of which is the pursuit of desirable outcomes while avoiding the undesirable ones. The second system is rational, basing on abstract and analytical reasoning. It operates according to general rules, reasoning and evidence. It is associated with culture and not directly affective. Epstein (2003) also believes that the system which is based on experience often gains advantage over the rational system. His opinion has been confirmed by the results of the experiment on the impact of stereotype priming on the accounts of the experiment participants whose responses were not consistent with their views (Bargh 1999). Moreover, Epstein's thesis has been supported by a study on two groups of children (aged 10–11 and 13–14). The study revealed that older children more often overestimate size over ratio than younger children. However, it may happen that System 2 influences System 1. In one of his experiments Epstein (2003) instructed participants to list three thoughts that came to their mind after imagining the following situation: Sophie bought a lottery ticket and crossed some numbers taking advice of a friend rather that following her intuition. Sophie failed to win a lottery. The participant's most common thoughts were that the friend was to blame. However, their next thought was that no one was to blame because the failure was due to chance. The second thoughts show that System 2 was activated.

Sloman (1996) defines the first system as associative and claims that information-processing in this system is based on similarity and temporal contiguity, where the source of information personal experience. It is a system that is automatic, reproductive but capable of similarity-based generalization and generally referring to the past. The second system is rule-based. Operations realized by the rule-based system are based on language, culture and formal systems. It is responsible for creative and systematic reasoning, abstraction of relevant features from irrelevant ones and strategic processing. Sloman believes that both systems are parallel and can simultaneously participate in solving the same problem. The examples illustrating this particular form of mental information processing are the considerations how to explain the Muller-Lyer illusion. The illusion consists of two parallel arrow-like figures. The fins of the upper arrow point inwards, while the fins of the lower arrow point outwards. The viewer's task is to tell which shaft is longer. At first glance they say that the bottom one is longer (the first system basing on perception is launched), but on the second thought they realize that both lines are of the same length (the second system basing on rules is activated).

Evans (1984) proposed a slightly different concept of the heuristic and the analytic systems. The former is not directly linked with consciousness, processes information fast and refers to the data associated with a concrete task. The latter is closely embedded in consciousness, processes information in a step-by-step and controllable manner. In contrast to the authors of above mentioned three concepts, Evans maintains that during decision making both systems operate sequentially because the process of analytic information-processing in the second system relies on representations coming from the first system. It often results in biased reasoning as the representations of a problem in the first system are the effect of heuristics (a cognitive shortcut), which means that some relevant pieces of information can be omitted in favor of the irrelevant ones. In his extended concept, Evans (2006) states that the second system operates basing on three rules: (1) generation of a single mental model which represents a single outside world situation, (2) adjustment of mental data mental data collected basing on information coming from the heuristic system, (3) satisfaction which results from testing the solution in a fast, or heuristic, manner. When making decisions, people usually follow the first and the second rule, which reflects their capacity to test one model and abandon it when it is not satisfying.

Similar concepts have been proposed by Stanovich and West (2000). Their concept states that the first system depends on the context, is launched automatically and unconsciously and relies on the heuristic information-processing. Therefore, cognition via the first system will always be burdened with an elementary error, i.e. automatic placement of the problem in a context. This is why individuals often fail to address tasks in accordance with their logical structure, use information originating from the context and interpret the problem situation in reference to the everyday life. The second system in turn is based on analytic reasoning isolated from the context. Mental information-processing taking place in the course of decision making is performed sequentially: initially, the first system instigates an automatic reaction that depends on the context; then, the second system generates the intervention function by stopping and fading out the first system responses on the one hand but, on the other hand, it suggests another, better response based mainly on analytic thinking, thus facilitating the isolation from the context (Stanovich et al. 2008). According to Sokołowska (2005), there is a controversy among the authors as for the characteristics of individual systems. What is questioned is the possibility of the two systems to cooperate (in a parallel or sequential manner) and the involvement of unconscious processes on the lower level (i.e. emotions or intuition).

2.4 Heuristics in Decision Making

In psychological literature the decision-making heuristics are defined as choice strategies. Their two main characteristics are fastness (the time criterion) and frugality (the criterion of the problem complexity and the engagement of processes

necessary to make a decision: Gigerenzer et al. 1999). Due to such strategies individuals can cope in a short span of time with highly complicated decisions, which would not be possible if they attempted to solve the problem in all its complexity. One of the most commonly used heuristics is the elimination-by-aspects strategy where decision makers create a set of criteria and then gradually eliminate the alternatives that do not meet one of the criteria. In the next step, they eliminate options that do not meet the next criterion from the set. Eventually, the number of alternatives is significantly reduced, which facilitates making the final decision (Tversky 1972). Another heuristics is the satisficing strategy which entails searching through the alternatives and finally making the choice which is sufficiently satisfying. Having made a decision a decision maker is satisfied not because their choice has been the best possible, but because it has been good enough, mainly from the point of view of satisfying their needs. This is an example of a compromise of some sort, as the option chosen is not the optimal one, but it has saved time and other resources and, first and foremost, the decision has been made at all. Moreover, it would not be possible to review all the options, particularly that many of them may become unavailable because of other competitors (Simon 2013). The next strategy is choosing what is most important, i.e. following cues of varying relevance. In other words, decision makers select one cue which they consider the most important and then compare individual options in pairs, each time rejecting the one whose value is lower or unknown in terms of the selected cue. If this system turns out ineffective, we can take into consideration the next ranked cue and repeat the process until the decision is made (Gigerenzer et al. 1999). There is another strategy where decision makers rely on what has worked well before. They apply the criterion which proved effective in the last trial of the same kind. The above outlined heuristics are simple decision-making formulas when the number of options exceeds the individual's capacity to analyze all the possible choices. The decision-making strategies not only govern our search for solutions, but also allow us to give up the search when there is no point for them to be continued.

The application of strategies in decision making may or may not be effective. One of the studies reveals that the outcomes of both simple and sophisticated strategies are similar in terms of the decision correctness as well as their universality (or validity in other life situations). What is more, the advantage of simple heuristics is that they the decisions are made faster (Gigerenzer et al. 1999).

However, the application of heuristics can lead to biased decisions. A classical example is replacing the natural probability judgment with the assessment of resemblance. The reason for this is that the probability judgment is more difficult and time-consuming, while the assessment of resemblance is easier and faster. Research has shown that when making choices individuals tend to replace the probability of some phenomenon with its resemblance to another, usually known, one, hence making an assessment error (Kahneman and Frederick 2002). It is an example of a kind of biased reality judgment, i.e. concentrating on irrelevant elements of the situation, which results in a biased decision.

2.5 Decision Making Under Uncertainty

Decisions made in the situations of uncertainty are the ones when we do not know what will happen or when we are not certain what results our actions will cause (Sokołowska 2005). From the economic perspective, the purpose of theoretical models is to provide answer to a question what choices should be made to be considered rational. The most popular concepts in this respect are: (a) maximisation of the expected value depending on which individuals calculate not only the potential losses, but also their probability (Bernstein 1997; Mlodinow 2009), (b) maximisation of the expected utility which means that the subjectively expected value is not a linear function of the objective value because in certain circumstances some people do not maximize the expected value (Bromiley and Curley 1992), (c) maximisation of the subjectively expected utility where the assumptions about the utility and about the subjective resemblance are combined (Bernstein 1998) and (d) minimisation of variance (the portfolio theory) according to which decision-makers minimize risk (variance) while simultaneously maximizing the rate of return, or gains (Markowitz 1952). Yet, the above models cannot be of use in all possible situations in which decision makers have found themselves because they mainly refer to known probability. Psychological studies show that making decisions under uncertainty does not follow the model of subjectively expected utility. Instead of maximizing the expected value, individuals tend to minimize or ignore it. There are several psychological concepts whose authors attempt to explain this discrepancy. One of them is the prospect theory by Kahneman and Tversky (1979). The main elements of this theory stem from the observation of real-life choices. The authors assume that economic decisions under uncertainty are made in two phases: editing and evaluation. In the editing phase we make a decision with a view to simplifying and ordering the decision-making process, usually by means of a specific heuristics (applied consciously or unconsciously). In the evaluation phase we decide on the value of individual alternatives and choose the one that has the highest subjective value. The research conducted by Kahneman (2003) point out that gains and losses are relative and evaluated according to a specified point of reference (e.g. a positive financial value can be perceived as a loss when the corresponding point of reference even more valuable). Moreover, individuals tend to change their risk preference which depends if they are in a loss or gain situation (e.g. when in the gain context the aversion to risk is predominant, while the loss context encourages the propensity to risk). Over the last few decades, plenty of studies have been published that confirm high applicability of the prospect theory, particularly when explaining decision-making mechanisms in business, law or medicine (Sunstein 2000; Camerer 2004; Schwartz et al. 2008). A similar approach is represented by Lopes (1987) who maintains that people make choices in the situations of uncertainty by referring to their adopted level of aspiration and to their individual propensity to risk. Brandstätter et al. (2006) believe that information about outcomes and probability are computed in a sequential manner, which means that in the first step decision makers analyze data about losses, then they focus on

gains. Zaleśkiewicz (2011) notes that out of the above outlined models the prospect theory has been most widely recognized by researchers.

2.6 Decision Making and Volition

Making choices is also associated with volition and self-control. Baumeister et al. (1998) claim that the acts of free will and self-regulation require some effort and people are able to exert limited self-control at the same time. Therefore, the resources allowing self-control are depleted. The power of self-control varies individually. The above mentioned authors describe the limitation of volition resources taking place in the course of diverse activities involving self-control (effort) as ego depletion. The loss of self-control may be detrimental to performance in the individual, group or social dimension, such as uncontrollable shopping, overspending, incapacity to save or risky borrowing (Baumeister et al. 2006). Similar views on the involvement of self-control in decision making are shared by Moller et al. (2006) who maintain that the resources are depleted when individuals are forced to make decisions, but they are not exhausted by autonomous decisions. Research has shown that the resource depletion can also be conditioned by the attributes of goods whose quality and prices are most difficult to estimate (Wang et al. 2010). In different situations people make choices in a similar way, which probably reflects the presence of a universal set of cognitive abilities. These abilities may fail at different stages of decision making; therefore some decisions may be perceived as inadequate or illogical (Hastie and Dawes 2010).

2.7 Consequences of Decision Making

Psychological concepts explain how individuals make their choices, including those made under uncertainty. Nevertheless, these concepts do not address the consequences of the decisions. The situations when we are not certain about the outcomes of our choices are usually associated with strong emotions. Yet, in some people they can cause mental conditions, such as severe stress, anxiety or even depression. One of such situations is the lack of job security resulting in an increased number of absentees, more health-related complaints or decreased general well-being (Davis et al. 2003; Quinlan and Bohle 2009). Additionally, people at risk of redundancy more often experience anxiety and depression (Avčin et al. 2011; Snorradóttir et al. 2013). However, the described above phenomenon has caused considerable controversy. The results of another study revealed that job insecurity is more likely to induce high blood pressure than depression (Modrek and Cullen 2013). Unfortunately, the findings of the aforementioned studies are difficult to compare because some of them are vitiated by methodological errors, e.g. the evaluation of staff's mental problems was made on the basis of their own

declarations instead of objective measurement tools or the analysis covered only the group of employees that were at risk of redundancy, while ignoring the general population of employees.

Usually the predictable consequences of simple decisions are not serious, in contrast to the situations when we are not able to foresee all the effects of our actions, such a decision to take a consumer loan or mortgage. It has not been scientifically proved yet if such a decision can be detrimental to our mental health. This may become a broader problem because mentally ill people tend to accumulate debt more often than the mentally healthy (Jenkins et al. 2009). It emerges that, on the one hand, mentally healthy individuals that become indebted because of various reasons (e.g. gambling, drug addiction or compulsive shopping) are more susceptible to anxiety and depression. On the other hand, however, psychiatric patients lose jobs more often and are less likely to receive government support hence they tend to accumulate debt (Meltzer et al. 2013). Nevertheless, study results reveal that consumer debt (Brown et al. 2005; Taylor et al. 2007), mortgage credits (Drentea 2000; Drentea and Lavrakas 2000) as well as consumer credit and mortgage credits as a whole (Cooper et al. 2008; Bridges and Disney 2010) are linked with diagnosed anxiety and depression. What is more, people who are in debt, disregarding what type, suffer from obsessive-compulsive disorders, phobias and panic attacks (Meltzer et al. 2013). Bentley et al. (2011) suggest that the correlation between mortgage credit and mental disorders is stronger in a group of low-income people. Other researchers have obtained contradictory results, indicating that the socio-economic status does not have effect on the relationship between debt and the prevalence of mental diseases (Drentea and Reynolds 2012; Mauramo et al. 2012). Also in this case the comparison of results is difficult because of the lack of uniform operationalization of debt (Martin-Carrasco et al. 2016).

2.8 Conclusions

The review of literature about psychological aspects of decision making allows for several elementary conclusions.

First, from the psychological point of view decision making is a complex process consisting of three stages: the pre-decision phase, the decision phase and the post-decision phase, each representing different activities. Mental operations preceding the actual choice presumably follow a similar pattern in all humans.

Secondly, basing on psychological theories, a universal model was built of two systems of computing information involved in decision making. The first one is termed intuitive or affective, while the second one—as analytic or logical. This distinction reflects the classical division existing in psychology into processes that are unconscious, fast and automatic and the ones that are conscious, slow and reflective. The controversy relates to such issues as the interaction between the two systems (parallel or sequential) and the role of unconscious processes in System 1 (emotions or intuition).

Thirdly, when making decisions, individuals tend to apply various strategies called heuristics (cognitive shortcuts). Thanks to heuristics they can make their choices in a fast and frugal manner in both simple and intricate decision-making situations. The authors reveal that the elimination-by-aspects strategy, the satisficing strategy, the strategy of choosing what is the most important as well as the strategy of relying on what has worked well before. However, recourse to heuristics may lead to biased decisions, e.g. by replacing the natural probability judgment with the assessment of resemblance individuals may inaccurately evaluate available options.

Fourthly, it is essential to understand how individuals make decisions under uncertainty, i.e. when they do not know what will happen next or they are not certain about the result of their choice. Concepts that have been built on the basis of economics are not applicable in every decision-making situation because they relate mainly to known probability. Psychological theories in turn aim to explain how individuals make actual decisions in the real world. They provide a way to understand better how brains of people dealing with law, medicine or business cope with decision making.

Fifthly, more and more researchers begin to recognize the role of volition and self-control in the process of decision making. Some psychological theories indicate that individuals can exert self-control only to a limited extent, so their resources become depleted in the process, thus leading to biased decisions.

Sixthly, the decision-making situations, particularly the ones when individuals lack certainty about the outcomes, are accompanied by strong emotions. Some people may experience mental problems, mainly increased anxiety, stress or even depression. Generally, it is essential to comprehend the potential detrimental effects of complex decisions made not only by healthy individuals but also by people suffering from mental disorders.

In sum, psychological theories explain what is happening in the minds of decision makers before, during and after the decision making. Also, the understanding of information-computing mechanisms that are involved in the decision-making process can be particularly useful in practice.

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Chapter 3
Emotions in Decision Making

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Abstract A blend of research methods applied in psychology, economics and neurology has contributed to deeper understanding of the causes and effects of emotional processes in decision making. New paradigms initiated the studies on the role of emotions and cognitive processes in decision making. When making choices, a human being formulates their cognitive judgments on the basis of their affective experience. The studies point to both the adaptive and nonadaptive effect of emotional experience. Intense emotions moderate or modify the cognitive processes that are a part of decision making. Therefore, in the light of current scientific knowledge, the complexity and importance of emotional processes must be taken into account when analyzing the decision-making processes.

Keywords Decision making • Rationality • Emotionality • Efficiency of decision-making • Consumption behavior

3.1 Introduction

Until now, the researchers who deal with decision-making processes have been focusing on cognitive, situational and socio-cultural variables, paying less attention to the emotional component. A new approach, called neuroeconomics, aims at building a complex theory which addresses the processes accompanying decision-making. Combined research methods traditionally applied in economics, psychology and neurology allow for more comprehensive description of a given phenomenon and for more effective prediction of potential human decision-making behavior. Rational economic models do not embrace such relevant factors of decision making as risk, ambiguity or uncertainty. Hence, the investigation into the role of emotions has become the subject of new theories and research methods applied in the neuroeconomic approach which focuses on defining the function of

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_3

emotional and rational systems as well as on risk evaluation in predicting human behavior. The progress in cognitive neuroeconomics has greatly contributed to our understanding of the effect of emotions and cognition on people's choices in the situations of risk and uncertainty (Gutnik et al. 2006).

Decision making includes both the perception of benefits, information processing and the assessment of its outcomes. Modern models approach the decision-making process on many levels, abandoning the axiom of rationality and favoring emotionality instead. The perceived affective state influences the way the information is processed, thus enhancing the effectiveness of choices. Particularly, in the situations when decision must be made quickly, it is our emotions rather than an objective analysis that are a driver for our actions.

The diversity and complexity of emotional processes is an obstacle to define clearly whether the impact on decision making is positive or negative. Numerous studies point to many factors that are employed in the process. Theoretical considerations and research results outlined below indicate both conscious and unconscious participation of emotions. The first part of the chapter presents a review of classical and neoclassical concepts of decision making. Further considerations focus on the role of emotions in the situations requiring a choice. Individual cognitive analyses are based on emotional experience. The results of studies on the decision-making efficiency imply that affectivity is vital to the process. Some authors also describe the consumer behavior that is determined by emotional states, differentiating between the emotions that accompany buying situations and the consumer behavior. It seems important that several research projects look at the quality and effectiveness of decisions made by the elderly people. Their authors have found out that cognitive processes deteriorate with age, which is not parallel with emotional functioning. Thus, a question arises how aging is correlated with decision making.

3.2 Classical Decision-Making Theory and New Paradigms

Classical and neo-classical economic theories adopt the concept of homo oeconomicus that give primacy to rationality and optimality of human behavior in choice situations (Begg et al. 2000). According to classical decision-making theories, the decision-making process consists in the choice of the optimal course of action out of at least two options based on the choice of an explicit objective. Therefore, the important components of each decision are the possibilities and the direction of action, beliefs and expectations concerning the successful realisation of the objectives as well as positive or negative expectations regarding the outcome. The normative character of decision making means that actions are optimized in order to maximize gains while using rational methods to reach the goal (Dzik and Tyszka 2004). It seems important, however, to focus on these decisions that deviate from the adopted standard of rationality. The descriptive character of decision making takes into consideration the complexity of factors involved in

decision making, such as personality traits, emotions, motivation, propensity to risk, social determinants, etc. (Falzer 2004). The classical approach has its limitations and has not been used in practice because each decision-making process is treated in identical, standardized way (Beach and Lipshitz 1993).

In accordance with the normative model, uncertainty is an expression of the assessment of likelihood of a given event to happen in a specific situation. Bayes' theorem of probability, which is applicable to the decision-making rules, is based on the conditional probability of an event that can be corrected depending on the available evidence. Subsequent events may become a source of new evidence that can modify the likelihood of the new event. The benefit of this model is that it provides an opportunity to compare the decision that has been made with the available standard and to evaluate the rationality, or correctness, of one's behaviour. In fact, the weight of a rational element of the decision is lower than the one assumed by mathematical models (Patel et al. 2002).

The ongoing discourse on this subject provides a ground for new paradigms. Herbert A. Simon, the author of the theory of bounded rationality, points to the situations when an individual, basing on imperfect rules, makes decisions that are the most satisfying but not maximizing, i.e. the ones that seem to be the most gratifying in a given moment. Bounded resources, in a form of time or information limitations or our brain's incapacity to make decisions, preclude us from satisfying all the basic assumptions of the classical theory of rationality. The paradigm changed in 2002 when Daniel Kahneman integrated psychological sciences and economics when referring to the process of decision making in a situation of uncertainty. Prospect theory highlights the importance of heuristics in the decision-making process that can lead to cognitive biases in judgment (Kahneman 2012; Gruszecki 2001).

The adoption of the paradigm of the impact of emotionality and cognitivity on decision making gave impulse to dynamic progress of studies on emotions in organizations. Therefore, we accept the paradigm of bounded rationality where a crucial role is played by poorly measurable factors stemming from the imperfections of an information system; from uncertainty and propensity to self-restraint in finding solutions that are generally affiliated with the human system of values; from human skills, capacities, habits, motivation or sense of satisfaction. Hence, it is believed that, despite their capacity to optimize the decision-making factors, a modern human being cannot ignore their emotionality (Wach 2010). The cognitive approach is also present in theories that are founded on information processing models in which an individual makes their choice basing on a selective judgment of incoming information that is relevant in a given situation, rather than on the previously presented behavior pattern (Payne and Bettman 2004).

The studies on the perception of HIV risk and risky sexual behavior have failed to confirm that impulsivity is a good predictor of actual patterns of sexual behavior (Breakwell 1996). The research by Gutnik et al. (2006) based on cognitive neuroeconomic models referred to the role of emotions in public health-related decision making. The study on 60 young adult heterosexual men and women was aimed at analyzing the decision-making process concerning risky sexual behavior

(Steinbrook 2004). The rational and cognitive situation judgment did not explain the differences in the subjects' behavior. The analysis of the research results revealed a key role of emotions in risk decision making (Gutnik et al. 2006).

3.3 Affectivity and Decision-Making Efficiency

Emotions are an indispensable part of human life. They determine our actions and choices, being a vital element of our adaptation process. The complexity and diversity of human emotions condition human individuality. The ability to recognise emotions and cope with them is important in the decision-making situations.

Let us consider the following situation: at a demonstration of bed-linen and household appliances at her home a 70-year old woman buys a set of bed-linen at a price of 4000 zloty. There would be nothing unusual in the situation if not for the fact that the same product is sold in shops at a much lower price. Objectively speaking, it was the woman's independent purchasing decision that could seem surprising for some of her acquaintances. This is an example of the role of affect in making a consumer decision.

In some circumstances the decisions are made under the influence of emotional experience generated by marketing campaigns, while in other situations it is the consumer's temporary emotional state that determines their decision to buy (Achar et al. 2016). Being an objective observer of people making decisions in diverse situations, we can hypothesize that such behaviors result from the personal freedom of choice. In a long term, the consequences of all such choices may vary, so as do the reasons that initiate these choices. Sometimes, as a result of these decisions people suffer loss which leaves them emotionally shaken. It means that under some circumstances or interpersonal relations the freedom of choice may appear to be something that an individual would by no means want to experience and will strive to avoid it in the future. It should be noted that such a thesis partly stems from the cognitive dissonance, meaning that the more sense of freedom an individual feels when making an important decision, the stronger is the cognitive dissonance that evokes their aversive emotional experience. Hence, it can be assumed that the freedom of choice is to some extent a form of the individual's helplessness with its fear of responsibility and independent actions in the future. "Human activity is rooted in a human themselves, even though the extent to which people use this attribute varies greatly" (Brzeziński and Cierpiałkowska 2008).

The analyses of human behavior and their life decisions reveal that there are individuals who can control their lives and those who become substantially dependent on others in various domains of social functioning. However, people tend to believe that their actions and decisions are a consequence of their rational thinking and judgments. Recent psychological studies have revealed that human effective functioning in decision-making situations is determined by people's emotions and needs because they influence human cognitive judgments (Kunda 1990, 1999; Dunning 2000; Gollwitzer and Moskowitz 1996; Forgas 1995; Kruglanski 1996).

It can be assumed that arousal plays a critical role in shaping perception of people's own emotional states, which is a potent decision trigger. The more aroused we are, the more we accept the fact that we are experiencing strong emotions which can influence our beliefs concerning our motivated reasoning. Yet, even in such situations a human is strongly motivated to justify their actions in order to defend the structure of one's own "I" (Kunda 1990, 1999). It is in line with the fact that when we waive the cognitive dissonance, we change our attitude which leaves us vulnerable to other people's lies, for example when selling to us an overpriced product after having created an atmosphere of friendliness and confidence (a personalized product demonstration at our home).

When confronted with their own decision, an individual needs to devise a justification for their action. To this end, they search their memory in order to find judgments that could substantiate their choice and explicitly validate its rightness. These attempts are often biased because people tend to justify and rationalize their decisions (Klayman and Ha 1987). Both the judgments and their justifications are based on specific motivation. As some psychological studies reveal, self-esteem strongly influences one's motivated self-perception (Kunda 1990). People tend to perceive themselves in a good light, hence for their own sake they construct theories that strengthen their self image after they have come to a desired conclusion (Dunning et al. 1995). It can be assumed that such optimistic judgment of one's own decisions becomes a gratification, thus contributing to a general feeling of happiness and improved quality of life. According to the existing studies, illusions about ourselves and our future existence as well as about our control over events give people more satisfaction than just a sense of well-being (Armor and Taylor 1998). It should be added, however, that unrealistic judgments of their own choices may lead to real risks and, in the future, cause failures in diverse domains of social life.

A human is a social being and in their striving for self-actualization they make decisions in diverse domains of their existence. Human choices may be essential factors in their pursuit of self-fulfillment because they provide feedback about their functioning. It is a long-lasting process which brings many emotions (Strelau 2000). According to Abraham Maslow, human behavior is motivated by unmet needs. Maslow called them deficiency needs and growth needs. The growth needs are meta-needs. They are governed by the rule 'the more, the better' and they bring positive emotions, while the growth-related stress is experienced as pleasant and desirable. Carl Rogers, another representative of humanistic psychology, said that people shape themselves through their own choices and actions where their self-actualizing human 'I' is in the center of their experience. Carl Roger believed that the conscious 'I' is a current experience of who a person actually is, how they react to and influence their environment and what decisions they make in this environment. In a social decision-making situation a human bases their choices on their own values, judgments and perceptions about themselves, such as "I can afford it" or "It is necessary for me" that they have developed over years. Every individual has their own well-established views that determine their understanding of other people's and their own world, thus contributing to his or her self-actualization or

growth. Rogers distinguished five major characteristics of the human growth: emotionally intensive openness to new experience; focus on the present; trust in your own body—instincts and gut-reactions (emotional arousal) are trusted; sense of freedom, which means that people have a cognitive control over their lives; creativity—originality of thinking (Strelau 2000).

We can hypothesize that it is through trust that humans exert influence on one another and on social groups. It is essential for people to be aware that the social and cultural context as well as information about the world and other people conveyed by diverse media have a non-neutral effect on human decisions in all domains of life. No human being is independent self-sufficient enough to make their decisions in isolation from what others want or expect of them. People tend to fall under influence of others who consciously manipulate them into choices that they will perceive as their own unbiased decision. The central factor is the need to be accepted by others (Zimbardo 2002).

The studies on affective experience and decision-making performance indicate that the process becomes more effective along with the increased intensity of emotions. Individuals who better identified their feelings and were more capable of controlling them achieved higher decision-making performance (Seo and Barrett 2007). Other authors pointed to the functionality, adaptability (Damasio 1994) but also to non-adaptability of affective experience in the decision-making processes. The level of functionality and disfunctionality of emotions indicates individual differences that are predictable to some extent.

Emotions relate to different affective states and are understood as intense affective experience directed at specific objects (Russell 2003). In literature the affective experience in decision making is viewed from two angles. The first assumes that in the decision-making process emotions can evoke various forms of prejudice and distort the reality. Hence they can have a negative effect on the decision itself or on the contents of the processed information. Research has shown that feelings may affect personal choices or judgments (Meyer et al. 1992). Intense feelings make people choose the most immediate goal, e.g. the one that temporarily uplifts your spirits disregarding its long-term effects. The second perspective states that emotions can improve decision-making performance as they underlie the controlled awareness necessary to employ cognitive processes in the decision-making process. Transient emotions make us focus on goals that are most relevant to us in a given moment (Ketelaar and Clore 1997). Emotions can make it easier to choose our priorities and to adapt to circumstances (Schwarz 1990).

Momentary affect determines the way information is processes, thus contributing to the decision-making effectiveness. Positive affect elicits the integration of cues received by an individual, increases flexibility or creativity (Staw and Barsade 1993). Negative affect in turn is conducive to effective decision making in situations requiring accuracy, objectivity, perseverance or realism (Elsbach and Barr 1999). Both perspectives implicate the importance of emotions in the decision-making process. What needs to be taken into consideration, however, is how these emotions are experienced and how an individual handles these emotions. When describing individual differences in affective information processing, the researchers refer both

to the scope of individual affective experience, its intensity as well as to the way the feelings are handled, expressed and integrated in a decision-making situation (Gohm 2003).

These two perspectives put emphasis on two affective processes involved in the internal stimuli processing. Emotions can be a moderator in the decision-making process by way of boosting the capacity of working memory or induce the decision-making process via behavior modification. Therefore decision making is associated with both a reaction to affective experience as well as with the launch of processes that regulate the effects of emotions. Properly regulated emotions can contribute to better performance (Forgas 2000).

Researchers emphasize the discrepancies in the ways of emotional regulation in decision making. In an influence situation people get involved in two types of affective information processing. On the one hand they deal with an open, constructive form of processing both affective and non-affective information, while on the other hand—with a rational and controlled affect processing (Larsen 2000; Forgas 2000). Individuals with high ability to regulate the influence of affect are less susceptible to emotions while making decisions. High objectivity and low vulnerability to emotions implicate high decision-making performance. Individuals whose choices are made as a result of induced affect are more likely to rely on their own biased judgments (Seo and Barrett 2007). High emotional responsivity increases the possibility of more intense feelings in the decision-making process. These intense feelings can moderate cognitive processes and reduce motivation to act by generating a larger number of resources (Seo et al. 2004).

3.4 Effect of Emotions on Customer Behavior

Alice Isen (2001) and Gordon Bower (1981) highlighted the role of affect at the time the decision is taken. The emotional state in which an individual is in a given moment as well as the organization of memories can determine the choice. Good mood enhances the availability of positive memories, which in turn instigates an individual to make favorable assessment of their environment or objects. In conclusion, information processing and object assessment are associated with better availability of positive emotions in one's memory when the individual is in a good disposition.

Schwarz (1990) stresses the importance of emotional signals that are treated by humans as a source of information about an object to be evaluated. This is particularly the case in a situation when one has to choose between alternative options that are difficult to compare. Metcalfe and Mischel (1999) point to two systems that rule decision-making processes. The affective system stimulates people to actions that are more impulsive and intuitive, where decisions are more prompt and effective and problem-solving strategies are more creative. It should be noted, however, that such a way of decision making is often based on stereotypical thinking or heuristics, which often leads to numerous errors in information

processing. On the other hand, the cognitive system is based on more rational, strategic thinking. In this case the response behavior results from launching one of such mental strategies.

The Affect Infusion Model developed by Joseph Forgas (1998) concentrates on the role of cognitive processes in decision making. When an object is familiar to an individual, information that can be retrieved from their memory affects the process the most. The affectively loaded information exerts influence on triggering the cognitive process, thus modifying the ultimate decision. One of the information-processing strategies is the direct access strategy when an individual refers to a stored opinion or approach toward the object of judgment. Another strategy is motivated processing that is launched when the individual in question is strongly motivated and has a clearly defined goal in mind. Sometimes, we take a shortcut and, with low personal involvement, we use the heuristic strategy where our mood provides feedback about our judgment. The Affect Infusion Model is best applicable in the analytic processing which the individual interprets available information, particularly in a situation when the object of judgment is atypical or complex. The more detailed the analysis, the more the affect disturbs the cognitive process (Gaczek 2015).

According to Bodenhausen (1993), arousal plays a vital role in interpreting emotions. The absence of arousal, e.g. when experiencing sadness, can prolong the process of thinking, making it more meticulous and systematic. Decision-making processes are also conditioned by the individual's expectations regarding the judged product or object. The anticipation of emotional benefits can accelerate making a decision. It may happen, however, that the anticipated affective state is not the one which actually occurs after the action has been taken (Patrick et al. 2007).

The listed literature distinguishes between the affect accompanying purchasing and consumption decisions. When an individual is making a purchasing decision, they evaluate the benefits of owning the good in question, i.e. process information, make a judgment and then make a final decision. In the case of consumption emotions are evoked by experience of using the purchased good. However, many researchers point out that purchase-related and consumption-related emotions overlap. The affect elicited at the time of decision making has an impact on the subsequent satisfaction of having the purchased good (Derbaix and Pham 1991).

The feeling of content during consumption has a positive effect on the assessment of the purchasing process. Consequently, the individual more eagerly undertakes purchasing activities and more often is willing to recommend the product (Hanzaee and Khanzadeh 2011). The study by Antonetti and Maklan (2013) reveals the effect of guilt and pride on the propensity to consume. People who feel pride in the consumption situation are more willing to behave according to their own standards and they are more motivated to pursue their goals. The feeling of guilt induces the need to reduce stress resulting from the experienced dissonance. Both the above affects contribute to more balanced decisions.

Studies on compulsive personality show that such people have an inclination for uncontrolled buying under the influence of negative emotions. When making a

purchasing decision, their actions are impulse-driven and they fail to carry out a rational loss/benefit analysis. The decision-making process is short and often triggered by a momentary stimulus. The individual is driven by a desire to own a good in order to reduce anxiety, regain control over their own behavior or to boost their mood (Silvera and Lavack 2008; Baumeister 2002).

Impulse buying is powered by the need to experience a positive effect, to improve one's mood and to satisfy one's urge. Positive atmosphere that accompanies a purchasing situation has a considerable effect on spontaneous decision-making devoid of rational, critical analysis. Therefore, the good mood increases the likelihood of a decision to buy a product that, in this case, serves the need to indulge a hedonistic desire (Beatty and Ferrell 1998).

3.5 Aging and Decision Making

To address problems arising from the process of society aging, more and more researchers conduct studies aimed at identifying impediments in the elderly people's functioning and needs. The decision-making performance changes with age. Scientists point to both qualitative changes as well as to changes in strategic choices or in satisfaction with the made choice. Transformations occurring with age also have impact on changes in cognitive functioning, which results in delayed reactions, reasoning or decision making. The emotional-empirical system processes information quickly, automatically and often unconsciously. The rational system is based analytical reasoning mode that is consciously controlled and employs cognitive processes (Kahneman 2003). Disturbances in the rational system make controlling impossible, thus leading to numerous errors and to intuitive information processing. Cognitive biases occurring with aging affect the reasoning performance in the absence of changes in the emotional-empirical system (Sobków 2011).

The studies by Mikels et al. (2010) have shown that the quality and effectiveness of decisions made by the elderly significantly decline along with the deterioration of cognitive processes. In the information-search situations their choices will be of the lowest quality. In situations involving the emotional-empirical system no marked differences in effectiveness were observed between the young and the elderly, excluding the circumstances when they had to concentrate on details. Then young people's decisions were of better quality.

Finucane et al. (2002) point to the presence of two components confirming the decision-making competence: the comprehension skills consisting in accurate interpretation of data, and the consistency skills meaning the ability to recognize similarities between two alternative possibilities, disregarding the differences in their presentation. The elderly individuals found it more difficult to understand information properly and their decisions were less consistent and more dependent on the way the data were presented to them.

Older adults show stronger propensity to decision making basing on their recalled beliefs and using the accessible cognitive schemes. Such a situation occurs

even when they receive feedback which indicates that their beliefs are wrong (Mutter and Pliske 1994). The changes in cognitive performance prolong the older individuals' decision-making processes. When deprived of time, they analyze a smaller amount of information and rarely re-consider their decision. The decision-making performance of seniors declines markedly when they have to deal with plenty of data and when they need to concentrate on details (Mata et al. 2007). Taking into consideration difficulties in functioning in older age we can assume that the limited number of alternative choices can reduce the probability of wrong decisions. Research has shown that in the process of decision making seniors prefer the Take the Best heuristic where the decision is made on the basis of one cue of the highest validity. Such a strategy seems to be the simplest, particularly when making a complicated choice. The second strategy preferred by the elderly is the Take Two strategy where the decision is made on the basis of two most valid cues (Gigerenzer 2007; Mata et al. 2007). Studies clearly indicate that when making decisions seniors have more difficulty in processing an excessive number of alternatives. They need significantly more time to make their choices, prefer simpler strategies that are less burdensome to cognitive processes and use less data treating them as equally important. In sum, in situations requiring substantial cognitive involvement, in older age the decision-making performance declines.

These considerable changes in cognitive structures observed in older age are not identical to the changes in emotional performance. Antonio Damasio points to the importance of the so called somatic markers being physiological signals sent by our bodies on the basis of our past experience in order to warn us against biased decisions. These signals are emitted before we even realize the weight of the situation. When making their decisions, both older and younger people are guided by emotional cues. Among a great deal of data they tend to choose and remember those that evoke pleasant emotions (Kovalchik et al. 2005).

3.6 Conclusions

As many scientific works emphasize, the impact of affect on decision making is significant. The individual's affective state influences the course of their decision-making process as well as their satisfaction with undertaken actions, thus becoming valuable information for their future performance. The information with a specific emotional load plays an important role in cognitive processes. Emotions modify information processing, thus influencing the end effect through changing the contents of our beliefs, judgments or our mode of reasoning. The complexity of affective processes as well as the role of other factors in decision making imposes the necessity to conduct inter-disciplinary studies. Due to emotions, individuals categorize and evaluate available goods. Basing on our own experience or preferences, we increase the likelihood of making the right choices. On the other hand, decision making leads to satisfying our individual needs and to experiencing expected emotions.

The adoption of the hypothesis about a significant impact of emotions on decision making contributed to better understanding how emotions distort this process and how they can improve our decision-making performance.

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Chapter 4
Application of Neuroscience in Management

Łukasz Sułkowski and Michał Chmielecki

Abstract Examination of the human mind is a subject of various disciplines that belong to the natural or social sciences, or that straddle the line between them. The most important include biology, psychology, neurology, neuroscience, psychiatry, anthropology and sociology. The interest in exploring the potential links between neuroscience and management as a social science as well as organization studies is constantly growing. This brings a fair amount of attention to mental processes and their role in explaining human behavior and effectiveness. The aim of this chapter is to analyze the application of neuroscience in management.

Keywords Neuroscience • Management • Neoevolutionism • Neopositivism • Management paradigms • Neuroleadership

4.1 Neurosciences

Most people believe that neuroscience is just about developing a map of the brain and identifying what each part does. If it were that simple, there wouldn't be any need for management scholars and practitioners to take notice. Why should it matter—at least for management—where it gets done provided it is clear what the brain does? The reality however, is that neuroscience has started to make clear the principles of brain organization and functioning, which in turn are fundamentally changing what we think the brain is trying to achieve. Another wrong notion is that neuroscience focuses only on the more basic processes of perception, inspiration and deeds shared by living beings, at the cost of higher functions found only in humans. As we shall see, neuroscience today is exploring the most subtle aspects of human social perception and cognition.

According to Ochsner and Lieberman (2001), neuroscience is as much a biological science and a social science (Table 4.1).

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_4

Table 4.1 Disciplines of neuroscience (own study)

Neurosciences						
Neurology	Neurobiology	Neurochemistry	Neurophysiology	Neuropsychology	Neuropsychoterapy	Cognitive neuroscience

4.1.1 Neurology

Neurology is the part of human medicine that deals with the study of nervous system disorders. This means dealing specifically with the diagnosis, therapy and prevention of sickness in the nervous system including peripheral, central and vegetative nervous system disorders.

4.1.2 Neurobiology

Neurobiology is the study of the structure, function and development of nerve cells and the nervous system. The term neurobiology can be used interchangeably with neuroscience. However, Neurobiology specifically is the study of the brain and its biological functions while Neuroscience is the broader science of the entire nervous system.

4.1.3 Neurochemistry

This is the study of the chemical processes at a cellular level in the nervous system. The primary focus of Neurochemistry is on the chemical transmitters in the synapses and how the receptors function as well as the function of the hormone system.

4.1.4 Neurophysiology

Neurophysiology, a subdiscipline of physiology, is the study of our nervous system's performance and reaction to external stimuli. The dynamic processes between nerve cells and how they process information is the main focus of Neurophysiology.

4.1.5 Neuropsychology

Neuropsychology refers to the study of the border between psychology and the neurosciences. Here, with neuroscientific technologies, neuropsychologists study human behavior. For instance, a decision-making task will also be analyzed using brain scanning to identify which areas are activated in making specific choices. The

objective is to connect behavior to diverse regions of the brain and their specific processes and functions.

4.1.6 Neuropsychotherapy

Neuropsychotherapy leverages insights from neuroscientists to treat psychological disorders. This is based on the understanding that the brain forms its world view through structural communication in the brain and that personality dysfunction can also be represented by dysfunctions in the brain biology. Also, the brain's biology shows that the brain is plastic and so new pathways and behaviors can be shaped and reshaped. Additionally, neuropsychotherapy seeks to comprehend the brain's chemical processes and how they are manifested in different cognitive processes and are also linked biologically through the brain's ability to build respective receptors to these chemicals.

4.1.7 Cognitive Neuroscience

Cognitive neuroscience deals with the study of biological processes that bring about cognition specifically focusing on the neural connections involved in mental processes such as reward, attention, memory and fear.

To sum up. Neuroscience can be defined as the study of how the nervous system and the brain functions. Neuroscience can provide many interesting answers in the field of management.

4.2 Neurosciences, Neoevolutionsim Paradigm and Management

The neoevolutionary paradigm in the area of social sciences is in the initial stage of development. The use of neoevolutionism in research on individuals, cultures and societies involves a radical change of perspective in the social sciences and leads to man being dethroned by science once again (Buss 2008). "The history of science indicates that humanity must have gradually rid itself of the conviction of its central role in the universe. The milestones of the emancipation of thought were: the Copernican Revolution, Darwinism and quantum mechanics. Copernicus put an end to the theory that the Earth was the center of the universe. Darwin and his successors destroyed the image of man as the crown of all living creatures. Twentieth century physicists described a fundament of reality that proved unimaginable for man and was based on a coincidence. The time has thus come for another

scientific revolution. Neoevolutionism forces its way into the social sciences and leads the challenge to the traditional vision of the subjectivity of man in favor of a hybrid called 'the gene vehicle' (Dawkins 1976)" (Sułkowski 2012a).

Pinker (2004) believes that, neoevolutionism is characterized by assumptions that are contrary to the standard model of the social sciences. In objectivism, which is the main postulate of both neopositivism and neoevolutionism, the social world is recognisable through science. In epistemological monism, the mental world can be described by means of such categories of the physical world as information and calculations with the use of methods from the natural sciences (Dawkins 1976). Verificationism and falsificationism involve practicing science through seeking to confirm or reject scientific theories (falsificationism by C. Popper) (Popper 1934). Epistemological universalism (anti-relativism) is a belief in the possibility of reaching general and unquestionable rules of science based on the correspondence theory of truth. In cultural universalism, surface cultural diversification hides deep, universal mental mechanisms that constitute "human nature" (Pinker 2004). In comparison, according to evolutionary cognitivism, human cognitive skills find their place in the brain, whose development results from the coupling of genes and the environment, and were created in the process of biological evolution (Sułkowski 2012a, b) (Table 4.2).

Neoevolutionism itself has certain characteristics of a paradigm, mainly because it proposes a coherent epistemology and methodology based on a theory that is highly verified and is used in many disciplines of science. Nevertheless, in biology, the neoevolutionary theory is a dominant and verified concept which is based on a great number of scientific proofs; whereas in the social sciences neoevolutionism is one of many concepts for research on the human mind, culture and society, alongside functionalism, critical theory or interpretivism (Sułkowski 2012b).

Bradie believes that neoevolutionism in the social sciences realizes two separate epistemological programs (Bradie 2004). The first one examines the evolution of human cognitive mechanisms, and the second one—the evolution of scientific theories. The evolution of cognitive mechanisms is an issue largely under empirical research that analyzes the functioning of the brain. The evolution of scientific theories is an epistemological and philosophical issue in which the theory of evolution is a source of analogies and metaphors rather than cause-effect explanations (Sułkowski 2012a, b).

Although there are many aspects of neuroscience, social cognitive neuroscience specifically may have the most applicability to studying leadership. Social cognitive neuroscience as defined by Ochsner and Lieberman (2001), is a developing, interdisciplinary field that seeks to understand the interactions of humans at the intersection of cognitive, social and neural spheres of science.

Recent developments in this region present proof of how leaders are supported in various aspects of cognition and behavior by the human brain. For example, a proposal on using neural basis are shaped to construct social knowledge, particularly the approach to social inferences about thoughts, intentions and feelings of others, was presented by Adolphs (2009).

Table 4.2 The standard model of the social sciences versus neoevolutionism (Sułkowski 2012a, b)

Criterion	The standard model of the social sciences	Neoevolutionism
The nature of reality and cognition	Dualism	Monism
Characteristics of cognition	Subjectivism and inter-subjectivism	Objectivism
Epistemological assumptions	Interpretivism or constructivism	Verificationism or falsificationism
Influence of the context of cognition and culture	Cultural or cognitive relativism	Epistemological and cultural universalism
Subject's cognition of reality	Essentialism	Evolutionary cognitivism
Research methodology	Understanding, hermeneutics, phenomenology (search for meaning)	Cause-effect explanation, experimental method (search for explanation)

David Rock (2008) labeled "NeuroLeadership" as the point where management and/or leadership with neuroscience intersects. According to Ringleb and Rock (2008), NeuroLeadership focuses on the application of neuroscience in management training, leadership development, education, change management, consulting and coaching. NeuroLeadership being an emerging field, we expect to have a better understanding of the science behind neuroscience and then use that knowledge to improve leadership practices, change management efforts, and positively affect creativity and innovation, as well as engage employees, stated Schaufenbuel (2014).

Lieberman et al. (2007) reported that brain study, specifically within the area of cognitive, social and emotional neuroscience is beginning to give some fundamental brain insights that we can apply in the real world. He went on to state that the biological foundations of the way humans interact are explored by social neuroscience and covers various topics that have a different degree to which they can be practicable and explicitly tested. These topics include: mind theory, self theory, emotional regulation, mindfulness, stereotyping, attitudes, social pain, empathy, status, fairness, connectedness, collaboration, morality, persuasion, compassion, trust, deception and goal pursuit. Most of these topics and issues are applicable to workplaces and leading the people within those workplaces.

Schaufenbuel's whitepaper gives us some application of neuroscience to three such areas, providing some initial information. They include: Leadership, Change management and Innovation.

1. **Leadership:** Neuroscience findings such as trust and relationship building can easily be applied by Human Resource professionals to their leadership development activities. The conjecture is that great leaders open pathways in the brains of their employees that support engagement and positive working relationships.

Schaufenbuel states further that findings of neuroscience are very helpful in connecting the dots between human interaction and effective leadership practices. As we continue to map the human brain, we expect to find out more about the way the brain functions and how leaders can best apply this knowledge in leading people and organizations.

2. **Change management:** At the very least, neuroscience corroborates what has been known to industrial psychologists and managers for decades: People are afraid of change! Change is usually perceived as a threat since the brain is hardwired for survival. The thought is that our brains are looking out for threats subconsciously, five times in a second. Some people may be wondering how this is relevant to today's organizations. It matters because workplaces are filled with uncertainty. Think about the great rise in mergers and acquisitions, loss of jobs, etc., these caused a lot of stress and fear, brought about by uncertainty. A deep understanding of the fear of change and of the unknown has huge implications for leaders, managers, and other change agents as they bring about change. Schaufenbuel noted that by focusing on the positive aspects of the proposed change, asking direct questions and listening actively to people's concerns, leaders and change agents can help reduce stress and nervousness for those that will be affected by the change. Applying this strategy can improve the ability of the brain to adjust how it'll respond to the change and see it as nonthreatening. As a leader, you must understand that the feeling of threat is contagious. Seeing colleagues or leaders around us feeling worried and scared will further spread the fear. Uncertainty negatively affects the memory, ability to concentrate, job satisfaction, etc.
3. **Innovation:** Schaufenbuel and her associates also reported that neuroscientists have discovered two capabilities of the human brain attached to innovation and creative thinking. First and foremost, is the default network. This network is capable of transcending or envisioning what it looks like to be in a different place or time. Second, is the control network in the area of the brain that keeps people on task. By making use of this strategy, leaders can connect with the default network to egg on innovation and the control network to encourage focus. According to this logic, it is advisable that organizations set up programs like those at Google which gives employees protected time to work on any inspired project of their choice that in some way moves the organization forward. Also, companies may wish to create time blocks when staff put away any form of distraction including cell phones to enable them focus on specific assignments instead of multitasking.

The greatest amount of insight into how neuroscience can be applied to people in the workplace, especially leadership and related issues has been provided by David Rock and Schwartz (2006). According to Rock (2012), Gordon and Lieberman & Eisenberger, have identified two promising themes from social neuroscience. The first is that most of the motivation that drives our social behavior is ruled by an overarching organizing principle of reducing threat and making the most of reward (Gordon et al. 2008). Secondly, more than a few areas of social experience relies on

the same brain networks used for survival needs to maximize reward and reduce threat—Taylor et al. (2008). Another way to put it is that the brain treats social needs exactly the way it treats its need for food and water.

4.3 The Methodology of the Social Sciences

Methodology adequate for social sciences facilitates an understanding of the functioning of objects at the highest level of complexity. Regardless of the cognitive perspective, problems of the society, organization, culture or human psyche are considered most difficult, as far as cognition is concerned. The systemic school indicates the highest level of the organization, complexity and emergence of mental and social and cultural processes (von Bertanlaffy and Sutherland 1976), while the symbolic-interpretive paradigm, hermeneutics and phenomenology reject the possibility of reducing the world of 'sense' and 'understanding' to the level of the natural sciences (Geertz 1973). Most postmodern scholars are skeptical of the cognition of the mind and culture (Rorty 2009). Nevertheless, it seems that research on the mind, culture and society is making progress, within many paradigms and disciplines of science. It is therefore worthwhile to reflect on concrete research problems and possible methods of their analysis (Sułkowski 2012a, b).

Examination of the human mind is a subject of various disciplines that belong to the natural or social sciences, or that straddle the line between them. The most important include biology, psychology, neurology, neuroscience, psychiatry, anthropology and sociology. The human psyche can be analyzed on the basis of (Alexander 1989):

- Functional, physiological and morphological examination of the brain.
- Clinical, psychological, psychiatric and neurological examination.
- Medical history and psychoanalytical examination.
- Research on AI, neural and cell networks (mathematical modeling).
- Palaeoanthropological research on hominids and anthropoids.
- Ethological, behavioral, sociobiological and primatological research, comparing humans to other species (Lorenz 1950).

Society, organization and culture in general can be examined directly by means of all research related to the human mind, but also in an indirect manner, by trying to reach the level of the consciousness of society, culture or other group entities. The research conducted primarily includes (Sułkowski 2012a, b):

- Qualitative research (ethnographic and biographic research, focus groups and in-depth interviews, grounded theory) (Denzin and Lincoln 2005).
- Observation of social and cultural processes.
- Social experiments and quasi-experiments (Shaughnessy et al. 2009).
- Interrogative research with participants of social situations (surveys and opinion polls) (Nowak 2007).

- Statistical data analysis (Babbie 2008).
- Descriptive studies and analysis of historical data.

Scientists don't just use scientific technologies as tools to explore areas of interest; new equipments describe new scientific fields, and removes old limitations—e.g., astronomy was shaped by the telescope and removed a lot of speculations. We can also say the same of economics; its limitations have been continually reshaped by tools such as econometric, mathematical and simulation methods (Sułkowski 2009).

Also, the recent interest in neuroscience by psychologists is as a result of new techniques. In this section, we review some of them:

4.3.1 Brain Imaging

Presently, brain imaging is the most popular tool for neuroscientists. This involves comparing people performing "experimental" tasks and "control" tasks. The difference between images taken while the subject is performing the two tasks gives an image of the areas of the brain that are set off by the experimental task.

4.3.2 Single-Neuron Measurement

Brain imaging techniques measure only the activity of circuits comprising thousands of neurons. To measure single-neurons, small electrodes are inserted into the brain with each of these electrodes measuring the firing of a single neuron. As discussed below, there have been some major findings in the study of single-neuron measurement believed to be relevant to economics. One constraint of this measurement is that, it is mostly restricted to animals because inserting the wires harms neurons.

4.3.3 Electrical Brain Stimulation (EBS)

Another technique that is largely restricted to animals is Electrical Brain Stimulation. Psychologists James Olds and Peter Milner in 1954, found out that rats could be trained to perform novel behaviors if rewarded by short pulses of EBS at certain locations in the brain—Olds and Milner (1954).

4.3.4 Brain Damage in Humans and Psychopathology

Nearly all types of illness have been linked to specific areas of the brain. Developmental disorders (e.g., autism), chronic mental illnesses (e.g., schizophrenia) and degenerative nervous system diseases help in understanding how the brain functions. Sometimes, the progression of a disease has a controlled pathway in the brain. At first, Parkinson's disease (PD) affects the basal ganglia and then extends to the cortex. Therefore, the early symptoms of PD offer clues as regards the function of the basal ganglia (Lieberman 2000).

Both neuroscience findings as well as methods will undoubtedly play an increasingly prominent role in management. Indeed, a brand of neuroeconomics shaped by neuroscientist is already emerging and attracting attention, whether management scholars approve of it or not (e.g. Montague and Berns 2002; Kable and Glimcher 2002). Participating in the development of a shared intellectual enterprise will help us ensure that the neuroscience helps answer management questions we care about.

Research on organization, society and culture belongs to various disciplines of the social sciences, such as economics, cultural anthropology, sociology, linguistics and cultural studies.

Neoevolutionism, which to some extent imitates neopositivism, using equally strict cognitive criteria for the social sciences as for the natural sciences, constitutes an ambitious cognitive attempt, while trying to avoid its mistakes. Therefore neoevolutionists do not seek certainty of cognition, and are not enthusiasts of full verificationism and focus on the development of empirical research, while rarely dealing with problems of the philosophy of science (Table 4.3) (Sułkowski 2012a, b).

4.4 Neoevolutionary Methods in Management

Management is dominated by archaic social basic theories related to human nature, the mind and society. For instance, one can quote excellent theories of motivation developed by A. Maslow and F. Herzberg, which are nevertheless inadequate to the modern level of knowledge in psychology and sociology (Maslow 1943; Herzberg 1959). A significant amount of research indicates the evolutionary origin of the complexity of motivational mechanisms, which can be explained, for example, by the modular structure of the mind (Tooby and Cosmides 2000; Gazzaniga 2000; Fodor 1983) or by needs originating from the human environment (competition in a social group) (Sułkowski 2012a, b).

Attempts to apply neurosciences in management studies have been very limited. The use of neurosciences in describing human behaviors in the organizational process is still scarce. From the point of view of management studies, the neoevolutionary methodology is important mainly as a source of basic theory. Models of human behavior related to exertion of power and leadership, creation of social structures, the process of forecasting the future and planning, the creation

Table 4.3 The levels of neoevolutionary epistemology (Sułkowski 2012a, b)

Level	Content	Relationships
Paradigm	Scientific realism	Basic level, philosophy of science and generalized theory applied to many disciplines of the natural and social sciences
	Objectivism	
	Reductionism	
	Verificationism, falsificationism	
	General theory of evolution	
Methodology	Scientific method modeled on the natural sciences	Intermediate level of general rules for research within the paradigm
	Neopositivist	
Method	Social experiments	Operational level, proposals of cognitive and pragmatic methods
	Brain examination	
	Standardized observation	
	Statistical methods	

of culture, cooperation with other people and organization of work—all facilitate the creation of effective management rules (Sułkowski 2012a, b).

It seems, however, that examining the process of organization and management could also take the form of research programs using the neuroscience methodology. Such research could formulate cognitive objectives in the form of identification of biological conditions of organization, management, power and leadership, organizational culture, the process of planning and strategizing, and many other aspects of organization. In such programs, it would be possible to conduct interdisciplinary research based on methodological pluralism (Sułkowski 2012a, b) (Table 4.4).

The methodology of neoevolutionism has proven its efficiency with valuable research in evolutionary psychology and neuroscience. Research programs conducted gather increasingly rich empirical material that makes it possible to describe the human world being the subject of the social and humanistic sciences. Research results lead to a new image of the human mind, society and culture, which is largely inconsistent with traditional assumptions regarding human subjectivity accepted by the social sciences (Sułkowski 2012a, b).

Therefore it seems that several postulates should be proposed in the methodological sphere, which derive from the rapid development of the neuroscience methodology:

- In the various scientific disciplines related to man, culture and society, an analysis should be made of the cognitive adequacy of the neuroscience methodology.
- Representatives of the social sciences, especially sociologists, economists, specialists in management, anthropologists and linguists, should start using the methodology developed by the neurosciences.
- Research programs conducted by interdisciplinary teams and facilitating the exploration of human behavior should be integrated.

Table 4.4 Suggestions for integrated research programs involving management studies using the neoevolutionary methodology (Sułkowski 2012a, b)

Area of management	Sample research questions	Hypotheses	Research methodology
1	2	3	4
Organization	To what extent is organization genetically conditioned? What is the influence of evolutionary variables on the process of organization? Does the process of organization involve genetic-environmental coupling. If yes, what does this involve?	Organization is a natural feature of human community Organization is based on cooperation and competing for resources Organization is man's primary need Organization is a coupling of unconscious and conscious actions	Ethnological research, comparative studies of primitive communities Literature and anthropological data on primitive communities Social experiments using brain examination Palaeoanthropological excavations of primitive people, hominids and anthropoids Comparative primatological studies (chimpanzees) Quantitative comparative intercultural studies in search of cultural universals (survey method with large representative samples) Qualitative intercultural studies exploring cultural diversity (in-depth interviews, ethnomethodology) Qualitative comparative studies—studies of cases of organizational activities
Power	What are the sources of power in a social group? Is power genetically conditioned? How flexible is the hierarchy in a human community?	Power stems from the animal pecking order People have various levels of need for the exertion of power On average, women have a lower need for power	
Leadership	To what extent does leadership derive from innate or acquired characteristics? How does informal leadership form in a small group?	Leadership skills derive from the innate and acquired characteristics of a leader and from the social characteristics of the group Leaders in a small group emerge from among those individuals showing Machiavellian intelligence	
Organizational culture	Does culture emerge spontaneously in an informal group? How can leaders form the culture of their groups?	The culture of a small group is inherently xenophobic. Organizational culture cannot be managed	
Planning and strategy	Among living creatures, is man the only one who attempts to foresee the future? Are planning skills related to brain features (neuronal level)?	Planning appears only in humans and within a group of people Strategy is an advanced planning skill	

- The neuroscience perspective should be included in training programs for researchers in all scientific and humanist sciences.

4.5 Conclusions

The chapter concludes that neuroscience research methodology has already provided quite important insights regarding the management and especially, leadership, innovation, change management and decision making.

A critical look at the application of the neoevolutionary paradigm in the management sciences initially shows its inadequacy on the subject of interest of organizations and management. From the point of view of biological evolution, economic entities, markets and sectors are not the units of research and scientific scrutiny. However, a more profound analysis leads to the conclusion that the basis of the functioning of all market components is human behavior, which can be described from the evolutionary point of view. The management sciences should accept challenges that stem from the development of the neoevolutionary paradigm, and especially form neurosciences because all actions related to organization and management are marked by biological evolution (Sułkowski 2012a, b).

Applying the neurosciences methodology to social sciences leads to creative results. It allows for a verified theory describing human activities, appropriate for use in a number of social sciences. Neuroscience is more and more effective in explaining and foreseeing human behavior, often distancing itself from a purely behaviorist vision of human nature.

Neoevolutionism and especially neurosciences is the subject of many controversies, related mostly to its departure from the traditional vision of people and society rooted in European culture. This reductionist approach undermines the vision of human nature based on subjective and rational decision making. Its explanations of behavior refer to deep motivations hidden in the human mind (Sułkowski 2012a, b). However, there is much to be done, and more neuroscience research will further influence management field.

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Chapter 5
Neuroeconomics: Genesis and Essence

Danuta Miłaszewicz

Abstract Making choices and decisions is one of the most important issues in the theory of economics. Neuroeconomics is a subfield of behavioral economics which uses empirical evidence of limits on computation, willpower and greed to inspire new theories of economics. The aim of chapter is to present the milestone on the development path of neuroeconomics, the essence of this science and areas of its researches. The literature analysis method and the induction and deduction method are applied here.

Keywords Neuroeconomics • Definition • Creation • Research areas

5.1 Introduction

Neurosciences which, "analyze the nervous system, including the brain, to understand the biological basis for behavior" (Bloom 2008: 3) have the capacity for the scientific examination what processes occur in the human brain during thinking, feeling, wishing, learning, or entering interactions with the surrounding environment. Undertaking the attempt to clarify thought processes, feelings, emotions, decision-making processes (choice or lack of choice) allows us to explain and anticipate conducts and attitudes of people. The dynamic development of this science has become on the other hand the basis to deepen searches conducted within the scope of other disciplines, going far beyond medicine. Thanks to the above mentioned, such disciplines of knowledge as neuropsychiatry, neuroinformatics, neuropsychology, neurocognitive science, neurophilosophy, neurodidactics (neuroeducation), neurosociology, neuromarketing, neuromanagement, neuroleadership, neuroaccounting or neuroeconomics have been developed. The latter one in general may be determined as the field developing slightly beyond the main stream of economics. The interdisciplinary approach implementing the

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_5

possibilities of the brain imaging and cognitive neuroscience to deepen the knowledge in the field of economics. Neuroeconomics has emerged on the canvas of the neoclassical economy, or rather criticism of its assumptions with regard to microfoundations for individual's decisions. Utilizing new research methods and techniques, it criticizes assumptions and creates new possibilities with regard to the clarification of economic decisions undertaking processes.

The main goal of the study refers to the presentation of the genesis of neuroeconomics, its essence, research areas with the specification what possibilities have occurred in the field of economic decisions studying in relation to the implementation of advanced technologies of the brain imaging. The execution of that purpose requires the implementation of the method for the subject matter literature analysis and tits synthesis.

5.2 Milestones Toward the Creation of Neuroscience

One of the most important issues in the theory of neoclassical economics refers to the manner of undertaking economic decisions by individuals. According to its assumptions, it takes place in a rational manner—the individual operates in compliance with its own function of utility, undertaking economic decisions on the basis of full information (the assumption on the absolute knowledge[1]), with the unlimited possibilities, the individual acts in its own interest, in such a manner so as to maximize the expected utility and the individual follows preferences which meet determined requirements—axioms.

The theory of the expected utility has been often criticized, pointing out that in reality the individual does not undertake decisions according to the manner highlighted by the theory. The need for modification occurred first of all when it started to be perceived also as the descriptive theory, that is, the theory describing how a rational individual behaves and how to use it in that role for other economic models. Very often, researchers have formulated rules governing the expected utility hypothesis on the basis of conducted experiments, based on the game theory. The purpose of such experiments referred to the examination of individual preferences and choices as well as the presentation of the individual's decision-making processes occurring in reality. Such experiments may be considered as the first milestone on the development path of neuroeconomics. Their results created the foundation to formulate examples which did not confirm the postulate of the expected utility (so called paradoxes of rationality, that is, the discrepancy between the theory and reality, e.g. Allias in 1953, Ellsberg in 1961). Moreover, such

[1]The hypothesis regarding the absolute knowledge means that the researcher assumes that people undertake economic decisions in such a manner as if they knew all the facts which in reality could exert influence on their decisions.

experiments highlighted a series of inconsistencies between actual conducts of persons examined (players) and theoretical optimal conducts models (axioms).

The second milestone leading to the neuroeconomics development shall refer to the works of Herbert A. Simon, who has elaborated a limited rationality concept. As one of the first, he criticized and negated the paradigm adopted in economic sciences, and in particular the assumption on ideal rationality with undertaking economic decisions as unrealistic ones due to a limited cognitive capacity of the decision maker. The decision maker, in his/her opinion, focuses rather on a satisfactory choice, satisfying certain adopted by him/her requirements with the implementation of a limited rationality (Simon 1972, 2000). In spite of the fact that the decision maker attempts to be rational, such rationality has certain visible limits with a dual nature—internal (mental) and external (environmental) limits. The decision maker is limited by intrinsic values, reflexes, skills, social standards and habits, incomplete information on alternative choices, as well as his/her own computational capabilities. Being aware of his/her limited possibilities, the decision maker knowingly ignores information or knowledge, the acquisition of which would outdo benefits that could be brought by such information or knowledge (Simon 1990).

For the purpose of enhancing the current theory and the creation of the more realistic model for making a choice, Simon postulated to refer to the literature in the field of psychology and so called procedural rationality, named by him the psychological theory of rationality. According to Simon, the transition from rationality which denominated the classical economy (instrumental rationality), to procedural rationality requires a change in the manner of approaching the science "from an emphasis on deductive reasoning from a tight system of axioms to an emphasis on detailed empirical exploration of complex algorithms of thought" (Simon 1976: 147).

Simon, recognized as the "behavioral economy prophet" (Barros 2010), believed that one of the tools useful with regard to studies concerning the rational choice hypothesis refers to the creation of a simplified laboratory simulation in order to observe human conducts. Thus, he supported conducted experiments which were not perceived by the traditional economy as reflecting proper research methods (Miłaszewicz 2016: 16–17). On the other hand, the behavioral economy resorts to experiments, in particular, the experimental economy, while their implementation and development shall be considered as a subsequent milestone toward the development of neuroeconomics. The fact that Simon was awarded in 1978 with Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel for his pioneering research into the decision-making process within economic organizations came as a confirmation of the necessity to take into consideration numerous factors within the scope of the economic analysis.

Simon's works supporting the consideration of numerous psychological factors in studying decision-making processes constitute an important step toward the development of the psychological trend of the economy as well as the basis for the so-called "old" behavioral economy (Sent 2005: 230; Altman 2000, s. XVII; Frantz 2013: 13–14). On the other hand, achievements of two psychologists, Daniel

Kahneman and Amos Tversky, referred to by Simon in his Noble Speech (Simon 1978: 361) are directly associated with the "new" behavioral economy.

The reason for differentiating between the "old" and the "new" behavioral economy refers to differences in perceptions of the human brain functioning and normative suggestions regarding rationality. Adopting such approach, the achievements of Simon demonstrate a limited influence on the development of the "new" behavioral economy (Angner and Loewenstein 2012: 659), as the works of Kahneman and Tversky, focusing initially on decision-making mechanisms in conditions of hazards, "started from the rationality assumption that has characterized mainstream economics and next analyzed departures from this yardstick, rather than developing an alternative one" (Sent 2005: 230) and "capture human cognitive biases within a framework of utility maximization" (Bossaerts and Murawski 2015). The basic discriminant of the "new" behavioral economy refers in fact to attempts of the implementation of a bigger dose of reality into the analysis of decision-making processes, however, on the other hand, it is less critical with regard to the neoclassical economy, recognizing instrumental rationality as the model and observing from that perspective actual mechanisms of human conducts as subjected to errors. It introduces the notion of heuristics and the theory of two systems of thinking (quick, automatic, based on associations, emotional thinking *versus* free, rational, conscious thinking) into the studies over decision-making processes (Kahneman 2002: 1451; Kahneman 2012: 31 and others). A. Tversky and D. Kahneman related the notion of heuristics to their conception of cognitive deviations featuring human thinking and decision-making processes. In their understanding, heuristics refer to the strategy of reasoning handled by people in an unconscious manner, ignoring some information and more complex methods of reasoning so that the decision-making process is quick and absorbs less energy (Tversky and Kahneman 1974: 1124; Tversky and Kahneman 1992: 317). Human brain implements heuristics due to cognitive limitations, and heuristics themselves lead to decisions less favorable than optimal ones or they violate axioms of rational decisions.

The fact that D. Kahenem was awarded in 2002 with Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel "for having integrated insights from psychological research into economic science, especially concerning human judgment and decision-making under uncertainty" (The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2002) shall be perceived as a subsequent mile step in the process of neuroeconomics development and recognition of changes of the paradigm in economic sciences. Kaheman obtained the prize together with V. Smith, who was honored "for having established laboratory experiments as a tool in empirical economic analysis, especially in the study of alternative market mechanisms" (The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2002). Those awards strengthened the position of such sub-fields of the economic knowledge as the economic psychology, behavioral economy and experimental economy.

However, V. Smith's perception of rationality presented within the scope of so-called ecological rationality theory, was competitive toward the one presented

by Kaheman. On the canvas of the psychology itself it was developed by G. Gigerenzer and A. Kruglanski. Their point of view was presented in the form of so–called Neurosciences:adaptation rationality adaptation rationality and it is equivalent to the view presented by Smith, as they share not only a critical approach to the realism of neoclassical economy assumptions, but also negation of instrumental rationality as the normative conception. They may be also distinguished by the approach to heuristics themselves. V. Smith is of the opinion that the immanent feature of the human brain and its limited calculation resources (Smith 2005). In the light of adaptation rationality, heuristics are decision-making strategies, rules adopted to solve a given decision-making problem (Evans 2010: 98). They demonstrate a normative and descriptive character, they are based on the compromise between the precision of the forecast and efforts undertaken to assess it. The adaptation decision maker implements heuristics in a conscious manner and strategically modifies them accordingly to the changing surrounding (Sloman 2002: 382; Frederick 2002: 668). Heuristics related to a constant decision-making compromise maintained by the decision maker between the precision of the decision and the cost of its undertaking. Effective decision-making strategies on purpose ignore a part of information. People undertaking decisions in such a manner achieve satisfactory, however, not optimal results (Gigerenzer 2008: 9).

Authors of adaptation rationality highlight that it is not possible to assess decisions exclusively from the perspective of axioms of economic rationality. One shall take into consideration first of all the role of the decision-making environment in which the decision is undertaken, as it determines a better or worse effectiveness of the decision. On the other hand, predispositions and the personality of the decision maker which influence his/her decisions play a role. The above mentioned aspect is more precisely expressed by Gigeranzer himself (2015: vii) highlighting that the basic principle of his research program refers to the claim that "behavior is funcion of mind and enviroment".

Studies maintained within the scope of behavioral economy led to the discovery of the set of mechanisms confirming that the assumed so far by economists rationality of *homo oeconomicus,* exists in principle, however, it demonstrates deviations from the model rationality which in a significant manner decide about the conducts of individuals. Thus, rationality shall be perceived rather as a personal entity and not a subpersonal one (Stanovich 2011: 5).

Numerous regularities in conducts of individuals, confirmed by experiments, highlight the existence of a series of mechanisms, biologically in-built into the human body causing that the choices made by individuals considerably deviate from models stemming from the expected utility. Additionally, such studies have revealed a tremendous complexity of the decision-making aspect. They would have been, however, impossible without the development of medical techniques allowing for a more precise *in vivo* examination of the nervous system and the human brain at the moment of the decision-taking. Such techniques allowed to take a closer look at the brain during its operation and to look for relations between its conditions and states of mind. They allowed to look at the whole spectrum of

aspects in an entirely new manner, empathizing the significant role of unaware and uncontrolled processes in undertaking every day decisions.

First non-invasive methods of examining the living brain were applied in the second half of 20th century. They included: electroencephalography (EEG), computed tomography (CT) and computerized axial *tomography* (CAT), techniques implementing positron emission as positron emission tomography (PET) and single-photon emission computed tomography (SPECT). Other devices applied for that purpose refer to magnetic resonance imaging (MRI) and functional magnetic resonance imaging (fMRI). The most recent methods include: magnetoencephalography (MEG), transcranial magnetic stimulation (TMS) and single neuron imagining (SNI)[2].

Examining the living brain with various methods of neuroimaging created new possibilities with regard to discovering secrets of that organ and it constitutes a subsequent milestone leading to the development of neuroeconomics. Those methods allow to image the activity of various centers of the brain exactly to the millimeter and the millisecond as well as to examine reactions of individual neurons. They enable direct inhibition or activation of such areas with the magnetic field and pharmaceuticals. Their effects are supplemented by techniques of examining various peripheral systems in the human body as well as the study referring to the psychological role of hormones and neurotransmitters. Thanks to such methods and techniques we obtain answers to questions in economy referring to motives of the individual in the decision-making process.

5.3 The Essence of Neuroeconomics

Neuroeconomics refer to a relatively new field of knowledge commenced in 1990s of 20th century. The moment of its birth is associated with the article by M. L. Platt and P. W. Glimcher published in 1999 *Neural correlates of decision variables in parietal cortex,* which formalized for the first time an economic-mathematical approach for the physiological study of decision making, which pointed to potential neurobiological constraints on the algorithmic processes involved in decision making (Sharp et al. 2012).

According to T. Zaleśkiewicz (2013: 446) neuroeconomics refers "to the field of science which examines neuronal correlates of decisions and economic assessments". In the opinion of et al. neuroeconomics is the study of the biological microfoundations of economic cognition (includes memory, preferences, emotions, mental representations, expectations, anticipation, learning, perception, information

[2]The description of methods and devices used for neuro-imaging, that is for examining the structure and functions of the living brain, may be found in: (Kosslyn and Rosenberg 2006: 133–138; Camerer 2007; Jaśkowski 2009: 42–77; Fritz 2011: 18–27; Kable 2011).

processing, inference, simulation, valuation, and the subjective experience of reward) and economic behavior (Camerer et al. 2015: 153).

However, most often neuroeconomics may be defined as an interdisciplinary field that brings together psychology, economics, neuroscience, and computational science to carry out in vivo investigations of the brain processes involved when individuals make economically relevant decisions (Mohr et al. 2010; Sharp et al. 2012).

According to some researchers, neuroeconomics has its root in behavioral economics (Mohr et al. 2010) or behavioral economics is the first set of shoulders that neuroeconomics stands on (Sharp et al. 2012). Other researchers emphasize that neuroeconomics is a subfield of behavioral economics which uses empirical evidence of limits on computation, willpower and greed to inspire new theories. It is also a subfield of experimental economics because requires mastery of difficult experimental tools which are new to economists And to many neuroscientists supply theories and experimental designs for neuroscience (Camerer 2007).

The combination of the traditional economy based on the hypothetical and deductive method as well as behavioral economy taking into consideration psychological aspects of human conducts, and simultaneously, the implementation of experimental economy tools and methods applied by cognitive neuroscience allowed for better examination of economic entities with regard to decision-making. Representatives of such fields dealing so far with the examination of the decision-making process from their own perspective, have undertaken, within the scope of neuroeconomics, the cooperation allowing for multi-aspect analysis of complex phenomena. The implementation of neuroscience tools has effected the opportunity of combining economic experiments with a simultaneous observation of the activity of the nervous system of the human being and the human brain. The development of technologies implemented in neuroscience has additionally created the platform for cooperation between representatives of natural and social sciences, in particular biology. Its role should be extended to providing some of the foundations of theories of human behavior. The contribution of biology to research on choice should not be limited to providing a mechanistic account of human decision-making. "Biological variation may be used to identify potential behavioral variation that would be missed (or absorbed by the error term) if one were to follow economic theory alone. Biologists observe phenomena relevant to choice that traditional models do not capture, and they have research methods to manipulate these phenomena (e.g., pharmacological interventions) that behavioral scientists do not have" (Bossaerts and Murawski 2015).

Interdisciplinary aspect of neuroeconomics constitutes a tremendous challenge for researchers and conducted by them studies. Neuroeconomics is becoming skilled in the sheer diversity of methods used by the different parent fields. Thus, a neuroeconomist shall be equipped with "...some working knowledge of the analytical tools used by choice theorists, the analytical tools used by computational modelers, experimental design in psychology and economics, statistical techniques ranging from those used in neuroimaging to those used in the analysis of behavior, and the full suite of neuroscience methods available for investigating cognition"

(Kable 2011). For that reason, wide-ranging studies in the field of neuroeconomics referring to actual decision-making processes are conducted in principle by interdisciplinary research teams, where knowledge, skills and competences of individual participants complement each other.

5.4 Areas of Neuroeconomics Research

The subject of neuroeconomics focuses on the explanation of the decision-making process. As a relatively new field of knowledge it has not developed so far a common theory explaining neurobiological mechanisms of decision making, and within its scope various concepts are developed and tested. Areas of interest and research topics in the field of neuroscience have been developing along with the development of the field and the number of conducted experiments conducted. In 2003, in which "a group of economists, psychologists and neurobiologists began to identify themselves as neuroeconomists and to explicitly shape the convergence between the fields" (Glimcher et al. 2009: 8). Camerer et al. (2003) highlighted that neuroeconomics should provoke thought, and suggest interesting, fresh perspectives on old problems. Considerations conducted within its scope might affect the way that two traditional topics in economics (1) intertemporal choice and self-control, (2) decision making under risk and uncertainty.

Since that time the number of research conducted in the field of neuroeconomics has been increasing rapidly. Five principal motivations for pursuing neuroeconomic research include (Camerer et al. 2015: 153):

- some researchers, including economists, are willing to study neuroscience for its own sake,
- neuroeconomic research will likely provide a new way of (imperfectly) measuring human well-being, neural activity has been shown to correlate with reports of subjective well-being, receipts of reward, and revealed preferences,
- neuroeconomics will serve as a catalyst for model development. Neuroscientific data and neuroscientific models have inspired economists to develop many new economic models,
- neuroeconomics will provide a new, powerful way to test economic models which ambitiously specify both how choices depend on observables, and what computational mechanism leads to those choices,
- neuroeconomics will improve our ability to predict behavior and to design interventions that influence the behavior of others and manage our own appetites and drives.

Camerer emphasized in one of his articles of 2007 that neuroeconomics is likely to provides three types of evidence about economic behavior (Camerer 2007):

- evidence which shows mechanisms that implement rational choice (utilitymaximisation and Bayesian integration of information), typically in

tasks that are highly-sculpted to make decisions that are useful for survival across species (vision, food, sex and danger),
- evidence which supports the kinds of variables and parameters introduced in behavioral economics,
- evidence which suggests the influence of "new" variables that are implicit, underweighted, or missing in rational-choice theory.

Moreover, the same year three major research (topics) fields in which the neuroeconomic can make important contributions to economic theories were distinguished by R. Yu and X. Zhou. They included (Yu and Zhou 2007):

- utility computation in decision making—one important area where neuroeconomics can contribute is in identifying neural substrates associated with economic concepts and in understanding their psychological functions. Neuroeconomic studies also support previously discovered economic rules concerning utility computation. Another important phenomenon concerning utility computation in economic decision is the time discounting of utility,
- the role of emotions in decision making—emotions influence people decisions, but traditional economic studies usually ignore such influence and leave emotion outside the scope of decision-making research. And the ability to experience and anticipate emotions is crucial to advantageous decision making. This field of interest included also moral decisions which play an important role in our daily economic decisions. Moral decisions, the evaluation of actions of other people or of our own actions made with respect to social norms and values, are not the main topic in economics,
- economic decisions in social context—the people always make decisions in social situations. Neuroeconomic studies have found evidence to support that people make decisions based on the prediction of others'possible actions and the associated outcomes.

Recently, active work in neuroeconomics is taking place in every choice domain, but the most important are the four topics of neuroeconomic research (Camerer et al. 2015: 172–191):

- risky choice—with three main topics in that field: statistical moments and evaluation of risky choice; prospect theory; causal experiments and their implications for economics,
- intertemporal choice and self-regulation—intertemporal preferences are one of the most active research topics in the field of neuroeconomics, researchers have identified a large group of empirical regularities, many of which are related to neural mechanisms,
- social preferences—in this area "the neuroeconomic approach aims to provide a micro-foundation of social preferences in terms of the underlying neural networks, which will eventually be achieved with the development of formal models of the underlying brain circuitry showing how the assumptions and parameters of behavioral models of social preferences relate to the empirically verified assumptions and parameters of the brain model. This will lead to a better

understanding of the nature of social preferences, and the sources of individual differences in other-regarding behaviors, including pathologies" (Camerer et al. 2015: 183),

- strategic thinking—in that field of research, neuroscience could contribute to game theory by identifying strategic algorithms that are being implemented in the brain. In addition, game theory could be of special use in neuroeconomics by parsing how general reward and learning structures combine with specialized social inference mechanisms (such as "theory of mind") to determine strategic choice. Conducted studies refer to four aspects of strategic thinking: strategic awareness that outcomes are affected by actions of other players; beliefs, iterated beliefs and strategic choice; learning about the value of strategies; strategic teaching and influence value.

According to G. Urbanik-Papp (2014) neuroeconomics deals with four groups of decisions in areas challenged with various research questions:

- in case of decisions undertaken within the conditions of risk and uncertainty:
  - how does the brain interpret and code financial profits and losses?
  - what are the brain's foundations for the operation in conditions of uncertainty?
  - what structures of the brain are related to undertaking decisions in the context of profits and what structures of the brain are related to undertaking decisions in the context of losses?
- in case of moral decisions:
  - are moral assessments formulated under the influence of strong emotions or as a result of rational analysis?
  - is the observation of moral standards of the absolute character (deontological) or is it based on considering consequences of decisions (consequentional)?
- in case of decisions with deferred effects:
  - what influences the decision of immediate consumption or deferred gratification?
  - what is the role of emotions and rational analysis in deferring gratification?
  - what part of the brain is responsible for comparing possible options?
- in case of decisions referring to the social context:
  - how does the brain shape the utility of own profits and the utility of disbursements for other persons?
  - what parts of the brain account for choices made by participants of economic games?
  - what are the neuronal correlations of decisions on sharing money with other persons?

The results of studies in the field of neuroeconomics in those areas allowed to create so called "economic mind map" being the evidence for a certain universal type of stimulating brain areas activated during making economic decision (Zaleśkiewicz 2013: 422–423).

5.5 Conclusions

With the increasing popularity of studies in the field of behavioral and experimental economy, at the end of 20th century, deviations from rigid rules of rationality started to be accepted. A considerable contribution to the above mentioned situation includes the development of science as well as, a more frequent associating with each other, interdisciplinary contents and tools within the scope of neuroeconomics which may be perceived as the interdisciplinary debate devoted to a new, holistic manner of perceiving the human with the comprehensive approach—treating the human as bodily, mental and social being.

Neuroeconomics focusses on testing the existing economic and it enhances settling the issue which of the competitive theories demonstrates corresponding to it neuronal correlations being more reliable. Knowledge provided by neuroeconomics may direct posed hypotheses, and methods applied within its scope enable the measurement of variables which in spite of their importance for the decision-making process so far have been difficult to be depicted (Gęsiarz 2011: 51). The importance of that field stems from the fact it is used within the scope of economic metaphors are used to study how neurons and neural networks make decisions. Therefore the excitement generated by neuroeconomics is because the metaphor of utility and value can be used across the different levels of explanation from cells to society, making this a rather unique field (Sharp et al. 2012).

Observed as a result of studies in the field of neuroeconomics reactions of the nervous system may become in the future the foundation for elaborating theories which subsequently will be tested on economic grounds (Gęsiarz 2011: 52). Camerer et al. (2015: 200) are of the opinion that neuroscience methods continue to rapidly advance it is likely that neuroscientific insights will significantly improve our economic vision. Glimcher et al. (2009) on the other hand expresses the opinion that developing at a fast rate neuroeconomics will be able in the future to execute tasks posed for the classical economy. M. Noga (2017) forecasts the development of neuroeconomics being able to build macroeconomic models explaining various general economic phenomena and thanks to its achievements economic laws will approximate, with their character, to deterministic natural laws (Noga 2017: 107–121).

Irrespective of the fact how the fate of neuroeconomics will run, whether or not it will elaborate its own paradigm and the whole research program, its current achievements and perspectives on decision-making processes are undertaken by a real man and the economy itself.

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Chapter 6
Measuring Economic Propensities

Mariusz Doszyń

Abstract In behavioral economics there are many very interesting insights and findings. But it seems that there is a problem with the measurement of chosen aspects of behaviors. Without proper methodology it is hard to verify a hypothesis describing behavioral effects. This is why the possibility of behavior measurement based on a propensity theory is proposed. These problems are connected not only with behavioral aspects of decision making but also with the neuroeconomics. In the chapter the main features of propensity theories are discussed. A definition of propensity as well as methods useful in measuring propensities are presented. The prepared questionnaire is used to measure and analyze such economic propensities as the propensity to consume, save, invest and money storing. These propensities are tested in three ways, as declared (by respondents) propensities, as observed propensities and also as propensities deduced from preferred choices. In the last case the method consistent with the AHP (Analytic Hierarchy Process) is verified.

Keywords Propensity theories • Measures of human propensities • Propensity to consume • Propensity to save • Propensity to invest • Propensity to money storing

6.1 Introduction

There is no doubt that in the economic world it is important to measure some quantitative aspects of behaviors. It could be helpful in forecasting. It is also true after realizing that there are many interesting findings proposed in behavioral economics (Kahneman 2011; Thaler 2015; Wilkinson 2008). We could find there very insightful ideas, but it seems that there is no agreement according to the methodology that could be useful in doing research. Many economic models are based on optimization. For obvious reasons, they are not applicable in behavioral studies, because utility is not maximized (we even do not know what exactly utility

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_6

is). Generally, statistical and econometric tools could be used, but it is not always clear how to measure attitudes, tendencies, preferences, etc. These problems are the main motivation to present concept of propensities, with some proposals of how to measure them, which is the main aim of this chapter.

6.2 Propensity Theories

The conception of propensity was proposed and described in the following monographs (Hozer and Doszyń 2004; Doszyń 2008, 2013). These monographs refer to problems connected with the measurement of propensities and their impact on economic events.

In the literature there are many varieties of propensity theories (Gillies 2000). They could be classified as follows (Doszyń 2013):

- theories in which propensity is understood as a result of all conditions that generate events (K.R. Popper),
- theories in which propensity is an internal feature of an object (C. Peirce).

Therefore we could have a propensity of a situation or propensity of an object. If an object is a person, we could talk about human propensity. In the first group of theories, propensity is treated as a characteristic of a situation (Popper 1959, 1990). Propensity is an objective tendency present in a situation that generates certain events. Such propensity depends on many factors, objective and subjective (psychological) and is a generalization of causes. This is some kind of "objective" or "external" propensity. Human (psychological) propensities are only one factor impacting the propensity of a whole situation. These theories are mostly based on K. Popper's works (Popper 1959, 1990; Gillies 2000). K. Popper defined propensity as a biased possibility that characterize a given situation (Popper 1990). He proposed a propensity interpretation of probability, where propensity is an objective force that generates a stable relative frequency, resulting from many causes.

Another philosopher—C. Peirce treated propensity as a characteristic of an object. An object could be a thing (for example a dice) or a person. Propensity depends on the structure of an object. In the case of people, propensities stem mostly from psychological factors. After C. Peirce, we could say that propensity is a generalized psychological cause of events.

In economics, after J.M. Keynes, propensities are usually identified with marginal or average propensities (to consume, save, invest, etc.). In The General Theory of Employment, Interest and Money (Keynes 2007) propensities are treated as functional dependencies between certain variables. For example, the propensity to consume is a relation between consumption and income, while the propensity to save is a relation between savings and income, etc. In these views propensities make connections between variables stable. J.M. Keynes' proposal is similar to K. Popper's theory with one difference. K. Popper thought that propensity generates a stable frequency of events. On the other hand, J.M. Keynes

claimed that propensity creates a (stable) functional dependency between variables (consumption and income, savings and income, investments and income, etc.).

What kind of economic propensities could be analyzed? Propensities of objects or propensities of situations? Both kinds. Let us say that we analyze propensity to save a stable share of savings in income. It could refer to a single person who is observed in a fixed period of time (several months, for example). This propensity might depend on many factors, among which the most important is income level. The higher the income, the more savings people might have and usually have. Also other factors could impact this propensity, such as interest rates, expectations, social status, etc. This kind of propensity, that could be named revealed propensity to save, is consistent with a theory of K. Popper and J.M. Keynes, in which propensity is a tendency entered in a given situation (circumstances). This kind of propensity depends not only on subjective (psychological) features, but also on many other "external", "objective" causes.

But we could also examine "internal" propensity to save which characterizes the attitude of a given person toward saving. In such kinds of propensities external factors are "taken away" and the relation toward saving is isolated and analyzed. This kind of propensity to save describes subjective (psychological) tendencies toward savings. It manifests itself if there is such a possibility. If external circumstances foster saving, "internal" propensity to save could be revealed. Sometimes people have an intense "internal" propensity to save, but a low propensity to save. This could be because of the lack of possibilities to save. Typical reasons are low incomes or necessary high expenses. But if circumstances would change, "internal" propensity to save would increase the revealed propensity to save. The difference between human ("internal") propensity and the propensity of a situation might be also a result of a lack of willpower. "Internal" propensity could be then revealed but the willingness of doing this is too weak.

To sum up, while analyzing propensities, it is important to know what kind of propensity is analyzed. For example we could focus on the "internal" or "external" propensity to save. "Internal" propensity depends mostly on subjective features. "External" propensity is an effect of all types of causes, not only subjective, but also economic, demographic, and social, etc.

Thus the following question arises: how to define propensity? Here propensity is defined as a "slope of posture" toward something (or somebody) that makes the probability of certain events greater (Hozer and Doszyń 2004). This definition applies to both groups of theories, because the "slope of posture" could be a result of either external or internal causes.

6.3 Two General Measures of Propensity

Psychological ("internal") propensities are qualitative variables, but we could try to measure their quantitative aspects. For example, how do we know that somebody has a high "internal" propensity to save, which is a qualitative feature? This person would often try to find possibilities to save, so the share of savings in income would be greater for this person. Revealed propensities are much easier to observe, by means of relative frequencies, which are sometimes treated also as probabilities. When there are no obstacles and propensity could manifest itself, "internal" and "external" propensities are the same.

Generally, propensity could be measured by means of frequency and trigonometric methods (Hozer and Doszyń 2004). In the frequency method, the level of a propensity is treated as a stable relative frequency:

$$p = \frac{m}{n}, \tag{6.1}$$

where p—the frequency measure of propensity, m—number of cases in which propensity appears, n—number of all possible cases.

Therefore, in the frequency measure, propensity (p) is calculated as a share of cases in which propensity appears (m) in all possible cases (n). This measure was proposed by K. Popper (1990). It is very useful in analyzing the propensities of situations, but sometimes also "internal" propensities could be measured in this way. It is possible when propensity could be freely revealed.

When we apply formula (6.1), we have to identify a fraction of cases with propensity. This could be a fraction of people with the given propensity. This formula is strictly applicable for discrete variables measured on a nominal scale. Let us say that we search 50 people (n = 50) and we assumed that twenty of them have a propensity to save (m = 20). We have some kind of cross-sectional data here. The frequency measure of propensity to save is then equal to p = 20/50 = 0.4. If we assume that there are no drawbacks if somebody wants to save, "internal" and "external" propensities are the same, but in certain conditions there could be differences. Such measure describes the propensity of a given collectivity, but it might be also used for individuals. Then m stands for the saving behaviors of a given person and n is a number of all possible cases, when savings could be made. This would create a time series for one object (person). We could also analyze propensities for panel data, for many objects observed in a certain time period.

Measure (6.1) could be extended to continuous variables. In economics, propensities impact how income is distributed. Income might be consumed, saved, invested or stored in a bank account. According to consumption, we all have to pay for certain things (housing, electricity, food, clothes, fuel, insurance, etc.), but let us assume that we analyze income that could spend "as we want", so it is disposable income after necessary expenses. In this case propensity to consume (save, invest, money storing) could be measured as a share of additional consumption (savings, investments, money stored) in income.

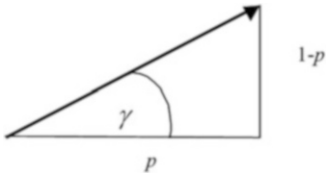

Fig. 6.1 Trigonometric interpretation of propensity (individual study)

Propensity might be also presented in degrees, by means of a trigonometric measure, where propensity is defined as a specified angle (Hozer and Doszyń 2004) (Fig. 6.1).

In the trigonometric method, propensity is measured as angle. The tangent of this angle could be obtained on the basis of the following formula, in which the frequency measure of propensity is used:

$$tg\gamma = \frac{1-p}{p} \tag{6.2}$$

p—frequency measure of propensity.

The higher propensity, the higher the "slope" (and the lower angle). The trigonometric method could be useful while presenting the strength of propensity in a graphical way. This is a complementary method of measuring propensity; consistent with the proposed definition of propensity, in which propensity is a "slope of posture" toward something (or somebody) that increases the probability of certain events.

Both presented measures (6.1) and (6.2) might be used for both types of propensity theories. If propensity describes the whole situation, these measures describe propensity that stems from all conditions. If propensity is an effect of psychological factors, the proposed measures characterize the internal tendencies of people.

6.4 Measures of Propensity to Consume, Save, Invest and Money Storing

In economics often such propensities as the propensity to consume, save, invest and money storing are discussed. These propensities were presented in The General Theory of Employment, Interest and Money (Keynes 2007). According to the proposed definition, propensity is a "slope of posture" toward something or somebody increasing the probability of certain events (Hozer and Doszyń 2004). Therefore the propensity to consume could be defined as a "slope of posture"

toward the consumption of goods (or services) that increases its probability. Of course we all have to consume, but it is easy to observe that some people like to consume more than others, even if it is not necessary or needed. This kind of behavior is usually the result of the propensity to consume (certain goods). In a similar way other propensities are defined. The propensity to save is then a "slope of posture" toward saving possibilities that increases the probability of saving. The propensity to invest is a "slope of posture" toward investment possibilities increasing the probability of investments. The propensity to money storing is a "slope of posture" toward storing money (for example in a bank account) that increases its probability.

What is the difference between propensity to save and propensity to money storing? The propensity to money storing could be understood as passive saving. There is no necessity to manage money, which is just in a bank account. In the case of propensity to save there is a need to manage money by buying bonds, post bank deposits, etc. This is riskless, but earnings are rather low. Earnings are usually much higher in the case of investments, but this is also more risky and there is a possibility of losing capital.

In the chapter propensities are analyzed in three ways:

- as declared (by respondents) propensities,
- as propensities calculated by means of the AHP method,
- as revealed propensities.

Declared propensities and propensities measured by the AHP method enable the searching of "internal" (human) propensities. Revealed propensities could depend on many factors, also different than subjectivity, so these are the propensities of a situation.

The declared propensities were analyzed on the basis of the prepared questions, in which respondents had to evaluate their attitudes toward consumption, savings, investments and money storing. In each question respondents have to choose one of five answers, which were presented on a scale from worse to best. It was assumed that a person has a given propensity if the attitude (toward consumption, savings, investments or money storing) was positive.

In the case of revealed propensity to consume respondents have to answer how often they go shopping. For the remaining propensities they have to estimate what is their share of savings, investments and money stored in a bank account in income.

The two above ways of expressing propensities are rather direct and people might want to present themselves in a "better light". Most of the people liked to present themselves as being economical, frugal, etc. The answers could be then not completely consistent with reality. This is why also the procedure based on the AHP (Analytic Hierarchy Process) is applied. AHP methodology is described in many work, for example (Saaty 1980, 2008). It is worth to mention that there are many other methods based on pairwise comparisons that could be used instead of AHP

method, such as: Promethee, Electre, ANP (Analytic Network Process), etc. AHP method was chosen but different methods will be also applied in the future (Tzeng and Huang 2011; Trzaskalik 2008).

In the AHP method the following options are pairwise compared:

- expenses (other than basic),
- bank deposits, bonds,
- capital stock,
- keeping money in a bank account.

Expenses are the expression of the propensity to consume. Bank deposits and bonds reflect the propensity to save. Capital stock stands for the propensity to invest. Money in a bank account describes the propensity to money storing. The propensity to money storing is sometimes called a propensity to thesaurisation (Keynes 2007). In each comparison respondents had to choose the preferred option and assess a number (from one to five), expressing how much the chosen option is preferred. In Saaty's proposal (Saaty 2008) the scale is from one to nine, but it was assumed that a narrower scale (from one to five) better exhibits judgment abilities. Too many options could disturb the respondents' choices.

In the AHP method many criteria could be taken into account. In the undertaken analysis only expressions of propensities (expenses, savings, investments, money storing) are compared. A big advantage of the AHP method is also the possibility of calculating the inconsistency coefficient (Saaty 2008) that shows the quality of the responses.

6.5 Empirical Results

The propensity to consume, save, invest and money storing were calculated on the basis of the questionnaire presented in Appendix 1. As many as 52 respondents completed the questionnaire, but 11 questionnaires were excluded from further analysis, because the answers were incomplete. Among the 41 respondents, 21 were men (51.2%) and 20—women (48.8%). The age range is between 25 and 60 years. The average age is 40 years (median is equal to 39 years).

In the AHP method the inconsistency coefficient was also computed. It is assumed that results below 0.1 indicate a high consistency of responses. For the 41 respondents who were analyzed this coefficient is between 0.022 and 0.584. Usually it is close to 0.1. The average for this coefficient is equal to 0.142 and the median is 0.119.

All propensities (to consume, save, invest and money storing) are calculated on the basis of the two presented methods: frequency (1) and the trigonometric method (2).

The declared propensity is calculated as a share of answers that indicate a positive attitude toward additional consumption (savings, investments and money storing). It is assumed that a given respondent has the propensity if one of the last

two answers in questions 1–4 is pointed out. For example, somebody is pointed out as a person with the propensity to consume if he/she likes (or really likes) shopping. Fractions of that kind of answers are the frequency measures of propensities to consume (question 1), save (question 2), invest (question 3) and money storing (question 4).

The observed propensity to consume is computed on the basis of shopping intensity, as a percentage of respondents who go shopping often or very often (question 5). The observed propensities to save, invest and money storing are obtained as the averages calculated for each propensity. In questions 5–8 subjects had to give percentages of income that is saved, invested or stored in a bank account. These shares are averaged, and thus give the observed propensities.

In the AHP method weights (shares) for the considered variants are computed. All of the shares sum up to one. It is assumed that "free" income (income that could be freely distributed) could be consumed, saved, invested or stored (in a bank account). Therefore it could be stated that these propensities sum up to one. Pairwise comparisons are made to estimate the weights for expenses, savings, investments and money storing (questions 9–14). These percentages could be treated as an extension of the frequency measure of propensity (to consume, save, invest and money storing). Therefore it was assumed that the weights (shares) obtained by the AHP method are estimates of propensities that could be treated as an extension of the frequency measure of propensity (1).

Declared, observed propensities and propensities calculated by the AHP method are presented below in (Table 6.1 and Figs. 6.2–6.5).

Generally, propensities to save and consume are the highest. On the lower level is the propensity to money storing and the lowest is the propensity to invest. There are some interesting and persistent differences between the declared, observed propensities and propensities obtained by the AHP method. In the case of all propensities, declared propensities are at the highest level. Very intense is the declared propensity to money storing and save. This shows that people "want" to save more than in reality.

On the lower level are the propensities obtained by means of the AHP method. Generally these measures are between measures for declared and observed

Table 6.1 Frequency and trigonometric (in degrees) measures of propensities (own calculations)

	Frequency method	Trigonometric method				
Propensity\measure	Declared	Observed	AHP	Declared	Observed	AHP
Propensity to consume	0.390	0.122	0.318	57.4	82.1	65.0
Propensity to save	0.463	0.082	0.319	49.2	84.9	64.9
Propensity to invest	0.317	0.046	0.145	65.1	87.3	80.4
Propensity to money storing	0.537	0.088	0.218	40.8	84.5	74.5

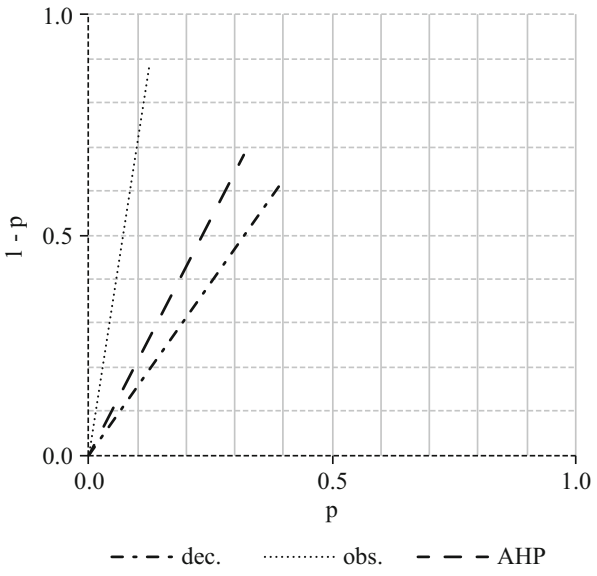

Fig. 6.2 Trigonometric measure of propensity to consume (declared, observed, AHP) (own work)

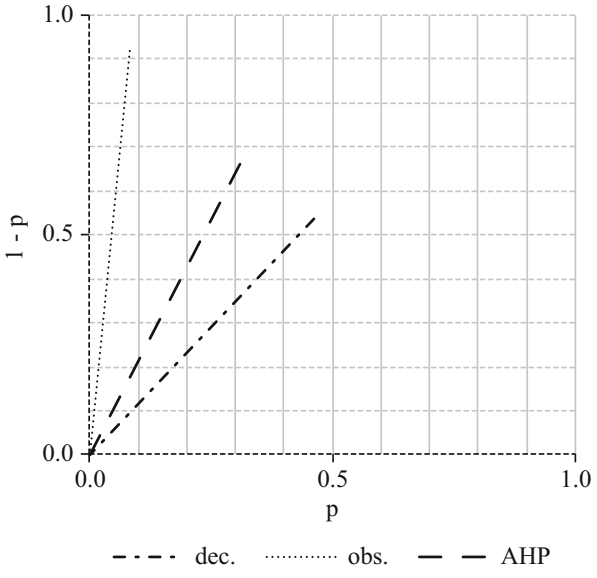

Fig. 6.3 Trigonometric measure of propensity to save (declared, observed, AHP) (own work)

propensities. The AHP method seems to give the best results because the inconsistency of answers could be checked.

These two types of propensities (declared and obtained by the AHP method) exhibit the "internal" propensities that could manifest themselves in favorable conditions, if there is also the willpower to apply them. The observed propensities

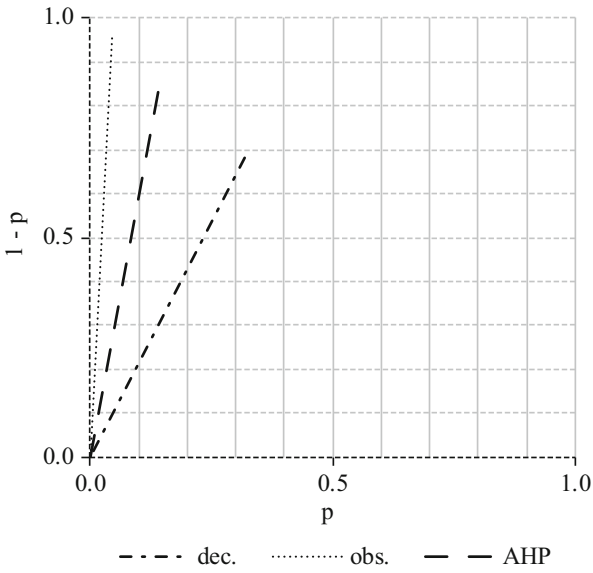

Fig. 6.4 Trigonometric measure of propensity to invest (declared, observed, AHP) (own work)

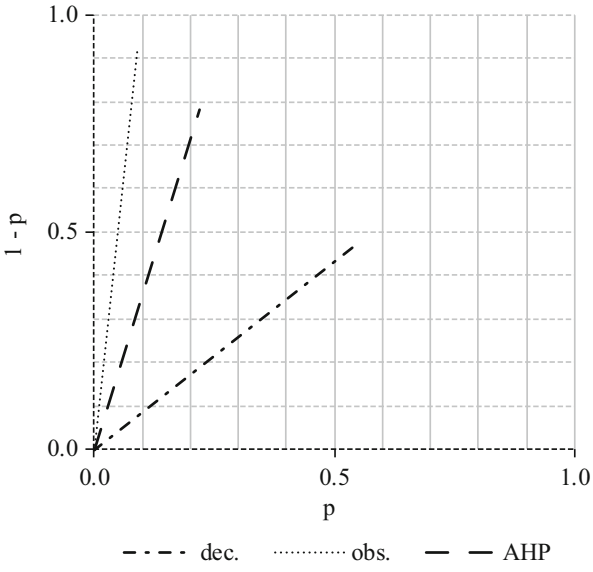

Fig. 6.5 Trigonometric measure of propensity to money storing (declared, observed, AHP) (own work)

are the result of all conditions, internal and external. They are at the lowest level. It could mean that in better conditions people would like to have more savings and consume and invest more.

6.6 Conclusions

If we want to analyze economic behaviors, the question arises: how to measure them? The proposed propensity theory could be one of the answers. Two general methods could be used to measure propensities, on the basis of which further extensions could be made. It is important to know what exactly we want to search for and how propensity is defined. If we are analyzing the "internal" propensity of a person, we have to try to extract a given propensity, irrespective of the fact if it is exhibited or not. Such a propensity, at least in the short term, does not depend on external conditions. These are the propensities of objects, similar to propensities in Peirce's theory.

If we analyze propensities that are the products of given situations, which is consistent with K. Popper's view, we could use statistical methods to estimate the relative frequency of events.

In the conducted analysis propensity to consume, save, invest and money storing were calculated. Generally, the highest are the propensities to save and consume. The lowest is the propensity to invest. The differences between declared, observed propensities and propensities obtained by means of the AHP method could be used to predict behaviors. If, for example, "internal" propensity is much higher than observed, and we could assume that future conditions would enable the realization of a higher propensity, the future propensity would be higher. If, on the other hand, observed propensity and propensity obtained by the AHP method are the same, a change of future conditions would not impact future actions. We should also remember that behind proper conditions always the willpower to take actions should stand.

Appendix 1 Questionnaire

Sex: □ man
□ woman
Age (years completed):
Place of residence: □ city
□ village

1. How would you rate your attitude toward shopping?
   - I do not like shopping
   - I rather do not like shopping
   - I am indifferent
   - I like to go shopping
   - I really like to go shopping
2. Do you consider yourself an economical person?

- definitely not
- rather not
- I am indifferent toward saving
- rather yes
- definitely yes

3. Do you consider yourself a person prone to invest (e.g. in stocks, real estate, etc.)?

- definitely not
- rather not
- hard to say
- rather yes
- definitely yes

4. Is the accumulation of funds in a bank account a good solution?

- definitely not
- rather not
- hard to say
- rather yes
- definitely yes

5. How often do you go shopping (other than purchases of basic products)?

- if I have to
- occasionally
- from time to time
- often
- very often

6. What percentage of your income do you save?
7. What percentage of your income do you invest?
8. What part of your monthly income (in percentage) is stored in your bank account?

You have extra disposable income (in the form of cash), which can be spent in the following ways:

- expenses (other than basic),
- bank deposit or bonds (small but sure profit),
- capital stocks (higher profits, but higher risk),
- stored in a bank account (the ability to withdraw funds at any time).

9. From the point of view of my disposable income more important for me is (are):

- stock
- bank deposits, bonds

To what extent the chosen option is more important? Rating from 5 to 1 (5—far more important, 4—much more important, 3—moderately important, 2—a little more important, 1—options are equivalent for me): ....

10. From the point of view of the management of income more important for me is (are):

    - stock
    - expenses (other than basic)

    To what extent the chosen option is more important? Rating from 5 to 1: ....

11. From the point of view of the management of income more important for me is (are):

    - keeping money on non-interest bearing account.
    - expenses (other than basic).

    To what extent the chosen option is more important? Rating from 5 to 1: ....

12. From the point of view of the management of income more important for me is (are):

    - keeping money in a non-interest bearing account
    - stock

    To what extent is the chosen option more important? Rating from 5 to 1: ....

13. From the point of view of the management of income more important for me is (are):

    - bank deposits, bonds
    - keeping money in a non-interest bearing account

    To what extent is the chosen option more important? Rating from 5 to 1: ....

14. From the point of view of the management of income more important for me is (are):

    - expenses (other than basic)
    - bank deposits, bonds

    To what extent is the chosen option more important? Rating from 5 to 1: ....

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Chapter 7
Convolutional Representation in Brain Simulation to Store and Analyze Information About the Surrounding Environment for the Needs of Decision Making

Mariusz Borawski

Abstract The chapter describes the capability to utilize convolutional representation in brain simulations to facilitate the storage and analysis of information about the surrounding environment. The convolutional representation allows for easy storage and updating of statistical information about objects. For each number in convolution representation a mean value and variance can be calculated. They can be used to describe objects in 3D space. In this chapter a transformation method of such vectors is presented. Moreover, a method for comparing two numbers in a convolution representation based on mean and variance is shown. The chapter also describes an example of the simulation, where convolutional representation and ordered pairs; mean value, variance increment were utilized. It is the one of possible examples how the presented methods can be used. These methods were developed for data analysis in assessing public awareness campaigns to take account of the uncertainty of respondents' responses in questionnaires.

Keywords Convolutional representation • Ordered pairs • Mean value • Variance increment • Brain simulator

7.1 Introduction

Any activity of a human being involves decision making which is based on recorded and remembered information. However, this information is not precise. Much data is estimated, for example, the size or weight of an object. A man lifting an object can define what effort he invested in this activity, which translates into the

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_7

weight of an object. However, this effort depends also on his current condition, which can be affected e.g. by illness. Parameters of objects occurring for the first time can be assessed based on the similarity to the other one, similar and already known. The values of these assessed parameters are a certain statistical approximation. To limit the amount of information stored, it is not required to remember individual object's data, but only limit it to the object class. In this case, it is not enough to just save the parameter values, but it is necessary to store data about their statistical variability. Numbers from fuzzy arithmetic can be applied in this purpose (Jankowski et al. 2016). In the case of statistical information, the convolutional representation proposed by Mareš is very useful. This representation reflects the behavior of the distribution while adding random variables. Mareš is proposing the use of convolution as an operator of addition in fuzzy arithmetic, firstly in an integral form (Mareš 1977) and later in the form of sum (Mareš 1989). A description of convolution as an operator of fuzzy number addition can also be found in Dubois and Prade (1987), Harman (1992), Mareš (1994). In (Mareš 1989) Mareš demonstrated the group properties of convolution, using equivalence relation, including the existence of an opposite element. He also pointed out the two essential problems related to the application of convolution as an addition operator: membership function can exceed the value of one, and difficulty in composing the operators of addition and subtraction.

But Mareš was not the first person to investigate group properties of convolution. In the 1950s, such a subject was studied by Mikusinski, who investigated the possibility of using arithmetic operation over functions. His aim was to generalize the notion of number (Mikusiński 1983). Unlike Mareš we used convolution as a multiplication operation. His investigation showed that the inverse element to function does not have to be a function. He introduced the notion of operator as a generalization of the notion of function.

The convolutional representation was created as the result of seeking fuzzy numbers that meet group axioms. Such numbers can be applied in vector space as vector coordinates. The convolutional representation can rise some problems with regard to the difficulty of determining the opposite object. The alternative may be to use a different representation of fuzzy numbers satisfying the group axioms, such as ordered fuzzy number algebraic operations (Kosiński et al. 2003; Kosiński and Prokopowicz 2004; Faizi et al. 2017). The advantage of using convolutional representation is the relationship with the probability density function, so instead of the convolutional representation the parameters describing the random variable might be applied. The examples of such parameters are the range (interval) and mean value as well as the standard deviation. An arithmetic operation on intervals is the area of interval arithmetic. In this scope Kaucher proposed an extension called extended interval arithmetic which satisfies group axioms (Kaucher 1980). By replacing the mean and the standard deviation with the mean increment and the standard deviation increment, it can be demonstrated that the ordered increment of the mean value and standard deviation increment form a group together with the addition operations (Borawski 2012a).

7.2 Convolutional Representation Numbers in Data on Objects Storing

Numbers in the convolution representation can be calculated directly from the histogram for frequency of values. For example, if information on the weight of a certain class of objects is stored then the whole range can be divided into subranges. If the expected total range would fall within 0 and 4 kg, it could be divided into equal subranges, each of 1 kg width. As a result, there will be four ranges, the first—<0; 1) kg, the second—<1; 2) kg, etc. A numerical value is assigned to each range, specifying the number of objects having a weight that falls within this range. Such a number can be called the object of a given weight occurrence frequency. In addition, ranges are assigned a number representing the weight of all objects within the range. One can assume that this is the middle of the range. All these elements form a frequency histogram. The example of a frequency histogram might look as follows:

$$A_H = \begin{bmatrix} \overset{0,5}{0} & \overset{1,5}{3} & \overset{2,5}{1} & \overset{3,5}{0} \end{bmatrix}. \tag{7.1}$$

Such a histogram of frequencies means that three objects fall within the range <1; 2) and one object falls within the range <2; 3).

To transform it to a number in a convolutional representation, all instances must be divided by the aggregated number of objects:

$$A = \begin{bmatrix} \overset{0,5}{0} & \overset{1,5}{0,75} & \overset{2,5}{0,25} & \overset{3,5}{0} \end{bmatrix}. \tag{7.2}$$

In this case the frequency of instances has been replaced by the probabilities of the occurrence of the value, and the number in the convolution representation presents the probability density function.

At data registration, all frequencies of occurrences are assigned a zero value. When object occurs for the first time, its weight is measured and an object is assigned to the specified interval. The value in this interval will be increased by one. In this way, statistical information about a given object class is generated. It is assumed that the object class can evolve, which means that its weight will change over time. In order to take the above mentioned into consideration, it can be assumed that the information will be stored only for n most recently occurring objects. When data on n objects is registered, the frequency histogram is converted to a number in the convolution representation. Before a new object is considered, values assigned to the intervals have to be multiplied by $(n-1)/n$, whereas the value within the interval to which the object was assigned is increased by $1/n$. This will cause that when adding a new object, the sum of these values still equals 1, and the information about the old objects will be gradually degraded.

Two frequency histograms can be summed up. Let two histograms be considered:

$$A_H = \begin{bmatrix} 0 & 1 & 2 & 3 & 4 & 5 \\ 0 & 1 & 2 & 0 & 0 & 0 \end{bmatrix}, \tag{7.3}$$

and

$$B_H = \begin{bmatrix} 0 & 1 & 2 & 3 & 4 & 5 \\ 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix}. \tag{7.4}$$

For simplicity it can be assumed that the first histogram represents the values 1,2,2 and the second 2 and 3. To aggregate, values from the first group have to be added to the values of the second group in all possible combinations:

$$1+2=3, 1+3=4, 2+2=4, 2+3=5, 2+2=4, 2+3=5. \tag{7.5}$$

The result is the set of values: 3,4,4,5,4,5 what gives the frequency histogram:

$$A_H + B_H = \begin{bmatrix} 0 & 1 & 2 & 3 & 4 & 5 \\ 0 & 0 & 0 & 1 & 3 & 2 \end{bmatrix}. \tag{7.6}$$

This operation can be performed using the convolutional operator. Likewise, the operation of adding numbers in a convolutional representation and multiplying them by an integer can be performed using the convolution operator (Mareš 1989; Borawski 2012a). Using the convolution properties a general multiplication can be generalized by multiplying the integer to the multiplication by the real number (Borawski 2012a).

Frequency histograms can be compared to each other by applying a similar rule when adding frequency histograms. However, the result will not be true (1) or false (0), but only value within the range <0; 1>, where values close to 1 could be said to be similar, and values close to 0 will be considered of little similarity. For example, for 1,2,2 and 2 and 3 the notation is as follows:

$$1=2\ (f), 1=3\ (f), 2=2\ (t), 2=3\ (f), 2=2\ (t), 2=3\ (f). \tag{7.7}$$

There are six comparable values of which two gave the truth. The result will be the number of comparisons that gave the truth to all comparisons. Thus 1/3 was obtained.

In the case of determining similarity, the result will depend on the number of intervals. The more intervals, the registered values will be distributed into the higher number of intervals, thus the result will be lower. In the case of convolutional representation the number of intervals can be increased to infinity. Then determination of the similarity of values will be according to the formula:

$$comp(A,B) = \int_{-\infty}^{\infty} \int_{x}^{x} f_A(x) f_B(y) dy dx, \tag{7.8}$$

where $f_A(x)$ and $f_B(y)$ are functions describing probability density function for A and B in convolutional representation.

Each probability of value x for the A number is multiplied by area under the curve at point x for B. Except for one specific case, the area under the curve at point x equals to zero. When the interval's width aims to zero $comp(A,B)$ will also aim to zero.

For a number in a convolutional representation, the area under the curve is always equal to one. If the values are always the same then the probability density function will feature Dirac delta shape. For two Dirac delta functions:

$$comp(A,B) = \int_{-\infty}^{\infty} \int_{x}^{x} \delta_{A,a}(x) f_{B,b}(y) dy dx. \tag{7.9}$$

If both Dirac delta functions have peaks in the same place, then $comp(A,B)$ equals to one, otherwise equals to zero. It proves that equalizing two numbers in a convolutional representation makes sense only if the measured data for both numbers is always the same. If this condition is not met then the comparison should always give zero, which is false, even if the numbers are very similar to each other. Yes, when the number of intervals is infinite. However, at the finite number of intervals, the result is not zero, but not very practical, as it strongly depends on the number of intervals.

For example, for values 1,2,2 and 2 and 3 we get:

$$1 = 2\ (\mathrm{f}), 1 = 3\ (\mathrm{f}), 2 = 2\ (\mathrm{t}), 2 = 3\ (\mathrm{f}), 2 = 2\ (\mathrm{t}), 2 = 3\ (\mathrm{f}). \tag{7.10}$$

There are six comparable values of which two resulted true. The result will be a number of comparisons which resulted true compared to all comparisons. Thus 1/3 was gained.

Similarly to equitation, it can be verified if one number is greater than the other one. For example, taking 1,2,2 i 2 i 3 the result will be:

$$1 > 2\ (\mathrm{f}), 1 > 3\ (\mathrm{f}), 2 > 2\ (\mathrm{f}), 2 > 3\ (\mathrm{f}), 2 > 2\ (\mathrm{f}), 2 > 3\ (\mathrm{t}). \tag{7.11}$$

There are six comparable values of which zero gave truth. The result will be the number of comparisons, which gave truth to all comparisons. Zero was gained. The following formula can be applied in convolutional representation:

$$comp(A,B) = \int_{-\infty}^{\infty} \int_{x}^{\infty} f_A(x) f_B(y) dy dx. \tag{7.12}$$

If $f_A(x)$ and $f_B(y)$ are not Dirac delta functions, there is no difference between >a > =. In case of discrete one for >we get:

$$comp(A,B) = \sum_{y} \sum_{x>y} f_A(x) f_B(y), \tag{7.13}$$

and for >=:

$$comp(A,B) = \sum_{y} \sum_{x \geq y} f_A(x) f_B(y), \tag{7.14}$$

x and y are the middle of intervals, in this case. The more intervals, the received values be closer to each other.

The logical operations can be performer on the result of comparison. The logical produst will be as follows:

$$a \cap b \equiv ab, \tag{7.15}$$

suma logiczna:

$$a \cup b \equiv a + b - ab, \tag{7.16}$$

i negacja:

$$\sim a \equiv 1 - a. \tag{7.17}$$

Arithmetic operations on numbers in convolutional representation are quite complex, therefore the ordered pair: mean value, variance increment $(\mu; \Delta\sigma^2)$ can be used instead. Difference between the variance increment and the variance is that the variance may be negative value (Borawski 2012a). Mean value for A in convolutional representation may be calculated as follows (Borawski 2012a):

$$\mu_A = \sum_{x} f_A(x) p(x), \tag{7.18}$$

where μ_A is the mean value of A, a $p(x)$—probability of occurrence of value belonging to the interval where its middle falls at x, the variance increment (Borawski 2012a) is given as:

$$\Delta\sigma_A^2 = \sum_x p(x)(f_A(x) - \mu_A)^2, \tag{7.19}$$

where $\Delta\sigma_A^2$ is the variance increment of A.

Adding operation $(\mu; \Delta\sigma^2)$ can be performed according to the formula (Borawski 2012a):

$$\left(\mu_A; \Delta\sigma_A^2\right) + \left(\mu_B; \Delta\sigma_B^2\right) \equiv \left(\mu_A + \mu_B; \Delta\sigma_A^2 + \Delta\sigma_B^2\right), \tag{7.20}$$

while multiplication (Borawski 2012a) is given as:

$$\left(\mu_A; \Delta\sigma_A^2\right)\left(\mu_B; \Delta\sigma_B^2\right) \equiv \left(\mu_A\mu_B; \mu_B^2\Delta\sigma_A^2 + \mu_A^2\Delta\sigma_B^2\right). \tag{7.21}$$

Ordered pairs can be vector coordinates which form a vector space (Borawski 2012b). If vectors' transformations are performed in this space, the vector should include covariance between all axes of the coordinate system. The example of a vector might be as follows:

$$\left(\mu_x; \Delta\sigma_x^2; \mu_y; \Delta\sigma_y^2; \mu_z; \Delta\sigma_z^2; \sigma_{x,y}; \sigma_{x,z}; \sigma_{y,z}\right), \tag{7.22}$$

where μ_x, μ_y, μ_z are mean values for x, y, z, $\Delta\sigma_x^2, \Delta\sigma_y^2, \Delta\sigma_z^2$—variance increments for x, y, z, $\sigma_{x,y}$—covariance between x and y, $\sigma_{x,z}$—covariance between x and z, $\sigma_{y,z}$—covariance between y and z axes.

The sum of two vectors can be defined as follows:

$$\begin{aligned}\vec{A} + \vec{B} \equiv \Big(&\mu_{Ax} + \mu_{Bx}; \Delta\sigma_{Ax}^2 + \Delta\sigma_{Ax}^2; \mu_{Ay} + \mu_{By}; \Delta\sigma_{Ay}^2 + \Delta\sigma_{By}^2, \\ &\Delta\sigma_{Az}^2 + \Delta\sigma_{Bz}^2; \sigma_{Ax,Ay}^2 + \sigma_{Bx,By}^2; \sigma_{Ax,Az}^2 + \sigma_{Bx,Bz}^2; \sigma_{Ay,Az}^2 + \sigma_{By,Bz}^2\Big),\end{aligned} \tag{7.23}$$

while the vector multiplication by scalar:

$$b\vec{A} \equiv \left(b\mu_{Ax}; b\Delta\sigma_{Ax}^2; b\mu_{Ay}; b\Delta\sigma_{Ay}^2; b\sigma_{Ay,Ay}^2; b\sigma_{Az,Az}^2\right). \tag{7.24}$$

Given the matrix:

$$\begin{bmatrix} m_{x,x} & m_{x,y} & m_{x,z} \\ m_{y,x} & m_{y,y} & m_{y,z} \\ m_{z,x} & m_{z,y} & m_{z,z} \end{bmatrix}, \tag{7.25}$$

is a transformation matrix, then mean values transformation will be according to the formula:

$$\begin{cases} \mu'_x &= m_{x,x}\mu_x + m_{x,y}\mu_y + m_{x,z}\mu_z \\ \mu'_y &= m_{y,x}\mu_x + m_{y,y}\mu_y + m_{y,z}\mu_z \\ \mu'_z &= m_{z,x}\mu_x + m_{z,y}\mu_y + m_{z,z}\mu_z \end{cases}, \tag{7.26}$$

variance increment:

$$\begin{aligned} \Delta\sigma'^2_x = \; & m^2_{x,x}\Delta\sigma^2_x + m^2_{x,y}\Delta\sigma^2_y + m^2_{x,z}\Delta\sigma^2_z + 2m_{x,x}m_{x,y}\sigma_{x,y} \\ & +2m_{x,x}m_{x,z}\sigma_{x,z} + 2m_{x,y}m_{x,z}\sigma_{y,z}, \end{aligned} \tag{7.27}$$

$$\begin{aligned} \Delta\sigma'^2_y = \; & m^2_{y,x}\Delta\sigma^2_x + m^2_{y,y}\Delta\sigma^2_y + m^2_{y,z}\Delta\sigma^2_z + 2m_{y,x}m_{y,y}\sigma_{x,y} \\ & +2m_{y,x}m_{y,z}\sigma_{x,z} + 2m_{y,y}m_{y,z}\sigma_{y,z}, \end{aligned} \tag{7.28}$$

$$\begin{aligned} \Delta\sigma'^2_z = \; & m^2_{z,x}\Delta\sigma^2_x + m^2_{z,y}\Delta\sigma^2_y + m^2_{z,z}\Delta\sigma^2_z + 2m_{z,x}m_{z,y}\sigma_{x,y} \\ & +2m_{z,x}m_{z,z}\sigma_{x,z} + 2m_{z,y}m_{z,z}\sigma_{y,z}, \end{aligned} \tag{7.29}$$

and covariance increment:

$$\begin{aligned} \sigma'^2_{x,y} = \; & m_{x,x}m_{y,x}\Delta\sigma^2_x + m_{x,x}m_{y,y}\sigma_{x,y} + m_{x,x}m_{y,z}\sigma_{x,z} \\ & +m_{x,y}m_{y,x}\sigma_{y,x} + m_{x,y}m_{y,y}\Delta\sigma^2_y + m_{x,y}m_{y,z}\sigma_{y,z} \\ & +m_{x,z}m_{y,x}\sigma_{z,x} + m_{x,z}m_{y,y}\sigma_{y,z} + m_{x,z}m_{y,z}\Delta\sigma^2_z, \end{aligned} \tag{7.30}$$

$$\begin{aligned} \sigma'^2_{x,z} = \; & m_{x,x}m_{z,x}\Delta\sigma^2_x + m_{x,x}m_{z,y}\sigma_{x,y} + m_{x,x}m_{z,z}\sigma_{x,z} \\ & +m_{x,y}m_{z,x}\sigma_{y,x} + m_{x,y}m_{z,y}\Delta\sigma^2_y + m_{x,y}m_{z,z}\sigma_{y,z} \\ & +m_{x,z}m_{z,x}\sigma_{z,x} + m_{x,z}m_{z,y}\sigma_{y,z} + m_{x,z}m_{z,z}\Delta\sigma^2_z, \end{aligned} \tag{7.31}$$

$$\begin{aligned} \sigma'^2_{y,z} = \; & m_{y,x}m_{z,x}\Delta\sigma^2_x + m_{y,x}m_{z,y}\sigma_{x,y} + m_{y,x}m_{z,z}\sigma_{x,z} \\ & +m_{y,y}m_{z,x}\sigma_{y,x} + m_{y,y}m_{z,y}\Delta\sigma^2_y + m_{y,y}m_{z,z}\sigma_{y,z} \\ & +m_{y,z}m_{z,x}\sigma_{z,x} + m_{y,z}m_{z,y}\sigma_{y,z} + m_{y,z}m_{z,z}\Delta\sigma^2_z. \end{aligned} \tag{7.32}$$

In order to compare numbers assumptions about the shape of the probability distribution function are required. Mean value and variance can describe a random variable of any distribution. The most common are distributions close to the normal one. So it can be assumed that this is a distribution of this nature. The density function of such a distribution can be approximated by the triangular function (Fig. 7.1):

$$f(x) = \begin{cases} y = a_L x + b_L & for \quad x \in \langle \mu - c; \mu) \\ y = a_R x + b_R & for \quad x \in \langle \mu; \mu + c \rangle \\ 0 & otherwise \end{cases}, \tag{7.33}$$

where:

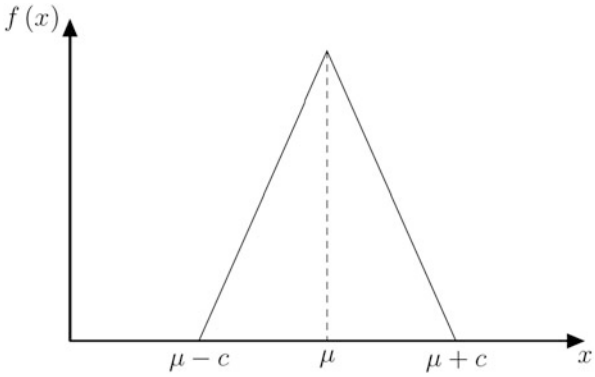

Fig. 7.1 Triangular function

$$\begin{cases} a_L = \dfrac{1}{c^2} \\ b_L = \dfrac{c-\mu}{c^2} \end{cases}, \tag{7.34}$$

and:

$$\begin{cases} a_R = -\dfrac{1}{c^2} \\ b_R = \dfrac{c+\mu}{c^2} \end{cases}. \tag{7.35}$$

The c value is a multiple of the standard deviation σ determined so that the triangular function is close to the normal distribution. Unlike triangular function used in fuzzy arithmetic, the triangular function approximating density function should meet the same condition as the latter one:

$$\int_{-\infty}^{\infty} f(x)dx = 1 \tag{7.36}$$

At $c = 0$ the triangular function transforms to Dirac delta function. Comparing triangular numbers, like numbers in convolutional representation, equality occurs only when two Dirac delta functions occur. In order to determine which number is greater, the following formula should apply (7.12). Since the triangular function consists of three functions, nine cases (each function of the first number with each function of the second number) should be considered. Combinations with the function $f(x) = 0$ always equals zero, so it is sufficient to have calculations limited to only four cases and get the results summed up. Figure 7.2 represents two triangle numbers. To verify if A is greater than B the following have to be calculated:

- Coefficient r_1 for overlapping part of triangular numbers, following the formula (7.12). For example Fig. 7.2 according to the formula:

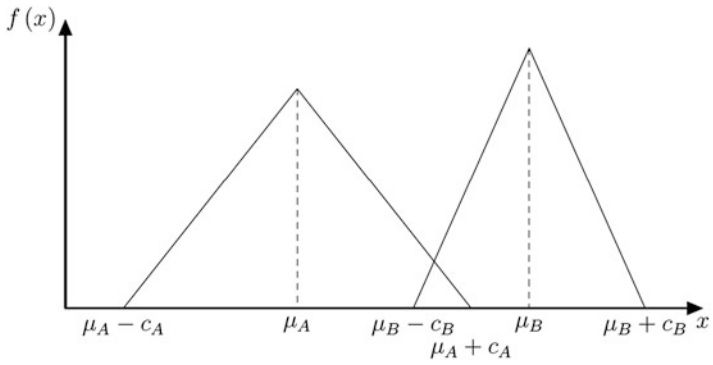

Fig. 7.2 Comparison of two triangular values

$$r_1 = \frac{l_A^4 - u_A^4}{8c_A^2c_B^2} - \frac{(c_A - 2c_B + \mu_A + 2\mu_b)\left(l_A^3 - u_1^3\right)}{6c_A^2c_B^2} - \frac{\left(-\frac{1}{2}l_B^2 - c_Bl_B + \mu_Bl_B - c_Ac_B + c_A\mu_B - c_B\mu_A + \mu_A\mu_B\right)\left(l_A^2 - u_A^2\right)}{2c_A^2c_B^2} - \frac{\left[\frac{1}{2}(c_A + \mu_A)l_B^2 + (c_Ac_B - c_A\mu_B + c_B\mu_A - \mu_A\mu_B)l_B\right](l_A - u_B)}{c_A^2c_B^2}, \tag{7.37}$$

within the range $\langle \mu_B - c_B; \mu_A + c_A \rangle$. In the above formula l_A is the lower limit and u_A upper limit for A, while l_B and u_B lower and upper limit for B. In case under consideration $l_A = l_B = \mu_B - c_B$ and $u_A = u_B = \mu_A + c_A$.

- Coefficient r_2 (under formula (7.12)) for A value fraction to the left from B value. In the case under consideration it equals zero, because none A fraction is to the left from B value.

  The final result is the sum of r_1 and r_2.

7.3 Simulation of Environment Tracking

Tracking the environment is an important part of brain function. When moving within three-dimensional space, it is necessary to record the shape of the base and location of objects as well as their properties. This is important in order to be able to orient in space and reach key places when needed. Key places for animals might be watering places and places where large food amount is available. Memory limitations make it impossible to memorize all objects. The objects in some degree not

typical, which uniquely identify specific places, are the best to remember. Uniqueness with omitting the remaining elements is the best to be noted. This leads to the method how the brain simulator can and should memorize objects. Simulator should store two components of an object: an object class, and a description of its non-typical properties.

Class is a statistical description of a group of objects similar to each other. For example, such a class may be a class of strawberries. Strawberries have a very similar shape and size. Their size, width to height ratio and radius are always close. They are also subject to certain deviations from the average parameters. Numbers in convolutional representation fit very well to remember these features. They allow to add new information to already existing data so that the average parameters of the object class and possible typical derogations from the average values are easily memorized. These deviations can then be expressed by numerical parameters such as standard deviation. This makes it easy to point to non-typical objects and to remember their unusual characteristics. For example, in case of strawberry size, it is sufficient to check that the strawberry's size is greater than the average value plus a certain standard deviation to indicate that it is unusually large, which may be remembered as its characteristic.

Not only features related to appearance but also other properties can be memorized. For animals and humans, this can be, for example, the amount of food associated with the given object. For example, the fisherman must decide which water area to go. Each water area is associated with specific fish species. These water area have two important characteristics: how big fish can be caught there (the amount of food) and the ease of catching. These are information which can be estimated, provided back data is available. With such estimates, numbers in the convolution representation reflecting the amount of food that will allow estimating where more food will be obtained should be compared. In the case of easiness in obtaining food, there is information about the number of successes and failures, which clearly indicates the probability of success.

As a result of the comparison, two numbers, for example 0.4 (amount of food) and 0.7 (probability of gaining food), will be obtained for the first option. For the second option, these values can be, for example, 0.5 and 0.4. The final result gives the logical product, for the first option 0.28, and for the second 0.2. It is visible that in this case the first option is better.

Numbers in convolutional representation are very useful for collecting statistical information about object classes. However, they require a large number of calculations, which in the case of simulating a large number of objects can cause limitations in the complexity of simulated objects. To avoid this, they might be converted to$(\mu; \Delta\sigma^2)$. For example, if a predator is simulated, the numbers in convolutional representations can be used to memorize information about its victims. In parallel ordered pairs can be memorized $(\mu; \Delta\sigma^2)$, updated at every update of the number in the convolutional representation. When making decisions, only ordered pairs can be used $(\mu; \Delta\sigma^2)$. For example, if a fisher is to decide whether to go to area A where there are large fish or to area B where there are small fish, then he must perform a relevant comparison. If a longer fish is involved, he must take

into account that it should catch a few fish, so it must multiply ordered pair $(\mu; \Delta\sigma^2)$ representing the amount of food by the number of needed fish. In the case of easy access to food, fish catch events must occur during one catch, so the probability of catching them should be raised to the power equal to number of needed fish. Finally, as before, the result of the comparison of the size of the animals should be multiplied by the probability of catching, which will allow comparison of the two options.

An ecosystem simulator was developed to explore the possibility of using a convolutional representation to describe objects. In this simulator, there are static objects that map plants to food for dynamic objects representing herbivores. Simulation involves three types of plants, differing in the amount of food provided. There are two types of dynamic objects called (A and B). In addition, predators feeding on objects of A and B type are simulated. Plants are mapped with spheres and herbivores and predators by cuboids. Simulation was created in the Unity environment (Fig. 7.3). It includes a rectangular piece of terrain that no object can leave. In this area there are hills and a lake, fall into which result in that all the objects die.

Figure 7.4 shows the simulator classes. Any object that can move itself (herbivores and predators) is created based on the TAIObject class. It can record and track all objects in its immediate surroundings. They are stored in a TCollectionPositionObject class object. Each moving object has one object of TDecisionMaker class. It analyzes objects in the vicinity and issues commands for specific actions (change of movement direction). For herbivorous animals, there are two types of TDecisionMaker classes: TDecisionMakerNoDecision and TDecisionMakerNearObject. The first class concerns herbivores, which can be called passive (B type object). They move in a certain direction, but do not analyze the properties of close objects, which means they do not change the movement direction. A second-class object collects statistical information about plants (A type object). This way, it can decide to change the direction of movement based on the comparison of plants in its vicinity.

During the simulation the plants appear in random places, at equal intervals, until they reach the maximum level. Herbivorous animals appear in predefined areas in the number of 5 for Type A and 10 for Type B. They have a predetermined amount of food that decreases over time. If it falls to zero, the animal starves to death.

Consumption of each plant increases the amount of food. If the amount of food exceeds a certain threshold, the animal is divided into two separate animals, each with half the amount of food available at the time of division. Predators behave similarly. In the beginning there are only six of them. If they accumulate enough food they also divide.

Figure 7.5 presents changes in time of objects population. At first, the number of plants quickly grows. For herbivores, this gives them better access to food, so they are starting to reproduce more and more. Type A animals, however, have the advantage of being able to compare the amount of food associated with the objects surrounding them. That is why their population is rapidly growing. This causes a

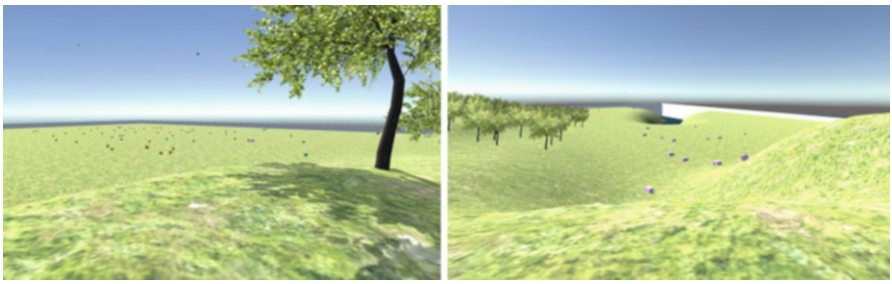

Fig. 7.3 Ecosystem simulator

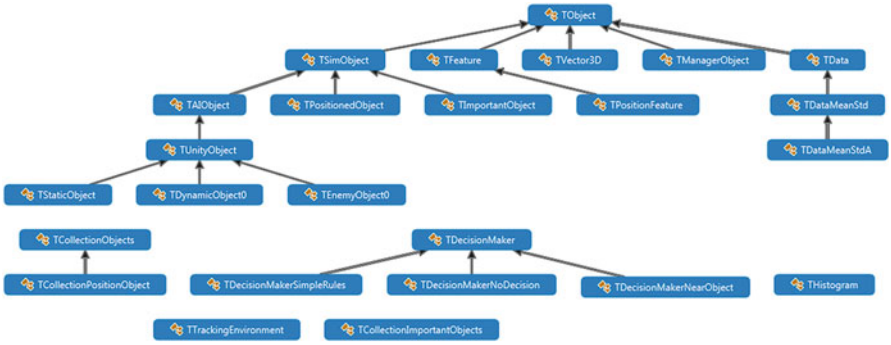

Fig. 7.4 Simulator classes

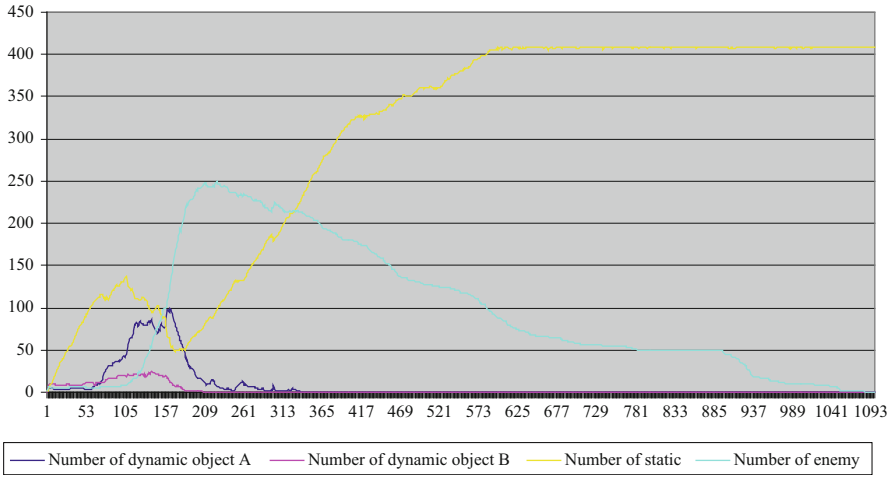

Fig. 7.5 Objects population changes over time

decrease in the number of plants, but also an increase in the number of predators. Finally, the number of predators is increasing so much that they eat all herbivores and die of hunger.

7.4 Conclusions

The brain memorizes a lot of information, many of which are statistical in nature, such as the size of a certain class of objects which differ slightly from each other. To remember this type of information convolutional representation and ordered pairs mean value and variance can be used. They give not only the ability to store information, but also the ability to perform arithmetic operations and comparisons. This facilitates analysis of stored information. This allows simulate the recording and storage of surrounding information by the human brain. As it was presented in this chapter, it is possible to make a simulator that maps brain activities related to processing of information about the surrounding objects.

The methods presented in this chapter allow you to analyze information that is not accurate. For example, if a person responds to the same survey twice in a certain time interval, the answers will not be the same. This allows us to determine the degree of uncertainty of the answer, which can be further used in the research. Further study is planned to determine the utility of the proposed methods in the research of public awareness campaigns effectiveness.

Acknowledgement The project was financed with the NCN funds allocated according to the decision DEC-2016/21/B/HS4/03036.

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Part II
Behavioral Aspects of Economic Decision Making

Chapter 8
Identification of Heuristics in the Process of Decision Making on Financial Markets

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Abstract In the chapter we focus on the behavioral determinants of the decision-making process on financial markets. The aim of the research is to indicate and discuss an experiment as a method of identification of behavioral heuristics from the perspective of an investor's attitude toward risk. The experimental studies are considered on the basis of such behavioral models as the LSV model, the BSV model and other. When the experiment has been completed, an appropriate method of analysis of the interrelations between identified factors is a Structural Equation Model, which is rather rarely applied in behavioral finance but is widely known in empirical psychology.

Keywords Decision Making • Behavioral Finance • Experiment • Structural Equation Model (SEM)

8.1 Introduction

The use of experiment in economics does not have a long history and is not a preferred method in economics research, either. The first experimental attempts made on groups of students by Chamberlin (1948) were a kind of incentive to look for a new way of verifying already well-established or new hypotheses in economics that were being formulated in the emerging subdisciplines at that time. The awareness of the existence of a strong relationship between economics, sociology and psychology formed the foundation for the development of experimental economics (Ariely 2008; Tyszka 2010). One of the most important achievements in this aspect was the so-called 'The Allais paradox' (1953) propagated in the version commonly known as the 'Prospect theory' developed by Kahneman and Tversky (1979).

The experimental method in economics has many proponents as well as adversaries. Allegations are raised about the lack of realism in various laboratory experiments or about the unauthorized transfer of results obtained from a student test group to larger social groups. Experimental study is to identify the differences in

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_8

economic decisions made by the test group and the control group. Experiments presented in literature often do not possess the characteristics of appropriate experiments. These are most often mental experiments—the respondent provides his or her answer to questions on the posed problem such as, for instance, 'what he would do if . . .'; they have to select an option out of the presented ones, or otherwise externalize their perception of an economic phenomenon and their attitude toward that problem. One needs to realize the fact that if we conduct an experiment, then we create certain conditions affecting its performance. It happens quite frequently in experiments that a task to be done is introduced with the words 'Imagine that you have received the amount of . . .'. A participant in the experiment makes a choice of a particular way of investing in the stock market in by means of a virtual game where he does not need to settle the amount invested which is completely different from the actual game with the amount previously obtained by the investor as a result of financial operations or earned by performing a hard work. The differences between a declarative description of 'what would you do . . .' and the actual choices can be seen best in the study of attitudes toward financial risk when at the end participants are proposed to be paid for the effort undertaken either in the form of a proposal of the payment of a certain amount (guaranteed payment) or payment of twice as much of that but after tossing the coin (the probability of winning is equal to 0.5). This procedure shows how declared attitudes differ from the actual choice. Despite declarative risk-taking attitudes, the choice that is actually made is usually a risk avoiding one.

Many researchers recognize that a proper way to conduct research is to observe the behavior and the effects of the decisions taken. This historical approach assumes ergodicity of economic processes and the stability of investor's behavior. It can be considered that there are no significant differences in human behavior in different epochs. The subject and the technique do change, however, the essence remains unchanged. It is worth citing Zbigniew Herbert's essay entitled 'The Bitter Smell of Tulips', which ends with the announcement of the arrival of another tulip mania or a similar phenomenon.

'So you cannot put a great full stop after the date of 1637 and consider the matter to be completed definitely. It is not wise to erase it from memory or classify it as incomprehensible quirks of the past. If the tulip mania was a kind of psychological epidemic—and so we dare to believe—there is a probability approaching certainty that one day, in one form or another, it will visit us again.

In some port in the Far East it is just embarking a ship.' (Herbert 2003; in authors' free translation for the needs of this article).

8.2 Rationality and Irrationality in Finance

The proper understanding of probability as a measure of events in relation to history, either in the form of the empirical distribution or the estimated density function, is transferred to future events or is intended to examine the rationality of

investors. Thus it is crucial for further discussion. Zielonka explicitly says that the investor that perceives the probability of future events properly, and represents consistent preferences is considered to be rational (Zielonka 2011). Deviations from this way of looking at probability does not have to be a mistake, it may only be another way of estimating the probability. Behavior other than reasonable within the meaning of the theory of von Neumann and Morgenstern (1944), and probability estimated in other ways, according to many scholars, leads to anomalies in the capital market. Particular anomalies are related to investor behavior and therefore some heuristics are considered to have their psychological roots. A comprehensive review of these anomalies and potential links was prepared by Szyszka (Szyszka 2009). Many anomalies indicated in the subject literature were identified by means of statistical and econometric methods (Barberis et al. 1998, Czerwonka and Gorlewski 2008). This is particularly true with regard to calendar anomalies, but not only to them. Heuristics assigned to anomalies as their causes cannot be indicated to and interpreted explicitly. In the absence of testing based on well-designed experiments, the models proposed in the literature remain only hypotheses. The words that appear then are 'a mysterious phenomenon' (according to Zielonka 2003, 2011). The tests proposed in the subject literature identify only the phenomenon (e.g., the phenomenon of underpricing) and not the cause. An analysis quite frequently takes the form of a presentation and the conclusions are derived on the basis of the observed frequency without the use of statistical tests (Aziewicz and Dobrowolski 2014). Such an analysis does not always confirm the presence of anomalies. Examination of strong correlations (Lizińska and Czapiewski 2015) followed by a suggestion about the reaction of investors characterized by excessive overconfidence is not scientifically proven. The appropriate experiment with the task of examining a particular phenomenon (e.g., the phenomenon of excessive investor overconfidence) should take into account panel (cohort) research before deciding to purchase shares in the initial public offering and after the first public quotation. Ljungqvist conducted in-depth studies of the above-mentioned phenomenon of IPO (Initial Public Offering) (Ljungqvis and Wilhelm 2003) and stated that the exorbitant prices reached in 1999 and 2000 show that a change in the regime in the initial declarations and other elements of the pricing policy may be at least partly responsible for changes in the property structure and investor behavior during this period. The results refer to the period called 'dot.com bubble'.

Calendar effects have been known since the middle of the last century. The January effect was observed by Wachtel (1942). However, the fundamental discussion was initiated only in the 1970s and the issue has been debated until now. The sheer testing of the phenomenon has become possible thanks to the development of dynamic econometric methods using the methodology of stochastic processes and the creation of a new discipline, which is financial econometrics broadly applying this methodology (Osińska 2016). Calendar anomalies are associated with heuristics such as mental accounting, the individual investors' disposition effect, unrealistic optimism, and wishful thinking. Identifying and testing calendar effects have been attended to by many scholars. Fiszeder in his works used a lot of statistical and econometric methods. In one of them (Fiszeder and Kożuchowska 2013), he

applied two methods that do not require the assumption of normality of returns distribution, namely the permutation test and GARCH model. The survey was carried out for the stock market indices WIG and WIG20. The results obtained by the authors of the study indicate the occurrence of the turn of the month effect, the lack of seasonal fluctuations and very poor weekly fluctuations. The research shows that the strength of the observed and identified calendar effects is much weaker in comparison with the results presented in other publications. Thus, this research stream is still being exploited and newer tools will be used for their diagnosis. However, this does not lead to the identification of heuristics that can directly lead to calendar effects.

8.3 Foundations of Experiments in Finance

The most important role in the development of behavioral finance is ascribed to the departure from the generally accepted model of decision making under risk presented by von Neumann and Morgerstern (1944). According to this theory, the best way to make decisions is the one in which rationality is reduced to maximize the expected utility. The axioms describing preferences (i.e. elimination, transitivity, dominance, constancy) form a coherent theory. These axioms can be expressed formally for a risk taking situation where a choice of project within which effects x_i with the number i are ascribed the probabilities p_i. In this way, whether it be in an experimental situation of or in a real decision situation, we have a description of the form $(x_1,p_1;\ldots;x_n,p_n)$, where $p_1 + p_2 + \cdots + p_n = 1$. A special situation is that when the project is narrowed to the possible existence of two effects x_1 and x_2 in the form $(x_1,p;x_2,1-p)$. such a situation is most frequently presented in experiments. According to von Neumann and Morgerstern's theory, the usefulness of the entire project is related to the usefulness of its individual effects. The theory takes the axiomatic form which assumes the correctness of the following statements:

1. Expectations: $U(x_1, p_1; \ldots; x_n, p_n) = p_1 \cdot u(x_1) + \ldots + p_n \cdot u(x_n)$.
2. Assets integration: $U(w + x_1, p_1; \ldots; w + x_n, p_n) > u(w)$.
3. Risk aversion: $u'' < 0$.

Allais (1953) was the first to show through experiments (a hypothetical decision problem and the choices made by students) that the descriptive power of the theory described by von Neumann and Morgenstern could be undermined. Allais' experiment refuted the principle of elimination in the von Neumann and Morgenstern axioms. The problems related to such axioms were also raised by Samuelson (1963). Samuelson did not carry out experiments. What was obvious for him was that the axiom of the choice of that decision whose probability of winning is greater. From that he derived his statement on irrationality of behavior in case of rejection of a single-choice game of chance and its acceptance in case of the repeated choice of the same game of chance. This is connected not so much with the judgment of the probability but with its execution in multiple samples. One of the important issues

that cause deformation of preferences under circumstances of uncertainty and risk is neglecting probability or its deformation. Here, we should present a comprehensive debate on the objective and subjective probability (Szreder 2004) and refer to the understanding of probability in the context of the mathematical and logical ignorance.

Interesting examples are shown by Paulos in his popular book entitled Innumeracy (Paulos 2011). Transformation of probability underlies Kahneman and Tversky's perspective theory (Kahneman and Tversky 1979). The experiments conducted in a group of students by Kahneman and Tversky consisted in presenting to a group two situations in which they could win certain amounts with a specified probability. The choice of option A or B was not explicit. A greater percentage of the choices refuted a particular rational behavior described in the theory of von Neumann and Morgenstern. Similar experiments carried out by other researchers as well as by students within their diploma works confirmed certain effects.

- The effect of certainty and underestimation of high and medium probabilities. This leads to a way of thinking that 'the one hundred per cent probability' is still worse than certainty.
- Revaluation of low probabilities shows that even a small chance of obtaining a large amount is tempting.
- The rebound effect explains the observed phenomenon of a smaller grief after a single large loss than after two smaller ones.
- The isolation effect leads to the inconsistence of preferences and is about the choice focused on exposing differences in the presented situations and not the whole decision-making process.
- The effect of operationalization of a decision-making process, which is based on a preliminary analysis of the decision-making problem and subjecting it to operations such as coding, combining, separation, reduction aimed at making the right choice in the next stage, i.e., the valuation of options presented.

Presenting analyses of various decision-making situations and choices made in experiments, the authors of the prospect theory proposed replacing the utility function with the evaluation function (Kahneman and Tversky's example).

$$v(x) = \begin{cases} x^{\alpha} & \text{for } x \geq 0 \\ -\lambda(-x)^{\beta} & \text{for } x < 0 \end{cases} \tag{8.1}$$

where γ is the coefficient of loss aversion and the following conditions: $\alpha,\beta \in (0,1)$, $\gamma > 1$ are met.

The values of these parameters can be estimated on the basis of empirical research. Experiments conducted by Kahneman and Tversky enabled them to determine the coefficient of risk aversion at $\gamma = 2.25$ which indicates a strong risk aversion. The research also led to the conclusion that while taking decisions under risky circumstances decision makers transform pre-defined probabilities that were treated in the experiments as objective. The function proposed by Prelec

(1998) satisfies the properties postulated by Kahneman and Tversky. The form of this function is as follows:

$$\omega(p) = \exp(-\beta(-\ln p)^{\alpha}), \tag{8.2}$$

where $0 < \alpha < 1$.

Due to the prospect theory and effects observed in the experiments conducted by Kahneman and Tversky, it was possible to explain the decision-making mechanisms applied to the financial markets.

8.4 Anomalies, Biases and Heuristics

When treated as anomalous attitudes, these actions cause anomalies in the market. These attitudes are observed directly and are confirmed by many experimental studies conducted by psychologists. They are also confirmed by the observations of specific behaviors in the financial market. A broad overview of these effects with research examples and the description of their significance for the market are presented by Barberis and Thaler (2003) Czerwonka and Gorlewski (2008) and Forbes (2009).

Below are some of the effects observed in investment activity, or more generally, in the sphere of economic decisions (Thaler 1999a).

- The effect of sunk costs.
- Mental accounting.
- The disposition effect.
- The endowment effect.
- The status quo effect.
- The effect of myopia and loss aversion.

The observed psychological effects are the basis of behavior or rather a strategy for reasoning and quick decision making. Instead of using the strict rules of reasoning deliberately, the investor uses a simplified pattern frequently not being fully aware of that. This happens in the absence of access to full information, lack of time, or lack of willingness to give things much insight. These patterns are called heuristics and their use is referred to as 'heuristic reasoning'. The meaning of the word 'heuristics' (in the Greek language 'heúresis' means 'finding' and 'heúrēka' means 'I found' and is a form of the verb 'heurískein'—to discover, to find) refers to a method of discovering new facts and relationships between them. Originally these patterns had a positive connotation. Tversky and Kahneman through their experimental studies linked the notion to the concept of multiple cognitive biases that characterize human thinking processes and decision making. Kahneman and Tversky's hypothesis is that people make decisions based not on rational premises and strict rules of reasoning but on heuristics. Thus, heuristics were opposed to rationality. Heuristics should be looked

at as a simplified way of expressing opinions while making decisions. However, they should not be perceived only as an error or anomaly.

There are many types of heuristics but the most distinctive, recognizable and researched are the following:

- Representativeness heuristic.
- Anchoring and adjustment heuristic.
- Conservative heuristic.
- Overconfidence heuristic.
- Hindsight bias.
- Self-attribution bias.
- Positive and negative recency effects.

The representativeness bias in making judgment about the probability of belonging of a certain object to a class set ignores the principles of probability theory and evaluates them according to the degree of similarity to the representatives of this class. While making judgments about the probability of occurrence of events, the principles of statistics are ignored with the assumption that a small sample displays the peculiar characteristics of the entire population. In case of financial markets, this heuristic is manifested in reliance on stereotypes or familiar patterns. This may concern the knowledge of patterns in the analysis of graphs.

The anchoring heuristic is a cognitive heuristic where decisions are made on the basis of arbitrary initial values. Anchoring can be an intentional activity, for instance, applied by sellers while giving the value of the traded object to achieve a higher transaction price. In case of the capital market, such a reference point may be the nearest whole value achieved by the observed rate.

The conservative heuristic on the financial market happens when investors are slow to review their beliefs in spite of the fact of receiving new pieces information. Under some circumstances, it is opposite to the representativeness heuristic. Analysis of the applicability of this heuristic points to two factors: the strength of the impact of information on the recipient's mind and the significance of this finding in the understanding of statistical properties. Ignorance of statistical knowledge, or simply lack of it, causes severe impacts of only the first factor.

The overconfidence heuristic captures the definitional property of human tendencies most. Extremely high assessment of one's own skills and knowledge is not typical of only young investors, though in this case it may be the highest. Many studies confirmed through experiments the use of this heuristic by investors, for example, when narrowing the interval of forecasts (Barberis and Thaler 2003).

The hindsight bias manifests itself in the natural reaction assuming one's ability to foresee an unlikely event. Such an opinion is formulated at a time after this event occurred. This way of thinking is transferred to future events as cases that are easy to predict. In this way, the whole set of prognostic tools applied for the conditions of randomness are omitted. The self-attribution bias is about attributing successes to one's own talents and abilities and failures to other people, e.g., to investment advisors. Faith in one's own abilities and conviction about one's successes may result in taking excessively risky positions on the market.

The positive and negative recency effects refer to the representativeness bias. It is can be observed while preparing forecasts. The negative effect means assigning a much greater probability to an event that will occur after a long series of adverse events. A positive effect is observed when the projection for an event expects this trend to continue. This effect is fairly easy to identify within experiments involving making judgments about the probability by means of tossing the coin. In the context of the market it refers to taking long or short positions based on the observation of the trend and not on the fundamental information.

8.5 Statistical Analysis in Behavioral Finance

8.5.1 General Remarks

In three previous parts of this chapter the remarks on experiments in behavioral finance have been presented and now we focus on the methods of statistical inference. The difference between experimental and inferential approaches in behavioral finance is such that an experiment enables to observe the decision making process in real time, while statistical methods can be used only ex post, i.e. after the decisions have already been made. On the other hand, the real-time experiments are rather limited to selected cases and entities while statistical inference can cover a wider range of population in interest. One can argue that the experimental data are more trustworthy and more valuable for drawing conclusions, but the results of decisions made during the experiment can be often observed in a longer time period, which is not covered by the experiment. Furthermore the phenomenon of learning from experience can be observed over time (see: DeCanio 1979; Daudelin 1997). These facts can be—by contrast—caught by statistical methods. Anyway, both forms of observing heuristics on financial markets, i.e. experiment and statistical inference are valuable and should be considered as complementary.

When statistical methods are to be applied it is useful to identify the investors according to their 'rationality' in the decision-making process. Despite of the fact that some researches indicated departures from normality of financial returns (Mandelbrot 1963) until Kahneman and Tversky's experiment it was common to assume that all investors behave as if they were rational ones. Later the individual and institutional investors have been considered, but in the recently developed market microstructure models (O'Hara 1995), it is assumed that three types of investors can be distinguished: rational and irrational ones, and the market makers. The rational investors use all available information in a decision-making process and they have substantial impact on the number of transactions and the price creation process, while the irrational ones are vulnerable to behavioral biases or heuristics, however their impact on the price creation process on the market is rather small. The market makers are professionals who are responsible for market

liquidity and they possess the widest access to information at a given moment. It is common to assign institutional investors to the group of rational and individual investors to the group of irrationals. This can be a false assumption because the research made by Lakonishok et al. (1992) shows that institutional investors are vulnerable on behavioral biases, such as herding behavior. Herding behavior on financial markets have been widely studied and described on the basis of sociological and psychological factors (see for example: Lakonishok et al. 1992; Wermers 1999, and recently, Baddeley et al. 2012). If an investor considers two possibilities of a gain and a loss with given probabilities his decision can be thought as independent. That means that the investor uses publicly available information set as well as his private information. The situation changes when he additionally sees the decision made by another investor. Then he extends the information set of the observed decision of other investor and he ignores his private information. Under some conditions it starts a cascade of herding. Bikhchandani and Sharma (2000) considered three models of herding such as: information-based herding and cascade, reputation-based herding and compensation-based herding. All the types are called 'the rational herding'. The most popular test for herding behavior comes from Lakonishok et al. (1992) who observed herding tendency among fund managers in the case of shares small companies. This finding was both important and surprising for the typical understanding of 'the rational investor'. It was indirectly proved by other researchers. For example Grinblatt, Titman and Wermers (1995) observed changes in portfolios of mutual funds in the USA and using the test published by Lakonishok et al. (1992), finding that phenomenon of herding took place. Other anomalies observed on financial markets also refer to both groups: i.e. institutional and individual investors (comp. Schwert 2003).

Depending on the purpose of the analysis and data accessibility one can use different statistical methods. The most intuitive division of the models is based on the type of statistical data. When, based on a large sample, a survey data are collected the structural equation models (SEM) are applicable. If, on the other hand, the data have a form of time series then a time series models such as ARMA (Box and Jenkins 1970) model or Treynor and Mazuy (1966) model can be applied. The possible methods of statistical inference have been summarized in Table 8.1.

As our study concentrates on the experiments in finance the structural equation models methodology will be discussed in details.

8.5.2 Structural Equations Models

Referring to the results of psychological experiments (Brzeziński 2003; Konarski 2011), a structural equations model can be indicated as an appropriate tool of statistical inference when the survey data are available. These models enable an

Table 8.1 Methods of statistical inference about behavioral hypotheses in finance

Type of the data	Survey data	Time series
Model for conditional mean	Structural equations model	Time series models: ARMA, ARIMA, TAR
		Treynor-Mazuy model, Henriksson-Merton model
Sample references:	Byrne (2010), Kline (2005), Żurek (2016)	Box and Jenkins (1970), Tong (1990), Treynor and Mazuy (1966), Henriksson and Merton (1981), Zamojska (2012)
Model for conditional variance	Not applicable	GARCH model, SV model
Sample references:	–	Bollerslev (1986), Pajor (2003), Fiszeder (2009), Będowska-Sójka (2014)
Microstructure models	Applicable as theoretical description of the process observed on the market	ACD model, ACV model
Sample references:	Bagehot (1971), Admati and Pfleiderer (1988), Kyle (1985)	Engle and Russell (1998), Manganelli (2005), Doman (2011), Bień-Barkowska (2016)

analysis of sequences of causes and effects and, what is particularly important, the analysis of relationships between both: latent (unobserved) and manifested (observed) variables. Pearl (2000) underlines an equivalence of Structural Equations Models and traditional econometric models, but it can be stated that the SEM models base on the Bayesian network theory which gives a new insight into the relationships under consideration. Furthermore, SEM allows inference about relationships between qualitative variables (Gatnar 2003).

Usefulness of the SEM methodology in behavioral finance lies in the fact that the behavioral heuristics as unobserved directly can be observed via different decisions made by the investors. When an appropriate (large) sample is available one can generalize the results of the mentioned decisions and refer them to a set of possible causes, confirming or rejecting the relationship in the light of the data.

Structural equations models can be perceived as a generalization of traditional regression models because they are more flexible. They allow non-linear relationships, correlations between explanatory variables and latent variables resulting from the impact of different indicators. The assumption of normality of the distribution of an error term is exactly the same as in traditional regression models. Apart from the regression model the SEM model includes: path analysis, confirmatory factor analysis and covariance analysis. The initiator of the path analysis was Wright (1920, 1934), who used this methodology in genetics. As Pearl (2000) demonstrates the inspiration for developing SEM can be found in the early publications of Simon (1953) or Strotz and Wold (1960). Its foundations are particularly developed by Heckerman and Shachter (1995), Halpern (1995), Spirtes et al. (2000) and obviously Pearl (2000).

Structural equations modeling concentrates on three following aspects:

1. Strictly confirmatory approach. It means that model is verified using goodness-of-fit indicators.
2. Comparative approach. It assumes a comparison of alternative specifications and determination which model is better fitted to the data set.
3. Model construction approach. It consists in joining of confirmatory approach with looking for a better model.

The models constructed is such a way are useful only in the ex post analysis. That is why they can serve for confirmation of the attitudes and tendencies observed within the experiments. It is particularly useful when the number of persons as well as the period of the experimentation is limited.

General form of a structural equation models consists of two models: i.e. structural (internal) model and measurement (external) model. A structural model takes the form:

$$\eta = B\eta + \Gamma\xi + \zeta, \tag{8.3}$$

where: $\eta - (m \times 1)$ vector of latent (unobserved) endogenous variables,
$\xi - (k \times 1)$ vector of latent (unobserved) exogenous variables,
$B, \Gamma - (m \times m)$ respective matrices of coefficients,
ζ–vector of error terms, $E(\zeta) = 0$,
$\Psi(\zeta\zeta') - (m \times m)$ variance-covariance matrix of error terms,
$\text{cov}(\xi\zeta') = 0$.

Measurement models are related with the confirmatory factor analysis. The measurement equation for latent endogenous variables is defined as:

$$Y = \Lambda_Y \eta + \varepsilon, \tag{8.4}$$

where: $Y - (p \times 1)$ vector of manifested (observed) endogenous variables,
$\Lambda_Y - (p \times m)$ matrix of loads that show impact of latent variables η for the observed ones,
$\varepsilon - (p \times 1)$ vector of error terms where $E(\varepsilon) = 0$,
$\Theta_\varepsilon(\varepsilon') - (p \times p)$ variance-covariance matrix of error terms,
$\text{cov}(\eta\varepsilon') = 0$.

In similar way the measurement of latent exogenous latent variables is defined:

$$X = \Lambda_x \xi + \delta, \tag{8.5}$$

where: $X - (q \times 1)$ vector of manifested (observed) exogenous variables,
$\Lambda_x - (q \times k)$ matrix of loads that show impact of latent variables ξ for the observed ones,
$\delta - (q \times 1)$ vector of error terms, where $E(\delta) = 0$,
$\Theta_\delta(\delta\delta') - (k \times k)$ variance-covariance matrix of error terms,
$\text{cov}(\xi\delta') = 0$.

SEM can be perceived as a set of statistical techniques connecting both: a path analysis and a factor analysis. The path analysis allows graphical presentation of causal structure of the observed factors as well as determination of their mutual relationships whereas factor analysis confirms the identification of unobserved variables. The term 'path analysis' is reserved for the special case when only observed variables are used in the analysis and it is used instead of SEM. If, at least one latent variable appears in the model then the term 'SEM' is applied.

It is important to emphasize that when a structural model is to be constructed one has to identify a priori the entire set of relationships and test the model based on the sample and variables included in the measurements. As concerns the identification whether the factors developed in (8.4) and (8.5) correspond to the assumed ones the Cronbach's alpha coefficient is typically used (Cronbach 1951). This statistic measures internal consistency reliability i.e. the degree to which responses is consistent across the items within a single measure. The values of Cronbach's alpha larger than 0.7 are considered satisfactory (Kline 2005).

Furthermore, the number of parameters to be estimated—including covariances, path coefficients, and variances must be known at the very beginning. At the stage of the data collection one should remember that the covariances are the basis for structural modeling that requires: a set of quantitative data and an assumption of multivariate normality. In practice some variables are collected in the ordinal form what generates additional requirement of mapping them onto one of possible scales, typically Likert's scale. It has been recognized that responses to several Likert questions may be summed providing that all questions use the same Likert scale and that the scale is an approximation to an interval scale, in which case the Central Limit Theorem allows treatment of the data as interval data measuring a latent variable. If the summed responses fulfill these assumptions, parametric statistical tests can be applied (see discussion provided by Norman 2010).

The path diagram starts the analysis. The following rules of drawing it are very helpful in practice:

1. Latent variables (factors) are represented with circles and measured (observed directly) variables are represented with squares.
2. Lines with an arrow in one direction show a hypothesized direct relationship between the two variables. It should originate at the causal variable and point to the variable that is caused. The absence of a line indicates there is no causal relationship between the variables.
3. Lines with an arrow in both directions should be curved and this demonstrates a bi-directional relationship (i.e., a covariance). Covariance arrows should only be allowed for exogenous variables.
4. For each endogenous variable, an error term in the form of circle should be added in the model.

An example of a SEM diagram is illustrated in Fig. 8.1.

It is worth noting that path analysis allows describing the following linear relationship $X \rightarrow Y \rightarrow Z$, which means that it is possible to find out the impact of X on Z through the moderation of Y.

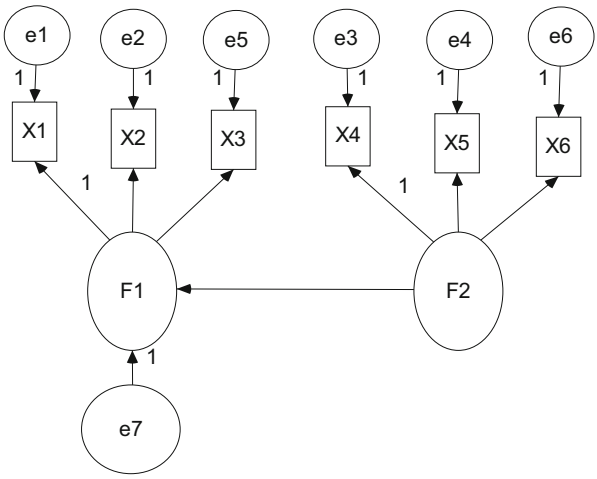

Fig. 8.1 An example of SEM diagram. Notation: X1, X2, X3, X4, X5, X6—observed variables, F1, F2—latent variables (factors) e1, e2, e3, e4, e5, e6, e7—errors (disturbances)

It can be written using the following linear regressions

$$Y = aX + \xi_Y, \tag{8.6}$$

$$Z = bY + \xi_Z, \tag{8.7}$$

As the starting point of the model construction is a covariance (or correlation) matrix which is symmetric by definition the identification task is not a trivial one. For example, when a correlation and partial correlation coefficients are in the following relations $\rho_{XY} \neq 0 \wedge \rho_{XZ,Y} = 0$, then one of the possible moderated relations can hold:

$$\begin{aligned} &X \rightarrow Y \rightarrow Z, \\ &X \leftarrow Y \leftarrow Z, \\ &X \leftarrow Y \rightarrow Z. \end{aligned} \tag{8.8}$$

A researcher decides which one is actually observed basing on his experience and a priori knowledge.

In the path analysis it is assumed that: the relationship between the variables is linear, the sequence of variables is ordered both logically and according to occurrence in time, the relationships take the additive form. The path coefficients are usually presented in the standardized form i.e. they are standardized regression coefficient (beta coefficients). They measure a partial impact of one variable on another using all previously related variables that occurred in a path diagram.

The estimation of structural equation model is a special issue. The proper selection of the method relies on the sample size and the error distribution. When the error distribution is normal the general least squares or maximum likelihood methods are proposed with the following function to be minimized

$$Q = (\sigma - \sigma(\theta))' W(\sigma - \sigma(\theta)), \tag{8.9}$$

where: σ is a vector of variances and covariances between observed variables, $\sigma(\theta)$ denotes a corresponding vector of variances and covariances for fitted values and W is a matrix of weights. Matrix W depends on the choice of the method of estimation. In the case of the least squares method $W = \sum^{-1}$ where $\sum$ is a matrix of observed variances and covariances. In the case of the maximum likelihood method, where the likelihood function is given as (Gatnar 2003):

$$L_{ML} = \log\left|\sum(\theta)\right| - \log\left|\sum\right| + tr\left(\sum\sum(\theta)^{-1}\right) - k, \tag{8.10}$$

$W = \sum(\theta)^{-1}$ is an inverse matrix containing fitted variances and covariances based on the model. Furthermore, k represents a number of variables included into the model and *tr* denotes a trace of the matrix. If the model does not meet the requirements of normality the Asymptotically Distribution-Free (ADF) method of estimation can be applied (Byrne 2010).

There are some limitations of the SEM methodology. One of them is such that the structural model does not allow testing the direction of causal relationship between the variables in interest. It must be assumed on the prior knowledge and experience. Another limitation is related with the large sample size of sample used in the research. Some methods rely on minimum of 100 or 200 observations (ML, ADF), the others (GLS) requires even 3.000 as a starting point (Ullman 1996; Byrne 2010). This is inevitably connected with the methods of goodness-to-fit evaluation in the SEM methodology. Yet another important element, which has already been mentioned, is using data that are observed as numerical values or ordinal values, mapped onto the Likert scale.

Goodness of fit in the SEM modeling is a special issue. Usually it relies on a comparison of two models: a model with zero covariances and a given (estimated) model. The criteria of the goodness-to-fit assessment in SEM are not always clear but some suggestions can be found (comp. Bollen 1989; Steenkamp and van Trijp 1991; Hu and Bentler 1999; LISREL for Windows). Unlike in traditional regression models single parameter significance is not of particular interest also it is possible. The care is concentrated on the fit of the entire model. The software dedicated for SEM modeling offers many different indicators which are computed automatically. Among the most popular software one can mention at least the following: AMOS—a package available with SPSS and LISREL prepared by Jöreskog and Sörbom from Uppsala University. Statistica and SAS also offer the possibility of structural equation modeling. Typically, many indicators are analyzed simultaneously. The basic indicator is a chi-squared discrepancy indicator which compares the observed variance-covariance matrix to the predicted variance-covariance matrix. It theoretically ranges from 0 (perfect fit) to $+\infty$ (poor fit). When testing procedure is provided it is considered satisfactory when the null hypothesis cannot be rejected (*p-value* > 0.05). The value of the indicator strongly depends on the number of observations and when the sample size is larger than 200 it is of no practical value.

For the greater number of observation the following statistics is applicable: $\chi^2(df)/df$ where df denotes the degrees of freedom. The model is considered satisfactory when the indicator is smaller than three in large samples (N > 200), smaller than 2.5 in medium-sized samples (100 < N < 200), and smaller two in small samples (N < 100).

Two following indicators rely on the models comparison. The first one, i.e. the *Normed Fit Index—NFI* takes the form:

$$NFI = \frac{\chi^2(M_N) - \chi^2(M_P)}{\chi^2(M_N)}, \tag{8.11}$$

where: M_N—denotes a zero-covariances model and, M_P—the estimated model. Its values above 0.95 show that model is well fitted to the data set. The disadvantage of NFI is such that it increases when the number of parameters increases.

That is why it has been modified to the form of *Non-normed Fit Index—NNFI*:

$$NNFI = \frac{\chi^2(M_N)/df_N - \chi^2(M_P)/df_P}{\chi^2(M_N)/df_N - 1}. \tag{8.12}$$

Values bigger than 0.95 means that the model is satisfactory.

Root Mean Square Error of Approximation—RMSEA is another recommended indicator:

$$RMSEA = \sqrt{(\chi^2/df - 1)/(N - 1)}, \tag{8.13}$$

where: N denotes the number of observations and df—the number of degrees of freedom. Its values lower than 0.05 indicate a positive result. The advantages of this measure are such that it is insensitive for the number of observations and it cares about the model parsimony.

Another group of indicators consists of the measures that are similar to multiple R-squared coefficients i.e. *Goodness-of-fit Index—GFI* and *Adjusted GFI—AGFI*. The first one is defined as

$$GFI = L_P/L_N, \tag{8.14}$$

where: L_N is a function of fitting the model with all parameters equal to zero and L_P is the analogue for the estimated model. Theoretical range of GFI covers the interval from 0 to 1. It is interpreted as the ratio of explanation of the observed covariances by the covariances described by the model. GFI greater than 0.9 indicates good fit of the model. It is accompanied by the AGFI which means adjustment of GFI for the number of the degrees of freedom:

$$AGFI = 1 - ((1 - GFI) \cdot df_P/df_N). \tag{8.15}$$

The interpretation of AGFI is the same as above.

If the estimated model does not satisfy the quality requirements it is to be modified. The modification of the model consists in eliminating the relationships that are insignificant and adding those which can improve the fit. Usually it is a sequential procedure that is based on the value of a modification index. The modification index is often computed by statistical software. It refers to the value of chi-squared statistics and denotes the minimum value that the chi squared is expected to decrease if the corresponding parameter is changed. The researcher usually tries to improve the model structure by changing the covariance structure taking into account the number of estimated parameters to keep the model identified (Kline 2005). It should be noted that all modifications must rely on reasonable assumptions not on simple data mining.

As the structural model relies on a priori assumptions it is a subject of careful validation. Two methods of validation are recommended. The first one refers to the cross-validation of the model using the samples drawn from different populations (Ullman 1996). The second method of model validation is based on bootstrap theory (Kline 2005).

8.5.3 Empirical Analysis in Behavioral Finance

Typically the investor uses not one but a few heuristics. Vulnerability to specific heuristics leads to similarities in investor behaviors. Searching for homogeneous groups of investors is a challenging task. Socio-economic characteristics such as gender, age, social status, etc. are frequently taken into account for educational purposes. This division of investors can result in identifying differences in decision-making, the use of appropriate strategies, or being susceptible to certain heuristics. This also applies to potential investors.

One can here point to a study (Czerwonka and Rzeszutek 2011) which compares three groups: professional stock investors, the Warsaw School of Economics students representing the University Stock Exchange Interest Group, and psychology students. An attempt to detect irrational behaviors in the light of behavioral finance (examining differences by means of Kruskal-Wallis test). The most irrational behavior could be observed among the Warsaw School of Economics students.

Another attempt to characterize groups of investors was made by Borowski (2014). Apart from classical criteria such as, for instance, the investment horizon, applied strategies and expectations of the direction of changes in market prices, the author also analyzes following Niederman (Niederman 2000) certain psychological profiles. In no division the author points to some advantage. Obviously, each division can be attributed to a selected group of specific heuristics. However, there is no explicit attribution. Also, despite the indications contained in the work by Czerwonka (Czerwonka and Rzeszutek 2011), we cannot say that professional investors are not susceptible to heuristics and act rationally. This study found the group to be declarative.

An interesting division of investors, and thereby a kind of typology, was proposed by the authors of the BSV model. If we apply a Markov chain model, then we will have an opportunity of changing groups. Martko (Martko 2008, master's thesis) distinguished four groups. The identification of these groups at the early stage of the thesis allowed ascribing the groups with specific investment strategies in the further part of the experiment.

The literature provides a relatively small number of examples where structural equation models are used as a tool of identification and modeling behavioral attitudes or inclinations observed on financial markets. Wang et al. (2006) analyzed selected psychological mechanisms of investors in Chinese Stock Markets finding that that good quality of information disclosure such as transparency, timely release, integration and authenticity influence reduction of investors' risk perception. Riaz and Hunjra (2015) emphasized that risk perception is an important mediation variable between information asymmetry and investment decisions on the Islamabad Stock Exchange. Deshmukh and Sanskrity (2016) examined decision making process among mutual funds investors in India. One of the most complex analyses has been a subject of an analysis in Żurek (2016), because it was validated using three samples exceeding 300 investors acting on the Warsaw Stock Exchange in Poland in 2010, 2012 and 2013. It enabled to confirm empirically that the longer experience on capital market increase cognitive bias due to greater self-confidence and consequently—overconfidence. Moreover, the research demonstrated the changes in the investor's attitudes toward risk over time. The earlier version of the described research was published in 2010 (Osińska et al. 2011). The following errors (cognitive biases) have been confirmed: control effect, optimism and disposition effect.

8.6 Conclusions

The aim of the presented study was to indicate and discuss an experiment as a method of identification of behavioral heuristics from the perspective of an investor's attitude toward risk. We considered the experiments in finance understood as watching the decision makers in actual time when the decisions have been made. We also described the examples of the ex post testing of observed and unobserved heuristics that affect the investors' perception of risk and expected return. The focus has been put on the methods of identification irrationality in investors' behavior on financial markets.

It must be noted that behavioral finance is not a novelty. Thaler published his article entitled 'The End of Behavioural Finance' already in 1999 (Thaler 1999b). There he wrote: *'Behavioural finance is no longer as controversial a subject as it once was. As financial economists become accustomed to thinking about the role of human behaviour in driving stock prices, people will look back at the articles published in the past 15 years and wonder what the fuss was about. I predict that in the not-too-distant future, the term 'behavioural finance' will be correctly viewed*

as a redundant phrase. What other kind of finance is there? In their enlightenment, economists will routinely incorporate as much 'behaviour' into their models as they observe in the real world. After all, to do otherwise would be irrational.'

Thaler's considerations sparked a debate that has been going on to this day and many are still astonished by the title Thaler used for his article (Mukul 2013).

On the other side it should be emphasized that the particular development of both behavioral economics and behavioral finance has been observed for last 30–40 years. Significant impact of the experiments on the economics and finance theories is mainly observed in a micro scale. The individual decision-making process is strongly affected by the situations, people, self-confidence and many other 'irrational' factors (Ariely 2008). Nowadays behavioral analyses enter the mainstream of economics and finance theories. They enforce some reconsideration in the traditional concepts of a rational homo oeconomicus and his role in the decision-making process. Nobody can question this process any longer. As the range of experiments is still not very wide, statistical methods and models can help measuring and evaluating the magnitude of 'irrationality' in people's behavior. It has been indicated that a Structural Equations Model (SEM) is becoming more and more popular tool used in behavioral analysis in finance. All the theories, examples and comments presented in this chapter confirm the fact that people's behaviour is present in the everyday finance and it has to be incorporated into the theoretical and empirical analyses as well.

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Chapter 9
The Impact of Behavioral Factors on Decisions Made by Individual Investors on the Capital Markets

Mirosława Żurek

Abstract Paying attention to the investors' behavioral inclinations is crucial, due to the relatively high incidence of all kinds of anomalies in the capital markets. Identified by researchers anomalies are manifested by excessive or delayed reaction of investors to the price changes and provided information. Understanding the schemes and motives that are used by individual investors on the capital market allow researchers to better characterize the decision-making process and it's determinants. Knowledge about the behavioral inclinations can be used to predict and simulate the behavior of investors on the capital market in the future. The aim of this chapter is to determine the strength and direction of the impact of the behavioral factors on the investors decision-making process on the capital market. The main hypothesis assumes that psychological factors, like behavioral inclinations in preferences and opinion area, have a significant impact on the investor behavior on the capital market, changing their risk tolerance and acceptable rate of return. The first part of chapter presents the principles of construction structural equation models (SEM) and methods of their verification. The second section includes a detailed description of the questionnaire used in the survey and analysis of the results. In the last part behavioral factors characterizing the investors in the Polish capital market, like risk tolerance, inclinations in the opinions and preferences area have been identified. Additionally to verify hypotheses one structural equation model have been specified, estimated, analyzed in subgroup and interpreted.

Keywords Structural equation model • Behavioral finance • Individual investors on capital market in Poland

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_9

9.1 Introduction

Paying attention to investors' behavioral inclinations is inevitable due to the relatively high incidence of all kinds of anomalies on the capital markets. Anomalies identified by researchers are manifested by investors' excessive or delayed reactions to changing prices and providing information. An explanation of the reasons of these kinds of phenomena seems to be crucial for a better understanding of the capital market, the interpretation of recession, stagnation and the financial market development, and characterize the decision-making process and its determinants.

The aim of this chapter is to determine the strength and direction of the impact of behavioral factors on investors' decision-making process on the capital market. The main hypothesis assumes that psychological factors, such as, for instance, behavioral inclinations in the preferences and opinion areas, change investors' risk tolerance and acceptable rate of return. Following this, the chapter tries to prove that behavioral factors have a significant impact on investors' behavior on the capital market. They change investors' behavior due to fundamental theories of finance.

The first step to achieve the research aim of the chapter was developing a questionnaire using Likert scale, so it was possible to measure unobservable variables such as risk tolerance and behavioral inclinations in preferences and opinion. The data essential for analysis was collected within a survey carried out on a group of individual investors in the Polish capital market. The survey was made by the Association of Individual Investors three times: in 2010, 2011 and 2013.

The second step was the identification of the factors that characterize both the attitude of individual investors and the factors describing the quality of the functioning of the capital market in Poland. Factors such as the level of risk tolerance, capital market quality, opinion and preference behavioral inclinations shown by investors in the investment process were identified. These factors (unobservable variables) reflect the maturity level of the capital market and behavioral tendencies which characterize investors.

Finally, the strength and direction of the impact of these factors on individual investors' reinvestment decisions, investors' satisfaction with the investment and on their risk tolerance was proved using the estimated structural equations model (SEM).

9.2 Using Structural Equation Models in Behavioral Finance: An Overview

The theory of behavioral finance, which assumes the limitation for rational investors attitude, is rapidly developing. The forerunner in this field was a prospect theory (Kahneman and Tversky 1979). The admission of the existence of behavioral

inclinations itself which interferes with the investors' decision making process led to the development of behavioral models (LSV, BSV, DHS, HS) and gave an opportunity to present anomalies on the capital market (Thaler 1994; Goldberg and Von Nitzsch 2001; Shleifer 2000; Zielonka 2015; Czerwonka and Gorlewski 2012).

Many of the available studies also consider the impact of institutional investors, especially mutual funds, on the capital market behavior (Lakonishok et al. 1994). Those papers focus on the herding behavior and the phenomenon of the positive feedback among managers. Some probable explanations of this phenomenon include ignoring of the private information available to managers, correlation of the private information held by investors because of the analysis of the same indicators, following 'the stronger' transactions and finally avoiding investments in companies with lower liquidity.

This chapter is focused on using structural equation modeling in finance. The subject matter and foundation of the models were developed for many years in the works of Bollen (1989), Kaplan (2000), Kline (2005). The usage of structural equation modeling is common in psychological and sociological analyses, because of the possibility to seize the unobservable variables. There can still be found relatively not many examples of its application in economics. However, it is becoming increasingly popular.

The works of Wang et al. (2006) and Lin (2011) are worth taking into account as examples of the structural equation modeling usage in finance. In all of these works various behavioral factors were specified and their impact on attitudes and behaviour of investors was defined. In Polish subject literature, studies on the structural equation modeling usage in the area of behavioral finance can be found in works of Osińska et al. (2011). In this study, a significant impact of behavioral inclination on investors' risk tolerance was confirmed.

9.3 Methodology

9.3.1 Structural Equation Model

The Structural Equation Models (SEM) are defined as a set of procedures and statistical tools used to measure the causal relationships in empirical research. The SEM methodology allows the relationships between independent and dependent, measurable (observable) and latent (unobservable) variables to be taken into account. In addition, it makes it possible to estimate potential measurement errors for all observable variables, calculate variances and covariances between variables, as well as identify the direct and indirect effects between them (Joreskog 1973; Wiley 1973).

The SEM methodology consists of a model describing the relationship between latent variables (known as internal) and measurement model for endogenous and exogenous unobservable variables (referred to as 'external'). The external model is

a representation of the factor analysis which allows calculating the loads of individual variables affecting the latent factor. The internal model is the path analysis which is used to define a cause-and-effect relationships between variables (Kaplan 2000; Pearl 2000; Bollen and Curran 2006).

The internal model (structural) has the following form:

$$\eta = B\eta + \Gamma\xi + \zeta \tag{9.1}$$

where: $\eta_{m \times 1}$—vector of endogenous latent variables, ξ_{kx1}—vector of exogenous latent variables, B_{mxm}—matrix of regression coefficients for endogenous variables, Γ_{mxk}—matrix of regression coefficients for exogenous variables, ζ_{mx1}—vector of random components.

In the structural model, the following assumptions for a random component are made:

$$\mathrm{E}(\zeta) = 0 \quad \sum\nolimits_{\zeta} = \sigma^2 I \,\text{and}\, \mid I - \mathrm{B} \mid \neq 0 \tag{9.2}$$

The external model (measurement) is given as:

$$y = \Pi_y \eta + \varepsilon \tag{9.3}$$

$$x = \Pi_x \xi + \delta \tag{9.4}$$

where: y_{px1}—vector of observed endogenous variables, x_{qx1}—vector of observed exogenous variables, Π_x, Π_y—matrix of factor loadings, $\varepsilon_{px1}, \delta_{qx1}$—vectors of measurement errors.

For the measurement model, the following assumptions for the random component are made:

$$\mathrm{E}(\varepsilon) = \mathrm{E}(\delta) = 0 \,\text{and}\, Cov(\eta, \varepsilon) = Cov(\xi, \delta) = 0 \tag{9.5}$$

In case of structural equation models, a confirmatory factor analysis is dedicated (Harrnington 2009) and the verification of the variables included in the latent factor is made using α-Cronbach's coefficient (Cortina 1993; Valadkhani et al. 2008). While estimating the structural equation model's parameters, the subject literature particularly recommends using the maximum likelihood method (Joreskog 1973) and the generalized least squares method.

9.3.2 Measures of SEM Model Fit

Most measures of fit SEM models based on a statistic χ^2 defined as:

$$\chi^2 = (n-1)\left[trace\left(S\widehat{\mathrm{E}}^{-1}\right) - p + \ln\left(\widehat{\mathrm{E}}|\right) - \ln\left(|S|\right)\right] \tag{9.6}$$

where: n—means sample size, p—amount of variables, S—covariance matrix for the sample, and $\widehat{\mathrm{E}}$ is an array of recreated S based on the estimated parameters. The use of this statistic directly is justified only if the variable distribution is a multidimensional normal distribution, sample is the right size, and tested hypothesis—true in population.

Critical N is one of the absolute model fit measures and it was first formulated by Hoelter as:

$$CN = \frac{1/2\left(z_{1-\alpha} + \sqrt{2df_h - 1}\right)^2}{T/(N-1)} + 1 \tag{9.7}$$

where $z_{1-\alpha}$ is the critical value read from the normal distribution for the significance level α, T is a statistic χ^2 for estimated model and df_h is the number of degrees of freedom of the estimated model. CN index indicates the maximum sample size at which the estimated model would be acceptable from the point of view of statistics χ^2. The subject literature emphasizes the fact that in the case of a small sample, the value of this statistic may be incorrectly reduced (Konarski 2011).

One of the SEM model fit measures that compare the estimated model to the base model is *Incremental Fix Index* (NFI). It is defined as (Bollen and Curran 2006):

$$NFI = \frac{T_b - T_h}{T_b} \tag{9.8}$$

where: T_h—is a statistic χ^2 for estimated model and T_b—is a statistic χ^2 for base (independent) model. NFI index value should be contained in the range $< 0; 1>$. The model is considered to be well fit, if the value of this statistic is greater than 0.95. This type of indexes tends to favor the more complex models, therefore, in practice, it is often used with modifications which take into account the complexity of the model, for example, index PNFI (Konarski 2011).

Root Mean Square Error of Approximation (RMSEA) is calculated as:

$$RMSEA = \sqrt{\frac{T_h - df_h}{(N-1)df_h}} \tag{9.9}$$

RMSEA index value less than 0.05 means a very good fit of the model to the data, while the case of the statistic greater than 0.10 means a bad fit of the model to the data (Browne and Cudeck 1992). This measure, however, can lead to favoring simpler models.

Since each of these measures have limitations, it seems reasonable to check the multidimensional distribution of variables and additional verification of the estimated model using the bootstrap procedure. To verify whether a multi-dimensional

distribution is normal, the test introduced by Mardi (Mardia 1970; Byrne 2010) can be used. In this method a multi-dimensional measure of kurtosis for distribution in the sample is defined as:

$$k = \frac{1}{N}\sum_{i=1}^{N}\left[\left(x_i - \vec{x}\right)S^{-1}\left(x_j - \vec{x}\right)\right]^2 \tag{9.10}$$

where: x_i—vector of variable values for observation i; x_j—vector of variable values for observation j, $\vec{x}$ —vector of average values of variables, a S^{-1}—inverse covariance matrix of the variables. According to data available in the literature, the total value of kurtosis should not be greater than 7, and the corresponding t-statistic—greater than 5 (Byrne 2010).

Using the maximum likelihood method or the generalized largest squares method for data with distribution other than normal causes increases in statistics χ^2. It can cause the standard errors undervaluation, which makes that covariance in path or factor analysis will be statistically significant, however, in the population it does not need to be so. That is why an additional quality verification of the estimated model, which would be independent of the variables distribution is needed. One of the methods used for this purpose most frequently is the bootstrap analysis.

9.3.3 Bootstrap Procedure

The bootstrap procedure, which is a statistical method for estimating the distribution of estimation error, was developed for the first time in 1979 by Efron (1979). It is a class of methods for resampling from the original data set. Its idea is based on replacing the unknown distribution of the population with known empirical distribution based on which the standard errors or confidence intervals of parameters are calculated (Efron and Tibshirani 1986).

Let $\sigma(F)$ denote the standard error of the parameter $\widehat{\theta}$ estimated based on a sample P. It can be expressed using the formula:

$$\sigma(F) = \sqrt{S_F^2\left(\widehat{\theta}_P\right)} \tag{9.11}$$

where $S_F^2\left(\widehat{\theta}_P\right)$ is the variance of parameter estimation $\widehat{\theta}$ based on sample P.

The application of the bootstrap procedure to estimate the standard error $\sigma = \sigma\left(\widehat{F}\right)$ uses three following steps (Efron and Tibshirani 1986):

1. Drawing an accordingly large number of bootstrap samples from the original data set labe P lled as: $P_1^*, P_2^*, \ldots\ldots P_B^*$.
2. For each $b = 1, 2, \ldots B$ estimation $\widehat{\theta}_b^* = \widehat{\theta}\left(P_b^*\right)$.

3. Calculation of the standard deviation as:

$$\widehat{\sigma}_B = \sqrt{\frac{\sum_{b=1}^{B}\left(\widehat{\theta}_b^* - \widehat{\theta}^*\right)^2}{B-1}} \tag{9.12}$$

where: $\widehat{\theta}^* = \frac{\sum_{b=1}^{B}\widehat{\theta}_b^*}{B}$, B—sample size.

If $B \to \infty$ then $\widehat{\sigma}_B \to \sigma(\widehat{F})$.

Bias measures allow to compare between the estimation of the parameter obtained based on the output data set P with the evaluation of this parameter obtained based on B samples from this set. Thus, they allow making comparisons between the parameter value obtained by using the classical estimation method and multiple resampling.

Bias estimator can be expressed by the formula (Byrne 2010):

$$b\widehat{l}_B^* = \widehat{\theta}_P - \widehat{\theta}^* \tag{9.13}$$

Designation remains as previously.

In the bias analysis applying the bootstrap method, it may be useful to take into account the standard error of the estimator bias $\widehat{\delta}_B^*\left(b\widehat{l}_B^*\right)$ which is counted as (Byrne 2010):

$$\widehat{\delta}_B^*\left(b\widehat{l}_B^*\right) = \widehat{\sigma}_B/\sqrt{B} \tag{9.14}$$

It is assumed that if the standard error of the bias parameter $\widehat{\delta}_B^*\left(b\widehat{l}_B^*\right)$ is greater than bias estimator value itself $b\widehat{l}_B^*$, it can be recognized as statistically insignificant.

9.4 Individual Investors on the Polish Capital Market

9.4.1 Questionnaire

The questionnaire used in this study consisted mostly of questions based on a five-point Likert scale (Oppenheim 1992), which allowed for identification of the unobservable factors such as the quality of capital markets, risk tolerance, ability to use technical and fundamental analysis by investors, their behavioral inclinations in the opinion and preferences areas.

The quality of the market should be understood as general market's characteristics which make its functioning efficient. These include a large number of buyers and sellers, the variety of investment needs, objective and available opinions,

information, location, reasonable transaction costs, market integrity, and fairness of all market participants (Maginn et al. 2007). In this study, the market's quality was limited to the subjective assessment of the public information by individual investors.

One of the most frequently described behavioral inclinations in the opinion area is overconfidence. It may be manifested both by frequent changes in the investment portfolio (Barber and Odean 2001; Glaser and Weber 2007), as well as making error calibration (Nofsinger 2011). The literature also points to bias predictions due to the limitation in information access (Kahneman and Tversky 1973) as well as to an excessive tendency to invest in the local market (French and Poterba 1991). These consist in another behavioral inclination—availability heuristic.

In addition, the last investors' investments and ownership effect (behavioral inclinations in the preference area) have a relatively common influence on their decisions related to the capital market. It turns out that after a successful deal, they are willing to invest more than ever before by taking risky decisions (Thaler 1987). On the other hand, the ownership effect means that there is a significant difference between the sales price for which the owner of the goods would agree to sell them, and his purchase price of the same asset (Thaler 1980).

Skill of using technical analysis by the respondents was measured based on questions relating to forecasts of indices and stock prices taking into account their current trend and formation. Because the skill of using fundamental analysis is difficult to measure, the questions in this area measure only the degree of the use of individual fundamental information by respondents (Table 9.1).

9.4.2 The Survey

The survey was carried out in three stages: year 2010 (315 respondents), 2012 (343) and 2013 (366). In each case, a survey was carried out by the Association of Individual Investors, which determines the properties of the sample. It targets and is limited to investors who are members of the Association of Individual Investors (AII), or those who use materials prepared by the Association. Currently, the AII counts about 11,000 members. Thus the sample size was indicated basing on the minimum sample size statistics. In the reported research each sample has a maximum estimate error less than 3% with a confidence level equal to 0.95. Maximum estimate error was calculated using formula for the minimum sample size for fraction:

$$N_{\min} = \frac{N_p(\alpha^{2*} f(1-f))}{N_P e^2 + \alpha^2 f(1-f)} \tag{9.15}$$

where $N_{\min}$ means minimum sample size, N_P—population size, α—confidence level, e—maximum estimate error and $f = 0.5$.

Table 9.1 Questions included in the survey (own study)

Variable	Question
	Market Quality
	1. How would you rate the quality of the public information about the companies which are available on the capital market?
	(Selecting the center square means no advantage of one of the two conflicting assessments; for each row please select exactly one answer)
x_1	Information is incomplete ☐ ☐ ☐ ☐ ☐ Information is complete
x_2	Information is useless ☐ ☐ ☐ ☐ ☐ Information is useful
x_3	Information is untrue ☐ ☐ ☐ ☐ ☐ Information is true
x_4	Information is delayed ☐ ☐ ☐ ☐ ☐ Information is prompt
x_5	Information is comparable ☐ ☐ ☐ ☐ ☐ Information is uncomparable
x_6	Information is ambiguous ☐ ☐ ☐ ☐ ☐ Information is unambiguous
x_7	Information is not available ☐ ☐ ☐ ☐ ☐ Information is available
	Risk Tolerance
x_8	8. Do you agree with the statement that you invest in a more risky way than others?
	(1—completely disagree, 5—completely agree)
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
x_9	14. Do you undertake actions that are on the edge of risk while making daily investments?
	(1—never, 5—yes, always)
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
x_{10}	21. Do you take a risk even though it is not necessary when investing?
	(1—no, never, 5—yes, often)
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Behavioral Inclination in the Opinion Area
x_{11}, x_{15}	24. How often do you make changes in the portfolio in your selected investment horizon?
	(1—I do not make any changes, 5—I try as often as possible to change the composition of my portfolio)
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	12. Please estimate the influence of the following factors on your investment decisions: (1—little significance, 3—medium importance while investing, 5—very important)
x_{16}	- Frequency of the occurrence of products/services advertised on television or the Internet
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
x_{17}	- Personal sentiment to the company, for example because of a location in the same region
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
x_{18}	19. Suppose that the value of the WIG20 index is currently at the 2524 level. What do you think of the probability that within a month the WIG20 index value will be outside the range (2056–2992)?
	☐ (0%–10%) ☐ (10%–20%) ☐ (20%–40%) ☐ (40%–60%) ☐ (60%–100%)
	Behavioral Inclination in the Preferences Area

(continued)

Table 9.1 (continued)

Variable	Question
x_{12}, x_{19}	5. You have earned lately a 30% profit on your stock investment. There has been a bull market for six months and there are not any clear signals of the trend change. What percentage of savings would you be willing to further invest?
	☐ 10% ☐ 25% ☐ 50% ☐ 75% ☐ 100%
x_{13}, x_{20}	10. Suppose that you have earned 5000 PLN on investment in shares of 20,000 PLN value each. Market analysts predict further growth and the maintenance of the bull market for at least one year. How do you plan your investments?
	☐ You make a review of your portfolio by investing 20,000 PLN and put aside profits for other purposes.
	☐ You invest 20,000 PLN along with the gained profits equal to 5000 PLN.
	☐ You invest 25,000 and part of your additional revenue (e.g. 5000 PLN)
	☐ You invest 25,000 and part of your additional revenue (e.g. 10,000 PLN)
	☐ You invest 25,000, the whole of your additional revenue (e.g. 10,000 PLN), and an additional 10,000 PLN (a loan).
x_{14}, x_{21}	16. Suppose you have a stock portfolio worth 10,000 PLN, which earns a profit of 10% per month. According to the market information, investment in company X would provide at least 60% profit in the period of two months. What would be your decision regarding changes in your portfolio?
	☐ No changes in the stock portfolio ☐ Purchase shares of X (3000 PLN)
	☐ Purchase shares of X (6000 PLN) ☐ Purchase shares of X (10,000 PLN)
	☐ Purchase shares of X (20,000 PLN) using 10,000 PLN obtained from the loan taken
x_{22}	7. Suppose you own a number of X company shares whose total market value is now 10,000 PLN. From the fundamental analysis and expert knowledge it is known that its value will rise by at least 15% within the coming year. In this situation, today you are able to resell them for a minimum value equal to:
	☐ 10,000 ☐ 10,500 ☐ 11,000 ☐ 11,500 ☐ 12,000
x_{22}	20. From the fundamental analysis and expert opinion it is known that the shares of Y will rise at least by 15% within the coming year. In this situation, today you are able to buy back the company's shares with a market value of 10,000 PLN, for a maximum value equal to:
	☐ 10,000 ☐ 10,500 ☐ 11,000 ☐ 11,500 ☐ 12,000
	The Skill of Using Fundamental Analysis
	2. Evaluate the rate of the importance of the following information for investment decisions:
	(1—little significance, 3—medium importance while investing, 5—very important)
x_{23}	- Macroeconomic information (GDP, foreign exchange rates, commodity prices, interest rates)
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
x_{24}	- The values and changes in the stock indexes (WIG, WIG20, DJIA)
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
x_{25}	- Fundamental information (stock market indices, indicators of financial analysis, Porter's analysis, SWOT)
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	4. Please, assess your usage of the following indicators of fundamental analysis in the decision process: (1—never used, 3—used sometimes, 5—always used)
	- current assets/current liabilities or other liquidity indicators
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

(continued)

Table 9.1 (continued)

Variable	Question
x_{26}	- turnover ratios of receivables and liabilities of the company
	□ 1 □ 2 □ 3 □ 4 □ 5
x_{27}	- total liabilities/total assets or other debt indicators
	□ 1 □ 2 □ 3 □ 4 □ 5
x_{28}	- net profit/net sales or other profitability indicators
	□ 1 □ 2 □ 3 □ 4 □ 5
	- market price/profit per share or other market value indicators
	□ 1 □ 2 □ 3 □ 4 □ 5
	The Skill of Using Technical Analysis
	3. Based on the signals (information) as specified below, say how, in your opinion, the WIG index will behave in the near future? (−2 means a strong decrease in the WIG index, 0 represents no effect, 2 indicates an increase in the WIG WIG)
	Breaking the levels of support by the falling WIG index
	□ -2 □ -1 □ 0 □ 1 □ 2
	Creating a head and shoulders formation after large increases of the WIG index
	□ -2 □ -1 □ 0 □ 1 □ 2
	The collapse of the main line of the upward trend in the WIG index
	□ -2 □ -1 □ 0 □ 1 □ 2
	The growing WIG index subsequently confirmed the main trend line
	□ -2 □ -1 □ 0 □ 1 □ 2
	After a decline in stock prices—a large excess of demand
	□ -2 □ -1 □ 0 □ 1 □ 2
	A significant increase in the value of the purchase order
	□ -2 □ -1 □ 0 □ 1 □ 2
	Profit Rate
y_8	20. Considering the current situation on the stock market, what return rate on investment would be satisfying for you in the next six months? How do you evaluate the probability of obtaining a satisfying rate of profit?
	satisfying profit rate (. . .. . .%) probability of obtaining this rate (. . .. . .%)
y_7	6. What was your return rate obtained from stock market investments in the last six months? Considering the current situation on the stock market during this period, what return rate would be satisfying for you?
	Obtained profit rate (. . .. . .%) satisfying profit rate (. . .. . .%)

9.4.3 Data Analysis

Most respondents—nearly two-thirds in all stages of the study were living in the city of over 100 thousand residents. In all analyzed years more than 80% of respondents claimed to have higher education and around 70% of respondents had a relatively short practice of investing on the capital market (5 years or less). In a survey conducted in 2013, 284 more than three-quarters of individuals invested primarily on the stock market. Only 16% of investors usually chose the derivatives market, 4%—NewConnect, and less than 2%—Catalyst.

Table 9.2 The usage of particular fundamental analysis indicators in 2013 (%)

Frequency of use	1—never	2—rarely	3—average	4—often	5—always
Liquidity indicators	13.42	16.99	31.51	27.12	10.68
Turnover ratios of receivables and liabilities	16.71	24.38	30.14	21.37	6.03
Debt indicators	9.04	14.52	26.03	35.89	13.97
Profitability indicators	5.21	8.49	17.53	35.89	32.33
Market value indicators	4.38	6.85	19.45	35.62	32.60

Most respondents declared no or low frequency of portfolio changes during the given time horizon. In analyzed years the percentage of investors who did not make any changes in the portfolio in a chosen time horizon significantly increased. In 2010 only 4% respondents chose option 1, and in 2013—33%. The reasons for such a large change in the structure of investors can be explained by the prolonged economic crisis during which investors seemed to represent higher risk aversion (Hoffmann et al. 2012).

About 60% of the respondents admitted that the information derived from technical analysis is important for investment decisions. However, the ability of using technical analysis tools was not on a satisfactory level. In 2013 in this section of the survey nearly 50% answers were correct, while three years earlier—only 40%.

Similar to technical analysis, more than 60% of the respondents admitted that in the decision-making process, fundamental information, which relates to the stock market indicators, financial analysis, SWOT and Porter, was essential. Particularly important for the respondents were indicators of profitability and market value (Table 9.2).

In the study carried out in 2010, the arithmetic average of the return rate achieved by respondents in the last period was 26.6%. Only 3% of respondents admitted to have closed the last time period with at a loss, but in no case this loss exceeded 25% of the contribution. Most responders, nearly 70%, achieved a gain, but lower than 25%. Around 7% of respondents could boast of the rate of profit higher than 50%.

In 2012, the average return rate on investments among the surveyed investors was 14.5% and in 2013 only 13.4%. In the last analyzed year 19% of respondents admitted to end the last period with a loss. Just as in the years 2010 and 2012, also in 2013 the most—of individual investors (around 68%) achieved a profit, but below 25%. Only 2.5% of respondents achieved the return rate over 50% in the last year of the study (Fig. 9.1).

Along with the reduction in the return rate, also investors' satisfactory profit level changed. In 2010, the average desired return rate for investors for the particular period was over 50%. In 2013, the investors' average satisfactory rate of return was only 34%. The decreasing of the expected return rate, as well as the decreasing risk tolerance can also be explained by the prolonged economic crisis (Hoffmann et al. 2012).

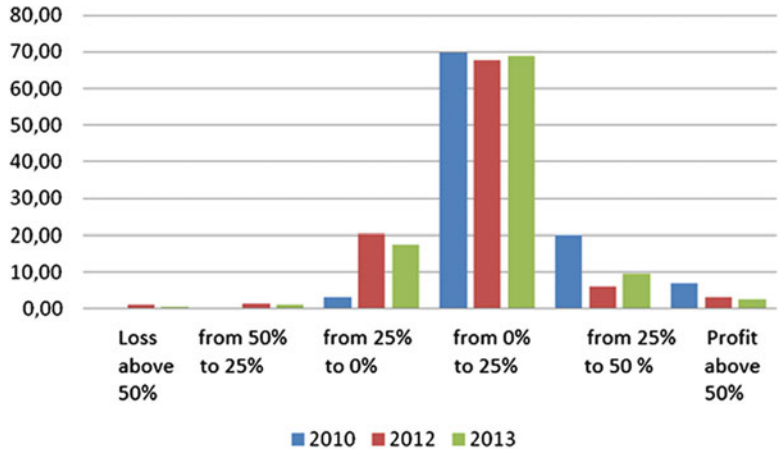

Fig. 9.1 Distribution of the returns obtained from investments in 2010, 2012 and 2013

Table 9.3 The factors, measurable variables and Alfa-Cronbach statistic (own study)

Factor	Description	Measurable variable	Alfa Cronbach statistic
y_1	Capital market quality	x_1, x_2, x_3, x_4, x_5, x_6, x_7	0.75
y_2	Risk tolerance	x_8, x_9, x_{10}	0.71
y_3	Behavioral inclinations	x_{11}, x_{12}, x_{13}, x_{14}	0.49
y_7	Lack of satisfaction with investment		
y_8	Expected return rate		

9.5 Model Solution and Empirical Implications

9.5.1 A Model of Psychological Mechanisms of Investment Behaviors

Table 9.3 includes all defined factors and measurable variables, which correspond to each question of the questionnaire and which create these unobservable factors. Additionally, two endogenous variables are included in the table, which are not latent variables: y_7—lack of satisfaction from investing and y_8—expected return rate. In this study, lack of satisfaction with the investment is defined as the difference between satisfactory and actual obtained return rate during the period. In this understanding, this variable should have the minimum value.

To analyze the mechanisms of decision-making processes by individual investors, the structural equation model was used. The estimation of the model was based on a database containing 1023 observations obtained in all three surveys. The specification, estimation (using maximum likelihood) and verification of the

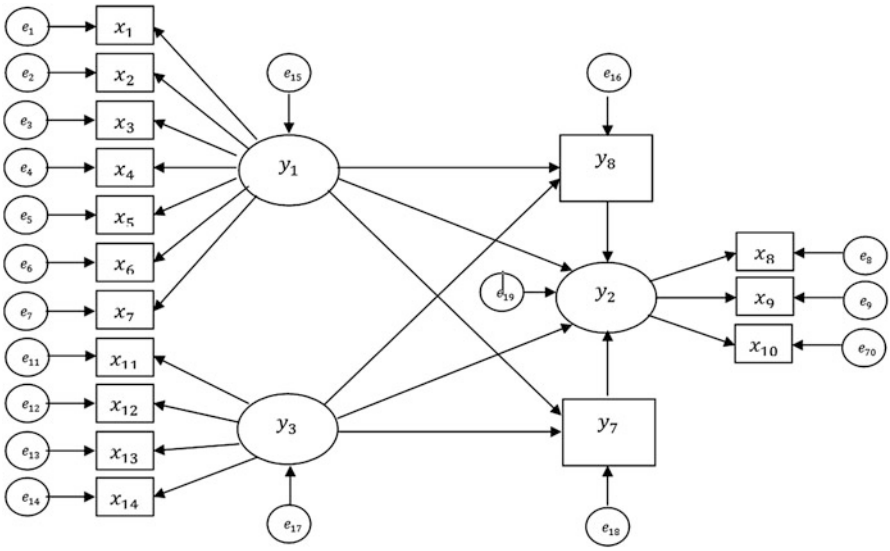

Fig. 9.2 Hypothetical model's scheme (own study)

model (also using the bootstrap procedure) was made using the AMOS v. 17 software. The hypothetical model's scheme is presented in the figure below. The designations are the same as in the table (Fig. 9.2).

The maximum likelihood method requires that all variables included in the model have a multivariate normal distribution. Table 9.4 shows the value of skewness and kurtosis for variables included in the model.

The total value of kurtosis and calculated statistics based on it are significantly higher than the values desired. Thus, the overall assessment of the model's quality is possible only after the assessment of the model's parameters and determining the ranges for parameter's values using the bootstrap procedure.

In order to evaluate the quality of the SEM model, a bootstrap procedure with the maximum likelihood estimator was used. For the confidence intervals' estimation the minimum number of 1000 bootstrap samples is required. Based on the simulations, the additional changes were not noted in the estimation of parameters' standard error or in the limits of confidence intervals between calculations based on 4000 samples and more (the comparison was carried out to make 10,000 samples). Therefore, the quality analysis for the SEM model was based on 4000 samples and the confidence level for the confidence intervals was set at 95%.

Table 9.4 Total value of skewness and kurtosis of variables included in the model (own study)

Variable	Min	Max	Skewness		Kurtosis	
			Parameter estimate	t-statistic	Parameter estimate	t-statistic
y_7	−10.000	297.000	7.140	89.565	80.648	505.792
x_{11}	1.000	5.000	0.279	3.501	0.044	0.276
x_{12}	1.000	5.000	0.318	3.987	−0.943	−5.915
x_{13}	1.000	5.000	0.475	5.961	−0.347	−2.177
x_{14}	0.000	5.000	0.518	6.497	−0.290	−1.818
y_8	0.000	4000.000	25.234	316.516	707.871	4439.505
x_8	1.000	5.000	0.010	0.125	−0.732	−4.593
x_9	1.000	5.000	−0.159	−1.999	−0.563	−3.533
x_{10}	1.000	5.000	−0.064	−0.801	−0.810	−5.081
x_1	1.000	5.000	−0.353	−4.431	−0.387	−2.426
x_2	1.000	5.000	0.045	0.567	−0.612	−3.840
x_3	1.000	5.000	−0.244	−3.058	−0.385	−2.413
x_4	1.000	5.000	0.216	2.707	−0.526	−3.301
x_5	1.000	5.000	−0.375	−4.700	−0.138	−0.865
x_6	1.000	5.000	−0.529	−6.640	−0.029	−0.185
x_7	1.000	5.000	−0.409	−5.130	−0.681	−4.269
Total					798.184	510.914

9.5.2 *Do the Behavioral Factors Have a Significant Impact on Investors' Decisions on the Capital Market? Results of Analysis*

Table 9.5 contains the results of the external model estimated by the maximum likelihood method and Table 9.6—the results of the internal model. The first two columns contain the parameters' estimation and p-value calculated using the maximum likelihood method, and the last one contains the average for each parameter estimate, load estimators, confidence intervals and p-values calculated using the bootstrap procedure. To fully confirm the quality of the estimated model, Table 9.7 contains the measures of the model fit degree.

The results obtained for the external model provided in Table 9.5 indicate that all of the factor loadings are statistically significant. However, the comparison of parameters' estimation obtained with the use of the maximum likelihood with average (bootstrap) indicates the existence of the estimators' loads. First of all, in the case of the internal model, load values for all parameters are higher than adequate load standard errors. Therefore, it was necessary to establish 95% confidence intervals for the parameters. All parameters' estimation obtained using the maximum likelihood method are within the appropriate confidence intervals. According to the *p*-value for *t* statistic and *p*-value for the bootstrap procedure, the parameters β_1, β_5, β_6 and β_8 in the internal model are statistically significant. The IFI index for the estimated model SEM is equal to 0.913, and the value of

Table 9.5 The results of the estimation external model (own study)

		MLM			Bootstrap					
Dependence	Parameter	Parameter estimation	Standard dev.	p-value	Average	Standard dev.	Load (b*)	Low limit	High limit	p-value
$x_1 \leftarrow y_1$	α_1	0.556		0.555	0.034	0.000	0.486	0.616	0.000	0.556
$x_2 \leftarrow y_1$	α_2	0.500	0.000	0.500	0.037	0.000	0.424	0.57	0.000	0.500
$x_3 \leftarrow y_1$	α_3	0.476	0.000	0.476	0.036	0.000	0.404	0.543	0.000	0.476
$x_4 \leftarrow y_1$	α_4	0.569	0.000	0.569	0.028	0.000	0.512	0.620	0.000	0.569
$x_5 \leftarrow y_1$	α_5	0.607	0.000	0.607	0.032	0.000	0.539	0.666	0.001	0.607
$x_6 \leftarrow y_1$	α_6	0.633	0.000	0.633	0.030	0.000	0.569	0.687	0.001	0.633
$x_7 \leftarrow y_1$	α_7	0.456	0.000	0.454	0.037	−0.001	0.381	0.525	0.000	0.456
$x_8 \leftarrow y_2$	α_8	0.610		0.611	0.034	0.000	0.540	0.671	0.001	0.610
$x_9 \leftarrow y_2$	α_9	0.799	0.000	0.798	0.029	−0.001	0.740	0.856	0.000	0.799
$x_{10} \leftarrow y_2$	α_{10}	0.639	0.000	0.638	0.031	−0.001	0.575	0.698	0.000	0.639
$x_{11} \leftarrow y_3$	α_{11}	0.533		0.530	0.046	−0.003	0.435	0.608	0.000	0.533
$x_{12} \leftarrow y_3$	α_{12}	0.605	0.000	0.595	0.063	−0.01	0.490	0.706	0.000	0.605
$x_{13} \leftarrow y_3$	α_{13}	0.421	0.000	0.411	0.051	−0.01	0.330	0.511	0.000	0.421
$x_{14} \leftarrow y_3$	α_{14}	0.253	0.000	0.255	0.053	0.002	0.150	0.356	0.000	0.253

Table 9.6 The results of the internal model (own study)

		MLM			Bootstrap					
Dependence	Parameter	Parameter estimation	Standard dev.	p-value	Average	Standard dev.	Load (b*)	Low limit	High limit	p-value
$y_1 \rightarrow y_2$	β_1	−0.135	0.059	0.022	0.087	0.066	−0.001	−0.275	−0.019	0.021
$y_1 \rightarrow y_3$	β_2	0.088	0.059	0.137	0.085	0.066	−0.003	−0.043	0.219	0.181
$y_1 \rightarrow y_8$	β_3	−1.223	1.388	0.378	−1.390	1.773	−0.167	−4.787	1.823	0.446
$y_1 \rightarrow y_7$	β_4	−6.294	10.286	0.541	−6.633	5.272	−0.339	−17.534	2.812	0.178
$y_3 \rightarrow y_2$	β_5	0.508	0.074	0.000	0.537	0.170	0.029	0.349	0.770	0.001
$y_3 \rightarrow y_8$	β_6	5.680	1.686	0.000	7.234	8.088	1.554	1.544	10.332	0.003
$y_3 \rightarrow y_7$	β_7	9.975	12.020	0.407	12.993	21.989	3.018	−18.940	39.683	0.511
$y_2 \rightarrow y_8$	β_8	3.086	1.243	0.013	2.389	4.146	−0.697	−0.050	6.461	0.052
$y_2 \rightarrow y_7$	β_9	7.642	9.146	0.403	5.981	12.662	−1.661	−8.230	28.607	0.287

Table 9.7 Measures of the degree of fit of the SEM model (own study)

Model	NFI	PNFI	RMSEA	CMIN/DF	Hoelter 0.05
Estimated	0.913	0.705	0.045	3.067	416
Saturated	1	0.000	–	–	–
Independent	0.000	0.000	0.128	17.642	70

RMSEA is at the level of 0.045, which proves correct fitting the model to the empirical data.

According to the results contained in Table 9.6, behavioral inclinations of investors have a statistically significant impact on their risk tolerance (β_5) and the expected return rate (β_6). It confirms the results obtained by Long, Shleifer, Summers and Waldmann in 1990. Additionally, if the public information provided by the company is of higher quality, the willingness to take the risks by the investors is lower (β_1).

For further verification of the hypotheses established at the beginning of the chapter, the author decided to analyze the results of the estimated model in subgroups. In the first case the first group of investors contained market participants, who never or rarely used the fundamental information in the investment process. In the second group there were investors who used the fundamental analysis regularly (Tables 9.8 and 9.9).

Both in the first and the second group of respondents the behavioral inclinations have statistically significant influence on risk tolerance (β5). In addition, in the group of investors for which fundamental information is not significant, behavioral inclinations have not only an indirect impact on the expected return rate—β8, but also a direct effect on the lack of satisfaction with the investment—β7. The behavioral inclinations in this group are influenced by the growth of the difference between the expected and the real return rate obtained. The results support the hypothesis that the influence of behavioral inclinations of rational investors, who use the fundamental analysis on investment decisions is smaller.

In another split of the respondents in the first group, the investors who use the tools of technical analysis below average were included, while the second group was included investors who use them efficiently (Tables 9.10 and 9.11).

In both groups of respondents behavioral inclinations are statistically significant for risk tolerance (β5). In addition, in the group of investors, who do not have the skills to use technical analysis, the behavioral inclinations have statistically significant influence on the expected rate of return (β6). The standardized size of this impact is 0.229. In the second group behavioral inclinations have no direct impact on both the lack of satisfaction with the investment as well as the expected return rate. There is only indirect influence of these values by risk tolerance. The total standardized impact of behavioral inclinations in this group on the expected return rate is only 0.062 and is significantly lower than in the first group.

Subsequently, the respondents were divided according to their experience gained while investing on the capital market. Investors were split, as earlier, into two groups. The first group contained investors who had been active on the capital market up to five years, the second—investors with more than five-year experience (Tables 9.12 and 9.13).

Table 9.8 The internal model results for investors who never or rarely used the fundamental information in the investment process (Group 1) (own study)

		MLM			Bootstrap					
Dependence	Parameter	Parameter estimation	Standard dev.	p-value	Average	Standard dev.	Load (b*)	Low limit	High limit	p-value
$y_1 \rightarrow y_2$	β_1	−0.122	0.086	0.157	−0.133	0.104	−0.011	−0.342	0.066	0.210
$y_1 \rightarrow y_3$	β_2	0.141	0.105	0.179	0.134	0.116	−0.007	−0.094	0.369	0.211
$y_1 \rightarrow y_8$	β_3	−3.363	2.350	0.152	−3.977	2.518	−0.615	−8.410	1.09	0.144
$y_1 \rightarrow y_7$	β_4	−5.383	5.277	0.308	−8.558	12.286	−3.175	−38.689	5.194	0.339
$y_3 \rightarrow y_2$	β_5	0.424	0.100	0.000	0.543	0.276	0.119	0.201	1.077	0.002
$y_3 \rightarrow y_8$	β_6	3.013	2.567	0.241	6.541	9.621	3.529	−4.665	29.747	0.455
$y_3 \rightarrow y_7$	β_7	21.401	6.424	0.000	43.686	63.133	22.285	2.533	187.009	0.020
$y_2 \rightarrow y_8$	β_8	6.433	2.659	0.016	4.032	8.002	−2.402	−13.24	17.135	0.270
$y_2 \rightarrow y_7$	β_9	0.329	5.902	0.956	−14.866	42.679	−15.194	−108.509	12.514	0.901
		IFI = 0.890								
		RMSEA = 0.053								
		CFMIN/DF = 2.027								

Table 9.9 The internal model results for investors who use fundamental analysis regularly (Group 2) (own study)

		MLM			Bootstrap					
Dependence	Parameter	Parameter estimation	Standard dev.	p-value	Average	Standard dev.	Load (b*)	Low limit	High limit	p-value
$y_1 \rightarrow y_2$	β_1	−0.154	0.079	0.050	−0.158	0.093	−0.003	−0.334	0.029	0.093
$y_1 \rightarrow y_3$	β_2	0.034	0.071	0.633	0.033	0.084	0.000	−0.130	0.201	0.678
$y_1 \rightarrow y_8$	β_3	0.303	1.700	0.858	0.075	3.546	−0.229	−5.227	4.733	0.897
$y_1 \rightarrow y_7$	β_4	−8.908	16.334	0.586	−9.169	9.461	−0.261	−32.478	5.751	0.229
$y_3 \rightarrow y_2$	β_5	0.565	0.104	0.000	0.625	0.287	0.06	0.341	1.363	0.001
$y_3 \rightarrow y_8$	β_6	8.955	2.251	0.000	13.008	22.925	4.054	3.681	17.804	0.001
$y_3 \rightarrow y_7$	β_7	4.002	19.391	0.836	8.674	33.465	4.672	−51.357	58.56	0.928
$y_2 \rightarrow y_8$	β_8	1.252	1.378	0.363	−0.277	9.655	−1.529	−4.672	4.207	0.382
$y_2 \rightarrow y_7$	β_9	9.366	13.046	0.473	7.213	16.064	−2.153	−13.77	38.276	0.297
		IFI = 0.907								
		RMSEA = 0.046								
		CFMIN/DF = 2.384								

Table 9.10 The internal model results for investors who use the tools of technical analysis below average (Group 1) (own study)

		MLM			Bootstrap					
Dependence	Parameter	Parameter estimation	Standard dev.	p-value	Average	Standard dev.	Load (b*)	Low limit	High limit	p-value
$y_1 \rightarrow y_2$	β_1	−0.035	0.077	0.653	−0.036	0.086	−0.001	−0.209	0.130	0.660
$y_1 \rightarrow y_3$	β_2	0.085	0.084	0.312	0.083	0.094	−0.002	−0.107	0.269	0.360
$y_1 \rightarrow y_8$	β_3	−1.084	2.481	0.662	−1.127	2.891	−0.043	−6.800	4.731	0.690
$y_1 \rightarrow y_7$	β_4	−11.869	20.364	0.560	−12.286	10.200	−0.417	−38.044	3.512	0.135
$y_3 \rightarrow y_2$	β_5	0.513	0.106	0.000	0.532	0.152	0.019	0.307	0.846	0.000
$y_3 \rightarrow y_8$	β_6	10.619	3.327	0.001	11.967	6.683	1.349	3.685	19.887	0.001
$y_3 \rightarrow y_7$	β_7	23.102	25.096	0.357	24.711	25.951	1.610	−28.247	66.269	0.358
$y_2 \rightarrow y_8$	β_8	5.166	2.387	0.030	4.593	3.885	−0.573	−0.245	11.980	0.060
$y_2 \rightarrow y_7$	β_9	9.173	19.255	0.634	8.337	16.117	−0.836	−14.076	48.065	0.434
		IFI = 0.905								
		RMSEA = 0.046								
		CFMIN/DF = 2.124								

Table 9.11 The internal model results for investors who use the tools of technical analysis efficiently (Group 2) (own study)

		MLM			Bootstrap					
Dependence	Parameter	Parameter estimation	Standard dev.	p-value	Average	Standard dev.	Load (b*)	Low limit	High limit	p-value
$y_1 \rightarrow y_2$	β_1	−0.229	0.088	0.009	−0.238	0.115	−0.009	−0.483	−0.022	0.030
$y_1 \rightarrow y_3$	β_2	0.097	0.08	0.228	0.093	0.096	−0.004	−0.087	0.292	0.271
$y_1 \rightarrow y_8$	β_3	−1.431	1.208	0.236	−2.686	6.484	−1.255	−11.729	2.412	0.375
$y_1 \rightarrow y_7$	β_4	−0.354	3.744	0.925	−3.935	20.972	−3.58	−31.467	15.558	0.943
$y_3 \rightarrow y_2$	β_5	0.504	0.104	0.000	0.642	0.424	0.138	0.25	1.858	0.001
$y_3 \rightarrow y_8$	β_6	1.617	1.361	0.235	8.647	31.341	7.031	−3.077	75.890	0.455
$y_3 \rightarrow y_7$	β_7	3.004	4.212	0.476	23.373	111.88	20.369	−16.035	308.179	0.713
$y_2 \rightarrow y_8$	β_8	1.117	1.023	0.275	−2.633	16.737	−3.75	−45.445	4.162	0.532
$y_2 \rightarrow y_7$	β_9	4.387	3.19	0.169	−6.722	60.416	−11.109	−153.05	22.126	0.531
		IFI = 0.813								
		RMSEA = 0.073								
		CFMIN/DF = 3.591								

Table 9.12 The internal model results for investors who had been active on the capital market up to five years (Group 1) (own study)

		MLM			Bootstrap					
Dependence	Parameter	Parameter estimation	Standard dev.	p-value	Average	Standard dev.	Load (b*)	Low limit	High limit	p-value
$y_1 \rightarrow y_2$	β_1	−0.130	0.093	0.163	−0.133	0.107	−0.003	−0.365	0.063	0.169
$y_1 \rightarrow y_3$	β_2	0.213	0.118	0.071	0.195	0.128	−0.018	−0.035	0.465	0.093
$y_1 \rightarrow y_8$	β_3	−2.339	3.041	0.442	−2.596	3.572	−0.257	−8.967	4.283	0.473
$y_1 \rightarrow y_7$	β_4	−15.443	9.106	0.090	−16.2	11.81	−0.756	−43.586	2.224	0.083
$y_3 \rightarrow y_2$	β_5	0.320	0.092	0.000	0.445	0.413	0.124	0.117	1.706	0.006
$y_3 \rightarrow y_8$	β_6	6.420	2.857	0.025	10.733	21.32	4.314	−0.036	35.216	0.051
$y_3 \rightarrow y_7$	β_7	24.062	8.781	0.006	38.791	69.679	14.729	−4.771	154.549	0.115
$y_2 \rightarrow y_8$	β_8	5.923	2.38	0.013	4.203	8.74	−1.72	−8.625	13.091	0.130
$y_2 \rightarrow y_7$	β_9	6.631	6.959	0.341	−0.16	28.674	−6.792	−44.810	26.424	0.428
		IFI = 0.856								
		RMSEA = 0.058								
		CFMIN/DF = 2.544								

Table 9.13 The internal model results for investors who had been active on the capital market more than five years (Group 2) (own study)

		MLM			Bootstrap					
Dependence	Parameter	Parameter estimation	Standard dev.	p-value	Average	Standard dev.	Load (b*)	Low limit	High limit	p-value
$y_1 \rightarrow y_2$	β_1	0.053	0.219	0.809	0.058	0.334	0.005	−0.442	0.953	0.777
$y_1 \rightarrow y_3$	β_2	−0.178	0.120	0.137	−0.184	0.173	−0.006	−0.562	0.120	0.232
$y_1 \rightarrow y_8$	β_3	4.950	6.391	0.439	5.903	12.136	0.953	−18.198	27.944	0.620
$y_1 \rightarrow y_7$	β_4	7.777	15.545	0.617	10.12	32.768	2.343	−39.48	89.723	0.682
$y_3 \rightarrow y_2$	β_5	1.990	0.517	0.000	1.987	0.84	−0.003	1.170	5.153	0.000
$y_3 \rightarrow y_8$	β_6	60.536	20.479	0.003	65.123	44.874	4.586	17.892	217.521	0.000
$y_3 \rightarrow y_7$	β_7	153.128	67.315	0.023	171.196	128.916	18.067	54.656	756.59	0.000
$y_2 \rightarrow y_8$	β_8	−18.066	8.006	0.024	−52.387	18.539	26.999	−93.654	−1.610	0.021
$y_2 \rightarrow y_7$	β_9	−52.387	26.999	0.052	−56.818	51.267	−4.431	−309.796	−12.583	0.002
		IFI = 0.856								
		RMSEA = 0.058								
		CFMIN/DF = 2.544								

Again, the impact of behavioral inclinations on risk tolerance (β5) is statistically significant in both groups of investors. Additionally, in both groups the impact of behavioral inclinations on the expected rate of return (β6) and the lack of satisfaction with the investment (β7) is significant. However, Parameter β6 of the second group of respondents has a much higher confidence factor. This suggests a stronger inclination behavioral impact on the expected return rate for investors with more experience in the capital market. This can be explained by the increase in self-confidence along with the acquired experience.

Lastly, the respondents were divided due to the level of education. In the first group there were investors with at most secondary education. In the second—with higher education. In this case, there are no significant differences between estimated parameters.

9.6 Conclusions

Based on the survey carried out in the years 2010, 2012 and 2013 among individual investors investing on the Polish capital market, unobservable variables like risk tolerance, behavioral inclinations in the opinion and preferences areas, market quality and ability to the use of fundamental and technical analysis were identified. According to the hypotheses, the strength and direction of the influence of the aforementioned mentioned factors on the decision-making process of individual investors on the capital market in Poland were measured using SEM models. In particular, the main hypothesis according to which psychological factors, which are behavioral inclinations in the opinion and preferences areas, have a significant impact on the behavior of investors on the capital market, changing their risk tolerance and a satisfactory rate of return was confirmed.

It also shows the differences in influence of behavioral inclinations between investors who properly use the fundamental or technical analysis, and those who do not have this ability. A detailed analysis was carried out by dividing the investors to the separate groups based on their experience in investing on the capital market or education level. It has been shown that investors' experience on the capital market increases their self-confidence so that they can have more risk tolerance. In addition, good quality of information provided by the company reduces investors' risk tolerance significantly. The value and significance of the parameters of the models obtained by maximum likelihood was confirmed by bootstrap procedure.

Analysis of the survey's results allows for the assessment of the changes in the behavior of individual investors on the Polish capital market each year. The results of SEM model estimation allow on the other hand to perform numerous simulations to assess the impact of changes in the quality of information, in ability to use technical or fundamental analysis and in behavioral inclinations on risk tolerance, expected return rate and satisfaction of investing.

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Chapter 10
Efficiency of Investment with the Use of Fundamental Power Aspects

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Abstract The study fits well with the behavioral aspects of investment decisions. In this scope, a special place occupies risk aversion and associated with this possibility of building strategies using a variety of techniques and methods. The final effect such an action is selection the way of investment and to take the investment decision. The chapter proposes the fundamental portfolio of securities. This portfolio is an alternative for the classic Markowitz model, which combines fundamental analysis with portfolio analysis. The method's main idea is based on the use of the TMAI synthetic measure and, in limiting conditions, the use of risk and the portfolio's rate of return in the objective function. Procedure for calculating TMAI is presented e.g. in (Tarczyński, Przegląd Statystyczny 3:275–300, 1994). Different variants of fundamental portfolio have been considered under empirical study. The effectiveness of the proposed solutions has been related to the classis portfolio constructed with the help of the Markowitz model and the WIG20 market index's rate of return. All portfolios were constructed with data on rates of return for 2005. Their effectiveness in years 2006–2016 was then evaluated. This allows for the evaluation of the solutions' flexibility in various extreme situations. For the construction of the fundamental portfolio's objective function and the TMAI, the study made use of financial and economic data on selected indicators retrieved from Notoria Serwis for 2005.

Keywords Fundamental portfolio • Portfolio analysis • Decision making

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_10

10.1 Introduction

Investment process on the stock market is complicated, depends on many factor and can be leaded by many ways. This matter is well established in the (e.g. Arnold 2010; Browne 2007; Boulton et al. 2001; Cassidy 2000; Graham and Dodd 2005; Hagstrom 1996; Łuniewska 2004, 2005a, b; Lintner 1965a, b; Markowitz 1952, 1959; Navellier 2008; Sharpe 1963; Tarczyńska-Łuniewska 2010; Tarczyński 1994, 1995b, 1996a, b, 2002a, b).

Among many methods to invest on the capital market, the portfolio analysis plays a particular role as it is the most advanced decision-making technique. Not only does it use information coming from the capital market, but it also takes behavioral factors into consideration. The activities of the investor focus on the issue of the portfolio construction. Important is the method of portfolio construction and the selection of appropriate investment strategy so as to retain conditions were associated with the risk diversification. In this scope, it is possible to use a classical approaches like Markowitz or Sharpe model, and non-classical approaches e.g. fundamental portfolio. Regardless of the approach, all activities fits well with the issues of decision making (especially investment decision—how to invest?) and risk aversion. Both of these elements are determined by the investor behavior. In this scope, one can speak about the behavioral factor in making investment decisions.

The main aim of the study is construction of the fundamental portfolio and verify its effectiveness against classical portfolios. On this basis, it is possible to refer to the issue of risk or the decision to choose the way of the portfolio construction in terms of its profitability for the investor.

10.2 Portfolio Analysis

Portfolio analysis deals with the techniques of investing in more than one kind of asset. The basic motive of purchasing more than one type of security is the will to minimize diversifiable risk to zero and optimize revenues and risk of investment. It can be proved that an appropriately constructed securities portfolio enables reaching the above-mentioned goals. Portfolio analysis methods are regarded as methods allowing for making long-term investments. This generally stems from the portfolio's low elasticity and liquidity. Undoubtedly, this results in methods of portfolio analysis being closer to methods of fundamental analysis, than to those of technical analysis.

In practice, securities with high rates of return are characterized by high risk. The investor seeks such opportunities of investing funds which will minimize risk while increasing the rate of return. A securities portfolio gives the possibility of making such an assumption feasible.

A securities portfolio is understood as any set of assets held by the investor. This means that the number of components of a given portfolio equals the exact number of different kinds of securities the portfolio contains. It has to be emphasized that the portfolio theory is one of the most important sections in modern finance.

10.2.1 The Classic Markowitz Model

The basis of portfolio management and methods of selecting efficient assets together with ways of their financing had been created by (Markowitz 1952, 1959). Then, Markowitz's ideas were developed by Sharpe (who introduced in 1963 i.a. the single factor model, which simplified the classic Markowitz theory, and proposed a model of capital market equilibrium), (Lintner 1965a, b) and (Mossin 1966).

According to Markowitz works, while constructing a securities portfolio great attention is drawn to qualitative profits achieved through the diversification of investment in securities. The Markowitz model is based on quantitative methods. The assumptions of the Markowitz model can be found in, for example (Markowitz 1952).

Taking into account these assumptions, diversification of investing in securities decreases the range of return values. Profit from securities' investment is twofold by nature. The first is the dividend paid out by the company, the second represents profit resulting from the growth of the securities' market value. The profit from securities investments is determined by its rate of return.

One way of minimizing risk in a securities portfolio is diversification as proposed by Markowitz, which consists in increasing the number of securities within a portfolio. As a result of portfolio diversification (increasing the number of elements comprised by a portfolio) one may decrease down to zero the participation of particular assets' variances in the portfolio's overall risk. On the other hand, the lowest possible risk of the entire portfolio may not be lower than the covariation, whose share in the overall risk cannot be decreased. The model first proposed by Markowitz may be written in the form below:

$$\begin{aligned} & S_p \rightarrow \min, \\ & R_p = R_0, \\ & \sum_{i=1}^{n} x_i = 1, \\ & x_i \geq 0, \end{aligned} \tag{10.1}$$

where:
S_p—portfolio's expected risk,
R_p—portfolio's expected rate of return,
R_0—desired rate of return,

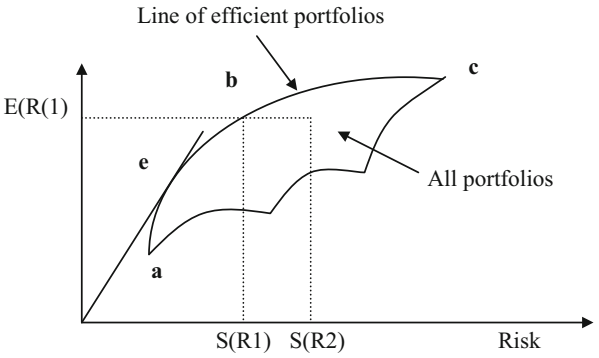

Fig. 10.1 Set of securities portfolios with regard to income and risk (own study on the base Markowitz 1952)

n—number of assets in a portfolio,

x_i—asset i's share in the portfolio (necessary to determine R_p and S_p).

Applying Markowitz's model it is not possible to exactly define the optimal investment portfolio. However, it is possible to use it to determine a set of portfolios profitable in terms of rate of return and risk, namely portfolios yielding maximum profits at a given level of risk or displaying minimum risk for a given level of profits. In practice, the analyses reject portfolios with a negative rate of return. This is possible to carry out through the application of dual programming technique (non-linear objective function with linear limitations). A graphic interpretation of a set of possible portfolios has been presented in Fig. 10.1.

Attention ought to be drawn to the fact that the potential portfolios' area corresponds to the risk-income map for single securities. The area limited by curves in Fig. 10.1 contains potential portfolios, i.e. all the possible risk vs. expected return comparisons. The boundary of profitability marked on the graph limits the area of potentially profitable portfolios. From the point of view of risk level, investors will prefer portfolios located on the boundary of profitability, which means the selection of maximum profit at a given risk. The problem that arises at this point is that there is an infinite number of efficient portfolios.

For instance, portfolios marked **b** and **d** produce the same income *E(R1)* at different levels of risk *S(R1)* and *S(R2)*. This is proved by the fact that investors will choose portfolios on the verge of profitability, because only in this way investment risk may be limited. Point **a** is the portfolio bearing the lowest level of risk, whereas point **c** is the one with the highest rate of return. Thus, this concludes that the choice of the optimal portfolio is an individual matter for each investor.

All portfolios lying on the boundary of profitability (curve **ac**) are **efficient portfolios**. These portfolios display the best parameters and are non-dominated. This means that for a portfolio's given rate of return, which is on the verge of profitability, it is not possible to find a portfolio carrying even lower risk. An example of such a portfolio is the one marked **b** in Fig. 10.1.

Portfolios preferred by investors who are risk-averse are called **conservative portfolios**. Their feature is that the shift to another conservative portfolio with a

higher level of minimally acceptable return is related to a smaller growth of risk than the growth of profit. Thus, on the line marked as the boundary of profitability, it is assumed that conservative portfolios are located on the most steep section of the curve. Such portfolios are, for instance, those in Fig. 10.1 contained between portfolios marked as **a** and **b**.

Another portfolio is the **minimal risk portfolio**. It is the one carrying the lowest global risk (marked as **a** in Fig. 10.1). We may say that by applying portfolio analysis in relation to the assets alone, it is not possible to further lower this portfolio's risk. What is left is risk resulting from the rules of the stock market. The minimal risk portfolio is always located on the end of the profitability curve.

In contradiction to the previously mentioned portfolio, the one located on the other end of the profitability curve is called a **critical portfolio** (in Fig. 10.1 marked as **c**). It is characterized by the fact that the growth of its return involves a faster growth in the level of risk. If a derivative from the curve of profitable portfolios is calculated, its value for the critical portfolio equals 10.1.

The **aggressive growth portfolio** is preferred by investors that are more prone to take risks. Portfolios from this group are characterized by the fact that a shift to another aggressive portfolio bearing a higher level of minimal acceptable profit involves a larger growth of risk than a growth of profit. They are presented in Fig. 10.1 between **b** and **c**.

The **optimal portfolio** may be found on the boundary of profitability as a point through which a straight line led from the beginning of the coordinate system is tangent to the line on which efficient portfolios are found. Figure 10.1 presents the optimal portfolio marked as **e**. A characteristic feature of this portfolio is that it carries the highest profit in relation to risk. Moreover, this portfolio has the lowest relative risk related to profit (obviously, when loss occurs, this does not hold true). An advantage of the optimal portfolio seems to be the fact that it bears relatively the highest profit (thus, the probability of loss is the lowest). In this type of portfolio it is not possible to include any risk-free securities, such as for instance bonds.

The last type of portfolio is the **market portfolio**. It differs from the optimal one in that the increment of profit in excess of the risk-free rate of return is compared against risk. In order to find this portfolio, one needs to lead a tangent from the point on the income axis corresponding to the risk-free rate of return (e.g. rate of return from bonds) to the line of efficient portfolios. The point of tangency corresponds to the market portfolio.

The main reservation toward the Markowitz model concerns the lack of possibility of its application in practice. To create the optimal portfolio even for a small number of securities in it, a great amount of data needs to be collected. What is more, these calculations do not present an easy task. Not questioning the advantages of the securities portfolio, Markowitz's model is not used in practice. Subsequent studies on the matters of creating the optimal securities portfolio led to the emergence of many models having larger practical significance than the classic Markowitz model.

10.3 Fundamental Criterion of Constructing a Securities Portfolio

Evaluating the classic concepts of securities portfolio from the pragmatic point of view, it may be said that these are techniques of analysis and conducting long-term investments. This stems from the portfolio's low elasticity. Constructing a portfolio seems pointless when the process of its construction may last even a few weeks, and change occurs after, for example a month. Even if we do see, evaluating the current market situation, that there is a need to reconstruct the portfolio, then the process is impossible to practically carry out in a short period of time. This is due to the limited liquidity of the stock exchange (on the Warsaw Stock Exchange, on average there is 1% of each company's shares floating in one quotation). Therefore, it seems obvious that the securities portfolio ought to be constructed with long-term investment in mind. From analysis of the stock exchange it follows that the criteria of rate of return and risk, determined on the basis of the variance of the rate of return, are not the best measures owing to their instability. This is particularly visible on developing markets (and the Polish market, as such), with low liquidity, where classic portfolios do not enable reaching premium income.

This is an incentive to search for new solutions that would allow for the construction of a securities portfolio which in a natural way uses long-term foundations for making investment decisions. It appears purposeful to combine methods of fundamental analysis with the notion of constructing securities portfolio. This not possible directly because fundamental analysis is too broad and formalizing it for the needs of constructing a securities portfolio requires significant simplification. Fundamental analysis, as a typical technique of analysis for long-term investment, seems to be an appropriate basis for forming a securities portfolio. A problem which has to be solved is bringing multi-element results of fundamental analysis to a form enabling its application in the construction of a portfolio. Such a problem is guaranteed to be solved with the proposed taxonomic measure of investment's attractiveness TMAI.

The proposed new concept of constructing a securities portfolio is creating a securities portfolio that will be a long-term one, taking into account important advantages of fundamental analysis, i.e. taking into consideration companies' factual strength at the expense of entities that are weak from the financial and economic point of view, defined as speculative companies. A portfolio constructed on these foundations will be stable and safe. For long-term investors the advantages of such an approach are obvious. The principal criterion under optimization is the asset participation-weighted sum of values of synthetic measures defining the portfolio's companies' fundamental strength. The value of a criterion understood in this way is maximized. Such a construction of the objective function ensures the portfolio's stability and security in a long period of time. The first proposals for constructing such a portfolio can be found in the works of (Tarczyński 1995a, b, 1996a, b, 1997).

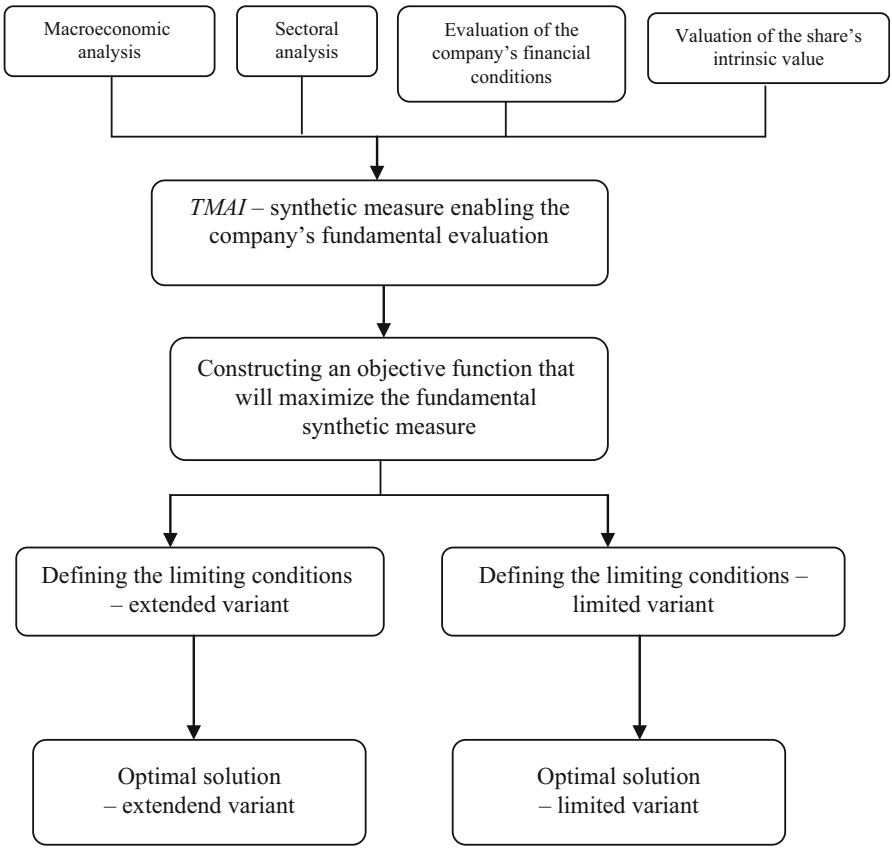

Fig. 10.2 Stages of constructing a fundamental portfolio (own study)

Stages of securities portfolio construction have been presented in Fig. 10.2. The proposed approach makes it possible to objectively asses the financial and economic condition of stock companies and to construct a securities portfolio accounting for the companies' fundamental strength and the investment's long-term character. On the basis of such a portfolio, further work is possible, for instance aiming at developing universal and stable criteria for synthetic measure and limiting conditions, which will be insensitive to the capital market's stage of development in a given country.

In the proposed method of constructing a fundamental portfolio TMAI values are the criterion under optimization. This is the principal change in relation to the classic concepts based upon rate of return and risk. A portfolio founded on the TMAI criterion is optimal from the fundamental point of view, i.e. it chooses the best arrangement in terms of companies economic and financial condition.

The proposed objective function and limiting conditions in the extended variant may be presented as follows:

$$f = \sum_{i=1}^{n} TMAI_i \cdot x_i \rightarrow \max, \tag{10.2}$$

$$\sum_{i=1}^{n} R_i \cdot x_i \geq R, \tag{10.3}$$

$$\sum_{i=1}^{n} S_i \cdot x_i \leq S, \tag{10.4}$$

$$\sum_{i=1}^{n} x_i = 1, \tag{10.5}$$

$$x_1, x_2, \ldots, x_n \geq 0, \tag{10.6}$$

where:

$TMAI_i$—taxonomic measure of attractiveness of investment in company i,

x_i—asset i's share in the portfolio,

R_i—weekly rate of return for company i,

R— portfolio's mean weekly rate of return desired by the investor,

S_i—weekly investment risk for company i determined as rate's of return standard deviation,

S—portfolio's mean weekly risk accepted by the investor,

n—number of companies.

The proposed model requires imposing additional limitations and explaining the occurrence of particular limiting conditions. The first stage is the limitation of potential securities that could become the portfolio's elements to those for which the rate of return in the analyzed period is greater than zero. Of course, in an extreme case this limitation may be omitted and all securities available on the market may be accepted. Formal criteria can also be used, such as discriminative analysis, which enables the isolation of a group of companies meeting specific requirements.

The second is the definition of the period under analysis. The principle of weekly time sections accepted in the model do not have to be the general rule. The period may be longer or shorter, which is first of all dependent on the investment's character. Generally, in a portfolio's long-term character resulting from its merit, the shortest period ought to be a week, while the longest—a month.

Thirdly, at the very beginning there is the necessity of defining the level of the investor's accepted risk and investment's expected rate of return. In this scope, the model is very flexible. Values R and S desired by the investor may be accepted in accordance with portfolio effect of rate of return and portfolio effect of risk, i.e. R as the minimal rate of return from companies used when constructing the portfolio, S as the maximum standard deviation of rate of return from companies used when constructing the portfolio. As limit values, it is possible to assume the levels of these measures estimated in a different way (e.g. arithmetic mean of rates of return

and risks for companies considered when constructing the portfolio or the rate of return and risk measured using stock index).

As far as limiting conditions (10.3), (10.4), (10.5) are concerned, the share of particular assets in the portfolio sum up to one, and (10.6), they are clear and do not require any explanation. The rate of return and risk of the portfolio determined by formulas (10.2)÷(10.6) may be calculated using the same formulas as for Markowitz model:

$$S_p^2 = \sum_{i=1}^{N} \sum_{j=1}^{N} x_i \cdot x_j \cdot \operatorname{cov}(x_i, x_j) \rightarrow \min, \tag{10.7}$$

$$R_p = \sum_{i=1}^{N} x_i \cdot R_i{}^i. \tag{10.8}$$

This offers the possibility to compare the securities portfolio with classic portfolios. The drawback of this method of measuring the rate of return and risk, both in classic models and in the fundamental approach, is the fact that these values are not a forecast but merely an exemplification of the future. An ideal solution would be one which makes use of forecasts. Values estimated on the basis of historical data, as experience show, are not credible enough and must be approached with great prudence.

The proposed model does not take into consideration the possibility of short sale (condition 10.6). Removing this limitation from the model would be equivalent to admitting the application of short selling in practice (the assets' share in the portfolio can be negative, yet still their sum will be equal to one).

In general, the model's formula does not impose any definite limitations here and, depending on the investor's preferences, other limiting conditions may be introduced to the model.

However, one must bear in mind that the most important piece of information is contained by conditions (10.3) and (10.4), and that further development of the model does not necessarily lead (this is often the case) to its better quality. Still, if the quality does improve, it is not significant enough to justify the model's complication with new limiting conditions.

As for the TMAI values appearing in the objective function, in order to precisely define the companies' condition, it is possible to calculate the values of selected economic and financial indicators as a certain mean from the last three or five years, which would actually reflect the essence of the company's condition. In case of difficulties with obtaining credible predictions of these magnitudes, such an approach is highly advisable. Finally, an attempt may be made to analyze the series of TMAI values calculated for the company in several time periods and also include in the model some means of these values. In the case of a stable economy and capital market in a given country, it is proposed to predict TMAI values and, then, construct a fundamental portfolio on their basis.

The modified fundamental securities portfolio includes risk in the objective function. The portfolio's risk is minimized in this variant, reduced by the fundamental strength of the portfolio's shares for a given level of the rate of return:

$$S_p^2 = \sum_{i=1}^{N} \sum_{j=1}^{N} x_i \cdot x_j \cdot \operatorname{cov}(x_i, x_j) \cdot (1 - TMAI_i) \cdot (1 - TMAI_j) \rightarrow \min, \qquad (10.9)$$

$$R_p = R_0,$$
$$\sum_{i=1}^{n} x_i = 1,$$
$$x_i \geq 0,$$

where symbols are the same as in previous formulas.

Thus constructed portfolio combines the classical Markowitz model with elements of the assessment of the fundamental strength of portfolio companies. It captures the essence of long-term investment, such as portfolio analysis.

10.4 Fundamental Portfolio Construction Procedure Based on the TMAI

The first step is to classify companies by their synthetic development measures TMAI. The classification criterion is the measures of economic and financial condition in the fields of: liquidity, profitability, indebtness and management efficiency. The base should comprise top 20 companies. Calculations were done based on 2005 end-of-year annual data. The calculations included all companies for which the economic and financial data were accessible and those listed on the exchange at least until the end of the year 2015.

The synthetic development measure "Taxonomic Measure of Attractiveness of Investments" (TMAI) can be estimated with the following formulae (Tarczyński 2002a, b).

Table 10.1 presents 20 companies with the highest values of the *TMAI* measure. The fundamental portfolio for companies included in Table 10.1 has been constructed with the use of formulae (10.2)÷(10.6) and the *Solver* tool available in *Excel* spreadsheet.

Analogically, portfolios have been set by the application of the Markowitz model—formula (10.1), and with the use of the modified securities portfolio—formula (10.9). The results have been presented in Table 10.2. Table 10.2 also holds the components of all studied portfolios (fundamental portfolio, Markowitz model, modified fundamental portfolio).

For the sake of comparison of analyzed portfolios' efficiency, the rates of return accepted here where those of portfolios constructed for companies listed in Table 10.1 on the basis of the Markowitz model, the fundamental portfolio, the

Table 10.1 Companies selected to database with the TMAI method and their distances for 2005 year (own calculations)

No.	Company	TMAI
1	ZYWIEC	0.4192
2	WAWEL	0.3785
3	KGHM	0.3697
4	ATM	0.3591
5	STALPROD	0.3560
6	SANOK	0.3222
7	APATOR	0.3182
8	ZPUE	0.3146
9	ORBIS	0.3028
10	PEPEES	0.2727
11	LPP	0.2651
12	ALMA	0.2631
13	KOPEX	0.2625
14	TVN	0.2622
15	SWIECIE	0.2556
16	RELPOL	0.2545
17	PERMEDIA	0.2536
18	ADVADIS	0.2511
19	COMARCH	0.2508
20	INDYKPOL	0.2479

modified fundamental portfolio as well as the WIG20 stock index for the ends of years 2006÷2016 (the results of the efficiency analysis are given in Table 10.3).

Each portfolio had been purchased on December 30th, 2005. In each variant (except the fundamental portfolio), the portfolio bearing the minimum level of the coefficient of random variation V_s was chosen as the method's representative, where:

$$V_s = \frac{S_p}{R_p}. \tag{10.10}$$

The value of volatility coefficient of random selected portfolios and their expected risk and rate of return are shown in Table 10.2. All calculations have been carried out with a weekly rate of return in mind. Figure 10.3 presents a map of risk/rate of return for the analyzed portfolios. Data in Fig. 10.3 show that in classical approach none of the structured securities portfolios should not be bought since their expected parameters (rate of return and risk) are worse than the rate of return on WIG20 (lower profit at higher risk). It means that in the proposed solutions the use of classical methods based on the expected returns is not appropriate as it does not take into account the essential advantage of the fundamental power which is not measured with historical return but with the synthetic measure of investment attractiveness TMAI.

Table 10.2 Structure of analyzed portfolios and expected rate of return and risk (own calculations)

Fundamental portfolio (FP)											
ZYWIEC	ATM	ADVADIS							V_p	R_p	S_p
0.5444	0.2586	0.1971							0.1317	0.0438	0.0058
Markowitz model (MM)											
WAWEL	KGHM	ATM	APATOR	PEPEES	LPP	TVN			V_p	R_p	S_p
0.1222	0.1054	0.1507	0.2348	0.0941	0.1489	0.1439			1.3470	0.0150	0.0202
Modified fundamental portfolio (MFP)											
WAWEL	KGHM	ATM	APATOR	PEPEES	LPP	ALMA	KOPEX	TVN	V_p	R_p	S_p
0.1643	0.1484	0.1676	0.2173	0.0763	0.1280	0.0073	0.0005	0.0903	0.9054	0.0150	0.0136

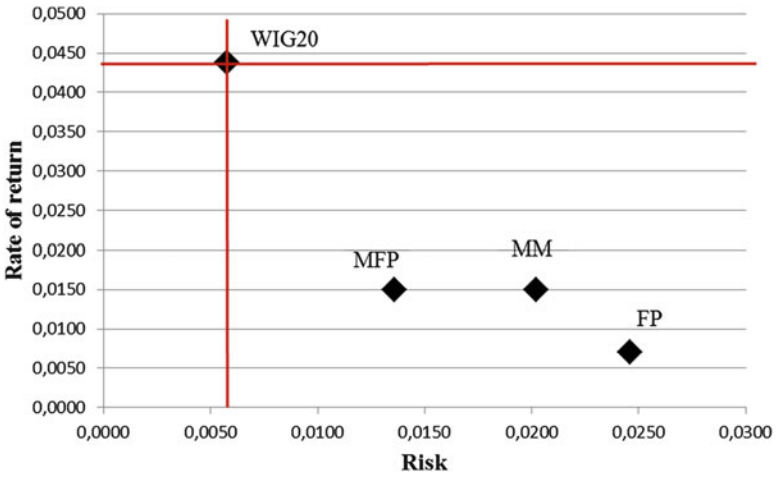

Fig. 10.3 Map of risk-rate of return for expected values (data 2005), where: MM—classical Markowitz model for companies selected on the basis of TMAI, FP—fundamental securities portfolio, MFP—modified fundamental securities portfolio. Source: own calculations

Table 10.3 Actual rate of returns on compared portfolios and index WIG20 (own calculations)

Years	FP	MM	MFP	WIG20
2006	0.6082	0.5187	0.5710	0.2375
2007	0.1352	0.6327	0.6419	0.3017
2008	−0.2698	−0.2474	−0.2637	−0.3259
2009	−0.0895	0.2333	0.2803	−0.1003
2010	0.0437	0.6976	0.8147	0.0336
2011	−0.2271	0.4714	0.5686	−0.1923
2012	−0.1979	1.6095	1.7604	−0.0271
2013	−0.1361	2.7792	2.8625	−0.0957
2014	−0.2239	2.2597	2.3190	−0.1277
2015	−0.2743	1.9197	2.0171	−0.2997
2016	−0.1819	1.9569	2.0420	−0.2663
Average	−0.0247	0.1779	0.1856	−0.0242

The data presented in Table 10.3 leads to the conclusion that the modified fundamental securities portfolio (*MFP*) and the Markowitz model (*MM*) are much better than the WIG20 stock index. In the analyzed time period from 2006 to 2016, which comprises the end of the bull market in 2004÷2006 and the crisis in 2007÷2009, the best *MFP* portfolio delivered a total return on investment of 204,2%, which gave an annual average of 18,6% (while the WIG20 index brought a loss of −26,6%, with annual loss at −2,4%). What proved to be doing well was the classical Markowitz model based on the fundamental criteria *MM* and achieving the rate of return of 195,7% (annual average of 17,8%). This confirms the validity of the studies carried out on the fundamental portfolio of securities.

The classical fundamental portfolio (*FP*) did not perform well with the loss at −18,2%. The research has shown that in practice the use of the fundamental portfolio with just TMAI in the objective function does not bring satisfying results. However, modification of the objective function from the Markowitz model with fundamental elements works very well. It should be borne in mind that the at the first stage of construction the model referred to as Markowitz's was also built with the use of TMAI. This is why the differences between these models are marginal. The application of the classical Markowitz model in reference to all listed companies in the long term does not bring as good results as the *MM* and *MFP* models discussed in this chapter.

10.5 Conclusions

The study proposes the concept of a modified fundamental securities portfolio which is an alternative to the classical Markowitz model. In the course of the empirical study we examined two variants of the fundamental portfolio (*FP* and *MFP*) and the Markowitz model built for the TMAI based database with the return on WIG20 as benchmark. The study covered the years between 2005–2016. It confirmed the validity of combining the portfolio analysis with the elements of the fundamental analysis. Further research into this subject is welcome. What seems to be theoretically accurate (i.e. the combination of the portfolio and the fundamental analysis) has been validated in practice. The advantages of the proposed *MFP* portfolio are its simplicity, easy construction, transparency and high effectiveness.

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Chapter 11
Investors Decisions in the Light of Exploitable Predictable Irrationality Effect on Warsaw Stock Exchange: The Case of UEFA EURO 2012 and 2016

Sebastian Majewski

Abstract Football, called in USA soccer, has the huge impact on everyday life especially during big events such as European Championships and World Championships. Information about results, players and teams appear everywhere and with every occasion. During near 30 days media exists thanks to football events (not only matches). The recent work of Edmans et al. (J Finance 62:1967–1998, 2007) indicate that there is a strong relation between soccer games and local stock exchange. The aim of the chapter is to verify hypothesis that there exists the effect of UEFA EURO cups on the Warsaw Stock Exchange. The research was conducted on the example of stock exchange indexes: WIG, WIG20 and WIG30. The case study is an example of an activity of irrational factors during the process of making investment decisions.

Keywords Behavioral finance • Irrationality • Stock exchange forecasting

11.1 Introduction

There are some very important events for big number of people in the world irregardless of levels of their interests. Every 4 year almost whole world take a part in celebrations of sport such as Olympic Games, World Cups, Euro Cups and many others. Their influence on everyday life could be so strong, that provoked people to extraordinary reactions. There are many countries where the soccer is equal to religion. Different culture provoked different emotional reaction of fanatic spectators. There are many forms of expressive reactions of fans. We could divide them on: fanaticism, hooliganism and expressive support (Gullianotti et al. 2005).

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_11

There is also another one form of fans behavior not included yet. They all conduct to the violent behavior not only during the football match. As we could imagine they also have an impact on the everyday life economic activity of fans. For example fanatic Turkish fans of Bestiktas Istanbul have the highest rate of fanaticism in Turkish league and results of this club have a strong impact on the stock exchanges index ISE (Berument et al. 2009).

But there is a difference between club and national team supporters. Fanatics and hooligans are focused on their pride—club beloved. They are proud of the history of the club, very involved to the club colors and organized like paramilitary troop fighting against their enemies (another club). National team supporters are also well-organized group of fans following the team through the world but they are not aggressive. Different are also states of minds and emotions accompanying activity of these two groups. The first group is oriented on continuous confrontation with enemies and a second one—on the guaranty of rooting for the team. More positive emotions accompanying national team supporters, so I decide to focus on this group of fans.

By the years Polish football has no spectacular success, so the appearing young, talented players like Lewandowski, Milik, Zieliński or Krychowiak push Polish fans to believe in sport success of the team. I decided to analyze last two UEFA Euro tournaments because of two reasons: first was the organization of UEFA Euro 2012 in Poland and the second excellent games of Polish team in road to France and during the tournament. According to literature review I decide to used mixed approach—based on the work of Kaplanski and Levy (2010) and Edmans et al. (2007) similar to the work of Demirhan (2013).

The aim of the chapter is to analyze relationships between main indexes on the Warsaw Stock Exchange and big sport events UEFA Euro Cups in 2012 and 2016. Because of that I raised hypothesis that there exists the effect of UEFA EURO cups on the Warsaw Stock Exchange. The second hypothesis that the wins of Polish National Team have an impact on the rates of return of three indexes—WIG, WIG20 and MIDWIG. The (G)ARCH type models are used in the research to verification of presented hypotheses.

11.2 Measuring Effects of Sport Events on Stock Exchanges

So far measuring the influence of sport results on the stock exchange activity could be divided into two parts: the influence of clubs' results on the share prices or values of indexes and the influence of national team's results on the main stock exchange indexes. Both this approaches could be classified as a methods of verification of efficient market hypothesis. Testing the impact of sport results (they are price sensitive information) on club's stock prices is a test for semi-strong market efficiency (Bell et al. 2012). On the other hand testing the impact of sport results on the whole market (market indexes) is a test for existing non direct affect, using

behavioral factors such as: mood, confidence and emotional state of investors (Kaplanski and Levy 2010).

First of all, the variable causing the mood behavior of investors has to satisfy three criteria:

- the variable must drive mood in substantial and unambiguous way,
- the variable must impact the mood of the large portion of population,
- the effect have to be visible for the major part of individual investors in the country.

As the it was said in the work of Edmans et al. (2007) the soccer games satisfy all these criteria. The large number of papers shows that the soccer seems to be more influential on human behavior then other sport disciplines (Edmans et al. 2007, p. 1970). The importance of soccer for the national team's fans could generate the "home bias" effect, documented by French and Poterba (1991).

The psychology literature gives another portion of information—there is significant difference between behavior of fans after wins and losses. Events like suicides, crimes and heart attacks are shown to accompany to a sporting losses, but there is no such evidence for wins (Edmans et al. 2007). Such asymmetry suggests that the impact of negative events is stronger than positive. It is also interesting that in case of the possibility of a win or a loss, larger effects are observed for the possibility of wins, according to known behavioral patterns—"basking in reflect glory" (BIRGing) and "cutting off reflected failure" (CORFing). They mean that fans cuts their relations with the losing team and increase the association with the wining team (Hirt et al. 1992). Such observations are similar to Kahneman and Tversky's prospect theory, where the determinant point of utility is the reference point against which losses and wins are measured (Kahneman and Tversky 1979). It is natural that soccer fans are subject of "allegiance bias", so they generate biased predictions. Thus, if fans expect wins of national team the change in rates of returns of stocks should be greater than after losses.

The following table presents main econometric researches of relationships between national football teams' results and stock exchange changes.

Majority of applications concerns on relationships between clubs listed on the stock exchange and their sport results. The (G)ARCH-type models are often used by researchers similarly to these presented in the Table 11.1. Usually the base for estimation is the econometric model describing the rate of return as a multiply regression function. The explanation of the rate of return of listed company using different independent variables is an extension of Sharpe's model (Sharpe 1964). Many authors have added new variables to the model to take into consideration every important effect having an impact on the dependent variable. Additionally such process increase an adjustment of the model to real data. We could find there variables representing sport performance (wins, loses, betting odds), market anomalies (week days), weather (sunny/cloudy days) or economic performance.

Another type of models are models trying to describe the rate of return of market indexes. In such case we don't have any benchmark in meaning of the Sharpe's

Table 11.1 Main researches and methods describing relationships between national football teams' results and stock exchange changes (literature review)

Author's name (year)	The subject	Method
Ashton et al. (2003)	National team of England	Binomial test
Tufan (2004)	World Cup 2002 football matches	Statistical tests
Edmans et al. (2007)	National teams	GARCH
Kaplanski and Levy (2010)	World Cup participants	GARCH
Klein et al. (2009)	European national teams	Regression
Klein et al. (2009)	National team of England	Binomial test
Demirhan (2013)	National team of Turkey	(G)ARCH

equilibrium, so we have to find every significant correlations to build a model. The approach proposed by Edmans et al. (2007) assume estimation of the model taking into consideration Monday effect and other confounding effects. Their proposition was as follow:

$$R_{it} = \gamma_{0i} + \gamma_{1i}R_{it-1} + \gamma_{2i}R_{mt-1} + \gamma_{3i}R_{mt} + \gamma_{4i}R_{mt+1} + \gamma_{5i}D_t + \gamma_{6i}Q_t + \epsilon_t, \quad (11.1)$$

where: Rit is the daily rate of return of the stock market index, Rmt is the daily rate of return of U.S. dollar return on Datastream's world market index on day t, Dt are dummy variables for Monday through Thursday and Qt dummy variables for days for which the previous 1 through 5 days are non-weekend holidays. The residuals $\widehat{\epsilon}_{it}$ of regressions are estimated as follow:

$$\widehat{\epsilon}_{it} = \beta_0 + \beta_W W_{it} + \beta_L L_{it} + u_{it}, \quad (11.2)$$

where: Wt are dummy variables for wins in different game subgroups an analogously Lt are loses for the same set of game subgroups. The estimation process was based on the panel-corrected standard errors (PCSE), which assumes that the error terms uit are mean zero and uncorrelated over time. But better results were obtained for the GARCH(1,1) model as developed by Engle (1982) and generalized by Bollerslev (1986).

Very interesting application was presented in the work of Kaplanski and Levy (2010). The rate of return of NYSE Composite Index is described by Eq. (11.3):

$$\begin{aligned} R_t = \gamma_{0i} + \sum_{i=1}^{2}\gamma_{1i}R_{t-1} + \sum_{i=1}^{4}\gamma_{2i}D_{it} + \gamma_3 H_t + \gamma_4 T_t + \gamma_5 P_t \\ + \gamma_6 E_t + \sum_{i=1}^{2}\gamma_{7i}J_{it} + \varepsilon_t, \end{aligned} \quad (11.3)$$

where: the Rt are daily rates of return of stock exchange index, Dt are dummy variables representing week days (rom Monday to Thursday), Ht is a dummy variable for days after a non-weekend holiday, Tt is a dummy variable for the first 5 days of the taxation year, Pt is a dummy variable for the annual event period

(June–July), Et represents the event days and Jit are dummy variables for the 10 days with the highest (i = 1) and lowest (i = 2) returns during the studied period. In such approach first problem is connected with the definition of the event day. Authors used to similar definitions. The first one treat the event day as the game day, the training day and subsequent training day. The second definition stands that all days of World Cup from the first to the last are game days. Authors used GARCH(1,1) model to estimate parameters of the equation.

The last research conducted on the example of Turkish national team is a work of Demirhan (2013). This model shows the rate of return of BIST-100 index of Istanbul Stock Exchange as a function of following variables:

- lagged values for stock market return (two lags),
- dummies representing wins and losses,
- dummies representing week days.

(G)ARCH models were preferred by author for estimation of parameters in this research.

11.3 Data and the Methodology of the Research

Football fans are very emotional—club fans treat football in category of religion and national team fans in category of theater performance (Antonowicz and Wrzesiński 2009). First kind of sport supporting is a fandom similar to invisible religion. The second one is commercial entertainment, where serial of weak performances causes very quickly the lack of interest of spectators and good performances—drive to the euphoria. Polish fans both club and national team are well known in the world of football, so I decided to conduct my research on the example of the relationship between Polish capital market and Polish national football team.

The last 25 years of history of Polish football on the international level was not a good period. In 2002 in Korea performance of Polish team was rather symbolic (Poland won only one—last match in the group phase). Four years later in Germany Poland lost all group matches. First attendance in Euro Cup in 2008 Poland finished with only one draw. The situation was changed in 2012, when Poland and Ukraine got a right to organization Euro 2012. Polish fans started to blow up "an euphoric bubble", which "bursts" after lost match versus Czech Republic. The good series of matches lasts from 2014 and it caused the last increase of the interest of matches of Polish national team. These facts are the reason of setting up time period for the research—the analysis has been conducted on the base of quotations of Warsaw Stock Exchange indexes from April 2007 (UEFA decision of organization of Euro 2012) to November 2016.

According to functions presented in previous chapter several versions of models were estimated in the research. I decided to use GRACH type models to examine relationships between signals flowing from Euro cups tournaments and Warsaw

Stock Exchange indexes—WIG, WIG20 and WIG30 (the time period is shorter than other). Finally, GARCH and EGARCH models approximated rates of return the best.

As it stands in previous chapter it has been assumed that the regression function on the basis of which the regression models will be built is:

$$y_t = \gamma_0 + \sum_{k=1}^{n} \gamma_k X_{kt} + \varepsilon_t. \tag{11.4}$$

The ARCH(q) model is written (Engle 1982)

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2, \tag{11.5}$$

where:

$$\alpha_0 > 0, \;\; 0 \leq \alpha_i \leq 1, \;\; \varepsilon_t \tilde{} N(0, h_t) \tag{11.6}$$

The general form of the GARCH model is (Bollerslev 1986: 307–327):

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j}. \tag{11.7}$$

The generalized form of the EGARCH model is (Xiuhongshi and Kobayashi 2009: 2797–2808, see also: Nelson 1991: 347–370):

$$y_t = \sqrt{h_t e_t}, \tag{11.8}$$

$$\log(h_t) = \alpha_0 + \beta \log(h_{t-1}) + \gamma \left| \frac{y_{t-1}}{h_{t-1}} \right| + \left| \frac{\theta y_{t-1}}{h_{t-1}} \right|, \tag{11.9}$$

where: $-1 < \beta < 1$.

The above models' parameters are estimated by means of the maximum likelihood method. In this study the author uses the GRETL program. According to presented models the first simple regression model tries to describe the rate of return of Warsaw Stock Exchange indexes by following variables:

- lagged indexes' rates of return (i = −1 and −2)—$R_{t\text{-}i}$,
- dummy variable for the first 5 days of the taxation year—T_t,
- dummy variables for week days—D_t,
- dummy variable for the annual event period (whole period)—P_t,
- dummy variable represents the event days (only match days)—E_t,
- dummy variable represents the match days of Polish national team—M_t,
- dummy variable represents the matches won by Poland—W_t,

- dummy variable represents the matches lost by Poland—L_t,
- dummy variable represents the matches of Poland with draw result—D_t.

11.4 Empirical Results

First of all, I decided to verify if the relationship between analyzed variables is linear. It turn out that there are not any linear correlation in case of any indexes on Warsaw Stock Exchange. So, I raised hypothesis that (G)ARCH type models approximate the relation between rates of return and variables showed previously. I test every the Kaplansky and Levy proposition of model and every nonsignificant (in statistical sense) variable I removed from the model. The models: ARCH(1), ARCH(2), GARCH(1,1), GARCH(2,2) and EGARCH(1,1) are tested. The results of estimation for the best models are shown in the Tables 11.2, 11.3 and 11.4.

As it was in the literature, the best approximation for rates of return of WIG20 index was obtained using EGARCH(1,1) model. There are three significant variables influencing on the dependent variable. They are: lagged rates of return (t-2), match days and losses of Polish national team in Euro Cups. Rates of return are negatively correlated with lagged rates of return and with losses, but they are also positively correlated with match days of Polish national team. It means that there exists an effect of Euro Cups for the index WIG20 and that the wins have not any impact on this index.

The second model EGARCH(1,1) for WIG's rates of return is not so good as the previous. Four variables have significant impact on the rates of return. The impact of match days and losses is stronger than in case of lagged rates of return. The direction of regression coefficients is similar to the relation obtained for WIG20. The difference is that this time we have fourth variable 1 day lagged rate of return positively correlated with dependent variable. It means that there exists an effect of Euro Cups for the index WIG and that the wins have not any impact on this index.

The last presented model is the model ARCH(1) for WIG30's rates of return. Obtained results indicate that the only one parameter has positive impact on the WIG30's returns—1 day lagged rates of return. Three variables have negative impact on the dependent variable. One of them indicates on the strong significant relationship. This relation is between the dummy variable representing first days of tax year and logarithmic rates of WIG30 index. The worst but still significant relation was obtained for the dummy variable describing European Championship period. The sign of the regression parameter is negative. It means that during the big event, such as the UEFA Euro is, investors are more interested in football matches than in making money via Warsaw Stock Exchange. The investing climate is not favorable for the rise of stock prices.

Table 11.2 Model EGARCH(1,1) for WIG20's rates of return (own calculations)

Variable	Coefficient	Standard error	z	p-value	Significance
Conditional mean equation					
Const.	−0.000329	0.000148	−2.213	0.0269	**
$R(WIG20)_{t-2}$	−0.038191	$7.18495e^{-06}$	−5315	0.0000	***
M	0.007204	$3.69515e^{-05}$	195.0	0.0000	***
L	−0.009587	$1.13487e^{-06}$	−8448	0.0000	***
Conditional variance equation					
Omega	−0.166549	0.037043	−4.496	$6.92e^{-06}$	***
Alpha	0.105183	0.018915	5.561	$2.68e^{-08}$	***
Gamma	−0.072482	0.010718	−6.763	$1.35e^{-011}$	***
Beta	0.990190	0.003207	308.7	0.0000	***
Llik		7053.494	AIC		−14090.989
BIC		−14044.690	HQC		−14074.149

** - a = 0.05
***- a = 0.01

Table 11.3 Model EGARCH(1,1) for WIG's rates of return (own calculations)

Variable	Coefficient	Standard error	z	p-value	Significance
Conditional mean equation					
Const.	$-4.42976e^{-05}$	0.000171	−0.2584	0.7961	
$R(WIG20)_{t-1}$	0.079629	0.048339	1.647	0.0995	*
$R(WIG20)_{t-2}$	−0.028463	0.015200	−1.873	0.0611	*
M	0.005675	$4.74577e^{-05}$	119.6	0.0000	***
L	−0.006920	$3.42001e^{-05}$	−202.3	0.0000	***
Conditional variance equation					
Omega	−0.229547	0.049085	−4.676	$2.92e^{-06}$	***
Alpha	0.126906	0.020217	6.277	$3.45e^{-010}$	***
Gamma	−0.074254	0.012923	−5.746	$9.15e^{-09}$	***
Beta	0.985323	0.004491	221.5	0.0000	***
Llik		7455.223	AIC		−14892.446
BIC		−14840.360	HQC		−14873.501

* - α =0.1
***- a = 0.01

Table 11.4 Model ARCH(1) for WIG30's rates of return (own calculations)

Variable	Coefficient	Standard error	z	p-value	Significance
Conditional mean equation					
$R(WIG20)_{t-1}$	10.109051	0.037638	2.8973	0.00376	***
$R(WIG20)_{t-2}$	−0.071473	0.031905	−2.2402	0.02508	**
T	−0.006531	0.002364	−2.7625	0.00574	***
P	−0.003893	0.002130	−1.8274	0.06764	*
Alpha (0)	$9.0972e^{-05}$	2.3996e−06	16.8478	<0.00001	***
Alpha (1)	0.165849	0.047133	3.5188	0.00043	***
Llik		3064.822	AIC		−6115.645
BIC		−6081.504	HQC		−6102.649

* - $\alpha = 0.1$
** - a = 0.05
***- a = 0.01

11.5 Conclusions

The main goal of the chapter was to analyze relationships between main indexes on the Warsaw Stock Exchange and big sport events UEFA Euro Cups in 2012 and 2016. Thanks to confirmation that such relation exists it is possible to positively verify of the exploitable predictable irrationality effect on Warsaw Stock Exchange. The second raised hypothesis concerns the results of Polish National Team during the tournament. It was assumed that wins of Polish National Team have an impact on the rates of return of three indexes—WIG, WIG20 and MIDWIG.

The different types of models were estimated but significant results were obtained only for (G)ARCH type models. Three best models were presented in Tables 11.2, 11.3, 11.4. In two cases (WIG20 and WIG) results indicate on the relation between indexes' rates of return and match days and losses of Polish football team. The best approximations were obtained for EGARCH(1,1) models. Both models show that investors' decisions are biased of matches as an event day and losses of the Polish team. Indirectly these two models positively verify the first hypothesis that the UEFA EURO effect exists. It means that the exploitable predictable irrationality could be used by investors as source of additional information.

The third case (WIG30) also showed that the relationship exists but generally by the dummy variable representing the annual event period (whole period of UEFA EURO tournament)—Pt. The negative sign of the parameter means the fall of the interest of investors in their stock exchange activity. The second difference between models is their analytical function. The simple ARCH(1) model gave the best results for WIG30.

Concluding, the research indicate on the existence of UEFA EURO effect on the Warsaw Stock Exchange in last 5 years.

The second hypothesis concerns the relation between match results (wins) and rates of return. Unfortunately, this hypothesis came out to be false. The relationship

between wins and rates of return was not detected in this research. On the other hand the relationship between losses and rates of return was detected according to the literature review. Two indexes prove the impact of losses on rates of return—main WIG and WIG20 of big companies.

The research shows that the world of football could influence on the stock exchange particularly when concerns big events.

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Chapter 12
Behavioral Aspects of Performance Measurement Systems in Enterprises

Wanda Skoczylas and Piotr Waśniewski

Abstract Enterprises apply performance measurement systems to communicate their business strategy to all their employees in a clear and explicit way. For this purpose they use key success factors and key performance indicators and their assessment. Performance measurement is most efficient when it is aligned with elements such as business strategy, organizational culture and external environment. Only then does it effectively interact with the communicative processes by requiring and providing relevant information that influences the way people think, work and collaborate. The real success of the enterprise is also determined by how efficiently and effectively members of the organization use the performance information to implement the strategy. The aim of the chapter was to identify relevant behavioral aspects of constructing a performance measurement system on the one hand, and of its impact on human behavior and organizational capabilities on the other. The presented analyses are a result of a critical study of views presented in the existing large body of literature in the field of management and performance measurement.

Keywords Performance management • Performance measurement • Social practice

12.1 Introduction

Providing information for decision making is inherently a behavioral function. An important, corresponding to the needs of decision makers source of information is properly constructed performance measurement system. The features of a performance measurement system, which provides that information, and its implementation are significantly affected by the behavior of people, especially people who

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_12

design and use that system. This leads to the conclusion that in a knowledge-based economy it is people representing the organization and the relationships between them that are crucial to the implementation and appropriate application of the performance measurement system, and thereby to the efficiency and effectiveness of the whole organization.

The aim of the chapter—as authors accepted—was to identify relevant behavioral aspects of constructing a performance measurement system on the one hand, and of its impact on human behavior and organizational capabilities on the other.

The realization of the stated aim of the chapter was preceded by presentation of behavioral theories, that underlie development of a performance measurement system which satisfies the needs of strategic performance management. These theories aim to predict how individual enterprises will behave in areas such as decision making, allocation of resources or goal setting. They result from the need for a more thorough investigation of the influence of motivation and cognitive theories on the theory of firm. Furthermore, the theories attempt to incorporate uncertainty as to the impact of future events on the company's condition.

12.2 Behavioral Theories in Development of Strategic Performance Management

Performance, performance measurement and performance management have become ubiquitous terms in business circles. The most superior term, i.e. performance management, can refer to an individual, operational or strategic level. Traditionally, performance management is associated with the first, i.e. individual, level. The aim of the second level, as a result of developments in accounting, is to strive to achieve goals of individual functional areas or groups. The highest and the most holistic level is where strategic management is performed. Amaratunga and Baldry (2002) define a strategic performance management system as a system which uses information to generate a positive change in the organizational culture, systems and processes. A performance management system is a set of formal and informal mechanisms, processes, systems and networks used by organizations for communicating the key objectives and goals indicated by the managers, for supporting the strategic process and the ongoing management through analysis, planning, measurement, control and rewarding, i.e. generally through performance management, and for supporting and offering opportunities for organizational learning and change (Ferreira and Otley 2009: 264). The main features of this definition refer to the following elements which indicate evolution leading to the development of management control:

- various types of mechanisms (both formal and informal),
- successful implementation of strategy,

- purpose of the performance management system, for instance assisting the organization with achieving its goals through learning and change.

Broad performance management has been a topic of numerous interdisciplinary research studies. The concept of performance management originated in economic, sociological, psychological and behavioral theories. Economic theories of organizational control[1] based on the theory of firm include in particular: the principal—agent theory and the transaction cost theory.

Since those theories fail to provide a satisfactory explanation for the phenomena occurring in the enterprise under an uncertain and changing environment, noneconomic theories have gained in importance and contributed to the knowledge on companies' behaviors. They include sociological theories of organizational control, i.e. functionalism, the general system theory approach, the contingency theory and the theory of bureaucracy. They explain and describe organizational behaviors by emphasizing primary behavioral tendencies in groups. From this point of view, organizational control is performed through principles, policies and hierarchy of authority.

Organizational control, under a psychological approach, encompasses the impact of behaviors of individual members of the organization both inside and outside the organization (Demartini 2014). The mechanisms of organizational control include goal setting, rewarding and interpersonal relationships. Through the personality effect, an efficient alignment is sought between variables such as organizational determinants, interpersonal relationships, reactions, organizational performance. From a psychological point of view, organizational control refers to recognizing appropriate individuals whose skills and motivation make them suitable candidates for given jobs, setting ambitious yet achievable goals for them, and keeping them in the organization while assuring alignment between their personal goals with the goals of the organization.

Behavioral theories form a link between the sociological and psychological dimension of organizational control (Demartini 2014). They attempt to predict how enterprises will behave in areas such as decision making, allocation of resources or goal setting. They result from the need for a more thorough investigation of the impact of motivation and cognitive theories on the theory of firm. Researchers indicate that business owners and managers set goals which go beyond profit or shareholder wealth maximisation, and result from their qualities or motivation. Furthermore, the theories attempt to incorporate uncertainty as to the impact of future events on the company's condition. Decisions are made, at least partially, by an unaware decision maker with limited knowledge, which significantly affects the rationality of the decision and the ability to predict its consequences and outcome. Table 12.1 summarizes the qualitative factors determining the final outcome of the decisions made.

[1]Organizational control refers to a coalition of agents which introduces a set of coordinated and cooperative activities aimed at performing individual objectives by means of the organizational objectives (Cyerth and March 1963, cited in: Demartini 2014). The interrelationships between individual and organizational goals are an essential component of management control.

Table 12.1 Qualitative determinants of the decision-making process (Majewski 2012)

Factor groups		
Information	Social	Personal
– Brand – Advertising	– Social status – Marital status – Religion – Place of residence – Ethnicity – Profession – Education	– Emotional state – Type of personality – Disposition – Character – Past emotional experience

Rationality of a decision can be assessed only when all the factors determining its making are considered, which refers in particular to any limiting factors. From the organizational point of view, organizational control refers to "integration of behaviors", which incorporates an alignment between "essential planning" (e.g. broad decisions concerning future goals which should be achieved) and "procedural planning" (e.g. daily decision making in line with the essential planning).

Based on the techniques used by organizational control in the early twentieth century, first management control was introduced, and then it was replaced by a strategic management control system. The latter was defined as a system designed to support managers in assessing relevance of the organization's strategy to its progress in achieving goals and reducing any underperformance in this area (cf. Lorange et al. 1986). The environment in which contemporary companies operate imposes the need to not only measure but also manage performance. Performance management is a process which involves defining goals, planning and control of both performance and organizational performance potential; it is also an instrument of change management, a focus on integration between designing strategy and its implementation. It includes performance measurement and relies on various methods, techniques and software. Czekaj and Ziębicki argue that it is a concept of an integrated and holistic approach to managing an organization (Czekaj and Ziębicki 2014; Skoczylas 2016). Performance management fulfills a variety of functions, which include (Hilgers 2008):

- operationalization of strategy,
- supporting the decision-making process,
- creating impulses for change management,
- incorporating causal relationships,
- implementation of IT infrastructure,
- functional integration,
- motivating employees,
- supporting communication,
- organizational performance management and improvement,
- starting point for organizational learning,
- focus on performance goals and determinants of performance results.

The functional scope of performance management goes beyond the budgeting processes and performance reporting, aiming primarily at supporting implementation of strategies and creating value for stakeholders using analytical and forecasting capabilities (e.g. Tonchia and Quagini 2010). When analyzing the effects of performance management, it should be added that adoption of strategic performance management systems, which has been recently witnessed in a growing number of enterprises, offers a variety of benefits, particularly related to the successful implementation of the intended strategy, as well as to the influence on its formulation (many authors, cited in: Bisbe and Malagueno 2012).

12.3 Performance Measurement System in a Company's Strategic Management

Performance management cannot be successfully implemented without an appropriate underlying performance measurement system, which encompasses identification of the category to be measured, measurement itself and performance evaluation. Measurement has always accompanied first human and later also organizations' activities. The process is performed on an individual, operational and strategic level. The latter is being developed in response to the existing gap between information needs raised by strategic management and the information delivered by periodic and annual financial reports, which still remain its major source. Financial measures were the right solution in the industrial era. In the information age, however, it is nonfinancial measures which gain in importance and complement the financial measures. They reflect and allow monitoring of the critical success factors derived from the vision, mission and strategy. Nonfinancial measures allow a precise and comprehensible description and communication of strategy as a basic action plan. They can be considered as a certain navigation system which focuses all the resources and activities on implementation of the strategy. They also encourage all the employees to act in an entirely new way. The system of financial and nonfinancial measures at a strategic level is a foundation for an analysis of the adopted strategic premises concerning the market situation, behavior of competition and customers' expectations, and hence for any modification of the strategy (Skoczylas 2016).

In the literature of the subject, there are multiple definitions of the performance measurement system. A team of researchers (Franco-Santos et al. 2007, cf. Haffer 2011) conducted an extensive overview of those definitions based on an overview and analysis of more than 300 publications from which only 17 different definitions of the performance measurement system were selected. In the next step, all these definitions were analyzed with respect to the number of their citations. As a result, it was found that the definitions emphasized one or a combination of several aspects of performance measurement systems provided below, yet no set of characteristics was referred to in more than one definition:

- Elements, understood as components which comprise a performance measurement system,
  - strategic objectives which are the starting point for designing activity measures that allow strategy monitoring,
  - an integrated set of performance measures in four key areas: financial, customer, internal and employee,
  - hierarchy/cascade, where indicators overlap and provide alignment between the strategic, tactical and operational level of activity,
  - targets for indicators allowing verification to what extent operational goals are met,
  - causal models which allow an analysis of relationships between selected indicators and hence different business areas,
  - infrastructure supporting data acquisition, collation, sorting, analysis, interpretation and dissemination,
  - guidelines for rewarding employees, related to the level of achievement of performance targets,
  - performance contracts with staff members responsible for their execution.
- Functions, understood as roles played by performance measurement systems,
  - business performance measurement and evaluation,
  - progress monitoring,
  - supporting the action planning process,
  - supporting strategy implementation and execution,
  - focusing management's attention on key performance indicators,
  - internal communication of performance, priorities and objectives,
  - external communication of performance, priorities and objectives,
  - providing data for benchmarking,
  - ensuring compliance with regulations (meeting specific legal/technical requirements),
  - influencing behavior of staff members,
  - providing data for the process of rewarding staff members,
  - managing relationships,
  - supporting the control process,
  - identification of areas requiring improvement and delivery of data for performance improvement,
  - providing feedback (measurement results lead to actions),
  - creating a learning organization.
- Roles, understood as purposes of or functions performed by performance measurement systems,
  - performance measurement,
  - strategic management,
  - communication,

  - influencing behavior,
  - learning and improvement.
- Processes, understood as series of actions which—when completed in order—comprise performance measurement systems,
  - selection and design of measures,
  - collection and manipulation of data,
  - information management (interpretation of data/decision making),
  - performance evaluation and rewards,
  - system review.

This list lacks the effects of implementation of those systems such as better efficiency, which leads to better performance. Sousa and Aspinwall (2010) emphasise that a performance management system should use resources in an effective way and generate notable short-term and long-term benefits so as to help maintain the momentum and enthusiasm of the development team; it should also be dynamic and flexible enough to allow strategic change. A "good" system should be comprehensive, causally oriented, vertically and horizontally integrated, internally comparable and useful (Cocca and Alberti 2010). Performance measurement models should incorporate logical interrelationships of cause and effect between actions and results. They should also allow identification of the relationships between processes underlying the company's activity (Taticchi et al. 2012, cf. Bourne et al. 2000).

On the one hand, such a definition of a performance management system incorporates elements, functions, roles and processes which aim to affect human behavior in a desired way. On the other hand, it reveals the impact of information delivered by the system on the decisions made by and behavior of people. It refers to the relationship between people and the form, design and use of an efficient performance measurement system (Marcinkowska 2009).

12.4 Designing a Performance Measurement System as an Efficient Way to Influence Human Behavior

Explaining and aligning the mission and vision so as to mobilize the organization and focus it on executing the strategy involves the following stages: designing the strategy to execute the vision and mission, aligning strategic goals, defining "should be/is" measures, suggesting ways to achieve goals and implementation. Enterprises implement a performance measurement system to create a consistent understanding of the business strategy by translating it into critical success factors and key performance indicators (KPIs) and their evaluation (Waal and de Kourtit 2013).

Critical success factors (CSF) are usually defined as a list of key areas, issues or aspects of activity which determine success of the business. They result from the strategy adopted to implement the company's vision and mission, and reflect the

managers' information needs, their hierarchy and relevance. They can be either hidden or disclosed. The former are usually identified by managers subconsciously, while the latter reflect the priorities recognized by means of special methods, such as literature study, interviews etc., in order to ensure better allocation of the resources. CSFs can originate in the structure of the industry, macro environment, competitive environment, internal factors or requirements of individual posts (Niemiec 2016). Identification of the critical success factors is a result of a holistic analysis of both processes taking place in the company and the stakeholders' expectations (Michalak 2008), and it leads to reduction of the so-called "information noise".

A performance measurement system involves also definition of strategic goals, which precisely describe the strategy and allow focusing on specific and relevant present and future competencies. An effective way to achieve goals requires their measurement, i.e. a process based on performance measures. Critical characteristics of these measures have been defined in the literature on the subject, and so they should (various authors, cited in: Hudson et al. 2001):

- be derived from strategy,
- be clearly defined with an explicit purpose,
- be relevant and easy to maintain,
- be simple to understand and use,
- provide fast and accurate feedback,
- link operations to strategic goals,
- stimulate continuous improvement.

While designing a measurement system, the following essential requirements need to be met (Chalmeta et al. 2012):

- making sure it offers proper alignment with the strategy,
- checking whether if provides information about the extent to which objectives are being reached and whether only desired objectives are measured,
- defining the most suitable way to implement measures to make sure their calculation is as clear and automated as possible.

The key performance measures ultimately define the strategy and allow its implementation. Their number, however, should be limited and the whole set ought to comprise a chain of causal relationships. Too high a number of measures distorts the picture and leads to wrong conclusions while calculations and analysis consume precious time (cf. Garengo et al. 2005). Lack of causal relationships between measures, in turn, makes it difficult to understand and execute strategy thus affecting the organization's ability to efficiently and successfully meet the goals of its stakeholders.

When selecting a set of measures, it is essential to take into account their representative and information value. Every measure should be defined precisely and individually for each company. This detailed approach relies on a clear and precise definition of the measure, providing a database essential to calculate the measure, and finding its present and future value, which allows comparisons and

contrasts between "what is/should be", assigning responsibility, linking it to the organization's incentive system and defining activities essential to achieve desired targets.

This link with the incentive system provides a strong motivation for involvement in goal achievement, with all its positive and negative consequences. It is, therefore, of the highest importance to link the targets with strategic goals, controlled by the owners who can thus influence their levels. Other desirable attributes include precision, simplicity, focus, reliability and high level of integration. These criteria are met only by a limited number of performance measures, so particular attention is paid to appropriate selection of measures which are later used as components of the final sets of measures. These carefully selected sets of measures serve as a foundation for constructing performance measurement systems in companies.

Performance measures and measurement systems perform three major functions: monitoring and control, communication and improvement (Franceschini et al. 2007; Sousa and Aspinwall 2010). Neely (2002, cited in: Garengo et al. 2005) indicates that measures are designed so as to help managers establish whether they are on the right path to achieve strategic and operational objectives. They are used as a way to combine the company's mission and strategy with its operations (cf. Melnyk et al. 2004; Koufteros et al. 2014). They allow control of the efficiency and effectiveness of actions against the targets (Tan and Smyrnios 2011; Melnyk et al. 2014).

Performance measures are used to communicate the strategy to members of the organization through breaking down strategic goals to individual goals of employees or teams. The comparison and contrast between "is/should be" enables managers to identify and communicate deviations in executing the strategy, which—following their thorough analysis and evaluation—are a foundation for making and implementing better decisions, and providing better alignment in the company.

Companies have understood that competing in a changing environment, also in an international dimension, requires an analysis and understanding of their own achievements which relies on adopting suitable performance measures (cf. Taticchi et al. 2012; Sharma et al. 2005). Micheli and Mari (2014) point out that appropriate measurement can have a positive impact on:

- formulation, implementation and review of the organization's strategy,
- communication of performance results to stakeholders, strengthening of brand and reputation,
- motivation of employees of all levels, development of a performance improvement culture and encouraging of organizational learning.

Hu et al. (2016) emphasize the role of performance measurement in the process of successful implementation of the company's strategy and the relevance of measurement to dynamic and complex decision making in these processes based on the right and relevant information. Many authors highlight also the significance of performance measurement to translating and communicating strategy to staff

members thus affecting their motivation, efforts and performance (cf. Koufteros et al. 2014).

Buhovac and Groff (2012), based on an extensive literature study, have identified four determinants of contemporary performance measurement systems, which influence their efficiency:

- Multidimensionality—financial perspective is complemented by a non-financial perspective as well as non-financial objectives and their measures, which is a key to better productivity and better performance.
- Strategic alignment—companies focus on the performance measures which deliver information directly relevant to their strategies and strategic success factors. Focused performance measurement aligned with the business strategy contributes to better profitability.
- Cascading—general performance measurement system should be broken down into sets of local measurements for lower levels in the organizational structure so as to cascade strategic objectives down into more manageable subsets. This cascading should be integrated with the overall business strategy thus ensuring that all stakeholders (including employees) are working together in the same direction.
- Alignment with the incentive system—lack of such alignment may result in failure at coordinating employee efforts and their decision making. The alignment between performance measurement and an incentive system focuses employees' attention on the measures which are crucial to the company's strategy, and hence rewarding employees translates into successful achievement of the desired business objectives.

It can be concluded that performance measures are a tangible expression of the company's stated vision and strategy by providing a set of specific (precise) measurable expectations which support employees in fulfilling their roles as contributors to the company's success (cf. Choong 2013). Buhovac and Groff (2012) observe that the use of financial measures delivered by accounting in a complex, dynamic and uncertain environment leads to dysfunctional attitudes and behaviors among managers and poor performance, which suggests that decision-making processes should be complemented by information provided by qualitative and subjective performance measurement. In the literature on strategic management there has been a methodological discussion going on for several decades on the results of research into selecting "the right" performance measures (many authors, cited in: Steigenberger 2014). It is highlighted that the main problem related to the practice of performance measurement is the misfit between the specification of performance in the theory and the way to measure performance used in empirical research when testing those theoretical premises. In the theory, performance is measured in relation to a holistic and complex approach to and understanding of the company's success, whereas empirical studies focus only on one or several aspects of business performance (cf. Steigenberger 2014).

12.5 The Impact of Performance Measurement Systems on Human Behavior and Organizational Capabilities

The aims of performance measurement systems are defined through indicating the most frequent ways of using the information about performance (cf. Simmons, cited in: Michalak 2008):

- Decision making—managers need reliable information on past, present and future performance of their business to make rational decisions.
- Sending signals (internal and external communication)—employees and external recipients base their perception of the company on available information about its performance. Better performance may lead to better perceptions among stakeholders, which can translate e.g. into lower cost of access to external sources of financing or a better opinion among potential employees.
- Education and learning—information about past events and its creative analysis is one of the basic conditions for making right decisions and drawing conclusions to determine future activity.

Performance measurement reflects the effectiveness and efficiency of operations and decisions made in all the areas of the company's activities with respect to stakeholders' satisfaction from the extent of achievement of various goals. Some authors show that learning is at present a distinctive feature—and at the same time the main role—of performance measurement (Nita 2009). It is essential to understand the link between performance measurement and knowledge, recognizing the latter as both a strategic resource and performance driver, since knowledge is one of the most important factors of value creation in contemporary enterprises (Laihonen et al. 2013). Knowledge is a result of making full use of the information and data combined with the potential of human skills, capabilities, ideas, involvement and motivation. Knowledge along with intuition and experience defines wisdom (Grudzewski and Hejduk 2004). Human dimension is an immanent attribute of knowledge; it is based on information, experience, human intuition and understanding. According to R. McDermott, people have a purpose to "know something", knowledge is created in the present, the old knowledge lays foundations for new knowledge, knowledge is a result of thinking and experiencing, knowledge belongs to the community of people, knowledge is exchanged in the society through multiple channels (McDermott 1999; Czerniachowicz 2003).

In the context of performance measurement, it should be highlighted that measurement itself is a relatively simple activity; it is much more difficult to use the results to change behaviors, which should lead to achievement of goals and improvement of performance. Micheli and Mari (2014) claim that the so-called "alternative approaches" to the problem of performance measurement tend to consider measurement a social practice rather than a technical process (cf. Covaleski et al. 1996).

The relevance of performance measurement systems has been well documented in the literature (many authors, cited in: Perera and Baker 2007).

Franco-Santos et al. (2012) carried out an extensive study of the consequences (people's behavior, organizational capabilities, and effects on performance) of contemporary performance measurement systems based on their review of 76 selected papers (empirical studies) published in high-ranked academic journals in the field of accounting, operations and strategy. As a result of their research they found that performance measurement systems had a significant influence on people's behavior, organizational capabilities, and performance; the systems play a crucial part in strategy, communication, and management processes, generating organizational capabilities that enable the organization to excel (Franco-Santos et al. 2012).

An important barrier to development of a performance measurement system is influence of the human factor. It is claimed that performance measurement systems are rarely implemented and supported by senior management, which is considered as one of the signs of aversion to change and impact of psychological and behavioral aspects on managing a company, including performance management. Lack of skills resulting from insufficient knowledge or experience is one the most common reasons behind inefficient functioning of performance measurement systems. Other reasons include obstacles and difficulties at work which have a negative impact on performance.

Another important factor is distortions in the process of communication (e.g. noises but also the use of "codes"). Ukko et al. (2007) argue that there is a clear connection between performance measurement and leadership. They also suggest that the main qualities of leadership are abilities for long-term strategic thinking, communication skills, integrity and ambition. Entrepreneurs need to constantly develop their competencies, skills and techniques, and acquire specific knowledge in order to survive and succeed and create new innovative growth opportunities (cf. Omerzel and Antoncic 2008).

Omerzel and Antoncic (2008) identify four dimensions of the owner's/manager's knowledge, which they used when constructing their model explaining the impact of the behavioral factor on the company's performance:

- Education level (1 variable).
- Work experience (10 variables).
- Knowledge about functional disciplines (14 variables).
- Self-confidence (8 variables).

Omerzel and Antoncic (2008), based on their research into the influence of various characteristics of managers/owners on the firm's performance, point to the following entrepreneur skills and knowledge which can be considered as crucial to growth of small- and medium-sized companies:

- critical/analytical thinking (the ability to analyze problems and situations in a critical and logical manner and to apply workable and logical solutions to such problems),
- leadership abilities (the ability to lead a team while taking responsibility for a task, giving direction, providing structure and assigning responsibility to others),
- knowledge of company management and organization.

Smith (2005) distinguished between four processes of key relevance to managers:

- performance analysis,
- ad hoc reporting,
- strategic planning,
- participation in meetings.

Performance management systems affect communication processes by requiring and delivering relevant information which influences how people think, act, and interact (Franco-Santos et al. 2012). Providing information on performance is not sufficient to improve business performance, and the real success is determined by whether the organization's members put this performance information to use (Nudurupati et al. 2011). It has been found that the effectiveness of performance management systems is moderated by internal factors such as the employees' experience or the organization's strategic orientation, structure, information systems, culture, and management style, along with external factors such as competition or the degree of environmental uncertainty in which the organization operates (Franco-Santos et al. 2012).

Studies which investigate the concept of entrepreneurial human capital usually focus on the effects of the entrepreneurs' education, their past professional experience as well as their family and professional background (many authors, cited in: Omerzel and Antoncic 2008). The authors argue that a higher level of entrepreneurs' education has a positive impact on productivity, which subsequently leads to higher profitability (Omerzel and Antoncic 2008).

The managers and employees may approach performance measurement from two different perspectives, which should be considered when designing, implementing and using such a system in the organization (Ukko et al. 2007). Staff members who will be the main users of performance measures should be actively involved in the process of designing the system, and the key principles for effective management of the performance management system development process have been defined as follows (Hudson et al. 2001):

- top management support,
- active involvement of all organization members,
- clear explicit objectives,
- time framed project management.

Cheng and Coyte (2014) delivered empirical evidence demonstrating how performance measurement systems can motivate certain behaviors in relation to performance areas that are not recognized by the formal incentive schemes.

The attitudes of staff members are crucial to successful implementation of a performance measurement system adopted in the company. Before any performance measurement methodology is introduced, employees need to be trained in performance evaluation. They need to understand the foundations of the performance measurement system and the evaluation system of their own performance results. It is also required to have a good understanding of and ability to translate objectives from the strategic to the operational level (cf. Chalmeta et al. 2012).

12.6 Conclusions

In conclusion, performance measurement reflects effectiveness and efficiency of operations and decisions made in all the dimensions of the company's activities with respect to satisfaction of stakeholders striving to achieve their various goals. Performance management, in turn, involves decision making based on performance evaluation and guaranteeing those goals are achieved. Performance measurement is at the moment an essential element of performance management.

Positive influence of a performance measurement system on the company can be observed in areas such as: performance measurement with respect to requirements of key stakeholders; explaining strategic objectives; focus of activities on critical processes, resources and changes in the organization's environment; showing how performance results (both positive and negative) change over time; identifying critical factors which require more attention; and delivering a clear foundation for performance evaluation and rewarding employees for their performance. Performance measurement is most effective when it is aligned with elements such as business strategy, organizational culture and external environment (Melnyk et al. 2014).

Further research is still needed on the influence of behavioral factors on implementation and use of performance measurement systems, particularly the impact of managers' overall experience and tenure on strategic focus of the performance measurement system. There is also a need for research on other factors related with the quality of information provided to managers, such as professional knowledge of accountants or the quality of management information systems (cf. Buhovac and Groff 2012). Research is also needed to analyze the relationships between the competencies and skills of owners, managers and employees and the overall performance of the company.

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Chapter 13
The Impact of Behavioral Factors on the Decisive Usefulness of Accounting Information

Teresa Kiziukiewicz and Elżbieta Jaworska

Abstract The chapter demonstrates how the neuroeconomic and behavioral aspects of accounting influence on decision making. The shape of accounting—as an information system created and operated by people—is affected by human behavior and so is the information delivered by this system. This is the subject of research of behavioral accounting. Decisions based on information provided by accounting are also affected by human behavior. The final choice of the decision maker is affected by factors, such as: the characteristics of his/her personality, his/her emotions, preferences, previous experience, and motivation. The aim of the chapter is to present—with the use of the research potential of behavioral accounting—the influence of non-substantive factors on the scope and quality of information provided by financial and management accounting, which may limit decision usefulness of this information. Furthermore, the importance of behavioral factors, which may affect decision makers using information from accounting, is indicated in this chapter. The chapter is based on a study of literature on accounting, management, psychology, sociology, neuronal processes in the human brain. In addition, source analysis, synthesis, induction and inference were used as main research methods.

Keywords Behavioral accounting • Decision making • Financial and management accounting • Accounting information

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_13

13.1 Introduction

Accounting refers to the development of information and its use in the formulation of opinions on the economic and financial standing as well as financial results of the business, creating the basis for decision making. Therefore, the important issues pertain to presenting information, its reliability and the accuracy of judgments (Einhorn 1976). The shape of the accounting should therefore be adapted to the specific characteristics of the company and also correspond to the information needs of different users (Kiziukiewicz 2003). The mutual interactions between the creators and users of accounting information translate into their choices. According to A. Riahi-Belkaoui (2004) accounting can affect the behavior of decision makers in two ways: directly through the information content of the message and indirectly by the behavior of accountants.

The impact of psychological aspects of human behavior on the activities in the field of accounting is the subject of studies in behavioral accounting. They include, among others (Woro Damayanti 2014):

- The analysis of the impact of human behavior on the design, construction and use of an accounting model implemented in the enterprise; the nature of accounting is then determined by the attitude and style of management of the business unit, which affects the behavior of accountants.
- The impact of an accounting model on human behavior, which means that the shape adopted by the enterprise affects, among others, the professional judgment of accountants, their motivation, decisions, as well as their job satisfaction, shaping their, sometimes negative, attitudes, such as the tendency to manipulate accounting procedures and information.
- Searching for ways to use accounting to influence behavior, including methods of predicting human behavior and the strategies to change it.

The aim of the chapter is to present—with the use of the research potential of behavioral accounting—the influence of extra-substantive factors on the scope and quality of information provided by financial and management accounting, which may limit their usefulness in decision making. There will also be indicated desirable behavioral factors which may affect the decision makers on the basis of information from accounting. For the sake of this chapter, there was employed the analysis of literature in the field of accounting, management, psychology, sociology, and neuronal processes in the human brain. In addition, there was used the method of analysis of sources, as well as the method of inductive and deductive reasoning.

13.2 The Impact of Behavioral Factors on Information from Financial and Management Accounting

The accounting model in the business units, as well as the information process implemented within its framework, is the result of actions by people who have specific preferences, habits, level of competence, emotions (Przytuła 2008; Bąk 2011). Under the influence of these factors, they can choose solutions that are not based on rational premises, but on individual emotions or intuition. Therefore, the concept of limited rationality became the basis of research regarding behavioral areas not only in economics and finance, but also in accounting (Sulik-Górecka and Strojek-Filus 2015).

The purpose of the creation of behavioral accounting is to identify such factors and study their impact on the reliability and credibility of information, which is especially important due to the fact that it is the basis for business decisions made by internal and external users. It should be kept in mind that the influence of behavioral factors applies both to information from financial and management accounting.

In financial accounting, in spite of its formalization, behavioral factors may occur in its various areas and at every stage of its operation, starting with creating a model of financial accounting for the entity, through successive phases of the information process—from data collection and processing, to the presentation of information in various reports and statements. The model of financial accounting adopted in an entity is reflected in the documentation of the accounting principles (policy) (Kiziukiewicz 2014). Art. 10 of the Accounting Act defines the scope of this document. Its preparation and subsequent updates are the responsibility of a manager of the business unit, but the development is usually done within a team. This involves making a series of decisions concerning, in particular:

- A choice of the financial year which may coincide with the calendar year, or due to the specific characteristics of an entity may include 12 other consecutive months.
- Clarification of the methods of valuation of assets and liabilities and determination of the financial result variant.
- Determining the method of bookkeeping, including rules on the classification of economic events in conjunction with the construction of the company's account plan with the presentation of a list of general ledger accounts and indicating the principles of subsidiary ledgers assigned to specific main (synthetic) accounts.
- Compiling a list of mutually related accounting records or corresponding data sets on computer data carriers with regard to their function in the processing of accounting data.
- Shape of a data processing system or a functioning system with descriptions of the adopted solutions, e.g. the version of the employed software, the algorithms, parameters, rules and methods for controlling access to data and its processing system.

- Organization of the system of protection of data and its sets, including source documents, accounting records and other evidence underlying accounting records, which involves the determination of the principles of archiving and access to these sets.

For all the above-mentioned issues, the persons formulating the model of financial accounting can manage not only the substantive aspects resulting from the provisions of the accounting law, general principles of proper accounting, or their own knowledge, but also their subjective feelings or preferences. For example, they can choose a simpler method of depreciation, even though it will result in the distortion of costs. By choosing the software, they can—not always rationally—favor a specific version or manufacturer. In formulating the principles of controlling and archiving accounting documents or procedures for verifying the accuracy of accounting records, they may unjustly limit their choice to the simplest and relatively inexpensive solutions, which may prove to be ineffective and will not provide an authentic picture of the financial position and financial results of the business entity. A similar approach can occur in matters not regulated by the law, when it is necessary to choose national accounting standards, and in their absence—international accounting regulations, which, however, some authors consider as a possible source of "...corruption in accounting at various stages of registration and the impact of its effects on the valuation, property and income of the business entity" (Kamela-Sowińska 2006, after Bąk 2011). It is worth noting that the effects of behavioral factors on the stage of development of the financial accounting model determining its functioning within the unit influence the information which it supplies and which is used by the managers and entities from its surroundings.

However, as previously mentioned, behavioral factors can also influence the information process of accounting in the field of data collection, its processing and presentation of information. The nature and type of these factors is related to the economic situation of the individual, the consequence of which is the balance sheet policy with a tendency to create a certain image of the entity. For this purpose, it is possible to, for example, disclose a better financial situation of the entity than the actual one, as a result of intentional selection of specific valuation methods, in particular estimates, as well as depreciation methods, the rules for updating the value of assets, provisioning, and settlements.

Particularly sensitive to the actions of the behavioral type is the financial result, which can be adjusted by the accountants to the level approved by the board of the entity for the purpose of its activities (Piosik 2016). A manipulative use of the adopted accounting policies, especially in the valuation methods and estimates, can be helpful in meeting the expectations of the management board. In that case—according to the needs, and regardless of reality—the accountants focus on demonstrating high profits or present underestimated profits. In the first case, their behavior may be related to situations such as the entity's wish to issue shares, the desire to increase their prices, sale of the entity, concealment of problems with maintaining financial liquidity, or dangers to the continuation of business activities.

The developers of information can then use instruments which enable influence on the reported revenues and expenses. Such instruments include, among others: understated write-downs, lower provisions, the deliberate certain transactions or procedures of deferred income or expenses. In the case of underreporting profits, their actions may be dictated by fiscal reasons, the desire to inhibit profit (i.e. hidden reserves) by limiting payments to shareholders. In these cases, there are utilized instruments in the form of maximized valuation of assets, depreciation and provisions, discretion in the identification of costs and revenues or their allocation in time. It should be emphasized that the proposed actions, even if they are consistent with the accounting policy adopted by the entity, due to the intentions of accounting are of behavioral kind, and their effects impact the reliability and credibility of information from accounting. For this reason, the accounting area is particularly vulnerable to the impact of behavioral factors is financial reporting.

The financial statement is, in fact, created on the basis of information derived from the accounting records (Kiziukiewicz 2016). Despite their verification before commencing work on the statement, they may be distorted as a result of behavioral accounting activities. Furthermore, during the development of a report there may arise subsequent behavioral factors associated with the aforementioned interference of the managers who expect to create a particular image of the business entity with the use of different balance sheet policy instruments depending on the part of the report. For example, in the case of the balance, it can be combined with a deliberately tendentious selection of principles and methods of valuation of the tangible fixed assets, financial assets (revaluation or devaluation of fair value), manipulation of write-downs (revaluation of receivables), inadequate estimation of reserves, accruals in assets and balance sheet liabilities. As a result, there will be shown factors which negatively affect the value of the business entity. With regard to the profit and loss account, there may occur previously discussed examples of actions related to financial management (Ronen and Yaari 2010; after Piosik 2016), aiming to over- or underreport income or financial loss due to behavioral factors from the environment or the individual preferences of the reporting person. The fact of connecting the elements of financial statements (Kiziukiewicz 2016) causes the choices made during the preparation of balance sheet and profit and loss account to affect the information presented in the statement of changes in the capital/own fund as well as the cash flow statement, if it is prepared by the business entity. This is especially important in the case of transactions related to cash flows.

The influence of behavioral factors influences in particular the additional information. This applies mainly to its descriptive parts, unrelated directly to the accounting records. For this reason, it is reasonable to conduct verbal analysis of these fragments, with emphasis on the frequency of use of adjectives, which can be a manifestation of a conscious influence on the recipient. A similar situation may occur in the case of activity statements and reports attached to them, especially at the points of such reports which refer to development plans of the entity, its research and development achievements, the expected financial situation, risk management practices, and the security of the planned transactions of significant

importance. The presentation of such information may be closely linked to the personality traits and preferences of the person preparing the report.

The information from the financial statements reaches the management of the entity and external stakeholders, to whom it is primarily addressed. It should be noted, however, that among these user groups there is an asymmetry in the reception. Management, as explained above, may influence the final shape of the information in the report by formulating expectations as to the desired image of the economic and financial situation of the entity and its financial result. This can result in the selection of specific accounting policy instruments, including: material (valuation methods, shaping the values of assets and liabilities), formal (use of the legal rights of choice, variant of design for the profit and loss account, the method of preparing the cash flow statement, detail and form of presentation of additional information) and time (balance sheet date, the moment of closing, approval, submission and publication of the report). Managers also have the option of access to the information contained in the report much earlier than external customers. They can receive detailed data and contact the people who develop the information and obtain additional explanations from them. External stakeholders do not possess the same possibilities.

In the case of management accounting, the recipients of information supplied by it are managers from various levels of the organizational structure of the entity. This information must be designed for their needs, resulting from decisions. This fact is taken into account in the construction of a model of management accounting, which often includes a variety of management variety of cost accounting, to ensure the satisfaction of financial and non-financial (quantitative, qualitative) information needs of the decision-making centers within the entity. Meanwhile, this model should be compatible with the model of financial accounting (Kiziukiewicz 2003), where the information is used in both the management and to meet the needs of specific management accounting logical-mathematical procedures, useful in the design and optimization of decision-making models. These procedures allow the selection of the optimal decision-making variant in certain situations. These may include, for example, evaluation of a strategy management unit, selection of raw materials, production methods and technologies, budgeting, planning, analysis of cost deviations, optimization of the cost-price relations, and other decision-making short- and long-term issues.

The indication of sets of information provided by management accounting requires an analysis of the information needs of individual decision-making centers. Information needs, reported by senior management, on the one hand stemming from their decision-making powers, and on the other—from individual assessments of the decision-making situations, can be individually influenced by behavioral factors, such as the possessed knowledge, degree of self-organization, confidence in one's ability to assess a situation, the tendency to take risks, innovativeness or susceptibility to yielding to the suggestions of the environment. It may therefore happen that the same decision-making situation, with the same information, two different people will make different decisions. This phenomenon in management accounting can be somewhat countered by using the previously mentioned decision-making models indicating the optimal solution. For this purpose, at the

level of individual decision making it is important to extract the decision-making centers, along with assigning them specific decision problems related to the objectives of the entity. Detailed analysis will enable the qualification of specific problems for specific groups according to the selected criteria, such as: thematic area, the range of time and frequency, cause and effect relations, the nature of the required information, the character of the decision-making model, the rules for the selection of the optimal decision-making variant (Kiziukiewicz 2012). However, even while maintaining the current procedure, it is impossible to rule out the impacts and multiplication of behavioral factors on the formulation and analysis of the decision problem, the quality of the information used, the selection of models, and the decision made on its basis. Therefore, it is important to know about the psychological assumptions of behavior and attitudes of both the people providing management information and the decision makers. The motivations of both groups are affected by individual perception of the real and achievable needs and results. Both groups can make choices based on comparisons with different reference points, which can be:

- A set of own goals—the theory of the level of aspiration, the theory of setting goals.
- The imposed and accepted targets in the enterprise, e.g. the objectives of budgeting—the theory of the level of aspiration.
- Own results and their attractiveness—the theory of setting goals.
- Systems and processes for determining the results, for example remuneration policy, the budgeting process—the theory of expectations.
- Inputs and outputs of other people employed on similar positions-the theory of justice.

13.3 The Overview of Behavioral Factors Influencing the Decision Makers on the Basis of Accounting Information

The inherent element in the decision-making process is the selection and proceeding in a certain way. Behavioral decision-making theories try to explain how people decide, and why a person engages or does not engage in certain behaviors. Descriptive, psychological decision theories indicate certain specific mechanisms, so-called mental processes, by which people process information, use it and interpret the environment in which they exist. Among the psychological factors affecting the decision-making processes, there should be mentioned, among others:

- The traits of the human personality, which are defined as relatively stable and consistent behavior patterns, which are a characteristic part of the personality of an individual (Corsini 2002), and which are developed under a system of values, attitudes, past experiences, as well as habits and skills (McAdams and Olson 2010),

so that they determine, inter alia, how a person performs the accounting profession (Smith 1999; Saadullah and Bailey 2014; Kabalski 2012).
- The cognitive abilities, including the ability to learn and the speed of the transformation of information for a specific decision-making situation (reasoning, perception, memory, or the ability to concentrate).
- The emotions and motivations associated with a particular situation, depending on one's values, beliefs, and attitudes (Oliveira 2007).

In formulating judgments or decisions, a person is often unable to analyze all the available information or circumstances. The properties of human cognition consist, among others, of (Baron 1998):

- Limited capacity of the mind in regard to the processing of information (limited capacity of memory).
- Reduction of human cognitive effort in the performance of mental tasks.
- Decision making under the influence of various factors, e.g. time pressure, strong emotions, preferences, motivations.

There are numerous factors that affect human cognitive abilities, limiting the usefulness of decision-making information from accounting, as well as resulting in their incorrect and incomplete use in decision making. These factors can be considered from the cognitive, emotional and motivational perspective.

Considering the cognitive perspective, it is important to note that in order to reduce the complexity of the judgment and decision-making processes, people use mental "shortcuts", so-called heuristics. They are simplification strategies, which are used to manage information and reduce uncertainty in decision making (Tversky and Khaneman 1973). However, the use of these strategies may lead to erroneous assessments, as a result of which the judgments or decisions taken based on information provided by the accounting may be irrational or sub-optimal (Artienwicz 2016; Jaworska 2015). Examples of cognitive errors made by decision makers in connection with the development and use of information from accounting are presented in Table 13.1.

Succumbing to cognitive errors can lead to wrong conclusions on the basis of the information contained in the financial statements, resulting in opinions based on them becoming a source of wrong decisions. Awareness of the occurrence of such errors can limit their consequences.

In addition to the cognitive factors, actions of decision makers are also influenced by emotions that trigger certain behaviors, inspire motivation or discourage actions oriented for a specific purpose (Lerner et al. 2015; Zeelenberg et al. 2008). Emotions can be seen from the perspective of their nature and intensity. Due to their nature, they are divided into positive and negative. The first group includes, among others, joy, pride, admiration, compassion, relief, satisfaction. The negative ones include: sadness, fear, anger, jealousy, guilt, contempt, disappointment, grief, shame (Milan and Weffort 2015). In the decision-making process, they can promote the use of the opportunities and deal with the threats, or have the opposite effect.

Table 13.1 Characteristics of selected cognitive errors made by decision makers (study based on the referenced literature)

Type of error	Characteristics
Overconfidence	Can be expressed in (Cabak 2013): • overconfidence about the accuracy of the information, as well as the relevance of opinions (overprecision), leading to the reduction of the level of distrust in relation to forecasts • overestimation of one's own abilities compared to others (overplacement) • overestimation of the capacity and skills in relation to those actually possessed (overestimation), an example of which may be one's conviction of the correctness of their answers, which are, in fact, wrong
Illusion of control	The conviction of a person that the greater their commitment, the more it will affect the course of events
Recency effect	The belief that the recently received information influences the judgments and decisions more profoundly than previously obtained information (Tyszka 1999), which may, for example, influence the selection of the information presented in the management reports
Confirmation bias	The assumption by the users that the information confirming their judgments is more valuable than the information (evidence) negating their preliminary evaluations (hypotheses), so that they may favor or even seek information that confirms their beliefs, hypotheses or other expectations (Bamber et al. 1997)
Hindsight bias	The tendency to overestimate one's own ability to predict the course of events when it is already known (Aronson et al. 2006). In hindsight, the events seem to be more predictable than they actually were
Primacy effect	The assumption that the point of reference for further information is the first information (Tyszka 1999)
Prospect theory	It presents the actual behavior of people facing risk, assuming that the preferences of decision makers depend on the point of reference in the form of profit or loss. If the problem (information in a report) is presented in a way that suggests the result of the decision will be profit, the decision maker will show aversion to risk. However, if the reference point is selected so that the result of the decision will be seen as a loss, then the decision maker will show willingness to risk (Kahneman and Tversky 1979)
Mental accounting	Irrational segregating of various types of investments and considering each one separately as a function of potential gains and losses (Thaler 1999)

Feeling positive and negative emotions by decision makers can have different consequences, which are presented in Table 13.2.

As follows, emotions affect the decision maker's approach to risk and their estimates, as well as the heuristics used by him or her, which may lead to different cognitive biases. People in a good mood have a tendency to overestimate the probability of positive results, and at the same time underestimate the probability of adverse effects and events (Schwarz 2000; Angie et al. 2011). Excessive optimism can affect the estimates, forecasts, budgets. Also, negative emotions such as anger, rage, sadness, fear and anxiety, determine the behavior of decision makers, as shown in Table 13.3.

Table 13.2 Impact of positive and negative emotions on the behavior of decision makers (study based on Raddatz et al. 2007; Hudlicka 2010; Resnick 2012)

	Positive emotions	Negative emotions
Influence	They increase the efficiency of decision making, improved creativity	Narrow scope of attention, which may in unusual situations lead to errors in decision-making
Types of errors	Higher (excessive) optimism Lower perception of risk	Increased pessimism Higher risk perception
Results	Revaluation of positive results Underestimation of negative results	Developing pessimistic forecasts
Impact on behavior	Depending on the context: the search for risk or risk aversion The use of heuristics	

Table 13.3 The impact of negative emotions on decision makers (study based on: Hudlicka 2010; Rahman 2009; Blanchette and Richards 2010; Resnick 2012)

Negative emotions	Effects
Anger	Greater tolerance of risk Preference for destructive behaviors
Rage	Increases the speed of decision making Increases the certainty of decisions
Sadness	Reduces the speed of decision making Reduces the certainty of decisions
Fear, anxiety	Greater concentration on information about risks than opportunities aversion to risk Choice of defensive behavior More conservative decisions

Depending on one's place in the organizational hierarchy, emotions can affect individuals in different ways. For example, the wrath of the person occupying a lower position can cause the recipient anger as well, but the anger expressed by a person occupying a higher position, it may cause subordinates to feel fear and shame (Lelieveld et al. 2012). Awareness of the impact of emotions on decision-making can reduce the risk of succumbing to all kinds of mistakes and instead strive for the objective evaluation of the information, guided by the precautionary principle, because the information itself may also be subject to the influence of behavioral factors on the person who developed them.

Equally important for the explanation of the mechanism of human behavior is the knowledge of the motivations, as it allows to determine why and what caused the person to take a specific action. The basic element of motivation are human needs and conscious actions that affect a person's behavior, i.e. which direct the effort toward a specific purpose. It is also noteworthy that the decision requires making a choice from among various options, which are affected by motives of the person in question. They can stem from the person's own aspirations or their values, or they can be associated with the impact of the environment.

In a study on motivation, there are important psychological theories concerning: the level of aspiration, setting objectives and expectations, and organizational justice. These theories can be divided into two groups. The first one contains the motivation factors that lead to action and give it direction. The driving force for action can be aspirations and the need for achievement. The theory of aspiration level indicates how important work is, the ability to develop, undertake challenges, meeting the need for success, which reinforces the sense of satisfaction at work. The second group of theories relates to a process of motivation. According to them, the person making the decision considers the favorable and unfavorable results of their behavior (Jaworska 2014). In doing so, they make a choice between the various reactions that constitute the operation to achieve specific objectives.

13.4 Conclusions

The shape of accounting as an information system created and supported by people, and the information supplied by it, is affected by human behavior, which is the subject of research of behavioral accounting. A similar case pertains to decisions based on this information. The final selection of decision makers, in addition to the available information, is influenced also by other factors, such as: emotions of the decision maker, the characteristics of their personality, preferences, previous experience, motivation, the context of the situation, as well as knowledge of the potential consequences of the choice of other activity options.

As a result of the creation of a chain of behavioral actions, they overlap, which may cause the effects of the decision to be different than expected. To prevent this, it is important to consider the fact that the decisive suitability of the information from the accounting is determined not only by the quality of the information according to merit, but also the influence of behavioral implications for system solutions in the field of financial and management accounting, as well as the behavior of the developers of information. The decisive usefulness of information from the accounting should also be perceived through the prism of its users (stakeholders), internal and external, who are also influenced by behavioral factors (cognitive, emotional, past experiences, mental image phenomena and others), which can cause incorrect and incomplete use of information from the accounting in decision making.

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Chapter 14
The Selected Problems of Behavioral Accounting: The Issue of Intellectual Capital

Tomasz Zygmański

Abstract Making decision process is influenced by many factors. Means that decision making cannot be guided only in the optimization sense. Decision making should take into account the behavioral aspects—it involves accounting decision as well. The changes occurring in the economy and science have given rise to behavioral accounting, which studies the impact of the "human factor" on the information generated by the accounting system and used in the decision-making process. The aim of this chapter is to present the correlation between psychological and sociological aspects and intellectual capital valuation and reporting in accounting. The literature analysis method and the induction and deduction method are applied here.

Keywords Behavioral accounting • Intellectual capital • Information system

14.1 Introduction

Behavioral economics and behavioral finance are underlain by the examination of the impact of individual and social cognitive and emotional behaviors on the rationality of the decisions made. The changes occurring in the area of social and economic sciences directly affect, among others, accounting (Cieciura 2015). The changes have resulted in behavioral accounting. What can be found in the "Report of the Committee on the Relationship of Behavioral Science and Accounting" is that behavioral accounting is a progeny of the relationship between accounting and behavioral sciences (Report of the Committee 127 1974).

The aim of this chapter is to describe accounting behaviorism through a confrontation of psychological and sociological aspects with intellectual capital valuation and reporting in accounting. The discussions presented here focus on

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_14

analyzing the impact of the broadly defined "human factor" on the shape of the economic information which is applicable in the decision-making process and has its source in the accounting system.

The achievement of this aim has required familiarity with the contents of the literature on behavioral accounting, informational demands of financial statements' users and intellectual capital measurement, valuation and reporting. Literature analysis methods as well as induction and deduction methods have been applied. The analysis has covered chiefly Polish literature on behavioral accounting.

This chapter is composed of three parts preceded with an introduction and ended with a conclusion. The first part of the chapter is dedicated to the problem faced by the contemporary accounting, that is fulfillment of its informative function. The next part concentrates on behavioral aspects in accounting. The last part indicates the behavioral aspects of accounting with a limitation to intellectual capital measurement, valuation and reporting in accounting.

14.2 Challenges of the Contemporary Accounting in the Age of the Knowledge-Based Economy

The essence and objectives of the accounting system have evolved as civilization has developed. Accounting has always endeavored to adapt to the current requirements imposed by the economic environment. The challenges posed to the twentieth- and twenty-first-century accounting have undergone transformations in the conditions of the global economy. The most significant problem of the contemporary accounting is a reliable and accurate valuation of economic values, which needs to be based on the postulate of a clear and honest image of financial statements (Jędrzejczyk 2015).

Accounting has been continuously criticized in the recent years. It is thought to be incapable of meeting the increasing needs and requirements of investors and other recipients of the information generated by the accounting system. Therefore, it can be acknowledged that one of the fundamental problems of the contemporary accounting is its performance of the informative function. The knowledge-based economy strives for generating, processing and using information and data for the purpose of managing economic entities. Accounting provides an enterprise with lots of important information required for making appropriate decisions. Yet the information relevance and adequacy of the traditional financial accounting has been increasingly more limited and less significant lately. It is intangible resources that play a more and more important role in managing the economic entities operating in the knowledge-based economy. However, the information generated by accounting as regards, among others, intangible assets is not comprehensive (Grądziel 2015).

The contemporary accounting strives for disclosing the information about all resources held by an enterprise. A big challenge for the informative function of accounting is measurement, valuation and reporting of all intangible assets of an

economic entity, including its intellectual capital (Grądziel 2015). There are numerous definitions of intellectual capital. The most popular ones were developed by Stewart (1998), Edvinsson and Malone (2001), Roos and Roos (1997). Despite the high number of definitions of intellectual capital, it is difficult to find one that would be generally accepted, especially in accounting. Although there is no uniform definition, the fact that many authors point to common elements, such as organizational values, knowledge and experience, when defining intellectual capital, deserves noticing (Sánchez Cañizares et al. 2006). In the author's opinion, intellectual capital in accounting should be understood as all intangible assets which have not been disclosed in obligatory financial statements to date, including i.a. knowledge, skills and experience of employees, contracting party bases, relationships between an economic entity and the environment, and its market position.

The research on the theory of accounting attempts at answering the question about how knowledge should be valuated, how intangible resources should be recognized in ledgers, how they should be presented in financial statements so that they are adjusted to the requirements of the knowledge-based economy (Wójcik-Jurkiewicz 2011). It is, however, an extremely difficult task and an enormous challenge for scholars and practitioners in the field of accounting. The lack of a commonly accepted definition of intellectual capital and the problem with fitting intellectual capital into the category of intangible assets results in the impossibility to recognize it in any item of the obligatory financial statements.

A number of researchers indicate the necessity to measure, value and report intellectual capital in their studies (i.a. Dobija 2004; Kwiecień and Iwasieczko 2009; Paździor 2009; Fijałkowska 2012; Derun 2013; Nóżka 2013; Niemczyk 2015). They argue that the introduction of intellectual capital accounting is a good method for adapting accounting to the conditions of the knowledge-based economy.

14.3 Behavioral Aspects of Accounting as an Information System

Making decisions on the activity of an enterprise is related to various human behaviors. Hence the interest of economic sciences and financial sciences in fields such as psychology and sociology. Behaviorism is a stream in psychology which examines human behaviors and their dependence on the physical and social environments. Behaviorists analyze how individual stimuli in the environment affect certain human behaviors (Bąk 2011).

There are numerous scientific disciplines that are interested in human behavior. It is studied by psychology, medicine, anthropology, philosophy, history, archaeology, law, pedagogy, and many more. A human being as an object of research is present also in accounting (Artienwicz 2011). Scholars make attempts at explaining

and anticipating human behaviors in accounting, including in particular (Breitkreuz 2009):

- usefulness of the data derived from financial statements,
- impact on the recipients' decisions related to applying alternative accounting procedures,
- impact of culture and language on the interpretation and application of accounting standards.

When making a literature review, it can be noticed that research in the area of behavioral accounting has been carried out for many years (i.a. Lord 1989; Birnberg and Shields 1989; Sorensen 1990; Meyer and Rigsby 2001; Borkowski et al. 2001; Reckers and Solomon 2005).

The financial decisions made by the recipients of the information derived from the accounting system are influenced not only by financial and economic aspects but also by behavioral ones (Bąk 2011). Based on literature analysis, it can be stated that "behavioural accounting deals with examining the impact of psychological aspects of the human behaviour on the processes implemented within the scope of accounting. They concern the role of people in processing accounting information and their attitude to making decisions." (Jaworska 2014). Hofstedt and Kinard (1970) define the research on behavioral accounting in a more general manner. According to them, such research consists in studying behaviors of accountants as well as behaviors of non-accountants who are affected by the functions of accounting and financial statements.

The people who process the information generated by the accounting system of a given economic entity can be divided into two groups:

- internal recipients (employees at various organizational levels of the economic entity, including accountants),
- external recipients (entities being directly related to the economic entity, in particular investors).

It needs to be remembered, however, that in the accounting system a human being is not only a link in the process of processing the data based on which he or she makes decisions but also an object of interest of the accounting system since accounting records and reporting disclose information about the human being (employees of an economic entity) (Artienwicz 2011). The behaviors of the recipients of the information coming from accounting are significant from the viewpoint of behavioral accounting. They are addressees and creators of such information at the same time (Lis 2016).

The quality of the information generated by accounting is influenced by psychological aspects. The method of formulating a decision problem is a significant behavioral determinant of decision making. Yet points of reference are also essential when making decisions. They are determined partly by the expectations of the decision maker and by the current status of the data held. On the other hand, a specific manner of presenting the information coming from accounting can provoke certain decisions (Gmińska 2016).

Financial accounting is gaining in significance in behavioral accounting. The behavioral aspects referring to financial accounting of an economic entity concern mainly decisions related to (Sulik-Górecka and Strojek Filus 2015):

- the selection of the legal grounds for preparing financial statements (if the economic entity has such a possibility),
- the formulation of the accounting policy,
- the selection of the valuation methods, variants and estimates which have a direct influence on balance sheet valuation,
- the scope, structure, methods and variants of preparing financial statements,
- the formation and grouping of economic operations in compliance with the economic entity's interests,
- the selection of cost settlement methods and procedures.

Behavioral aspects can be related to the financial statements themselves. They include (Sulik-Górecka and Strojek Filus 2015):

- reliability and relevance of the information presented in financial statements of economic entities,
- usefulness of the information disclosed in financial statements for their users,
- goals and motivations of the persons preparing financial statements,
- manipulation with the results through the information disclosed in financial statements.

When analyzing behavioral accounting aspects as an information system, one should consider the role of individual groups of participants in the process of generating information by accounting. Moreover, the relationships between particular groups of those engaged in the accounting system should be determined and the impact of such relationships on the decisions made should be assessed. It would also be recommendable to analyze the influence of emotions on the decisions made in the situation of moral dilemmas (Cieciura 2015). A person who is responsible for creating information in the accounting system is more and more often prone to various manipulations and abuses. Therefore, it can be stated that ethics is closely related to behaviorism in accounting.

As a result of an interdisciplinary approach, with behavior acknowledged as a component of accounting, it can be viewed from a broader perspective (Artienwicz 2013). The aim of such an attitude to accounting is to determine the relationships between the behaviors of decision makers and the information generated by accounting and the procedures applied there.

14.4 Behavioral Aspects of Intellectual Capital Reporting

As has been mentioned above, a human being is present in the accounting system in two roles: as an object of the accounting system and at the same time as a link in processing the information generated by accounting. Accounting records and

financial reporting disclose information about employees of an economic entity by generating information about settlements, labor costs, or methods of measuring and valuating human capital (a significant element of intellectual capital).[1] Such information is analyzed for the purpose of making decisions by a large group of users, i.a. managers, management board, or investors.

The problems of the contemporary accounting result in behavioral aspects being more and more observable in the persons who take part in creating information in the accounting system and in the users of such information. In the author's opinion, the problem of intellectual capital reporting is suitable for observing human (internal and external recipients who process the information generated by the accounting system) responses to the stimuli coming from the environment.

The main focus should be on internal recipients, i.e. accountants, management staff and employees of an economic entity. Accountants play a significant role in this group of recipients. Accounting sciences assume that the accountant acts in a rational and objective manner, in compliance with the guidelines of accounting standards and legal regulations (Artienwicz 2011). The fact that the areas handled by accountants are to a large extent regulated does not mean that their conduct is appropriate every time. Accountants can often make choices and interpret economic phenomena on their own. This brings the risk of them making mistakes. On the other hand, the possibility to exert impact by management staff on accountants is a problem, too. The enterprise employees also expect information about all factors influencing the value of an economic entity, including its intellectual capital. The impact exerted by management staff and employees on accountants can lead to a conscious or unconscious deformation of the information contained in financial statements.

It needs to be noted that intellectual capital reporting in an area that is unregulated by standards and legal regulations applicable to accounting. This means that the area creates great opportunities for manipulating the information about intangible assets of a given economic entity. Although the information about intellectual capital are not provided in the obligatory financial statements, it can be communicated in the form of additional statements. Depending on the applied methods of measuring and valuating intellectual capital and its components, the manners of their presentation and specification of the recipients of the information contained in reports on intellectual capital, such statements can considerably vary among each other. It is important that such reports can contain information that directly influences the behavior of specific persons. This means that intellectual capital reporting could be a very good area for analyzing psychological (sociological) functioning mechanisms of the participants in the process of generating useful information by accounting.

[1]Many practitioners suggest that intellectual capital consists of three elements: human capital, structural capital (or organizational capital), relational (customer) capital.

The expectations of internal stakeholders (management staff and employees) with respect to the information about intellectual capital concern (Nóżka 2013):

- the definition and components of intellectual capital,
- the methods of identifying, describing and measuring the elements and components of individual categories of intellectual capital,
- the patterns according to which intellectual capital should be presented inside the enterprise,
- the intellectual capital management methods which facilitate goodwill increase,
- the system of reporting the information about intellectual capital outside,
- the intellectual capital valuation methods which would present the actual goodwill.

Accountants will try to satisfy the information needs of management staff. They, in turn, could exert influence on the accountants to meet the information needs of the employees of an economic entity and the entire external environment, in particular prospective investors.

The behavior of accountants and management staff of economic entities is affected, as has been indicated above, by external recipients of the information coming from the accounting system. In the case of external stakeholders, these can be prospective investors, shareholders, customers and suppliers, state and local government authorities, creditors (financial institutions), and authors of the economic policy (Łukasiewicz 2015). In this group, it is investors that are most significant. They expect in particular (Lis 2016):

- greater transparency and extended scope of the information received,
- supplementation of historical results with the information that makes it possible to forecasts the enterprise's situation,
- supplementation of financial information (figures) with non-financial information (descriptions),
- information about value generators.

As regards intellectual capital, external stakeholders' interests could be referred to the information enabling the determination of (Nóżka 2013):

- the method of identifying individual components of intangible assets in an economic entity and valuating them,
- the extent of using intellectual capital,
- the extent and scope to which intellectual capital determines the present and future goodwill and its competitiveness level,
- if the economic entity differs from its competitors in terms of the potential, extent, and efficiency of using its intellectual capital,
- if there is a risk of losing a given intellectual capital component and what consequences could arise from that.

It is information needs of external stakeholders that could lead to certain behaviors of the persons who generate such information in the accounting system. Reliable information, including that regarding intellectual capital of a given

economic entity, held by external recipients could result in specific behaviors of such recipients. The rational decisions made by them will be strongly conditioned on the reliability and quality of the information they have.

To sum up the above discussions, it needs to be stated that the behavioral aspects referring to intellectual capital reporting can be connected primarily with:

- decisions related to selecting the best possible intellectual capital measurement and valuation methods,
- explanation and anticipation of human (mainly accountants) behaviors in the context of intellectual capital reporting,
- influence of the behaviors of accountants, enterprise management staff and employees on the quality and usefulness of the information about a given economic entity's intellectual capital,
- influence of the behaviors of the market as a whole on the quality and usefulness of the information about a given economic entity's intellectual capital and the market's response to the information about the economic entity's intellectual capital contained in its financial statements.

What follows from the above is that intellectual capital reporting offers great opportunities for conducting research on behavioral accounting. The correlations between the behaviors of those who process the information generated by accounting in this area is easily observable. This creates a chance for detailed research on psychological (sociological) factors influencing the functioning of the participants in the process of generating information by accounting and its processing.

14.5 Conclusions

The present chapter proves that the behaviors of internal and external recipients of the information generated by the accounting system is one of the subjects that could be studied by scholars as part of accounting. This is consistent with the current scientific trends in accounting (Artienwicz 2011). Analyzing accounting from the angle of psychological and sociological factors is a counterweight for the prevailing technical aspects of accounting (Mattessich 1994).

Accounting is not free from behavioral problems. The functioning of the accounting system is conditioned on human behaviors. The problem with fulfilling the informative function by accounting provides great opportunities for analyzing such correlations. The interest in the impact of human behaviors on accounting makes behavioral accounting become a popular direction of scientific research. This chapter indicates that the problem of generating, processing and reporting information about intellectual capital in the accounting system involves psychological and sociological factors. The information gap in the area of intangible assets of an economic entity offers a good opportunity for noticing the fact that the "human factor" affects the shape of the information which is generated by the

accounting system and used for making rational decisions. This refers also to the information about intellectual capital.

The discussions presented in this chapter prove that the application of psychology for explaining and anticipating human behaviors in the context of intellectual capital valuation and reporting could be an area of interdisciplinary research in the field of accounting.

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Chapter 15
The Impact of Information Usefulness of E-Commerce Services on Users Behaviors

Marek Mazur and Michał Nowakowski

Abstract Behavioral aspects of clients decision making is an important area of scientific research and a number of practical applications. This chapter is intended to present analysis and evaluation of the information usefulness applied in selected e-commerce sites, as well as the impact of such information on behaviors and also intrinsic and extraneous cognitive overloads of customers. Furthermore, the study describes the basic methodological assumptions, the research procedure of information usefulness evaluation and the results of data analysis from the study conducted on a group of respondents. Results of research presented in the chapter can be useful in the various stages of e-commerce sites creating. Moreover, the decreasing of cognitive overloads and the reduction of inconveniences with services operation will contribute to a more effective information assessment, and thus making business decisions better and increasing incomes for owners of e-commerce services.

Keywords Information usefulness • Customers behaviors of e-commerce services • Cognitive walkthrough method • Cognitive overload

15.1 Introduction

The e-commerce services, from 1 year to another, play an increasing role in the economy and are becoming an increasingly important instrument for market development. Therefore, sellers receive access to a huge number of potential buyers, while providing them with access to a wide range of goods. Internet business, on the

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_15

one hand, provides buyers a much broader access to information, on the other hand, unfortunately the use of information occurs at the expense of a greater burden for clients. The most common loads can be include, among others, the factor of time spent on the choice of product or service, as well as, the requirements for mental cognitive processes of its users during the interaction with the online service. Sellers and Internet service providers cannot forget, that it is a subjective feeling of users, while browsing stores offers, decide ultimately of taking the purchase decisions. In addition, it all is happening at the same time, under conditions of high and growing competition.

The information usefulness research of e-commerce services, especially the information quality and its impact on the buyers behaviors, becomes the key issues for companies interested in the rational use of IT technologies. Hence the need to concentrate in this chapter on the methodology of information usefulness evaluation, its impact on the participants of electronic commerce behaviors, as well as impacts on their intrinsic and extraneous cognitive loads. Not without significance is the use by economic entities in their business and the actual implementations of the results from the study of contents and forms of its presentation on the Internet. This increases the chances of providing customers the useful and user-friendly services, which in turn leads to the making of purchase transactions and increasing revenues for sellers.

The chapter describes application of hierarchical structure of criteria, usability testing method and cognitive walkthrough method for analysis and evaluation of information usefulness with particular emphasis on navigation systems, information retrieval systems and content of text and graphics. The research problem of the chapter is analysis and evaluation of information usefulness applied in selected e-commerce services. The purpose of the study is presentation of research methodology of information usefulness and its influence on behaviors as well as intrinsic and extraneous cognitive overloads of customers using e-commerce services.

15.2 Information Usefulness

According to the utility theory and concept of homo oeconomicus people consciously and rationally shape their economic situation by taking decisions, which in the greatest extent maximize their satisfaction. As from an economic point of view, the human life is needs, decisions and actions, so as claimed Ludwig van Mises, dissatisfaction with the existing state of affairs motivates people for further actions, and thus to improve their own situation (Van Mises 1962). Therefore, the utility is an important concept in economics, because it shows why someone has chosen specific combination of goods with a certain level of satisfaction. The utility function examines the relationship between the combinations of goods in the consumer basket, and utility achieved from this basket (Moss 2014). This holds true, both for physical goods and for such non-material goods which is the information.

In the literature, there are many different definitions and meanings of the information concept. Moreover, it is often associated with such terms as data and knowledge, which is often used interchangeably. The most popular approaches associated with the attempt to define the concepts of data, information and knowledge, may be included in the following two types of approaches: infologic and managerial.

The infologic approach by infologic theory of Langefors, explicitly distinguishes the information from the data, and puts the emphasis on taking into account the requirements of information users (Langefors 1973). The information in this approach, is a meaning which is given to the data, taking into account factors like psychological, sociological, linguistic, semantic, etc. The meaning of information (the sense and importance) is strictly related to the user's person (information sender or recipient), which implies that the same information can lead different people to a completely different conclusions. Information in this approach is subjective and describes the meaning, which a sender or recipient gives to the data (Pettersson 1993), therefore from specific data different people can extract different information (Langefors 1973). Whereas, the knowledge in this context, is interpreted as information enriched by the experience, moreover it is a human resource with significantly personal and subjective nature, and it should not be the objective truth (Stefanowicz 2004). The subjective aspect of information affects also on the value of information, which results from the fact, that it is taken into account factors depending on the evaluation from the person and conditions in which the information is utilized. For these reasons, a subjective assessment should be given the most attention in the searching for the problem solution of correct estimation of the information value. The attitude subjectivity in information evaluation has also an impact on decision making, where even in the case of the same information, it may bring different effects in dependence on the specifics of individual decision makers. Moreover, it is said that accuracy and pragmatics of information evaluation is a critical economic factor in the information society (Meyer 2005; Morrison and Cohen 2005).

The managerial approach usually assumes, that the data is raw numbers and figures expressed in a particular character of symbols (Webster 2014). As the clean and raw data do not usually have practical meaning, the information can be only called the data, that have been subjected to categorization and classification, or ordered in some other way (Devenport and Prusak 2000). The different data can provide the same information, but at the same time the same data may also provide various information. On the other hand, in this approach the knowledge can be called the information, which was organized and analyzed in order to make it understandable and usable in solving some problems or making decisions. It is worth emphasizing, that the knowledge goes beyond the information, because implies the ability to solve problems, intelligent behavior and activities (Turban 1992).

The above two approaches describe the information from the subjective level point of view. In order to show the aspect of information usefulness, it should be presented two basic theories of information approaches: quantitative and qualitative.

According to quantitative theory the information is considered as a primary concept and as a physical or structural parameter of objects. This theory focuses on purely mathematical aspects and ignores semantic aspect of information, so it eliminates the possibility of understanding the message in different ways by different recipients (Shannon 1948).

According to qualitative theory the utility of the information concept determines its quality (inter alia accuracy, authenticity, etc.), the amount (appropriate range of time and flowing frequency), and the relationship with the tasks (validity for the thing) (Sopińska 2004). The specified information is useful in the information system, if it is used to solve the problem, and more specifically, while it is an important condition for solving a given problem of decision making, research, analysis, management, etc. (Unold 2007). In one of the most synthetic approaches presenting the useful information, it is said, that this information should have the right content, delivered at the right time and in the right form (Olchowicz 1993). Furthermore, this information should have certain features, which value it and allow to evaluate its usefulness in the economic description. The evaluation criteria of information usefulness for their suitability for a user, may be features, such as: accuracy, veracity, timeliness, completeness, reliability, adequacy, form, frequency of use, scope, coherence, source, time horizon, etc. (Szapiro 1995). To conclude, on the one hand, it is difficult to identify just only one universal definition of useful information, and on the other hand, there is no useful information without reference to its user, its information needs, and the moment when it will be use the information.

Another approach for understanding information in the context of its usefulness in information systems are different concepts related to technical usability of these systems. Then for end users are important such aspects as perceived usefulness, perceived ease of use and usability of computer systems.

According to Davis the perceived usefulness is the degree to which a person believes, that using a particular system would enhance her performance (Davis 1989). This type of usefulness has been confirmed by many researchers as reliable and effective indicator to use for various information technologies by users at different level of knowledge and experience. However, according to Gahtani the perceived ease of use is the degree to which a person believes, that using a particular system will not result for her additional costs associated with its operation (Gahtani 2001). This type of usefulness describes the degree to which an innovation is not perceived as a difficult to understand, study or practical use. In addition, as stated Rogers perceived ease of use can be considered as the degree to which consumers perceive a new product or service as a better than its alternatives (Rogers 1983).

However, according to J. Nielsen the usability of computer system is the extent to which the system can be used by specified users to achieve specific purposes, consistent with the rules of effectiveness, efficiency and satisfaction in a specified context of use (Nielsen and Tahir 2001). In practice, the usability is a field of knowledge dedicated to the convenience and ergonomics of computer systems

using, and in particular from Internet sites. The web service is useful, when the first visit attracts the attention of visitors, and further browsing allows intuitive using of its resources (Kalbach 2007; Krug 2006).

15.3 Information Quality Aspects

As previously mentioned, one of the most important characteristics of useful information is the widely understood quality. Therefore, it is necessary to define and describe the qualitative features of information, that apply in the context of web services and the perception of them by the Internet users. The information is useful when it has an usable value, and if it increases the effectiveness of actions taken by the user, and also affects on growth of the success probability or reduces the risk. The information usefulness grows with increases of its helpfulness to solve a particular problem, which the user is trying to solve. The information assimilability is persisting within the permissible norm, by the user, additional work or costs to be borne, to be able to take full advantage from provided information (Jashpara 2011). The information intelligibility is a feature, which allows to understand the information by an average user, without special actions regarding the semantic interpretation of the content included in the message (Stefanowicz 2004). Information intelligibility also means, that the data presented on the website should be able to use easily in decision-making process by their users, which should also have a reasonable body of knowledge of the subject matter (Jaruga 2005). The information availability is a degree of ease of obtaining by interested recipient the necessary information (Stefanowicz 2004). Information availability is also a fact, that the information is available, e.g. on the website when it is needed to the right audience, preferably 7 days a week and 24 h a day (IT Governance Institute 2005; Miller 1996). The information readability is most of all an ease of understanding the information communication, addressed to the reader by the author of the information and presenting them in a convenient form for the recipient (Dudycz 1998). On the readability of presented content on websites, most frequently affects such visual elements, as: size of characters, shapes of characters, color, contrast with the background, composition or other relationship between them (Prussak 1995). The information currency is a feature closely related to the speed of its flow from the source to the receiver, and therefore it should be sourced within the shortest time. Besides, current information should relate to the selected period of decision making and to be delivered in an appropriate time, because outdated information is just as useless as the false one. This feature in the context of using on websites is so important for customers, because it significantly affects on their usability and compatibility with reality when it is used (Stefanowicz 2004). The information is suitable especially, when it meets the user's needs. Furthermore, information is also suitable, if it affects on economic decisions of users in such a way, that enables them predicting future events (so called predictive value) and facilitates the past

evaluation, confirmation or correction of earlier predictions (so called confirmation value). Suitable information provided to users must also be relevant, because the omission or misstatement of this aspect may cause, that the decision maker will take another and quite different decision, than in case of fulfilling by information of relevance criterion (Stefanowicz 2004). The appropriateness of the form of information visualization is an appropriate presentation of information and descriptions for this presentation, enabling correct reading and interpretation of the data in the textual and graphical form (Miller 1996).

15.4 The Research Assumptions of Information Usefulness Evaluation

The research problem of the chapter is analysis and evaluation of information usefulness applied in selected on-line shopping sites of e-commerce class with the use of selected methods. The evaluation of information usefulness was focused mainly on different forms of information presentation and visualization, such as: text, graphics, images, charts and animations. The selected research problem was prepared and developed on the basis of quantitative research (internet survey) and qualitative research. Analysis of the results was carried out with the use of hierarchical structure of criteria, usability testing method and cognitive walkthrough method in terms of respondents cognitive overload (De Jong 2010).

The research entity survey conducted in January 2017 was 80-persons group of respondents who represented various forms of education, from secondary education, and higher ending. They represented different age groups, more than half (58%) were young people (18–35 years old), while the rest of them (42%) were the representatives of the people with mature age (36–75 years old). Among the respondents, the majority were women (72%), and the remainder of men (28%). From the answers obtained from respondents it can be concluded that the vast majority of them (65%) use the Internet several times a day, while the rest connect to it: once a day (10%), several times a week (7%), once a week (10%) and several times a month (8%). It is not difficult to guess that greater frequency of using Internet belonged to the younger age group. The most popular form of communication with the Internet among respondents were mobile devices (70%) and stationary devices like laptops (58%) and to use the desktop computers (20%) and tablets devices (10%) admitted a significant minority of them.

Therefore it can be said that the group of surveyed respondents had a minimum sufficient knowledge and skills, for the purpose of research, in using various online shopping sites. This aspect is particularly important in the context of learning support of internet services as seen sometimes for the first time during the study, as well as the credibility of the results of the subjective evaluation of various criteria of information usefulness in terms of cognitive overload.

The research object were four Polish-language internet services with the possibility of on-line shopping. To the study there were selected the services, which in recent years were characterized by high popularity and trust among customers. In addition, all selected for the analysis on-line shopping sites are examples of the different classes of electronic commerce systems, such as auction and advertising services, price comparison sites and on-line shops. These services are also representatives of modern, powerful and highly advanced solutions both in terms of technical, quality and marketing aspects.

The first of selected services was the Allegro auction portal, which is the pronounced leader of e-commerce services and is a brand that most distinguishes of the on-line shopping in Poland (http://allegro.pl). The second service was the OLX advertising portal, which although in terms of destination differs slightly from its predecessor and gives way to its popularity, it has a strong position in the minds of Internet users (https://www.olx.pl). Another selected service was the Ceneo portal, which is one of the most popular price comparison sites and it is a leader in its category in terms of operating range and a huge number of visits (http://www.ceneo.pl). The last of the services was the RTV EURO AGD portal, which is a typical representative of specialized on-line stores of consumer electronics, which popularity among users is high and continues to grow (http://www.euro.com.pl). The foregoing sites were selected based on the results of e-commerce market research in Poland, which were carried out by the Gemius research company in May 2016 and made available in the report titled "E-commerce in Poland 2016. Gemius for e-Commerce Polska". The results of these studies were made available free of charge on the Internet in PDF format (E-commerce Poland Report 2016; Gemius Poland Website 2016) and in real time statistics on the GemiusNow site (http://now.gemius.com/category/455502).

The main objective of the research (subject of research) of selected on-line shopping sites was evaluation of text and graphics information usefulness presented in these services, in terms of potential problems that can be difficult to use of these services for end users. Main objective of the study was analyzed and evaluated on the basis of the electronic survey (quantitative analysis) and results of the activities and behaviors of respondents (qualitative analysis) within the selected websites. Among the activities that respondents performed and under which the usability testing method was applied were such operations as: searching for information about the products (the content of text and graphics), reading comprehension products descriptions (textual content), searching for products with the using of navigation systems and information retrieval systems in the service or browsing the additional materials associated with products.

In the context of study assumed, that the for wide understood information usefulness had also influence other, previously described, characteristics of the information quality, included in the main objective, such as: assimilability, intelligibility, availability, readability, currency, suitability and appropriateness of the form of information visualization.

15.5 Evaluation Methodology of Information Usefulness in On-line Shopping Sites

The research procedure of information usefulness evaluation in on-line shopping sites was based on performing the following actions:

1. creation of survey and collecting data from respondents,
2. construction of hierarchical structure of criteria, which contain a list of criteria, sub-criteria and obtained values of final results,
3. creation of sample scenarios of users behaviors in service for analysis using cognitive walkthrough,
4. analysis of data for different scenarios in terms of respondents cognitive overload,
5. drawing out conclusions from analysis.

In the first stage, in order to collect data from respondents, electronic survey was created using free of charge Google Forms on-line survey system (https://www.google.pl/intl/pl/forms/about). Survey study was based on evaluation of selected criteria and performing simple successive tasks, which were done in network environment using internet browser application and selected on-line shopping sites. All of the tasks were evaluated by respondents on a scale from 0 (lack or lowest rating) to 5 (highest rating), based on the level of satisfaction and usability fulfillment of specific quality criteria by selected internet services.

In this stage, while collecting data from respondents, the usability testing method was also used. Usability testing method is one of the most popular methods of usability evaluation, based to a great extent on the approach to the design of user-oriented (User-Centered Design). Usability tests have usually form of laboratory tests, in which testers perform tasks, that simulate user interaction with the website on a specially adapted computer stations. During the performance of specific tasks, participants are asked to pay attention to what they see, do and feel, and then describing their experience verbally or in writing form. The aim of this study is to validate the operation of the website and to detect areas where users have some problems and then to make recommendations for website improving (Krug 2006). The most frequently analyzed areas of internet services operating, within the usability testing, the following aspects can be included: visibility of navigation elements, labels transparency and comprehensibility, ease of navigating the website, ease of finding the information on service sites and performance of making tasks related to information retrieval (Kalbach 2007).

In the second stage, two-levels hierarchical structure of criteria was created. A list of the main criteria were the groups of tasks from the main purpose point of view of the study, while a list of sub-criteria were the tasks actually carried out and evaluated by the respondents.

A list of criteria and values for each main criteria (MC-1, MC-2, . . .), sub-criteria (C-1.1, C-1.2, . . .) and values obtained from the survey are presented in the following Table 15.1.

Table 15.1 Hierarchical structure of each criteria, sub-criteria and values obtained from the survey (self study)

Symbol	Short name of criterion/sub-criterion	Data from survey study On-line shopping sites			
MC-1	**Aesthetic and visual aspects of the service as a whole**	**Allegro**	**Ceneo**	**OLX**	**Euro**
C-1.1	Functional-visual clarity of the service as a whole	3/5	4/5	4/5	3/5
C-1.2	Clarity of used colors in the service as a whole	4/5	4/5	4/5	4/5
C-1.3	Clarity of used fonts in the service as a whole	4/5	4/5	4/5	4/5
C-1.4	Clarity of used multimedia content in the service as a whole	3/5	4/5	4/5	4/5
C-1.5	Clarity of used functionalities in the service as a whole	3/5	4/5	4/5	5/5
MC-2	**Searching for information using information retrieval systems**	**Allegro**	**Ceneo**	**OLX**	**Euro**
C-2.1	Ease and convenience of using information retrieval system in the service	4/5	4/5	4/5	4/5
C-2.2	Ease of finding a product using information retrieval system in the service	4/5	4/5	4/5	4/5
MC-3	**Searching for information usingnavigation systems**	**Allegro**	**Ceneo**	**OLX**	**Euro**
C-3.1	Ease and convenience of using navigation systems in the service	4/5	4/5	4/5	3/5
C-3.2	Ease of finding a product using navigation systems in the service	4/5	4/5	4/5	4/5
MC-4	**Information content aspects in the service**	**Allegro**	**Ceneo**	**OLX**	**Euro**
C-4.1	Attractiveness and readability of a product presentation in the service	4/5	4/5	4/5	4/5
C-4.2	Information availability about a full product name in the title/header of a site content in the service	5/5	4/5	3/5	4/5
C-4.3	Information availability about detailed description of a product in the service	4/5	4/5	4/5	5/5
C-4.4	Information availability about a product price in the service	4/5	4/5	3/5	3/5
C-4.5	Information availability about a product current availability for purchase in the service	4/5	5/5	3/5	3/5
C-4.6	Information availability about contact data to a person or company selling a product in the service	4/5	4/5	5/5	3/5
C-4.7	Information availability about forms of a product delivery to the customer after purchase in the service	4/5	4/5	5/5	4/5
C-4.8	Information availability about costs of a product delivery to the customer after purchase in the service	4/5	5/5	4/5	3/5
C-4.9	Information availability about forms of payment for a product after purchase in the service	4/5	5/5	4/5	3/5

(continued)

Table 15.1 (continued)

Symbol	Short name of criterion/sub-criterion	Data from survey study On-line shopping sites			
C-4.10	Information availability about possibility and costs of return/complaint of a product after purchase in the service	4/5	5/5	3/5	4/5
C-4.11	Information availability about period and principles of a product warranty after purchase in the service	4/5	4/5	3/5	3/5
C-4.12	Information availability about possibility and method of discount codes using to purchase a product in the service	4/5	4/5	4/5	4/5
C-4.13	Information availability about opinions of other users about a selected product in the service	4/5	4/5	4/5	4/5
C-4.14	Information availability about other similar products to a selected product in the service	4/5	4/5	4/5	4/5
MC-5	**Content usefulness aspects in the service**	**Allegro**	**Ceneo**	**OLX**	**Euro**
C-5.1	Intelligibility and assimilability of a text content about a detailed product description in the service	5/5	5/5	4/5	4/5
C-5.2	Suitability of a text content about a detailed product description in the service	4/5	4/5	4/5	4/5
C-5.3	Currency of a text content in a product description and offer in the service	4/5	4/5	4/5	4/5
C-5.4	Readability and forms of a text content visualization about a detailed product description in the service	4/5	4/5	5/5	4/5
C-5.5	Suitability of a graphical content associated with a product in the service	4/5	3/5	3/5	3/5
C-5.6	Readability and forms of a graphical content visualization associated with a product in the service	4/5	4/5	4/5	4/5
C-5.7	Readability and forms of a multimedia content visualization associated with a product in the service	4/5	4/5	4/5	4/5

The third stage of the research procedure relied on creation of sample scenarios of users behaviors in the service for analysis using cognitive walkthrough method. Cognitive walkthrough method is one of the popular methods of expert usability evaluation, which based on website testing by a chosen expert from the potential tasks point of view (e.g. searching for information in the service) performed by users. The main assumption of using this method in the field of websites research is to focus on usefulness aspects related to ease of learning to navigate on the service. As a result, this method allows to detect errors that hinder the implementation of the tasks, during the first users contact with service. The process of testing the service using cognitive walkthrough method usually consists on creating possible scenarios of recipients actions in the service, and the implementation of further steps, which check all the possible associated processes. It should be noted that the main

emphasis of the expert is put on study of liquidity and functioning correctness of individual processes, not just only individual pages in the service (Nielsen and Mack 1994; Rieman et al. 1995; Wharton et al. 1994). As follows from the above definition and description of cognitive walkthrough method, using it for information usefulness evaluation was justifiable in the context of the main objective of the study.

As mentioned previously, the cognitive walkthrough method is based on realization of the selected tasks according to established scenario to study the ease of website navigation. For the study of information usefulness in on-line shopping sites, three sample scenarios were created, which describe the most popular ways of users behavior interested in on-line shopping. The selected scenarios are described below.

- Scenario 1 (SC-1): Searching for a chosen/known product in the service.
  Goal: finding in the service a chosen product in order to know its specifications, the purchase price and shipping costs.
  This scenario consists of the following tasks:
  (S-1.1) opening the main page of shopping service and evaluation of its aesthetic and visual aspects,
  (S-1.2) writing into the search box, in the information retrieval system, a list of keywords that describe: type of a product, brand of a product and model of a product,
  (S-1.3) browsing the list of search results, selection of one product, going to subpage of this product, and then evaluation of information searching using information retrieval systems,
  (S-1.4) analysis and evaluation of information content aspects about chosen product.
- Scenario 2 (SC-2): Searching for any/unknown product/products in the service.
  Goal: finding in the service any product/products, intended for specific purposes and having certain features in order to know its specifications, the purchase price and shipping costs.
  This scenario consists of the following tasks:
  (S-2.1) opening the main page of shopping service and evaluation of its aesthetic and visual aspects,
  (S-2.2) browsing thematic categories of products, using navigation systems, in terms of different types of products,
  (S-2.3) browsing the list of results, in addition restricting their to chosen brand and product models, selection of one product, going to subpage of this product, and then evaluation of information searching using navigation systems,
  (S-2.4) analysis and evaluation of information content aspects about chosen product.
- Scenario 3 (SC-3): Searching for a chosen/known product in the search engine.
  Goal: finding in the service a chosen product in order to know its specifications, the purchase price and shipping costs, and then the credibility evaluation of on-line shopping site for potential purchases.

This scenario consists of the following tasks:

(S-3.1) opening the main page of chosen search engine (e.g. Google),

(S-3.2) writing into the search box, in the search engine, a list of keywords that describe: type of a product, brand of a product and model of a product,

(S-3.3) browsing the list of search results, selection of one subpage with product and opening it (going to subpage with chosen product without using information retrieval systems and navigation systems in shopping service),

(S-3.4) evaluation of aesthetic and visual aspects of the service,

(S-3.5) analysis and evaluation of information content aspects about chosen product,

(S-3.6) analysis and evaluation of content usefulness aspects about chosen product.

The fourth stage of the research procedure relied on data analysis for different scenarios in terms of the users cognitive overload. Cognitive overload is a term which originates from cognitive psychology and related with such issues as learning, remembering, perception and problem solving by human. Assuming that human cognitive performance is the amount of information that the brain is able to maintain in working memory in a short time, that cognitive overload can be defined as the number of percentage, how much of this performance is used for one action. It is believed, that the human working memory, who is processing information actively, may maintain an average of about 4–5 units of information for a few seconds. In the case of difficult concepts, human is forced to considerable mental effort, while doing routine actions does not cause too much overload, that is why it is possible to do several activities at the same time (Sweller 1988; Granholm et al. 1996).

Cognitive overload, in the context of internet services, determines the level of effort associated with the thoughts cognitive processes of its users during interactions with the system. According to Whitenton the cognitive overload is the amount of cognitive resources, which is required to perform operations on the system (Whitenton 2013). Excessive cognitive overload may lead to reduction of a satisfaction in using the service or feeling by user a phenomenon called information overload. These are situations in which a person has difficulty in making decision or understanding of this issue, because of useless navigation or excessive amount of available information. Facilitating users working in the service is that the interface is designed in such a way, that it minimizes cognitive overloads related to its operation, so that the user would focus his cognitive capabilities primarily on the implementation of selected tasks. It is important to note that users are trying to minimize their cognitive overload at all costs, avoiding complex reasoning, planning, reminding and decision making (Skulmowski et al. 2016). Existing literature research of cognitive loads on websites focus primarily on areas, such as: forms of information presentation, ways of websites navigation, hyperlinks analysis, e-learning systems analysis and multimedia learning (Khentout et al. 2006; Kelton and Pennington 2012; Bus et al. 2015; Isaksen 2014).

There are three basic types of cognitive overload: intrinsic load, extraneous load and germane load (Sweller et al. 1998; Whitenton 2013). Intrinsic cognitive load is

an effort which the user dedicates on understanding information presented on the website, taking into account the natural structure, complexity and degree of difficulty of the field and also the amount of information and their mutual interactions. Extraneous cognitive load in the internet service is associated with technological way of information presenting and is usually dependent on the designers and creators of the website. Germane cognitive load refers to the work put into creating a permanent store of knowledge or a schema (Zumbach and Mohraz 2008). For the purpose of discussed study, it was focused on two selected types of cognitive overloads, which were intrinsic and extraneous loads.

Application of the cognitive walkthrough method in the study, in terms of users cognitive overload was based primarily on taking into account the result data from the survey in terms of the main criteria and sub-criteria. In order to determine one resulting value for every sub-criteria, there was primarily used a value of arithmetical mean for data. In situation, when the results largely pointed to only one specific resulting value there was used a value of dominant. The next step was analysis of the resulting data in terms of selected scenarios of cognitive walkthrough in order to identify potential intrinsic and extraneous cognitive overloads for respondents. Cognitive overload values for every sub-criteria were calculated as the sum of the results obtained from the study, compared to the sum of the maximum realizable value, and then converted into percentages. The lower values obtained for every sub-criteria meant the higher cognitive overload for users, which they had with selected functionalities in the service.

All of the calculated values, according to the above assumptions, are presented in the following Table 15.2.

The last fifth stage of the research procedure relied on developing conclusions from the performed study. The final results were analyzed for selected scenarios of users behaviors in the service, taking into account the following aspects:

- aesthetic and visual aspects of service,
- information content aspects about chosen product,
- content usefulness aspects about chosen product,
- information searching aspects using information retrieval systems,
- information searching aspects using navigation systems.

The analysis purpose of the above-mentioned aspects, involved in each scenario of users cognitive walkthrough, was to determine the level of cognitive load, which respondents have experienced, during the study of selected services. The lower values they admitted for every sub-criteria (the second stage of research procedure), the lower the percentage values obtained aspects within the scenarios (the fourth stage of research procedure), what ultimately meant a greater cognitive load and less willingness to make purchase decisions. The analysis of the cognitive load level for purchasing services was primarily aimed at showing potentially problematic areas with the information usefulness in this type of services, but not to compare these services to each other.

The first of the analyzed areas were services aspects of aesthetic and visual. Although, the evaluation of aesthetic and visual side of e-commerce services may

Table 15.2 Results from the study for various scenarios of user behaviors in the service in terms of cognitive overloads (self study)

Symbol	Short name of scenario/tasks	Data from study after analysis On-line shopping sites			
Scenario 1 (SC-1)	**Searching for a chosen/known product in the service**	**Allegro**	**Ceneo**	**OLX**	**Euro**
S-1.1)	Evaluation of aesthetic and visual aspects of the service	68% (17/25)	80% (20/25)	80% (20/25)	80% (20/25)
S-1.3)	Evaluation of information searching using information retrieval systems	80% (8/10)	80% (8/10)	80% (8/10)	80% (8/10)
S-1.4)	Evaluation of information content aspects about chosen product	81% (57/70)	86% (60/70)	76% (53/70)	73% (51/70)
Scenario 2 (SC-2)	**Searching for any/unknown product/ products in the service**	**Allegro**	**Ceneo**	**OLX**	**Euro**
S-2.1)	Evaluation of aesthetic and visual aspects of the service	68% (17/25)	80% (20/25)	80% (20/25)	80% (20/25)
S-2.3)	Evaluation of information searching using navigation systems	80% (8/10)	80% (8/10)	80% (8/10)	70% (7/10)
S-2.4)	Evaluation of information content aspects about chosen product	81% (57/70)	86% (60/70)	76% (53/70)	73% (51/70)
Scenario 3 (SC-3)	**Searching for a chosen/known product in the search engine**	**Allegro**	**Ceneo**	**OLX**	**Euro**
S-3.4)	Evaluation of aesthetic and visual aspects of the service	68% (17/25)	80% (20/25)	80% (20/25)	80% (20/25)
S-3.5)	Evaluation of information content aspects about chosen product	81% (57/70)	86% (60/70)	76% (53/70)	73% (51/70)
S-3.6)	Evaluation of content usefulness aspects about chosen product	83% (29/35)	80% (28/35)	80% (28/35)	77% (27/35)

not seem like a priority, however due to the diversity of customers of these services, could not be ignored in the study. According to result data, aesthetic and visual aspects were usually rated at relatively high level of 80%. Whereas, in only one case respondents admitted 17 points of 25 possible (68%), what means, that just on the Allegro service they could feel more confused or overwhelmed by a multitude of appeared visual elements. Either way, customers usually count on possibility of using from convenient access to content and services, so it can be concluded, that the cognitive loads, in terms of aesthetic and visual aspects in the services, have proven to be not very high, that is they should not cause major problems for users.

The second of the analyzed areas were information content aspects about chosen product. On-line shopping sites, as interactive services, have in this area great presentational and functional potential. For this reason, widely understood information completeness on products is a very important factor for customers. As follows from the obtained data, the various purchasing services obtained different, although at a similar level, percentage values in this regard. The lowest value at the level of 73% and also the biggest potential cognitive load received the Euro service. The best in this regard was the Ceneo service, which reached the level of customers satisfaction at the level of 86%. Although, the difference of maximum and

minimum values for these services is only 13%, the potential problems with reaching and displaying necessary information at any time, can ultimately decide which of services will be chosen by Internet users.

The next of the analyzed areas were content usefulness aspects about chosen product. In this area, it was evaluated the widely understood information quality provided by the shopping services. Aspects of content usefulness are as important as their completeness, because such features like intelligibility, currency and readability of various content forms, present the level of services care for their customers, which is also appreciated by them. As follows from the obtained data, content usefulness in the selected services was rated a relatively high level at the average level of 80%. The lowest score in this regard (77%) and also the highest level of cognitive load the Euro service achieved in this aspect. Probably, obtained difference of only 3% from the average, does not clearly mean, that this service compared to other is much harder to use, but the lower final value may results for example from a different policy of content creation in the service.

The last of the analyzed areas were information searching aspects using information retrieval systems and navigation systems. Both of specified areas are very important systems for the logical navigation in the services by users and finding there of desired content, in the quickest way. For this reason, understanding and correct working is so important from the customers point of view. As follows from the obtained data, information searching using information retrieval systems and navigation systems received among respondents rates on very similar and high level, amount of about 80%. As the study group consisted of people in varying degrees of training in using the Internet, so it can be pulled a general conclusion, that the currently available information retrieval and navigation systems, meet the needs of potential customers. Therefore, when they use both of the systems interchangeably and depending on the needs, their cognitive load decreases, and the operation of the system is predictable. However, it should be noted, that for the full satisfaction the respondents lacked even further 20% of notes.

To summarize, the study of information usefulness of selected e-commerce services has shown, that the degree of cognitive overloads for users of these services is on relatively low and similar level, which means, that these sites are characterized by high quality of applied usefulness. For this reason, they enjoy for many years of a great popularity among Internet users, who usually like to use them and take purchasing decisions with them. A comparison of cognitive overloads values in the context of each scenarios and in terms of selected aspects are presented in the following Fig. 15.1.

15.6 Conclusions

Making research on the influence of information usefulness on the users behaviors of e-commerce services is fully justified from the theoretical and practical point of view, as they have an impact on meeting the needs of buyers, and consequently on the development of economic processes. Furthermore, because of the large variety

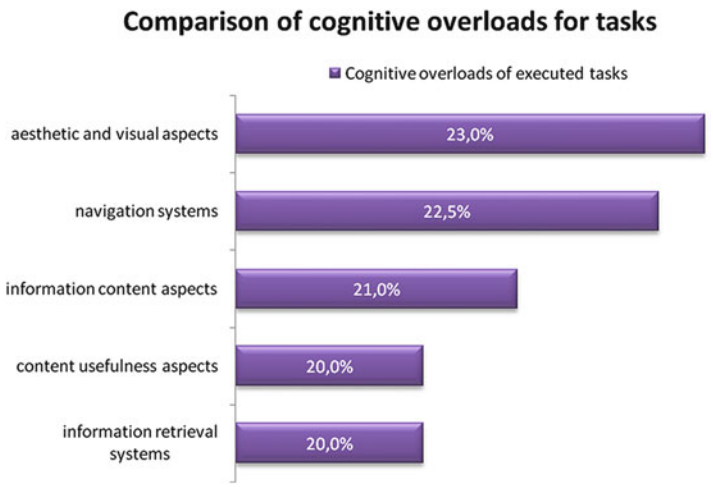

Fig. 15.1 Comparison of cognitive overloads values in the context of users behaviors scenarios and for certain aspects (self study)

of these issues is also needed the integration of different areas and applying different research methods.

The chapter presents the basic assumptions of methodological research in this area, developed research procedure, and analyzed the results of the evaluation of factors influencing on customers behaviors of e-commerce services. The purpose of the study and the results were not going to suggest the wrong approach from the owners of these sites, and most of all the presentation of potential areas to improve their usability. Additionally, taking into account the specific and subjective attitudes of different users, the made research may also provide interesting supplement to the analysis of transactions effectiveness in electronic commerce. This is the issue, which should be taken into consideration in the facilitating process of overcoming the difficulties in decision making or understanding the users behaviors, because of unsatisfactory visual side, useless navigation or excessive amount of available information. Facilitating users the using purchasing services by reducing the cognitive loads or reduction of disadvantages associated with their operation will cause, that buyers will be able to direct on, their cognitive capabilities to a greater extent, the effective information evaluation and therefore make better business decisions.

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Chapter 16
System Dynamics Modeling in Behavioral Decision Making

Małgorzata Łatuszyńska

Abstract Modeling behavioral aspects of decision making has become an important area for research and practice in recent years. System Dynamics (SD) method fits very well into this research area because takes care of the limitations to rational decision-making processes and captures the effect of psychological factors in the model. The aim of the chapter is the review of System Dynamics research in modeling behavioral aspects of decision making. The examples of system dynamics research presented in the chapter shows that SD models are able to represent characteristics of the human mind, the emotions, and the cognitive limitations of humans in individual and group decision making and evaluation of theories-in-use.

Keywords Behavioral decision making • Computer simulation • System dynamics modeling

16.1 Introduction

Nowadays there is a large increase in interest in behavioral decision making and a growing number of researchers consider this approach to be a full-fledged trend in behavioral economics (among others: Camerer 2003; Shiller 2005; Kahneman 2006; Ackert and Deaves 2010; Borowski 2014; Li et al. 2014). One of the important events for the development of this trend was the emergence of a new branch in psychology in the 1970s, referred to as *behavioral decision making* (BDM). BDM is related to a specific area of research in the decision-making process, in which the special interests of the scientists are the characteristics of the human mind, emotions, and cognitive limitations responsible for the diversion of decisions made by individuals from optimum choices (Mullainthan and Thaler 2000: 28–32; Kahneman 2011; Swacha-Lech 2012: 795; Dudycz and Matysek 2016: 39).

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_16

The focus on psychological realism and economic applicability of research promoted by the behavioral economics perspective suggests the immense usefulness of both empirical research outside the lab and of a broader range of approaches to laboratory research. At its inception, behavioral economics relied heavily on evidence generated by experiments. More recently, however, behavioral economists have moved beyond experimentation and embraced the full range of methods employed by economists (Camerer and Loewenstein 2003)—among them methods of computer simulation (Angeletos et al. 2001; Hommes 2006; Mechner 2008; Lombardi et al. 2012; Engel 2013).

According to many authors (for instance: Behdani 2012; Borshchev 2013), in studies on economic problems the researchers most commonly use three methods of computer simulation, for which dedicated computer tools and simulation languages have been created: discrete events simulation, multi-agent simulation and system dynamics. This chapter focuses on the latter, which grounded over the notion of structure leading to behavior, could act as a methodology that takes care of the limitations to rational decision-making processes and captures the effect of psychological factors in the model (Prusty and Mohapatra 2016).

The aim of the chapter is the review of system dynamics research in modeling behavioral aspects of decision making in the context of individual and group decision making and evaluation of theories-in-use.

16.2 The Essence of System Dynamics

System Dynamics (SD) has been described as a "rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organizational boundaries and strategies; which facilitates quantitative simulation modelling and analysis for the design of system structure and control" (Wolstenholme 1990). SD originates from cybernetic approach to system analysis and allows for describing especially complex systems in the form of interactive and combinatory relations. Its theoretical foundations were created by Forrester' and his colleagues from the Massachusetts Institute of Technology in the '50's of the twentieth century. Forrester's approach to industrial system modeling, the first application area for this method, is described in one of the earlier papers, entitled *Industrial Dynamics* (Forrester 1961). Seven premises of the System Dynamics application are presented there:

- decision-making process belongs to the class of control problems with information feedback,
- intuitive judgment of behavior of industrial systems is unreliable due to their complexity,
- experimenting on the model can facilitate understanding of anti-intuitive behaviour of complex systems,
- cost of collection of data to carry out experiments on the model is relatively low,

- decision processes mapped by the model are close to real ones to such an extent that they allow for forming an appropriate policy,
- industrial system behavior is determined by its internal structure, therefore, most problems are internally generated.
- real system behavior is so detached from the ideal one, that each effort of improving the system behavior, is justified.

On the basis of the premises, mentioned above, Forrester took a peculiar approach to modeling and analysis of a system behavior, which is based on the system concept in the way more closely related to practice than theory.

During above 60 years, the interpretation of System Dynamics underwent certain modifications, but it managed to preserve its theoretical assumptions, based on three scientific disciplines, i.e. traditional management theory, cybernetics and computer simulation (Fig. 16.1).

Traditional management is a process which consists in continuous decision-making. In a highly simplified perspective, this process begins from observation of external world, identification of purposes, connections and information streams. As a result imagined models are created, and the future behavior of systems in various conditions is predicted on the basis of these models.

The most difficult part of this process is selection of information and then finding the right course of action which should ensure that defined goals are met. Surprisingly, quite often mistakes in management stem not so much from incorrect view of particular cause-and-effect chains, but from wrong understanding of system dynamics as a whole.

Cybernetics, which bases on feedback theory, puts a strong emphasis on dynamic interactions between system elements and provides tools allowing for better understanding of system behavior. It gives guidelines for distinguishing between important and unimportant information in a given context, and then for structuring and formalizing it in a mathematical model.

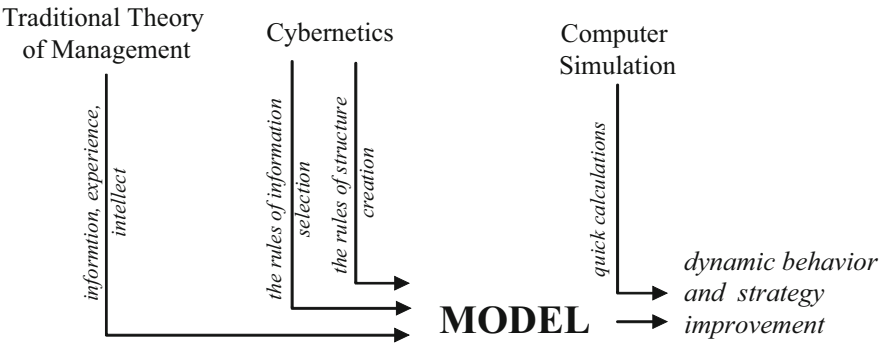

Fig. 16.1 Methodological background of System Dynamics (Łatuszyńska 2005: 32)

Theoretical assumptions and detailed rules of System Dynamics modeling and simulation have been defined in multiple publications, including (Meadows and Wright 2008; Łatuszyńska 2008).

16.3 Applications of SD as a Behavioral Simulation Method

System Dynamics, as a simulation methodology, has been employed successfully as a behavioral experimental tool. Kunc (2016) has listed three areas of SD applications as a behavioral simulation method: laboratory experiments of individual behavioral decision making, field experiments of behavioral group decision making and evaluation of theories-in-use by decision makers.

Research in the area of individual behavioral decision making has focused on identifying and documenting systematic misperceptions of feedback in decision-making processes across multiple industries and environmental conditions (Kunc 2016; Gary et al. 2008; Gonçalves and Villa 2016). Experimental studies exploring decision making and performance employ so called management flight simulators or microworlds, delivering a simulated environment that captures the interconnections between the different parts of the system under study and provides a computer interface which allows decision makers to interact with the model through a familiar "lens" (reports, graphs, and spreadsheets) (Kim 1992). Some of the most well-known microworlds are: People Express (Sterman 1988), Fish Banks (Meadows et al. 2001) and Salt Seller (Sterman 2014).

Examples of publications presenting the SD research in the area of individual behavioral decision making with the use of management flight simulators are shown in the Table 16.1.

The second area of SD application as a behavioral simulation method is connected with field experiments in behavioral group decision making. Research in this area has been embedded in broader organizational and institutional contexts, and explored the role of team decision making—for instance in a competitive aspect. The field experiments using SD can involve two modes (Kunc 2016):

- an experiment before and after using a SD model to support an organizational process. In this case the data collection must involve measures related to changes in the behavior of the participants during the field experiment,
- the evaluation of the impact of practice on participants involved in modeling stages, mostly the conceptualization stage. In this case, data collection attempts to use frameworks from diverse subjects, e.g. psychology, to measure the changes in the participants in terms of commitment to action.

Examples of publications presenting the SD research in the area of behavioral group decision making are shown in the Table 16.2.

Table 16.1 SD in laboratory experiments of individual behavioral decision making

Authors	The title	The purpose
Sterman (1987)	Systems simulation: Expectation formation in behavioral simulation models	Presenting a behavioral model of trend expectation formation
Sterman (1989)	Modeling managerial behavior: Misperceptions of feedback in a dynamic decision-making experiment	Reporting an experiment on the generation of macrodynamics from microstructure in a common managerial context. Subjects manage a simulated inventory distribution system which contains multiple actors, feedbacks, nonlinearities, and time delays
Paich and Sterman (1993)	Boom, bust, and failures to learn in experimental markets	Presenting experiments in the scope of systematic "misperceptions of feedback" where decision makers do not adequately account for critical feedbacks, time delays, and nonlinearities which condition system dynamics
Sengupta and Abdel-Hamid (1993)	Alternative conceptions of feedback in dynamic decision environments: an experimental investigation	Examining the feasibility of improving performance in dynamic tasks by providing cognitive feedback or feedforward
Diehl and Sterman (1995)	Effects of feedback complexity on dynamic decision making	Mapping the effects of time delays and feedback processes on decision making and performance in a dynamic task
Moxnes (2000)	Not only the tragedy of the commons: Misperceptions of feedback and policies for sustainable development	Research on how people understand and make decisions regarding dynamic systems has evolved in close relation with the development of system dynamics modeling
Gary and Wood (2011)	Mental models, decision rules, and performance heterogeneity	Reporting the results from an experimental study examining the relationships between differences in mental model accuracy and performance

The third area of SD application as a behavioral simulation method is connected with modeling theories-in-use, which are those deduced from the actual behavior (Argyris 1976). System dynamics research performed in organizations tends to uncover theories-in-use using qualitative research methods before transforming the findings into quantitative models depicting the theories employed by the decision makers. SD models are employed to discover new theories or test existing theories in behavioral or organizational science. System dynamics acts here as a behavioral theory development tool (Kunc 2016).

Examples of publications presenting the SD research in the area of evaluation of theories-in-use are shown in the Table 16.3.

Table 16.2 SD in field experiments of behavioral group decision making

Authors	The title	The purpose
Milling and Lehmann (1994)	Management games for group decision making in a dynamic environment	Presenting a management simulator for group decisions occurring during innovation process
Kwahk and Kim (2004)	A simulation based approach for group decision-making support	Presenting system dynamics modeling as a group decision-making support tool to deal with the group decision-making tasks having properties of dynamic complexity in terms of cognitive fit theory
Kunc and Morecroft (2007)	Competitive dynamics and gaming simulation: lessons from a fishing industry simulator	Studying decision making and rivalry among competing teams when they have to manage a fishery
Škraba et al. (2007)	The role of information feedback in the management group decision-making process applying system dynamics models	Investigating the influence of feedback information on the decision process supported by the application of system dynamics models
Kunc and Morecroft (2010)	Managerial decision making and firm performance under a resource-based paradigm	Demonstrating the value of context on strategic behavior responsible for developing resources in competitive industries
Kljajić-Borštnar et al. (2011)	The relevance of facilitation in group decision making supported by a simulation model	Clarifying the impact of different types and structures of information feedback on the task performance and efforts involved in decision making by measuring feedback-seeking behavior
Kazakov and Kunc (2016)	Foreseeing the dynamics of strategy: an anticipatory systems perspective	Employing SD in a strategic planning process conducted by a team of senior managers of a pharmaceutical company

16.4 Conclusions

Modeling behavioral aspects of decision making has become an important area for research and practice in recent years. System Dynamics method fits very well into this research area because takes care of the limitations to rational decision-making processes and captures the effect of psychological factors in the model. In other words is able to include both economic and psychological variables in the development of models, which represent dynamic decision-making situations in a various context.

Examples presented in the chapter of system dynamics applications show that this method has been used for modeling behavioral aspects of decision making for about 30 years. The most popular area of SD applications in this context is evaluation theories-in-use.

Table 16.3 Applications of SD in evaluation of theories-in-use

Authors	The title	The purpose
Gregoriades (2001)	Human error assessment in complex socio-technical systems—system dynamics versus Bayesian belief network	Presenting a model to study how factors like fatigue, motivation, and stress result in human errors
Repenning and Sterman (2002)	Capability traps and self-confirming attribution errors in the dynamics of process improvement	Evaluating the failure of organizations to adopt and exploit administrative innovations at two levels: Individual and group
Akkermans and van Oorschot (2005)	Relevance assumed: a case study of balanced scorecard development using system dynamics	Investigating how employee's motivation, satisfaction, and training influence productivity
Jones (2005)	Behavioral theory in simulation: ambiguous results from simple relationships	Presenting a SD model of individual performance as a behavioral factor depending upon and influences emotional and cognitive factors: stress, mood, and motivation
Kanaganayagam and Ogunlana (2008)	Making construction employment decent work: dynamic modeling of workers willingness to be employed in the industry	Presenting a SD model of workers' willingness to be employed in the construction industry taking into account commitment to the organization, necessity of having a job, achievement, and job satisfaction respectively dissatisfaction
Cronin et al. (2009)	Why don't well-educated adults understand accumulation? A challenge to researchers, educators, and citizens	Presenting experiments with the so-called department store task explaining why people are unable to understand and apply the principles of accumulation
Vancouver et al. (2010)	Using dynamic computational models to reconnect theory and research: socialization by the proactive newcomer as example	Applying system dynamics to model how a newcomer to an organization seeks building up job relevant knowledge
Shin et al. (2013)	An analysis of mental process within construction workforces for project-level safety management	Studying the decision-making process of a worker regarding safe behavior by the use of system dynamics including factors like optimistic recovery or habituation
Block and Pickl (2014)	The mystery of job performance: a system dynamics model of human behavior	Modeling job relevant mental processes and behavior of an employee
Atkinson and Gary (2016)	Mergers and acquisitions: modeling decision making in integration projects	An analysis of the behavior involved in mergers and acquisitions projects
Prusty and Mohapatra (2016)	Modeling judgment and decision-making process using system dynamics	Presenting SD models as experimental approach of behavioral scientists toward understanding judgment and decision-making situations

(continued)

Table 16.3 (continued)

Authors	The title	The purpose
Gonçalves and Villa (2016)	Misperception of behavioral operations and bodies of knowledge	Explaining how bounded rationality arises from misperceptions of feedback structure and feedback dynamics
Wang et al. (2017)	Realizing value from project implementation under uncertainty: an exploratory study using system dynamics	Presenting a SD model of a project monitoring and control system under a behavioral paradigm

In the author's opinion, a very promising direction of development of SD applications in behavioral decision-making research is to combine this method with multi-agent simulation. The latest literature discusses the possibilities of linking both approaches (Teose et al. 2011; Nava Guerrero et al. 2016) and gives examples of hybrid models (Martin and Schlüter 2015; Prasad and Park 2016). Thanks to such connection, more accurately reflecting of individuals' behavior and characteristics (for instance emotions and cognitive limitations of humans represented by agents) is possible—and consequently obtaining more valuable results of research on behavioral decision-making process.

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Chapter 17
Prediction of Decision Outcome via Observation of Brain Activity Signals During Decision-Making Process

Anna Borawska and Akeel Alsakaa

Abstract Making choices and decisions is one of the fundamental human activities. Due to its importance, over the years, different methods, designed to support decision-making process, were developed and used. Field of the decision-making support is still developing, and it uses the latest achievements of many sciences. Tools supporting the decision process fulfill their role in many different ways. Among them we can mention: information management, quantification of data or models manipulation. To this traditional approach, one more element could be added—indication of the conditions in which a better decision can be made. In this context, the cognitive neuroscience techniques can be very helpful. At the basis of this approach is the assumption that knowing the neurological grounds for decision making and decoding the decision-making process in the brain, we will be able to understand and take advantage of factors contributing to making the right decisions. In the presented research, we try to predict decisions on the basis of observations of brain signals activity during the time of the decision-making process. The data are registered with the use of electroencephalogram (EEG) due to its small size and low cost. The decisions made by participants are connected with the choice between two lotteries with different payoffs. The aim of the research is to determine, if by analyzing the brain signals, we are able to predict the decision adequacy.

Keywords Cognitive neuroscience • Decision-making support • Experiment

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_17

17.1 Introduction

Making choices and decisions is one of the fundamental human activities. In the work of managers it plays such a key role, that some authors put an equal sign between decision making and management (Drucker 1955). If we take into account the basic functions of management—planning, organizing, directing and controlling—decision making appears as their main ingredient (Soares 2010). Regardless of the function in which the decision-making process takes place, it is very important to ensure that it runs smoothly and brings the organization the best results. Making good decisions is a prerequisite for good management—the decision accuracy is the most significant measure of manager's performance (Harrison 1995). Due to the importance of the problem, over the years different methods, which are designed to support decision-making process, were developed and used. Regardless of whether these are theoretical models or IT systems, supporting decision makers in calculating the validity of each election, the goal remains the same and that is the desire to reduce the number of wrong decisions made by managers.

Field of the decision-making support is still developing, and it uses the latest achievements of many sciences. Tools supporting the decision process fulfill their role in many different ways. Among them we can mention: information management, quantification of data or models manipulation. Information management refers to storing, searching and reporting information in a convenient format for the user. Quantification of the data is a process in which large amounts of information are condensed and presented using some of the basic indicators that capture the data essence. Manipulation of models refers to the creation and implementation of different scenarios to answer questions such as "What would happen if ...?" (Gupta and Harris 1989). To this traditional approach of decision supporting systems, one more functionality could be added—this would be indication of the conditions in which a better decision can be made. In this context, the cognitive neuroscience techniques can be very helpful. At the basis of this approach is the assumption that when we will get to know the neurological grounds for decision making and we will decode the decision-making process that takes place in the brain, we will be also able to understand and take advantage of factors that contribute to making the right decisions. Research in this area are still at an early stage of development.

The aim of the presented research is to determine, if by analyzing the brain signals, we are able to predict the adequacy of a decision made by a subject. First section of the chapter shows, how cognitive neuroscience techniques can be used in decision-making support. Next part explains the scenario of the experiment and the following two sections describe certain phases of data acquisition and analysis: EEG recordings, pre-processing and signal filtering and artifact removal. In section four, an algorithm for feature extraction from signals is presented. Finally, the empirical result and conclusion are shown.

17.2 Cognitive Neuroscience Techniques in Managerial Decisions

Among the possible applications of cognitive neuroscience techniques in relation to managerial decisions several main directions, which have gained particular popularity, can be distinguished. These include research concerning (Yu & Zhou 2007; Loewenstein et al. 2008):

- the role of emotions in decision making,
- decision making under risk and uncertainty,
- decisions in a social context,
- determining the usefulness and rationality of decisions.

Exemplary publications concerning the research of the above-mentioned subject matter are summarized in Table 17.1. Their assignment to each of the groups is, to some extent, arbitrary, as very often experiments relate to several subjects.

Table 17.1 Examples of studies on the use of cognitive neuroscience techniques in relation to managerial decisions (own elaboration)

	Topic of the research	Cognitive neuroscience technique
The role of emotions in decision making	The relationship between the experience of the decision maker and the ability to restrain emotions when making decisions (Lo and Repin 2002)	Measurement of galvanic skin response, pulse and temperature; electromyography
	The impact of emotions on decision making during negotiations (Gimpel et al. 2013)	Measurement of galvanic skin response and pulse
Decision making under risk and uncertainty	The impact of sexual arousal on risky decisions taking (Knutson et al. 2008)	Functional magnetic resonance imaging (fMRI)
	The dependence of the decisions taken under risk from the context (gain or loss) (De Martino et al. 2006)	Functional magnetic resonance imaging (fMRI)
	Preferring risky situation over the uncertain (Hsu et al. 2005)	Functional magnetic resonance imaging (fMRI)
Decisions in a social context	Trust and reciprocity in economic interactions (McCabe et al. 2001; Sanfey et al. 2003)	Functional magnetic resonance imaging (fMRI)
	Collective decision making (Kimura and Katayama 2013)	Electroencephalograph (EEG)
Determining the usefulness and rationality of decisions	Discounting utility of time decision—decision making under the condition of postponed gains (McClure et al. 2004)	Functional magnetic resonance imaging (fMRI)
	Irrationality in making financial decisions (Polezzi et al. 2008)	Electroencephalograph (EEG)

The presented experiment and its results concern the topic of the decisions made in the conditions of risk and uncertainty. In this chapter, we try to predict manager decision on the basis of observations of brain signals activity during the time of the decision-making process. The data are registered with the use of electro-encephalogram (EEG) due to its small size and low cost. The decisions that are made by participants are connected with the choice between two lotteries with different payoffs.

17.3 Experiment Design

The proposed experiment scenario for each participant includes some basic steps. They are shown in the Table 17.2.

Registration of EEG for the experiment was carried out in accordance with the guidelines of the 10–20 system (Purves et al. 2013, p. 32), which specifies the location of the individual electrodes on the scalp. Scheme of their deployment, with particular emphasis on electrodes used in this experiment is shown in Fig. 17.1.

The focus remains only on 7 electrodes mounted on the frontal lobe head (Fp1, Fp2, F7, F3, Fz, F4 and F2), because according to the findings of neuroscience in this region are areas of the brain associated with higher cognitive functions.

After preliminary preparation of the participant, proper experiment begins. Starting the presentation with the black screen for 2 min is intended to make the participant calm down (Hosseini and Khalilzadeh 2010). Later in the experiment, the volunteers have to answer ten questions concerning the choice between the two variants of the lottery (Table 17.3). This element is taken from research publication of Holt and Laury (2002) and other articles that repeated their experiment in a slightly different configurations (He et al. 2012; Delaney et al. 2014).

Table 17.2 Scenario of the experiment (own elaboration)

Phase	Activities
Preparation of the experiment and the participant	Explanation of experiment to the participant
	Obtaining the written informed consent
	Preparation of the participant to the experiment by connecting the appropriate measuring devices
	Gathering demographic information by using experimental software
The course of the experiment	Displaying the black screen for 2 min, to calm the participant
	Presentation of a series of questions concerning the choice between lotteries with a specified probability of winning and the simulation of the lottery
	Ending of the experiment with presentation of total winning of the participant

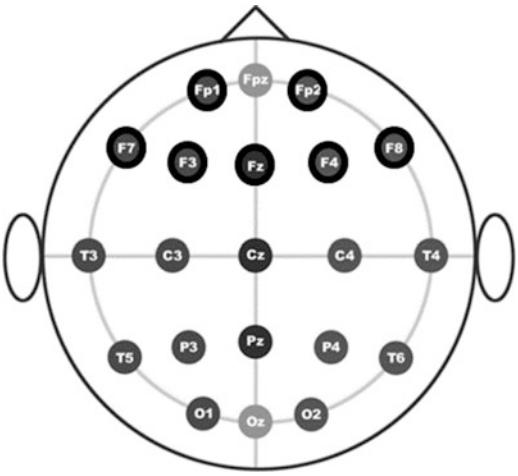

Fig. 17.1 Placement of electrodes according to the 10–20 system (Trans Cranial Technologies 2012)

Table 17.3 Terms of the lottery presented during the experiment (source: Holt and Laury 2002)

	First lottery	Second lottery
1	10% chance for 20$	10% chance for 38.5$
	90% chance for 16$	90% chance for 1$
2	20% chance for 20$	20% chance for 38.5$
	80% chance for 16$	80% chance for 1$
3	30% chance for 20$	30% chance for 38.5$
	70% chance for 16$	70% chance for 1$
4	40% chance for 20$	40% chance for 38.5$
	60% chance for 16$	60% chance for 1$
5	50% chance for 20$	50% chance for 38.5$
	50% chance for 16$	50% chance for 1$
6	60% chance for 20$	60% chance for 38.5$
	40% chance for 16$	40% chance for 1$
7	70% chance for 20$	70% chance for 38.5$
	30% chance for 16$	30% chance for 1$
8	80% chance for 20$	80% chance for 38.5$
	20% chance for 16$	20% chance for 1$
9	90% chance for 20$	90% chance for 38.5$
	10% chance for 16$	10% chance for 1$
10	100% chance for 20$	100% chance for 38.5$
	0% chance for 16$	0% chance for 1$

Neurophysiological data recorded during the entire study, will help us answer the question, if we are able to predict the decision adequacy. Due to the topic of the experiment we have decided to choose as participants students and teacher of Faculty of Economics and Management. There were 22 of them, aged 19–50. Because of their different native languages, experiment was provided in Polish, English and Arabic. Signal acquisition was done using a Contec KT88 device with

sample rate set to 200 samples per second. The obtained data were exported into an edf (European Data Format) file to enable more convenient processing with the use of Matlab environment.

17.4 EEG Data Pre-processing

Raw EEG signals acquired from brain activity contain many other nested surrounding signals from varying peripheral devices. Simple digital filtering methods are used to retain interesting frequency components. We have applied low and high pass filter to remove data with a frequencies below 0.4 Hz and above 50 Hz (Nitschke et al. 1998). When brain activity signals were recorded through the electrodes placed on the scalp of a participant, eye blinks and muscle movements caused contamination of the EEG signal. Therefore, the next phase is artifacts removing process. A variety of methods have been proposed for correcting ocular and muscle artifacts. One common strategy is artifact rejection. In our experiment we used automatic artifact removal based on Blind Source Separation (BSS) techniques. The main method which was applied is wavelet Independent Component Analysis (wICA, (Castellanos and Makarov 2006)), which has been proven useful for suppression of artifacts in EEG recordings, both in the time and frequency domains.

To explain this methods, we will use an example of eye blinking artifacts rejection. Such artifacts are present in EEG signal as large pulses and they have a great impact on registered data. Fig. 17.2a shows an example of EEG signal taken from one of the experiment's subjects. The data segment contains an eye blinking artifact. The episode is localized around 0.5 s and it spreads almost over all channels, strongly affecting the most frontal sites (Fp1 and Fp2). We clean the EEG signal by the wICA algorithm. It can be conducted by performing the following steps (Castellanos and Makarov 2006):

1. Applying a conventional ICA algorithm to raw EEG, obtaining the mixing matrix M and N independent components: $\{s_1(t), s_2(t), \ldots, s_N(t)\}$.
2. Obtaining representations of components using the wavelet transform: $\{W(j,k)\}_{s_i}$.
3. Thresholding the wavelet coefficients—setting $W(j,k) = 0$ for the coefficients that are higher than the threshold, $|W(j,k)| > K$.
4. Inversing wavelet transform of the threshold coefficients $W(j,k)$ thus recomposing components consisting sources of the neural origin only $\{n_i(t)\}$.
5. Compose wICA-corrected EEG: $\tilde{X}(t) = M \cdot [n_1(t), n_2(t), \ldots, n_N(t)]^T$.

Results of applying these steps on EEG signals to remove artifacts is illustrated in Fig. 17.2b.

Publications included in the tables do not cover all the research that is being done in experimental economics with the application of cognitive neuroscience tools.

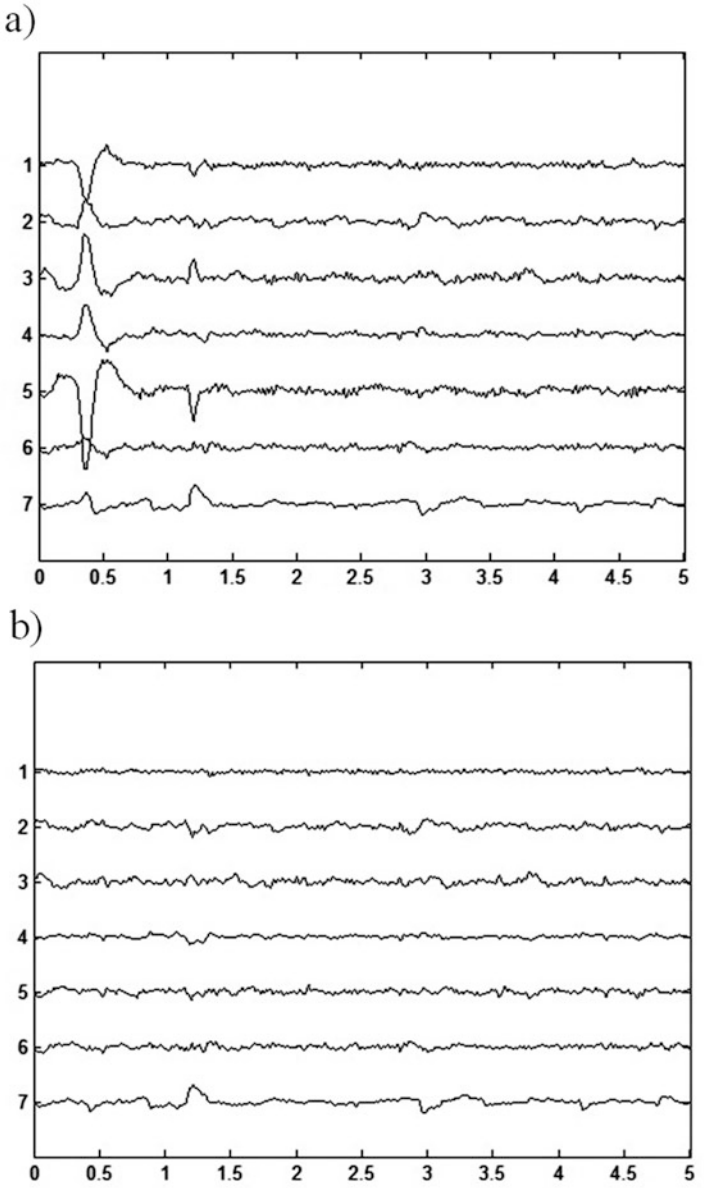

Fig. 17.2 (**a**) Eye blinking artifacts of EEG signal (from the top channels: Fp1, F7, F3, Fz, Fp2, F4 and F8) (**b**) EEG signal corrected by wICA; x-axis represents time (own elaboration)

They present, however, an overview of the most popular issues that have been recently examined by experimental economists.

17.5 Feature Extraction

Feature extraction is an important phase to the analysis of brain signals characteristic. During this stage major frequency sub-bands—delta, theta, alpha, beta and gamma, are elicited from signals. To perform this operation we have used discrete wavelet transform (DWT) that is considered to be more advantageous than Fourier transform (Schiff et al. 1994). For this method, selecting suitable decomposition level is very important for analysis of the signal. The scope of interest ranges between 0 and 50 Hz. The decomposition level which we have used is five, because all other ranges are considered to be noise or they are used for another purpose like epilepsy monitoring (Joyce et al. 2004). On the other hand, the decomposition process of the signal depends on the number of sampling frequency that was used for the signal recording. In our experiment, we used frequency of 200 samples per second. To obtain satisfactory outcome we applied the (db8) function (Malina et al. 2002). As a result we observe the signals band above 32 Hz for gamma, 13–31 Hz for beta, 8–12 Hz for alpha, 4–7 Hz for theta and below 4 Hz for delta as illustrated in Fig. 17.3.

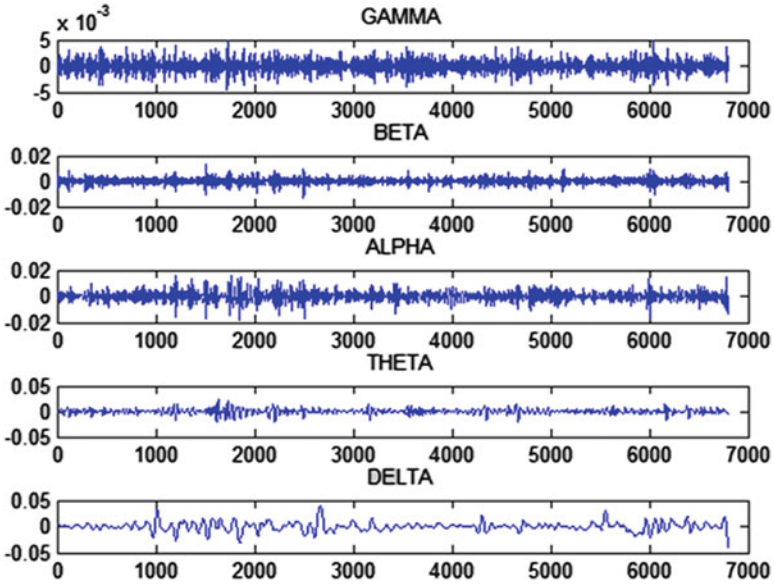

Fig. 17.3 DWT results for all five frequency bands; on x-axis is number of sample, y-axis shows the amplitude of signals (own elaboration)

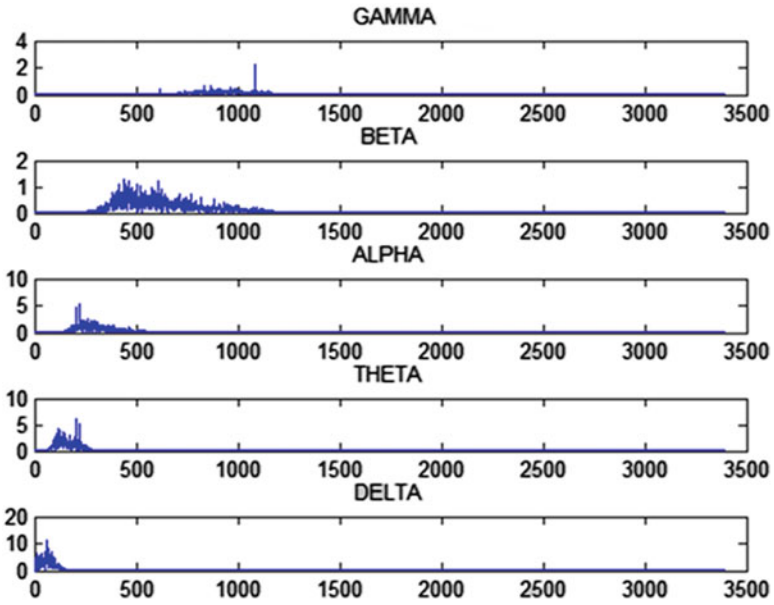

Fig. 17.4 High order spectrum (HOS) for each band; on x-axis is number of sample, y-axis shows the amplitude of signals (own elaboration)

Having separate frequency bands extracted from the recorded EEG signal we have used Fast Fourier Transform (FFT) to calculate high order spectrum (as shown in Fig. 17.4) that was used to obtain input values for a classification phase.

The entire procedure of feature extraction is illustrated in Fig. 17.5.

In our experiment every participant makes ten decisions and deals with each of them separately. Therefore, for every epoch that corresponds to a single decision, we obtain 35 features that are used to classify decisions into right and wrong ones. It has to be stated, that as right decision in the context of the lottery used in the experiment, we consider one that is made according to the expected utility theory (it maximizes the expected payoff of a participant).

17.6 Features Classification and Results

The brain signals classification problem is a difficult task. There are many techniques for the implementation of such classification. Most commonly used are supervised algorithms (Siuly et al. 2016). We focused on five different methods, namely: support vector machine (SVM), naïve Bayes (NB), K-nearest-neighbors (kNN), linear discriminant analysis (LDA) and probabilistic neural networks (PNN). In this section we will mention briefly how those algorithms classify data into two classes (right and wrong decisions).

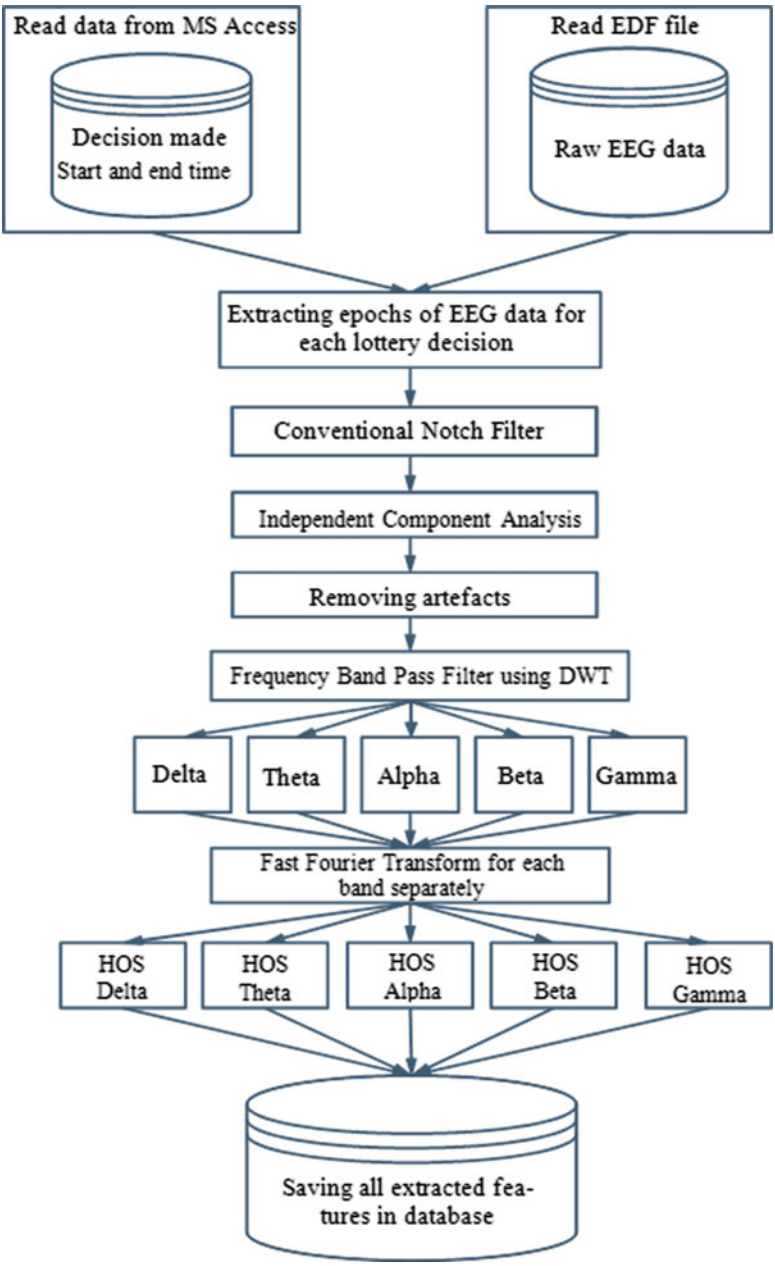

Fig. 17.5 Steps of feature extraction (own elaboration)

Among different supervised classifiers, SVM is the one that often performs significantly better than others. It was proposed by Boser et al. (1992). The concept of SVM is based on maximizing the margin between the training examples and the decision boundary. Optimal separation is achieved when there is no separation error and the distance between the closest data vector and the decision boundary is maximal (Stoean and Stoean 2014). Obtaining an optimal classification result with SVM is still difficult, therefore we have tested and applied other algorithms as well.

The Bayesian classification assumes an underlying probabilistic model and it allows us to capture uncertainty about the model in a principled way of determining probabilities of the outcomes. It tries to find the global minimum in the error function. In fact, Bayesian classifier separates the feature vectors by the comparing of decision functions of the classes and according to the largest output selects the class of input sample. This method calculates explicit probabilities for hypothesis and it is robust to noise in the input data (Chai et al. 2002). Naïve Bayes is a simplified case of the Bayesian classifier. In this classifier, it assumed that the features are independent from each other (Yaghoobi et al. 2014).

Another of the chosen methods was K-nearest-neighbors algorithm. The aim of this technique is to assign to an unseen point the dominant class among its nearest neighbors within the training set whose class is already known (Duda et al. 2000). The nearest neighbors are determined on the basis of a distance, for example using the Euclidean metric (Blankertz et al. 2002).

The next method, linear discriminant analysis, is a technique based upon the concept of searching for a linear combination of attributes that best separates two classes (wrong and right) of a binary attribute ("rightness" of decision). It is mathematically robust and often produces models whose accuracy is as good as more complex methods (Sayad 2011).

The last of applied methods was probabilistic neural networks (Specht 1990). This approach assumes replacing the standard neural networks sigmoid activation function with an exponential one. It allows to compute nonlinear decision boundaries that approach Bayes optimal. The most important advantage of the probabilistic neural networks is that training is easy and instantaneous. They can be used in real-time because as soon as one pattern representing each category has been observed, the network can begin to generalize to new patterns.

These five methods were tested in the research because they represent different approaches and as the literature overview indicates—they are very often used in the context of cognitive neuroscience experiments.

17.7 Experiment Results and Discussion

In this chapter correlation between brain signals activity during the decision making process and decision adquacy is studied. The major objective is to establish brain waves patterns for right and wrong decisions. In our experiment we have

Table 17.4 Classification results for decision prediction (own elaboration)

Classification algorithms	Training set (no. of decisions)	Testing set (no. of decisions)	Prediction rate (%)
KNN	150	70	56.25
SVM			55
NB			61.25
LDA			56.25
PNN			50

Table 17.5 Classification results for decision prediction—increased training set (own elaboration)

Classification algorithms	Training set (no. of decisions)	Testing set (no. of decisions)	Prediction rate (%)
KNN	210	10	73
SVM			57
NB			64
LDA			64
PNN			73

taken 70% of the collected data for the training set. Half of the samples were registered when participants made what was considered as right decisions and the other half when they made wrong decisions. Registered samples differ in terms of their duration, because every participant of the experiment, for every decision that was made, needed different amount of time. It does not have any impact on further analyses, because signals were examined in frequency domain. The end results are obtained on the basis of features that are extracted from the signals. Chosen set of training samples was used to teach every classifier to recognize two different classes (patterns). Remaining 30% of recorded data were used for testing. Since the total number of decisions that were made during the experiment is 220 (there were 22 participants, each of them made 10 decisions), therefore we have 150 decisions for training and 70 for testing set. Each decision is represented by 35 features (5 frequency bands multiplied by 7 EEG channels). Results of classification performed with the use of five chosen methods are presented in the Table 17.4. It is worth noting, that the prediction rate shown there takes into account all frequency bands in the analyzed signals (delta, theta, alpha, beta and gamma). The best method in this case was Naïve Bayes. For the chosen size of training set, only this classifier allowed for prediction rate that was greater than 60%.

In order to check, if we could get better results, when the database of patterns will contain bigger amount of samples (the training set will be greater), we have performed second analysis. The training set in this case was set to 170 decisions. The results that were obtained (presented in the Table 17.5), generally shown what was expected—in case of almost all classifiers, the prediction rate has increased. The best result could be observed for KNN and PNN, although LDA and NB also

allow for achieving relatively high prediction rate. The increase, where present, is not substantial, but it shows a trend—by expanding the database of patterns, we can achieve better results of decision adequacy prediction. It is a promising result for further research.

17.8 Conclusions

Conducted research has shown in what way cognitive neuroscience techniques can be used in predicting possible decision adequacy. It was tested in the case of decisions under risk. Such setting was chosen, because it is relatively easy to differentiate right and wrong decisions in this context. For this specific experiment, decisions were divided into two groups on the basis of expected utility theory. Registering EEG signals from the subjects that have participated in the study allowed for creating a database of brain waves patterns that accompany each decision that was made. This set of signals were classified with the use of five different methods of supervised classification. Division into two classes was made on the basis of 35 features that define each EEG signal. The results obtained for the most of classification methods exceeds 50% of accuracy. I could be assumed that this number could be greater, when we would limit the set of features to the most significant in the context of risky decisions. Finding such set of features would be a topic for further research.

The results of the study could be used for elaboration of decision support system (DSS), that could advise the user, if he can make a right decision in certain moment of time. The system would work in real-time, registering the brain signals, classifying them on the basis of collected patterns archived in the database. The feedback given from the system would inform the user, if he/she is able to make proper decision in a given situation, or not. The effectiveness of such DSS could be improved, if the database of patterns used would be created for its particular user. The potential of this solution is promising, especially in the context of managerial decision making.

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Part III
Practical Issues: Case Studies

Chapter 18
Validation of EEG as an Advertising Research Method: Relation Between EEG Reaction Toward Advertising and Attitude Toward Advertised Issue (Related to Political and Ideological Beliefs)

Dominika Maison and Tomasz Oleksy

Abstract In these last decades consumer neuroscience has developed very rapidly, both as an academic field and as a marketing research practice. In this chapter we discuss different tools and measurements used by consumer neuroscience. Moreover we discuss both the potential and the limitations of different tools and methods coming from neuroscience and the difference in their application to scientific consumer research and applied consumer research—marketing research. As we have identified there is a lack of neuroscience research on social campaigns, toward the end we present examples of using EEG (Frontal Asymmetry Index) to understand our reaction toward advertised objects, in relation to an individuals' political and ideological beliefs. In study 1 (n = 33), conducted prior to the presidential election in Poland, we tested EEG reaction toward the two candidates running for president representing the right wing and the left. The Frontal Asymmetry Index was analyzed in relation to respondents' political attitudes: conservatism vs. liberalism. In the second study (n = 33) we tested brain reaction (EEG) to two social advertisements referring to homosexuality. This was also analyzed in relation to attitudes toward homosexuality. Both studies showed a correlation between the Frontal Asymmetry Index and attitudes: analyzed brain waves when presented with stimuli (pictures and ads) reflected attitudes shown toward the studied object. For both studies we used the EEG tool Emotiv.

Keywords Consumer neuroscience • Frontal asymmetry • Social campaigns • Political attitudes • Attitudes toward homosexuality

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_18

18.1 Introduction

Advertising is a very important tool for marketing a product, and at the same time it is quite an expensive tool—advertising campaigns, and especially TV campaigns, cost a lot of money. However, in marketing there is a lot of evidence to show that many advertising campaigns are not effective and not worth the money spent on them (Hansen and Christensen 2007; Helgsen 1996; Ehrenberg 1992; Jones 1991; Tellis and Weiss 1995). Therefore testing the effectiveness of advertising before its exposure in the media is very important. However, the predictive validity of traditional advertising pre-testing methods used in marketing research is questionable (Hansen 1995; Wright-Isak and Faber 1997; Cook and Kover 1997; Maison 2005). The consequence of this is that for years there has been intensive searching, both in practice (marketing research) and in science (consumer science), for new advertising research methods, which are not only related to declarations, but more as indirect indicators (especially physiological) of their future effectiveness (Hazzlet and Hazzlet 1999; LaBarbera and Tucciarone 1995). The assumption underlying this is that consumers are not always conscious of their attitudes toward advertising or an advertised brand, or even sometimes do not want to express it (Maison and Gregg 2016). There is a lot of evidence proving that underlying consumers' attitudes and decisions are unconscious motives and automatic processes (Cohen and Areni 1991; Goldberg and Gorn 1987; McDonald 1920; Shapiro et al. 1997a, b; Shiv and Fedorikhin 1999; Ohme 2001). Moreover, many of these can influence our reaction toward advertising.

These observations from the consumer and advertising field are supported by contemporary psychology, which delivers much evidence that people are not as rational as was previously believed. People often make decisions intuitively, automatically, and without any conscious control or effort (Bargh and Chartrand 1999; Dijksterhuis 2004; Greenwald and Banaji 1995; Uleman and Bargh 1989; Wilson 2002; Zajonc 1968, 1980, 1998). Even conscious decisions can be triggered by unconscious stimulation, which a person is not conscious about, such as subliminal or implicit stimuli (Zajonc 1968; Murphy and Zajonc 1993; Ohme 2001). Further proof of automatic and unconscious human processes came from a study on implicit attitudes, especially when using reaction-time based methods as a tool, such as the most popular—Implicit Association Test (IAT—Greenwald and Banaji 1995; Maison et al. 2004; Perkins et al. 2008; Maison and Gregg 2016; Maison 2017).

As a consequence of those uncontested proofs about the consumers' automatic and unconscious processes and especially processes connected to their reaction to advertising, there is a lot of interest in finding advertising research paradigms, methods and tools which go beyond declarations and consciousness—methods which are based on implicit measures and not just declarations. These methods, which can overcome the limitations of traditional explicit measures, should be insusceptible to the potential distortions e.g. social biases, the need of coherence or the tendency to be 'politically correct'. Moreover, they should be able to detect

the consumers' reactions, which can go beyond their conscious awareness and introspective access.

One of the solutions to the above-mentioned problems that advertising research relies too much on declaration seems to be in the use of neurophysiological measures as an indicator of advertising's effectiveness. The first time that scientists got interested in neurophysiological measurement in the context of advertising was in the '80s (Olson and Ray 1989; Rothschild et al. 1988; Stewart and Furse 1982). It was as a consequence of the development of neuropsychology and the large interest among psychologists in such measures as indicators of unconscious (then understood as "real", "true") emotions. Most measures explored at that time were EEG signals (electroencephalography), GSR (galvanic skin response) and HR (heart rate). However, after a while this direction of advertising research was abandoned, both in practice and in academic research, probably because of the huge complexity of the measurement process, data analysis and especially data interpretation.

In the late '90s we can observe a big comeback of interest to physiological measures in academia and in practical marketing research. Firstly, it is as a consequence of the rapidly growing need for finding "biased-proof" research methods and forming more successful marketing strategies based on their results. Second, it happened thanks to the miniaturization of equipment and the introduction of a portable version of them (e.g. mobile eyetracking), invention of noninvasive solutions (e.g. Facereader instead of EMG, Maison and Pawłowska 2017), and the large support of computers in analyzing very complex data (new computational methods, complex algorithms). At the same time word "neuromarketing" became very popular (Fugate 2007; Lee et al. 2007; Madan 2010). However, this term was used in marketing practice, rather than "cognitive neuroscience" which was used more in academic research.

Consumer neuroscience is a growing field in academic research related to the understanding of consumer processes and economic experiments (Borawska 2016; Khushaba et al. 2013). It is at the intersection of economics, neurology, psychology, statistics and social studies. Consumer neuroscience's main goal is to merge knowledge about the consumer with knowledge that has emerged from the field of neuroscience (Plassmann et al. 2011; Couwenberg et al. 2016). Consumer neuroscientists implement strictly academic measures, used in the neurocognitive domain, to provide a deeper insight into customer behavior. This is done by enhancing the knowledge of a neural basis of processes relevant to consumer decisions, like evaluation and attitude formation, decision making, attention and memory, brand loyalty, and purchase intention.

18.2 Tools and Measures Used in Consumer Neuroscience

Consumer neuroscience is using tools developed and widely used in the field of neuroscience: the more traditional tools as psychophysiological measures (GSR, EMG, heart rate, eyetracking) and electroencephalography (EEG), as well as the latest, Functional Magnetic Resonance Imaging (fMRI).

Table 18.1 Tools and measures used by cognitive neuroscience (own elaboration)

	Measure	Interpretation
Psychophysiology		
Heartrate (HR)	Speed of heartbeat	Reflection of cognitive attention
Skin conductance response	Level of sweating	Arousal—positive or negative
Facial myography (EMG)	Arousal of facial muscles	Direction and strength of basic emotions
Eye-tracking	Eye movement in the presence of stimuli	Visual attention
Electroencephalography (EEG)	Brain signals produced by the cortex, electrical activity on the brain surface	Reflecting cognitive processes, emotions and behavior. Used for understanding consumer preference and choice behavior
Functional Magnetic Resonance Imaging (fMRI)	Track of blood oxygenation in the brain	Activation of a particular part of the brain in reaction to given stimuli

18.2.1 Psychophysiological Measures

According to Camerer et al. (2005), this family of techniques is the oldest and simplest technique used to measure neurophysiological changes in an organism, include heart rate, facial myography, skin conductance response and eyetracking (see Table 18.1). In the context of consumer research, psychophysiological techniques (also called biometrics) have been applied since the 1960s (pupillary dilation and electrodermal response), later followed by eyetracking and heart rate (Wang and Minor 2008). Heart rate is the speed of the heartbeat, measured typically with an electrocardiogram, which shows the electrical activity of the heart via external skin electrodes (Venkatraman et al. 2015). Heart rate is useful in the detection of cognitive attention, because it changes when cognitive attention is directed to a particular situation (Kenning and Linzmajer 2010; Cacioppo and Tassinary 1990). Skin conductance response is interpreted as an indicator of arousal, where the increased arousal is connected to a level of sweating, regardless of whether the arousal is positive or negative (Damasio 1994). For that reason, it is popular practice to combine this measure with facial myography for improving an understanding of direction and strength of emotion (Kenning and Linzmajer 2010). Eye tracking is a method for measuring eye positions and eye movement in the presence of stimuli. The method is based on the assumption that eye movement is linked to emotions, because our attention is more attracted by e.g. emotionally triggering images. Thus, eyetracking could be perceived as an indirect measure of emotions, most often supported by other techniques (Sørensen 2008).

18.2.2 Electroencephalography

According to Nunez and Srinivasan (2006), electroencephalography (EEG) is a "window of the mind" because of its ability to collect changes in a brain's signal produced by the cortex, closely correlated with cognition, emotions and behavior. Although the first use of EEG to register brain waves was by Hans Berger over 80 years ago, EEG is still one of the most popular methods for brain activity measurement, used widely by psychologist, neurologists and neuroscientists (Ohme et al. 2010a). EEG can measure electrical activity on the brain's surface using electrodes (up to 256) closely attached to the scalp of the head. Its main advantage is a high temporal resolution (about 1 millisecond), which enables precise detection of changes in brain activity, even in the case of fast changing stimuli (Ohme et al. 2011), and is typical for experiments on consumer preferences and choice behavior. On the other hand, EEG is characterized by poor spatial resolution, making attempts of the localization of specific brain structures very problematic. EEG analyses are based most often on two main techniques: event-related potentials (ERP) and an analysis of brain waves. The first are the average brain-reaction to stimuli and may indicate for example surprise, feeling of incongruence, emotional attitude or increased attention (e.g., Luck 2005). The second technique, analysis of brain waves, focuses on following waves: Delta (1–4 Hz), Theta (3–7 Hz), Alpha (8–12 Hz), Beta (13–30 Hz), and slow Gamma (30–40 Hz) which were shown to be associated with cognitive or affective processes in response to marketing stimuli (e.g. Bourdaud et al. 2008; Kawasaki and Yamaguchi 2012).

18.2.3 Functional Magnetic Resonance Imaging

Functional magnetic resonance imaging (fMRI) tracks blood oxygenation in the brain. Using different magnetic properties of oxygenated and deoxygenated blood (blood–oxygen-level dependent [BOLD] contrast), fMRI allows us to analyze changes between these two states in different brain regions, correlating this process with reaction to a given stimulus (Kenning et al. 2007; Kenning and Linzmajer 2010). When compared to EEG, fMRI offers a much better spatial resolution, enabling localization of brain activity changes within a spatial resolution of 1–10 mm even in deep structures of the brain (Plassmann et al. 2011). However, fMRI suffers from low temporal resolution, as it captures dynamic changes with a temporal resolution of 1–10 s.

18.3 Research Fields in Consumer Neuroscience

All of the above mentioned research techniques are used in consumer neuroscience in the hope of increasing the identification of neural regions and reactions potentially important for analyzing consumers' decisions and behavior. However, researchers should remember that the complexity of the interconnected cerebral regions and networks involved in any of those processes, require careful interpretation of the results (e.g. Phan et al. 2002). According to Solnais et al. (2013), the key brain mechanisms of interest for consumer research are those regarding: a) decision making and reward processing, b) attention and memory, c) emotions and motivation.

18.3.1 Decision Making and Reward Processing

The process of decision making is a core issue in all consumer research. The region of the brain especially involved in this process of assessing alternatives on the basis of potential benefits and costs, is the prefrontal cortex (PFC), situated in the frontal lobe of the brain (Solnais et al. 2013). The prefrontal cortex can be divided into smaller regions fulfilling different functions related to decision making: the orbitofrontal cortex (OFC), the ventromedial cortex (VMC) and the dorsolateral cortex (DLC) (Hubert and Kenning 2008). The VMC consists of interconnected regions that integrate information collected from affective sensory, value, long-term memory with representations of the 'self' (Karmarkar and Yoon 2016). For its close connection to the amygdala and hippocampus, the VMC is perceived as crucial for including emotions in the decision-making process (Wood and Grafman 2003). Together with OFC, parts of the prefrontal cortex encode various measures of individual subjective value, including for example a willingness-to-pay and the relative value of a product (Chib et al. 2009; Montague et al. 2006; FitzGerald et al. 2009). In turn, DLC is responsible for exerting self-control over emotions during choices, which is crucial for making optimal decisions (Karmarkar and Yoon 2016; Rilling et al. 2008). Another important brain region involved in decision making and preference formation is the brain reward system, responding to subjectively important rewards such as food or erotic pictures (e.g., Stark et al. 2006). Research regarding the activity of the rewards system included measurements of its activity in response to products perceived as attractive (e.g. symbols of social status and wealth), aesthetics of the product or influence of premium prices of different products (Solnais et al. 2013).

18.3.2 Attention and Memory

Because most of the marketing products (logos, advertising, packages etc.) are processed by the brain as visual stimuli (Solnais et al. 2013) measures provided by neuroscience offer useful insights into the consumers' attention processes. Also in the case of visual attention, the prefrontal cortex plays a crucial role that is responsible for directing attention to the subjectively most interesting or important stimuli. Some research also focuses on neural patterns related to advertising memory and product awareness, aiming at examining which advertisement or which part is particularly well remembered in comparison to forgotten advertisements. The part of the brain especially involved in the formation of memory, and its processing consolidation is the hippocampus (McGaugh 2008). Consolidation of memory is also improved by the activity of the amygdala, which is thought to be one of the most important modulators of the memory system in the brain (Solnais et al. 2013). Neuroscience studies on the consumer neuroscience of memory e.g. has demonstrated that the advertisements that produce localized brain activity in the left frontal hemisphere are also more likely to be memorable in the future (Rossiter et al. 2001).

18.3.3 Emotions and Motivation

Understanding the relationship between emotions and the process of decision making is of great importance for advertising as much research has shown that emotion-evoking marketing campaigns perform better in attracting consumers (Wood 2012; Bagozzi et al. 1999). A key region for processing emotional reaction in the brain is the amygdala, it is involved especially in responding to negative emotions, unknown stimuli and fear memory (Maren and Quirk 2004; Solnais et al. 2013). Positive and negative arousal and their effect are in turn processed in another crucial region for processing emotion—the insula. Research has shown that this region is particularly sensitive to risk, e.g. in the financial domain (Solnais et al. 2013). In addition, the anterior cingulate cortex has been related to the processing of internal conflict between cognitive and emotional/motivational factors regarding alternative choice options.

One of the most popular approaches in analyzing emotional processes on the neuronal level is based on the so-called frontal alpha asymmetry (FA), which is an indicator of the difference between the amount of alpha waves in the left and right frontal hemispheres of the brain (Ohme et al. 2010). The Frontal Asymmetry Index (FAI) is theoretically derived from a concept of two fundamental motivational systems, which organize behavior—approach and avoidance. The first involves behavior that is triggered by possible desirable outcomes (approach tendencies), the second involves behavior triggered by possible negative results (withdrawal tendencies) (Avila 2001; Ohme et al. 2010). According to Wheeler et al. (1993), the

left prefrontal cortex is related to the system that facilitates an approach behavior, whereas the right prefrontal cortex facilitates an avoidance of unpleasant stimuli. The amount of alpha waves in each of these regions indicates their level of activity, therefore the subtraction of alpha waves in the left hemisphere from the alpha waves in the right hemisphere indicates which of the two aforementioned behavioral systems is more dominant in a given moment. Research shows that the FAI could be a diagnostic tool in examining the potential for advertisements to generate approach related tendencies (Ohme et al. 2010).

18.4 Consumer Neuroscience in Practice

18.4.1 Neuromarketing—a Passing Fashion Or the Future of Market Research?

The last decade has brought an increased interest for using methods of neuroscience in marketing. The term "neuromarketing" has become very popular this is related to the practical implementation of obtained knowledge for managerial purposes (Solnais et al. 2013). Enthusiasts of this approach claimed that the discovery of these new techniques promised a "buy button" in the brain of the consumer (Daugherty et al. 2016). The possibility of an improved understanding of consumer decision making and their affective responses via an analysis of brain reactions has generated some enthusiasm among marketing companies—according to Plassman et al. (2015), most of the largest marketing research companies have started to use neuroscience methods in their research (e.g. Nielsen, Millward Brown, Ipsos). Market demands (including some of the largest companies such as Google) resulted in the development of specialized neuromarketing firms (Plassmann et al. 2012).

After this large amount of enthusiasm around "neuromarketing", which assumed that we can discover "real" and "true" reactions to the market (including advertising) and therefore give better recommendations to the client (Zurawicki 2010), marketing researchers and marketing companies have more doubts about the practical use of methods that come from neuroscience. Even though it was predicted that neuromarketing would dominate practical advertising pre-testing methods, rejecting more traditional ones (such as qualitative IDIs or FGIs or quantitative one—see more Maison 2005), this is not happening. When we look at the ESOMAR (European Society of Opinion and Marketing Research) annual reports, marketing research based on neurophysiological measures are still marginal, and their role in practice has not grown during the last 20 years. This is probably the consequence of the complexity of those methods and still the big difficulty in its interpretation.

Moreover, nowadays more and more people claim that rather than the popular term of "neuromarketing", the term "consumer neuroscience" is more appropriate. This term is not directly linking neuroscience measures with managerial decisions

(as was the case when using the "neuromarketing" term), but rather it is stressing the new methods, tools and measurements which are used when trying to understand the consumer. Managerial decisions, like in traditional marketing research, might or might not be linked to the data obtained from such research. However, in this situation we still have to make one crucial distinction: between "consumer neuroscience" as a scientific field aimed at understanding basic consumer processes and "applied consumer neuroscience", which is a marketing research tool that helps in making a managerial decision (however not so directly as it was assumed in neuromarketing).

18.4.2 Applied Consumer Neuroscience—Neurophysiology in Marketing Research Practice

Daugherty et al. (2016) identified two main reasons for this spectacular growth of business interest in neuroscience: (a) the comparison between scientific measurement and typical marketing research methods (like surveys or focus groups), where the first are more objective and precise, and (b) understanding that this kind of research could offer marketing companies the possibility of a reduction in uncertainty in a more cost-effective way. However the practice showed that first of all these methods do not give very clear and reliable answers to managerial questions, secondly they are not as cost-effective as was expected.

Fisher et al. (2010) suggested that the relatively small amount of reliable research in peer-reviewed journals may indicate that companies make premature claims about the ability of neuroscience to predict consumer behavior. It is important to remember, that brain responses (and other psychophysiological measures) are frequently not specific to only one stimulus or reaction. For example, neuroscientific methods are currently better at revealing positive or negative emotional responses, but not in measuring which specific emotion was experienced by the subject (O'Connell et al. 2011). The main goals of consumer neuroscience is to identify small changes in the brain's response to a given part of commercial stimuli, providing information about an appreciation of it which would not be obtainable by self-descriptive, explicit methods. The results promised by a neuroscientific method is based on the assumption that people cannot (or do not want to) explain their preferences when explicitly asked, because human behavior can be driven by processes operating below the level of awareness and analyzing brain traces of this motivation could help in bringing them to light. Moreover, identifying how the brain responds to marketing information would increase the marketing company's knowledge not only about preferences but also about the processes shaping them (Kenning and Plassmann 2008). In addition, neuroscientific methods allow us to simultaneously track consumers' neural responses and the presented marketing stimuli, decreasing the possibility of a recall bias associated with self-reporting measures (Solnais et al. 2013; Sudman and Bradburn 1973). Whereas the first research in

consumer neuroscience aimed at explaining the basic rules, e.g. how the value, preference and marketing-related concepts are encoded in the brain, current experiments focus on applying basic results to explain more complex processes, e.g. how the consumer responds to price, brands, persuasive messages, and a range of other marketing-related factors (Karmarkar and Yoon 2016).

The most widely used tool in neuroscience marketing research practice is eye-tracking which is mostly used to track visual attention to advertising, internet pages, packages and other visual materials (Sørensen 2008). This system became popular thanks to some very well developed equipment with a very good and easy to implement interface (e.g. provided by TOBII—www.tobii.com and SMI—SensoMotoric Instruments http://www.smivision.com).

For practical research purposes, EEG is much less popular, however its popularity is growing with the introduction of relatively low cost EEG systems and portable equipment like Emotiv (www.emotiv.com) or NeuroSky (www.neurosky.com). Despite having worse sensitivity and parameters than professional equipment used in scientific research, they have been proven to collect data of enough quality to reliably analyze different brain patterns related to personality or behavior. Such systems are very often portable, enabling the recording of brain activity in different real-life circumstances, as for example in supermarkets—however, conducting EEG experiments outside standardized laboratory conditions is often connected with a worse signal quality and some difficulties with the interpretation of the results. In marketing research, the EEG technique was used in testing new campaigns, moving trailers, website design and usability research, examining an in-store experience or key moments in an advertisement (Solnais et al. 2013). The last tool—fMRI—despite popularity in neuroscientific research, this technique is not widely used in marketing research due to equipment and operating costs (Telpaz et al. 2015).

There is no doubt that consumer neuroscience is a very important field of research aimed at a better understanding of consumer processes. However, wide use of those methods in marketing research practice is still very questionable and limited. Thus, neuroscientific measures in their current form are still perceived in marketing research rather as a useful addition, and not necessarily a replacement of classical methods. Nevertheless, there is still a big potential for using neuromeasures in scientific experimental research to better understand consumer and economic processes.

18.5 Research Goal

In reviewing research on consumer neuroscience, we observed that currently research is mainly limited to commercial advertisements. Therefore, the first goal of our research was to examine the possibility of using the neuroscience method in the field of social campaigns (PSA—public service announcement). In our research project we constrained ourselves to investigate only Frontal Asymmetry Index (FAI)—one of the EEG indicators. Much research has shown that frontal

asymmetry index could be a useful tool for assessing an implicit approach-avoidance reaction toward commercial ads (Ohme et al. 2010), therefore we assumed that it could be also applied to social ads (PSA). To record brain waves we used the Emotiv—tool more popular in marketing research than in scientific research, however its popularity in consumer neuroscience is growing (e.g. Badcock et al. 2013). Until now in the majority of research studying the application of EEG to advertising testing, the EEG signal toward advertising was confronted with an explicit attitude toward the same advertising (usually liking the ad). It means, the EEG and its declarations referred to the same object. Therefore the second aim of our research project was to investigate the relation between a brain waves (FAI) reaction toward the object (advertising or picture) when confronted with a more general attitude toward an issue related to the visual material (social or political attitudes of the participant). It means that in our study, the EEG and its declarations referred to a different object. Moreover we assume that neurophysiological measures (including EEG) is the best tool to study reactions toward controversial and ambiguous objects, because in such situations people might not be conscious of their attitudes toward an object or might want to hide them. Therefore in the first study we chose as our research object the political candidates for a presidential election and for the second study we chose some social advertising (PSA) that refers to homosexuality.

18.6 The Relation Between EEG (Frontal Asymmetry) and Attitude Toward an Advertised Object

18.6.1 Study 1—EEG Reaction Toward Political Candidates in Relation to Political Preferences and Level of Tolerance

The goal of the first study was to see whether EEG (Frontal Asymmetry Index) reaction to pictures presenting the faces of political candidates could reflect the political attitudes of the respondents.

18.6.1.1 Participants and Stimuli

Thirty-three persons (19 females) took part in the experiment. The study was conducted at the University of Warsaw just before the presidential election.

We measured the brain waves reaction to presented pictures of two candidates representing polarized parties. One picture depicted the former president Bronisław Komorowski, seeking re-election, a candidate associated with the center-liberal Civic Platform (PO) and a very well recognized politician in Poland (among other reasons, because of being a former president). The second picture showed Andrzej

Duda, a candidate of the conservative Law and Justice party (PiS), who had become recognized only after his decision to start a presidential campaign. Pictures were downloaded from the Internet using the Creative Commons license. The pictures of the presidential candidates were presented in order of rotation and in the context of other controlled stimulus. During the presentation of these materials on the computer screen to respondents, their brain waves were recorded.

Prior to the stimuli presentation the respondents were answering two questions regarding their level of liberalism (on a six point scale, from "I am a very conservative person" to "I am a very liberal person") and regarding their level of tolerance (on a six point scale, from "I am definitely intolerant" to "I am definitely tolerant").

18.6.1.2 Electrophysiological Recording and Data Preparation

The photographs of the presidential candidates were randomly presented to the participants on a computer screen while their brain responses were recorded by EMOTIV EPOC EEG system (www.emotiv.com) (Fig. 18.1a). Before showing the experiment stimuli, their baseline brain activity was computed during a one-minute rest session with their eyes closed. The Emotiv EPOC is a EEG device, containing 14 electrodes and operates as a wireless, portable system with a sampling rate of 128 HZ. The available electrodes are AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8 and AF4, where the letters F, T, P, C and O stands for frontal, temporal, parietal, central and occipital lobes (Fig. 18.1b).

Raw EEG data was processed offline using the EEGLAB, an application working in a MATLAB environment. In the first step, muscle and eye-movement artifacts were removed using the Independent Component Analysis (Delorme and Makeig 2004). This process is of extreme importance in order to remove the part of the signal not connected with reactions to the stimuli. Having the artifacts removed from the signal, the power of alpha oscillations (8–13 Hz) were extracted with a fast Fourier

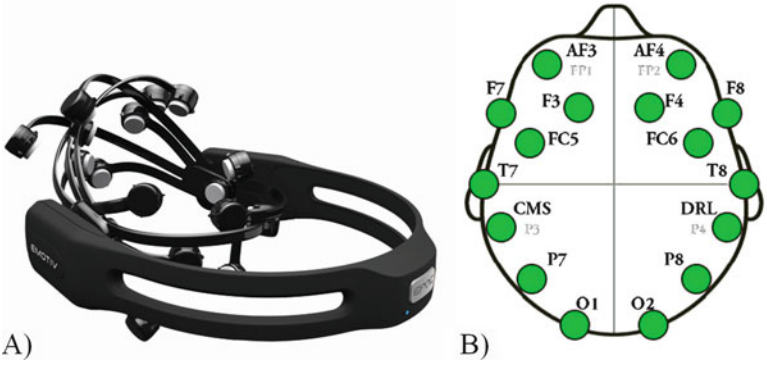

Fig. 18.1 (**a**) Emotiv EEG system. (**b**) Electrodes topography (pictures downloaded from the Internet by the Creative Commons license)

Table 18.2 Correlations between EEG (FAI) for presidential candidates and general political attitudes

	Frontal Asymmetry Index (FAI)—conservative candidate (Andrzej Duda)	Frontal Asymmetry Index (FAI)—liberal candidate (Bronisław Komorowski)
Level of tolerance (declaration)	-0.33^{+}	0.02
Level of conservatism (declaration)	0.03	-0.42^{*}

$^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}$ $p < 0.08$

transform (Harmon-Jones and Gable 2009). In the next step, to examine the relative activities of the right and left hemispheres of the brain, the frontal asymmetry index (FAI) was used. The FAI is understood as a difference between the natural logarithms of alpha power response of the right and left hemispheres of the brain, after the subtraction of the baseline. Regarding the fact that alpha waves are inversely related to brain activity, higher scores of FA index indicate a relatively greater left frontal activity—what could be interpreted on a psychological level as an approach reaction. We computed Frontal Asymmetry Index (FAI) from electrodes AF4 and AF3.

18.6.1.3 Results

Correlations between FAI in response to the photographs of the two presidential candidates, and the declaration of conservative and tolerant attitudes are presented in Table 18.2. FAI observed that the displaying of the photo of the liberal candidate Bronislaw Komorowski was negatively correlated with conservative attitudes declared by participants. This means that less conservative people had a more positive brain wave reaction toward this candidate (expressing an approaching reaction). In addition, we observed a marginally significant negative correlation between the frontal asymmetry approach index for the conservative candidate Andrzej Duda and the declaration of a level of tolerance, which may be interpreted as an avoidance reaction toward him of more tolerant people.

18.6.2 Study 2—EEG Reaction Toward Social Advertising Referring to Homosexuality in Relation to Attitudes Toward Homosexuality

The goal of the second study was to see whether the EEG (Frontal Asymmetry Index) reaction to two items of social advertising could reflect the attitudes of respondents toward homosexuality.

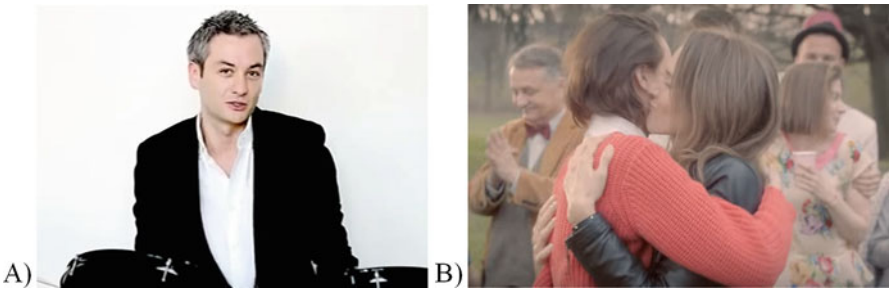

Fig. 18.2 (**a**) Campaign against Homophoby ad (**b**) "I live with a stranger" ad

18.6.2.1 Participants and Stimuli

Thirty-three persons (19 females) took part in the experiment (the same as in study 1). At the beginning all of them filled in a questionnaire measuring their attitudes toward homosexual people. The scale consisted of six items (e.g. "Homosexual people should have the right to marry") and respondents gave answers on a 6-point scale (from 1-I strongly disagree, to 6-I strongly agree) (Cronbach's $\alpha = 0.85$). During further analysis one indicator of attitudes was used toward homosexuality (average of all 6 items) where lower values indicated a more negative attitude (lower level of tolerance) and higher values indicated a more positive attitude (higher level of tolerance).

In the study there were two social advertisements used (PSA):

1. The first ad was created in 2011 by the agency Lowe GGK Warszawa as part of a social campaign, to convince people to donate 1 percent of their tax to the organization "Campaign Against Homophobia" (CAH). In this advertisement, Robert Biedroń (co-founder of CAH and currently president of Słupsk city), ironically persuades homophobic people to "make him redundant" by supporting CAH actions (Fig. 18.2a).
2. The second advertisement, "I live with a stranger", was also created by the agency Lowe GGK Warszawa in 2014 for the organization Partnership for Relationships. A 90-second spot shows the daily life of a young woman, viewed from the perspective of her close partner. Intimacy and warmth between the two people is contrasted with the narration, saying e.g.: "I wake up next to a stranger", "I laugh with a stranger" The reason for using the word "stranger" to describe this intimate relationship is in Polish law, according to which people living in partner relationships are treated as single (Fig. 18.2b).

18.6.2.2 Electrophysiological Recording and Data Analysis

For the pre-processing of EEG data, the chosen electrodes and the methods of analysis of the Frontal Asymmetry Index was the same as in Study 1.

Table 18.3 Correlations between EEG (FAI) for social campaigns and acceptance toward homosexual persons

	Frontal Asymmetry Index (FAI)	Frontal Asymetry Index (FAI)
	Advertising A	Advertising B
	"Campaign Against Homophobia"	"I live with a stranger"
Acceptance of homosexuality	0.40^{*}	0.36^{+}

$^{*}p < 0.05$, $^{+}$ $p < 0.08$

18.6.2.3 Results

We conducted an analysis of correlation between the acceptance of homosexual persons and FAI in response to two social campaign ads. Acceptance of homosexuality correlated positively with FAI (expressing an approach reaction) in the case of the Campaign Against Homophobia. In addition, we observed a marginally significant positive correlation between this attitude and FAI indicating an approach reaction to the second ad, "I live with a stranger" (Table 18.3). This means that in the case of both ads, people with a more positive attitude toward homosexuality were reacting more positively on the brain wave level (FAI) to advertising claiming tolerance to homosexuality.

18.7 Conclusions

Both conducted studies showed that brain waves (measured by EEG Frontal Asymmetry Index) reacted differently to researched objects depending on the attitudes of the participants. People who declared themselves to be more conservative showed a more negative reaction to the liberal candidate (interpretation based on brain waves—EEG). Similarly in the case of social advertising related to homosexuality. People who were more tolerant toward homosexuality (attitude scale) were consistent with their attitudes when reacting to the presented ads on the brain waves level. Those who were less tolerant had a Frontal Asymmetry Index expressing a more negative reaction toward those ads. Thus, we could show that the EEG frontal asymmetry could be used in consumer neuroscience research not only as an indicator of "liking" the advertisement, but also as a marker of an individual's political and ideological beliefs.

This presented data shows a big potential for using methods coming from neuroscience to better understand consumer processes in the field of experimental economics. Its potential for better understanding people's reaction toward advertising is without question. Moreover, the application of these methods in experimental economics will grow because of the introduction of a more non-invasive method for the subject, a lowering of price for the tools and the use of better

computation methods. However, thinking that those methods are better than the traditional one is a mistake. We should handle them as supplementary methods to the traditional one (based on declaration) and apply a multi-method approach when doing scientific research in consumer and advertising studies.

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Chapter 19
Assessing Cerebral and Emotional Activity During the Purchase of Fruit and Vegetable Products in the Supermarkets

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Abstract In this chapter, we presented the findings of an experiment aimed to investigate cerebral and emotional activity during the purchase of fruit and vegetable products in a supermarket. In particular, we measured the brain activity—through the electroencephalogram (EEG)—and the eye gaze of individuals visiting specific areas of a supermarket, and focused particularly on the purchase of some products in the fruit and vegetables department. The group was equally divided according to the occupation (50% workers and 50% non-workers), and chosen on the basis of specific socio-demographic features and of intrinsic characteristics, like the sensitivity to local rather than global food. Comparisons of neuro- and biometric indices previously defined (pleasantness, memorization, interest and, emotion) have been performed to highlight differences between the customers' perception of the products—also compared to other product categories. Findings show how EEG

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_19

methodologies, along with the measurements of autonomic variables, could be used to obtain information not obtainable otherwise with verbal interviews. The analysis of the emotions aroused during the shopping experience, investigated with modern techniques of brain-marketing, could help to analyze the perception of fruit and vegetable products—whose consumption is in decline in Italy since this is not an 'emotionally appealing' product category—according to the consumer's actions and emotions.

Keywords EEG • Eye-Tracking • Emotion • Memorization • Interest • Pleasantness • Brain-Marketing

19.1 Introduction

In Italy, fruit and vegetables' consumption is increasingly declining: notwithstanding the industry's commitment in fighting this trend, and a certain health enthusiasm among the Italians, this tendency does not seem to stop. However, according to Agroter's Fruit and Vegetables Monitor, several sales managers—interviewed in the last eleven years about this topic—give a contrary perception: according to their words, the fruit and vegetable consumption is growing. However, this perception clashes with reality, with that silent and insidious decline in fruit and vegetables' consumption that begins in the store during the purchase and goes on when the consumers taste the products and decide whether or not to buy them again (whether or not, therefore, there is the so-called 'customer satisfaction').

According to previous analyses conducted in the retail stores—and in order to better understand the gap between perception and reality—Agroter, in partnership with BrainSigns (a spin-off of the University of Rome Sapienza), has focused its Monitor Ortofrutta 2016 around the first experiment of brain-marketing in Italy entirely dedicated to the fruit and vegetables market. Furthermore—so as to close the circle of the "buy-back" process—during the launch of the Special Fruit & Vegetables 2016 (December 2, Milan), the results of another particular experiment were presented: here, the purpose was to investigate the actual level of the consumers' willingness-to-pay for a product that satisfies taste, sight and brain. Thanks to the use of modern technologies, this experiment has allowed understanding if fruit and vegetables are sold at a price that is perceived too high or too low.

BrainSigns is a spin-off of the University of Rome "Sapienza", which develops innovation from scientific knowledge by recording and analyzing the brain activity's signals, as well as those ones resulting from other physiological processes. This methodology is applied to several tasks, and in particular, in those fields of interests for the companies; in fact, monitoring the consumers' instinctive reactions can generate value for a company since it helps to improve communications, products and internal processes. The recording techniques of these signals are at the forefront of the scientific knowledge, in collaboration with the scientists of the "EEG laboratories at high spatial resolution" of "Sapienza University of

Rome" (the first Italian laboratory in this field since 1989). The need to use neurometric measurements of consumer's brain activity derive from the fact that standard marketing techniques, so far employed, involved the use of an interview and the compilation of a questionnaire after the exposition to novel commercial ads before the massive launch of the ad itself (ad pre-test). However, it is now recognized that often the verbal advertising pre-testing is flawed by the respondents' cognitive processes activated during the interview, being the implicit memory and subject's feelings often inaccessible to the interviewer that uses traditional techniques (Zaltman 2003). In addition, it was also suggested that the interviewer on this typical pre-testing interviews has a great influence on what respondent recalls and on the subjective experiencing of it (McDonald 2003; Franzen and Bouwman 2001).

Taking all these considerations in mind, researchers have attempted to investigate the signs of the brain activity correlated with an increase of attention, memory or emotional engagement during the observation of such commercial ads. Researchers within the consumer neuroscience community promote the view that findings and methods from neuroscience complement and illuminate existing knowledge in consumer research in order to better understand consumer behavior (e.g., Ambler et al. 2000; Klucharev et al. 2008).

19.2 Methodology and Sample

The test, which has been conducted in October, measured the brain activity and the eye gaze of individuals visiting specific areas of a supermarket, and focused particularly on the purchase of some products in the fruit and vegetables section. The experiments have been conducted in Rome, during the opening hours (in order to better simulate the shopping experience) of a store belonging to one of the leader chains of the Italian retailing: Conad, with its cooperative Pac 2000A. The sample involved in the experiment consisted of 20 buyers, chosen on the basis of specific socio-demographic features—in view of results as representative as possible—and on the basis of intrinsic characteristics, like the degree of sensitivity to purchasing local/Zero Food Miles products, or the greater or lesser difficulty in choosing among many alternatives with/without 'cognitive closure'. Deciding to set in-store the experiment has been very important in approaching and analyzing as much as possible a real situation, leading thus to a certain degree of confidence in the results. The sample size employed was of 20 persons, in which 30% were man and 70% women. Age distribution was 20% <34 years, 40% in the range of 35–54 y.o. and the remaining 40% was superior to 55 years. For all concerns the occupation they were 50% workers e 50% housewives/students/in retirement. The sample was also balanced in terms of Global and Local consumers. The latter are consumers oriented toward local productions and particularly respectful of their own gastronomic traditions.

During the day of the experimental observation, the testers had to respond to different stimuli: they have had a vis-a-vis contact in the store with a farmer, they have been in diverse departments—exhibiting different products' categories—and

Fig. 19.1 EEG headset (electroencephalogram) and eye-tracker glasses during the experience

they have dealt with brands different from the ones normally sold in that store, in order to measure the brands' impact on the customer. It is worth mentioning that, even if a sample of 20 individuals can be deemed not representative of the consumer behavior, in the brain-marketing research (thanks to the use of proper statistical models), the latter is enough to lead to significant results.

Unlike than in the traditional market researches, the experimental subjects' physiological reaction to the proposed stimuli here has been assessed with technologies monitoring the "biofeedback". Specifically, after having informed the participants of the experimental nature of the test, they have been asked to wear the equipment needed for the acquisition of the electroencephalographic signal (EEG headset) and for the monitoring of the eye gaze (by using an eye-tracking device) (Fig. 19.1).

The experiment participants—who had a shopping cart with them—have been asked to visit some store departments, among which: the Fruit and Vegetables' one, the Biscuits' one and the Soaps' one. The subjects brought with them a shopping list, according to which, they had to buy some particular products. In the end of the store visit, every tester has been asked to fill in a brief questionnaire concerning the purchased products, so as to compare the tester's perception of every product with the information he/she stored about that very same product at a conscious level. These information have been then crossed with the neurometric indexes (resulting from the brain-marketing devices utilized), among which: memorization, attention, pleasantness and workload—the so-called "mental workload", or "cognitive effort". Details on the employed indexes are provided in previous publications

(Vecchiato et al. 2013, 2015). The use of EEG allows following the brain activity on a millisecond base, bearing in mind that the recorded EEG signals are mainly due to the activity generated on the cortical structures of the brain. In fact, the electromagnetic activity elicited by deep structures advocated for the generation of emotional processing in humans is almost impossible to gather from usual superficial EEG electrodes (Nunez and Cutillo 1995; Urbano et al. 1998). However, nowadays high-resolution EEG (hrEEG) technology has been developed to enhance the poor spatial information content of the EEG activity in order to detect the brain activity with a spatial resolution of a square centimeters and the unsurpassed time resolution of milliseconds (Nunez and Cutillo 1995; Bai et al. 2007; He et al. 1999; Dale et al. 2000; Babiloni et al. 2005).

19.3 Results

19.3.1 The Department "Emotions"

The first evidence of the analysis is very explanatory: there is a continuous decline in the consumption of fruit and vegetables, and it starts in the retail store. In Italy, in fact, as already proved for the United States, the fruit and vegetables department stimulates our brain less than other grocery's departments. A very clear example is the comparison—during the purchasing phase—between the category 'fruit', the category 'vegetables' (included the fourth and fifth range) and shelf dedicated to the biscuits: in our sample, unlike the purchase of fruit and vegetables, the purchases of wafers has generated higher values of all the neurometric indexes—in particular, a greater level of gratification (pleasantness): one of the best predictors of the customers' future purchasing behavior (Fig. 19.2).

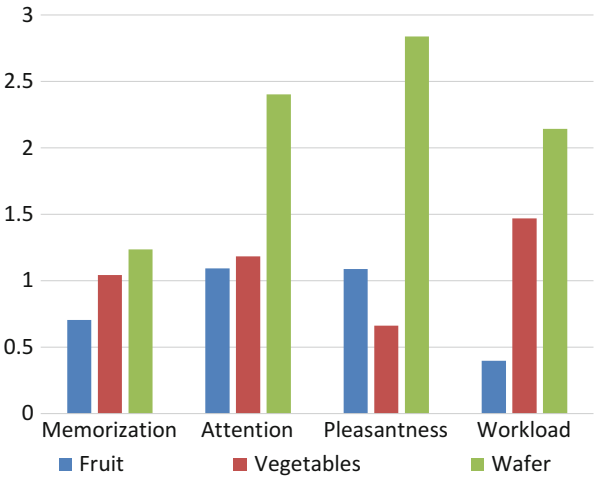

Fig. 19.2 The figure shows the levels of the different neurometric indexes measured during the purchase of the different products by the subjects during the experience. Results are given as average of the total sample investigated (own elaboration)

Fig. 19.3 Figure shows the shelf on which the vegetables and the products packaged such as salads were placed in the experiment

From a deeper analysis carried out in the fruit and vegetables department, it is possible to note the presence of substantial differences in the purchase of fruit (bananas and apples) and vegetables (tomatoes, fourth range and ready-made products).Meanwhile, from the analysis on the total sample of the neurometric indexes' average values, the results showed that the pleasantness index was higher for the purchase of the fruit than for the purchase of vegetables.

Therefore, the fruit and vegetables department could be ideally divided in two different parts, and this is probably due to the immediate palatability of the fruit compared to the vegetables. Moreover, the brain workload values—correlated to a greater difficulty in taking decisions—are higher during the choice of vegetables than during the choice of fruit, mainly for the presence of the refrigerated aisle, which included a higher number of references. Within the products purchased in the fruit department during the experiment, the area of the refrigerated aisle then showed levels of attention and pleasantness lower than those arising when the subjects were purchasing apples, tomatoes and bananas. Although the values are not statistically significant, they are still indicative of a trend that could be better verified by enlarging the number of observations. The shelf of the fourth and fifth range is, therefore, one of the most "emotionally cold spots" of the whole store (Fig. 19.3).

From the first preliminary analysis emerges thus a fruit and vegetables department that does not transmit emotions, even though its superior layout, shelves and exposition, as well as the visual merchandising and quality of the products. Here comes therefore the first critical point, already suggested by some American studies: fruits and vegetables are less stimulating than other products in the store, maybe because they are primordial elements compared to more thrilling packaged industrial products? Or maybe because of the lack of promotion and communication by

the producers and the distributors of the field? What is certain is that giving emotion is a possible thing, but not everybody knows the right way to do that.

19.3.2 Emotion Does Not Remember, but Pays

The packaging and the countless graphic customizations are just two of the many tools at disposal of the fruit and vegetable industry that are able to elevate or reduce the level of pleasantness and emotion. Inside the fruit and vegetables department of the store chosen for our research, the experiment has provided—as an "ad hoc sales promotion"—a Golden apple box, sold at the price of 2.25 euro/Kilo. The box has been presented in three different graphic variations: (1) a fully light brown one (in order to simulate a "natural packaging"); (2) a white box with just few words written on the surface: "Golden Apples" (a "descriptive" communication); (3) the third box reported, on the short side, several faces of different farmers and, on its long side, evocative images of flourishing apple orchards.In addition, during the test day, the positions of these three different boxes have been randomized, in order to avoid selection bias induced by the flow of customers in the department. The peculiarity of the third version resided also in the multiplicity of images in the pallets; in fact thanks to the new digital printing technology on corrugated board, it has been possible to include in this test more than 20 farmers' faces (two on every box), so as to test their visual and emotional impact (Fig. 19.4).

Fig. 19.4 Detail of the three boxes of identical apples but with different packages. The center package is printed with digital technology. The picture shows also the region of interest and the concentration of the eyegazes by all the subjected during the observation of the apple boxes. The greatest intensity of shades characterizes the areas that have collected the highest percentage of eye-gazes

Let us start from the most concrete results: 12 out of 20 testers (20%), that had in their shopping list the goal of buying only one apple box, have bought those apple 'branded' with the farmers' faces, while just 4 out of 20 people have chose the fully light brown packaging, and as well four subjects have chosen the box with the words 'Golden Apples'. Therefore, the ratio between the commercial income and the sales is 1:3 in favor of the packaging with the faces, and this is confirmed also by the purchases of all the non-tester customers that have shopped in the store during the experimentation day. Despite the apples inside the three graphic versions were identical (same kind, same quality), the customers' and the testers' preference has been clear. However, the reason for that does not reside in the conscious part of our brain.

As a proof of this, we can analyze the results of the questionnaire filled in by the testers immediately after the check-out: only 3 out of the 12 people who had purchased the apple boxes with the farmers' brands, spontaneously remembered the presence of faces or landscapes. The absence of memorization at a rational level—together with the fact that all the testers that had seen the farmers' faces on the top cases then bought that version of the packaging—determines an instinctive/unconscious effect of the faces in the customers' minds.

To further support this argument, also the fact that the sample's eye gaze has focused more on the boxes with the faces than on the other ones. Moreover, it has been noted that the boxes with the farmers' brand have brought the testers to focus more intensely on the apples within them, unlike what has happened with the apples contained in the other two box's versions. This suggests that the packaging, which always gathers, averagely, less than a third of the eye gazes than the product contained, in this case represents the "trigger" that elicits the interest and the emotion of the customer. The latter then transfers these feelings on the apple: the main protagonist during the purchasing process.

So, the product has a central role in the customers' observations. And the customer, who are driven by the restless research of the 'perfect product'—the most appropriate one for themselves and for their families—are unconsciously reassured by the farmers' faces, even though they do not remember it.

19.3.3 "Global" or "Local": The Power of the Faces Is Transversal to These Two Customers' Categories

Contrary to the expectations, there have been no statistically significant differences between the "Global" groups and the "Local" ones at the sight of the boxes' three graphic proposals—even for what concerns the apples (the product). But the eye gaze is not the only "clue" observed: thanks to the EEG helmet, during the purchasing phase the most important neurometric indexes have been measured too, and these one further justify the overwhelming victory of the boxes with the faces and landscapes. In fact, the testers who chose this version have lived a more pleasant and more attentive purchasing experience, on the contrary of those subjects

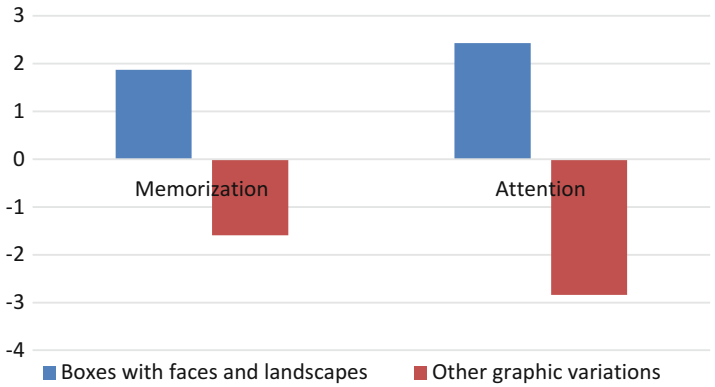

Fig. 19.5 Testers' neurometric values, arisen while purchasing the apples, grouped by different kinds of packaging. Values are expressed in z-score and are referring to the total sample investigated (own elaboration)

who have purchased the apples contained in the other two types of packaging. The experiment not only demonstrates that specific graphic subjects can attract the eye of the customer, but also that it is possible to significantly raise the level of "emotion" within the department. This represents a concrete commercial result, which enhances the quality of the products and allows people to get away as far as possible from the perception of "commodity" (Fig. 19.5).

19.3.4 Fourth and Fifth Range: The Cold Chain Is 'On Top'

Packaging can be seen as an emotional leverage, but also as an aid to simplify the product exhibition: this is, in short, the aim of the fruit and vegetable department's refrigerated aisle. The latter, in recent years, has been strongly enriched by new references: including products of the fifth range, with numerous product segmentations—actually more perceived by attentive experts, perhaps, than the customers.

The large and nebulous shelf exposure undergoes frantic adjustments in the sequences and in the number of facings—according to promotions, new suppliers, optimization of the unsold stocks and sales performance, as well as other various reasons—with the result of often creating an exhibition that the customers perceive as confusing.

As already mentioned, the refrigerated lane containing mostly fruits and vegetables of fourth and fifth range requires higher levels of cognitive engagement during the purchase, if compared to the levels required by the purchases of other product of this very same department—like bananas, tomatoes in tubs and apple boxes—which, on the other hand, provide to the customers lower levels of pleasantness. So many products, exposed in a disorganized way and not very sympathetic, need a greater commitment from the production and distribution side, in order to further develop a market that already enjoys wide prospects.

Fig. 19.6 Figure shows respectively the shelf before (**a**) and after (**b**) the product reorganization. Half experimental sample watched the shelf (**a**) and half watched the shelf (**b**). The second shelf have received the largest number of fixations by the experimental groups and higher values of appreciation when compared to the first one

For this reason, during the testing day inside the store, two types of exposure have been proposed—(almost) without changing the products references: (1) the first was a classical exhibition typology, led by the daily operations logic and by the on-going promotions: here, the innovative and premium products were placed at the top, while the lowest priced products were placed on the bottom; (2) the second exhibition typology was designed on the basis of the category management, vertically organized on three product families: the simple salads (mono), the area from the main dishes to the fruit (innovation) and the mixed salads (Fig. 19.6).

During the task of purchasing a packaged mixed salad, the 20 experimental subjects—that have been monitored with the eye-tracker- have focused their gaze in different ways.

In the case of the classical exhibition layout (the first one), the largest number of the eye gazes fell on the lowest rack, which contained the lowest priced products, confuting thus the dogma according to which the eye usually focuses on an height corresponding to the one of the face/shoulders. In fact, the higher concentration of

Fig. 19.7 The figure shows the intensity of the eyegazes received by the shelf arranged in the original disposition (**a**) and in the tested ones (**b**). The shadows overimposed on the picture summarizing the total fixations on the three product families involved in the purchasing phase: mixed salads and ready-made products. The greatest intensity of shadows characterizes the areas that have collected the highest percentage of eye-gazes

mixed salads' references was placed precisely in this area, leaving the third and fourth racks almost devoid of products.

The contrary situation can be outlined for the second exhibition layout (the one falling under the category logic), which attracted the eye-gazes mainly on its second, third and fourth shelves, involving thus a larger number of products. The products' exposition strongly influences the shopping experience, and can lead the consumers to unnatural (and unwelcome) behaviors (Fig. 19.7).

From a comparison of the two exhibitions' layouts, it can be noted that the number of fixations during the purchasing process of the mixed salad was superior in the display vertically organized, (the second kind). By calculating the total number of fixations on the refrigerated aisle, of all the 20 testers during their purchase of both the products, the results show that almost the 40% was recorded on references of fourth range in the rearranged shelf.

The situation is different for what concerns the ready-made products that, in both the exhibition layout versions, have captured the same number of eye-gazes. From a first glance at the data, it can be seen that the greatest benefit of a shelve vertically

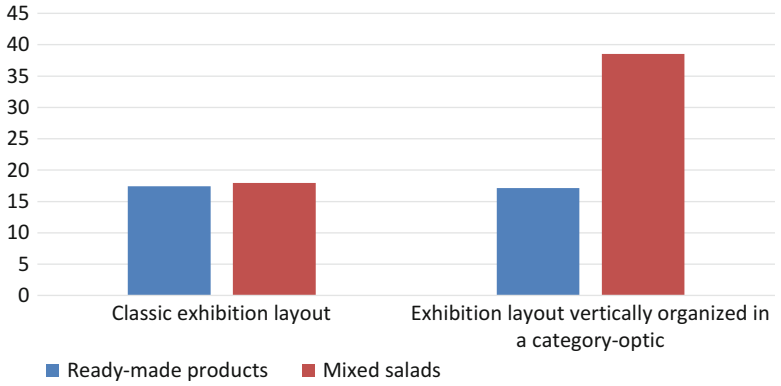

Fig. 19.8 Testers' total number of fixations during their purchasing of the fourth and fifth range products of the refrigerated aisle. The classic exhibition layout refers to the shelf arranged in the (**a**) positions of the Figs. 19.6 and 19.7 (own elaboration)

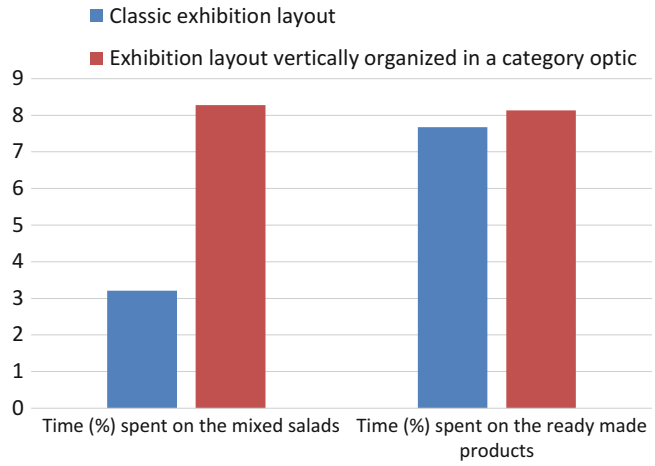

Fig. 19.9 Percentages of time spent by the testers in watching different kind of products exhibited in the refrigerated aisle. Same conventions as above (own elaboration)

organized 'according to product families' is the rationalization and distribution along the rack of the largest families, such as the one of the mixed salad (Fig. 19.8).

During the purchase of the ready-made product, in fact, there have been no significant differences in the number of eye-gazes regardless the exhibition layout, since the products belonging to this family (ready-made products) were in numerically reduced and merged.

So, from a first data analysis—yet to be further developed—emerges a higher comparison of the offer and a more informed purchasing when dealing with the mixed salads in their "vertically organized" version (Fig. 19.9).

This is due to the higher average time spent by the buyers in the evaluation of the products for sale, many of which had been ignored in the classic layout without vertical organization. With these suggestions, based on the preliminary analysis of the sample, it is possible to understand the great possibilities that the brain-marketing provides to the fourth and fifth range industry, along with: field observations, customers' interviews and a category-oriented management. The future of the category lies in an intuitive exhibition layout, first of all, and then in the management of the emotions.

19.3.5 The Farmer's Comeback to the Store

What could be the effect given by the presence of the farmers in the stores, if even their faces arouse emotion when printed the packaging?

In order understand this impact, we have provided for a meeting between ten subjects out of the total sample (20) and a farmer together with his products, outside the store. The farmer had the task to brief the subjects about history and the values of his own work—and, specifically, of his tomatoes—before they started to shop in the store. The effect in the ten testers who met the farmer are the following ones: in addition to a higher percentage of purchases of the products promoted by the farmer, during the purchasing process, the subjects showed neurometric values higher than those of the rest of the sample. The meeting with the farmer has fostered memorization, attention, pleasantness and workload during the purchasing process, demonstrating thus how his storytelling outside the shop was effectively transmitted to the customers and influenced them even several minutes later after the meeting (Figs. 19.10 and 19.11).

Fig. 19.10 Farmer explaining history and values of his work and products to the testers, before they start their shopping experience

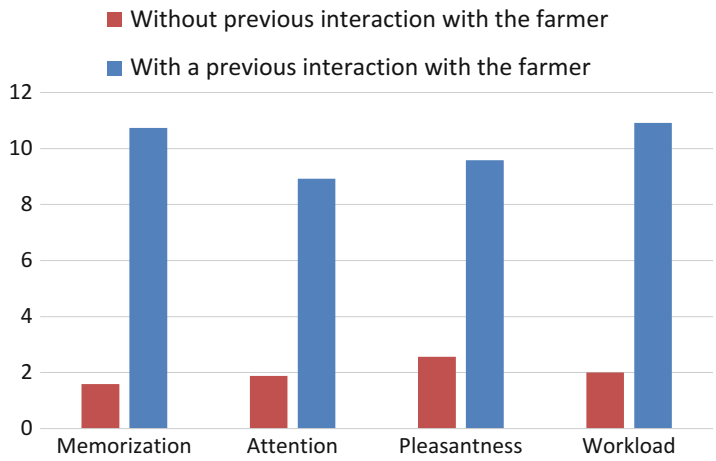

Fig. 19.11 Testers' neurometric values aroused while choosing which tomatoes in tubs to buy. It is clearly observed as the meeting with the farmer before the shopping arose the neurometric indexes related to the purchasing of the specific product publicized (e.g. tomatoes)

19.4 Conclusions

Through these observations, statistically significant for the investigated stimuli, it has been demonstrated that the "coldest" department of the store (the fruit and vegetable one), has the potentialities to fully engage the customers on the emotional level. And the store itself is the first place where this engagement can take place of in order to revitalize the fruit and vegetable consumption.

Innovative packaging, perfumes, exhibition, storytelling, simplicity and clarity are just some of the practices that should be further explored through an all-encompassing analysis that takes into account:

1. the customers' perception—investigated through interviews and questionnaires, even online;
2. the monitoring of the actions, thanks to big data, sales data and on-field observations,
3. the analysis of the emotions aroused during the shopping experience, investigated with the most modern techniques of brain-marketing.

For the future revival of the fruit and vegetable department, the production and distribution managers will have to consider all these three aspects of the research, in order to promote informed decisions that are as well in line with the real "owner" of the chain, that is the consumer. The present research demonstrates the value of the neurometric techniques applied in the context of the food selection in a supermarket. Other examples have been already provided in literature in different contexts, such in the observation of the advertising (Ariely and Berns 2010).

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Chapter 20
Using the Facereader Method to Detect Emotional Reaction to Controversial Advertising Referring to Sexuality and Homosexuality

Dominika Maison and Beata Pawłowska

Abstract The goal of the conducted research project was to test the usefulness of Facereader—a non-invasive method for detecting automatic facial emotional reactions—in order to test reactions to controversial advertising. Controversial or shocking advertising (so called "shockvertising") is used mostly in the context of social advertising (related to social issues) or in commercial ads to overcome advertising clutter. However there is no consistency as to what extent this type of advertising is effective. One of the reasons could be that the majority of results are based on declarations, but the actual reactions to controversial ads might not be conscious for the recipient or the person might not want to express them. In the first study (n = 219) we validated the Facereader methodology. In the second study (n = 76) we used Facereader to test the automatic emotional reaction toward ads referring to sexual violence. The results showed more complex information about the reaction toward ads from Facereader than from declarations. Moreover a comparison of the brand image measured before and after an ad exposure showed a decline of the brand image, which makes the effectiveness of shocking advertising questionable. In the third (n = 131) and forth study (n = 76) we explored people's reaction toward ads which refer to homosexuality (social and commercial ads). Again, data from Facereader provided more information about reactions toward those ads than the declarations. Furthermore, combining Facereader with eye-tracking delivered more precise information about different emotional reactions to different parts of the ads.

Keywords Advertising testing methods • Facereader • Cognitive neuroscience • Facial expression of emotions • Shockvertising • Homosexuality

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_20

20.1 Introduction

Advertising effectiveness is a very important issue for marketing practitioners, however a lot of ads produced are in the end not that effective. Therefore both practitioners and scientists, are looking for new research methods for pretesting advertising conducted prior to the launch of a campaign and aimed at estimating the future effectiveness of the ad (Davis 1997; Haskins and Kendrick 1997; Maison 2005). We now know from recent discoveries in psychology, that most of the processes concerning the impact of advertising takes place outside the consumer's conscious control, when attention is at a low level and with many distractions present (Petty and Cacioppo 1986; Dijksterhuis 2004). Supported by psychological discoveries about unconscious processes (Bargh et al. 2001; Bargh and Chartrand 1999; Dijksterhuis 2004; Greenwald et al. 1998; Maison et al. 2004; Wilson et al. 2000), biometric measures are becoming more and more popular in the context of testing advertisements. Also thanks to those methods, automatic and unconscious processes can be captured and so the data does not rely only on the declarations.

The most popular biometric methods used in an advertising context are eye-tracking. SCR—skin conductance response, and EEG signals (Plassmann et al. 2011). Eye-tracking is capturing visual attention, SCR—arousal and EEG—the brain approach-avoidance reaction which might be interpreted as a positive or negative emotional reaction toward the object (Maison and Oleksy 2017). Also another biometric method which has become popular recently is based on facial muscle activation—Facereader. It is a non-invasive method for detecting automatic facial emotional reactions based on Ekman's theory of six basic emotions: happiness, sadness, anger, fear, surprise, and disgust (Ekman and Friesen 1971). This method, when compared to EEG, provides more complex information about the emotional reactions of the respondent.

20.2 Method

20.2.1 Automatic Expression of Emotions

Psychologists for many years have studied facial expression as an indicator of emotions and especially automatic emotions. The most well known research program in this field was conducted by Ekman and Friesen (1971). They were studying human emotions in a cross-cultural context: in the US and New Guinea on the Fore tribe, which had minimal contact with the rest of the world. Despite this Fore tribe people were able to decode correctly the emotions expressed on the pictures of White people. The same was also observed among White Americans—they were able to decode emotions expressed on the faces of Fore tribe people. As a result of this research project Ekman concluded that there are six basic emotions: happiness, sadness, anger, fear, surprise, and disgust (Ekman and Friesen 1971; Ekman 1992,

1993). They are universal, shared by people coming from different cultures and having a particular muscle movement pattern accompanying the experience of each of these emotions. In Ekman's further work he elaborated the Facial Action Coding System (FACS) to become a system to taxonomize the human facial muscle movement pattern in relation to the experience of each of the basic emotions (Ekman and Rosenberg 1997).

20.2.2 Facereader—The New Way to Study the Facial Expressions of Emotions

The traditional way of studying the micro-expressions of emotion is by using EMG (electromigraphy). This is a technique adapted by the psychology of emotions from medicine. The electromiograph, through electrodes placed on the face of person, records the electrical activity produced by the skeletal muscles. There is proof that signals (especially coming from the activation of a combination of four muscles: frontalis, corrugator supercill, orbicularis occuli and zygomaticus major) are connected to the experience of Ekman's six basic emotions. For example, the zygomaticus muscle, which draws up the angle of the mouth, is activated when people are smiling. The corrugator is a brow lowerer and is activated when people feel negative emotions or are performing a difficult task and processing complex information. The frontalis muscle is responsible for brow raising and scowling, which is connected to fear and surprise. Orbiculari oculi is a muscle that closes the eyelids, and is activated when positive emotions are experienced (Moody et al. 2007; Ponari et al. 2012).

Thanks to the development of computer technology and advanced computational methods the Noldus company (www.noldus.com) created the Facereader methodology—a non-invasive method for detecting automatic facial emotional reactions (micro-expressions) (Lewinski et al. 2014). In this method the participant's face is filmed while watching stimuli that is placed on the computer screen (e.g. advertising). Afterwards the advanced computer program places a virtual grid consisting of 500 points on the recording of the participant's face (Fig. 20.1). Subsequently, the distances between the above-mentioned points are measured 25 times per second. After that the advanced image processing algorithm computes the points on the picture of the face (491 points/44 muscles) and as an outcome gives information about the different detected expressions of emotion: sadness, happiness, anger, fear, disgust and surprise. The program is analyzing changes in facial muscle activation based on the Facial Coding System (FACS) developed by Ekman and Friesen (1971). The validity of the Facereader methodology shows a high correlation in emotional expression decoding between data coming from Facereader and the classic decoding system based on an experts' evaluation as used in FACS (Langner et al. 2010).

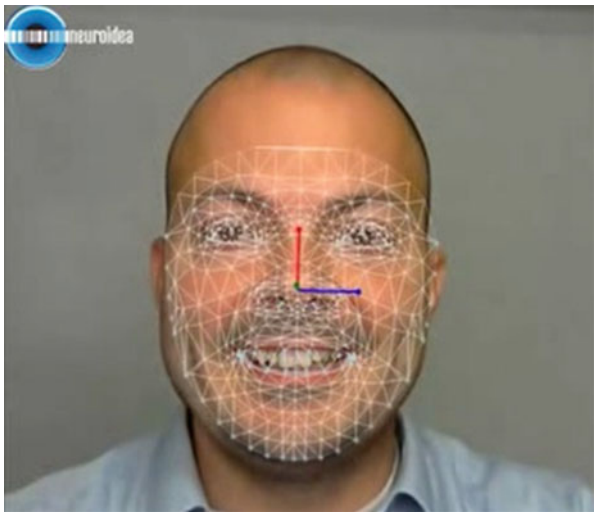

Fig. 20.1 Facereader—noninvasive way to measure micro-expressions of emotions

The Facial Action Coding System and the Facereader methodology that is based on it, even though it is not so precise as the EMG measurements, has two big advantages. First it is less invasive for the respondent (no need to place electrodes on the respondent's face). Secondly, it is coding the activation of 44 muscles at the same time, therefore the information about muscle movement analysis is more complex (however less precise) than in the case of EMG which is delivering information about the activation of only one muscle at any single moment.

20.3 Research Goals

The goal of the research project was to study the usefulness of the Facereader methodology for testing controversial advertising. We can assume that in the case of controversial advertising (for example within a sexual context or violating the norm) the attitude expressed by respondents does not have to reflect actual feelings or emotions evoked by the advertising, because he or she might want to hide them or is not conscious of them. Therefore we chose shock advertising (so called "shockvertising", Parry et al. 2013) as an object for testing in our studies.

Shocking messages are most often used in charity advertisements, in the hope that such messages can move people to help, and in public service messages, hoping to change people's attitudes and behavior (Manchanda et al. 2002). Shocking messages are also used in commercial advertising, in order to attract attention and break through the advertising clutter. However provocative and shock advertising, in addition to their popularity, are evoking a lot of discussion among practitioners concerning their effectiveness. Also academic research delivers inconsistent results. Some research claims that shocking content, which breaks social norms,

violates consumer expectations and leads to surprise, and as a consequence it attracts attention to the ad and facilitates memory of the ad (Manchanda et al. 2002; Dahl et al. 2003). This suggests that shocking ads should be more effective. However, if the ad is too shocking, there is a risk of it not being effective by drawing attention away from the brand and the main message of the ad or because of arousing our defense mechanisms (Hale and Dillard 1995).

Inconsistencies between the results of different studies investigating the effectiveness of shock advertising can be caused by methodological problems—most studies on a shocking ads' effectiveness conducted till now are based on declaration (Parry et al. 2013). We assumed, that in the case of those ads, the respondents might react in a different way on a conscious level—what is expressed by their declaration, and differently on an unconscious or automatic level—what might be expressed in an implicit measure, such as Facereader (more about explicit vs. implicit attitudes and measures: Maison and Gregg 2016).

20.4 Research Results Presentation

20.4.1 Validation of the New Algorithm Used for Analysis in a Facereader Methodology (Study 1)

In our research project we used a Facereader methodology with a converting algorithm of data processing developed by the Neuroidea company (www.neuroidea.pl). Because this algorithm was not used earlier in the scientific research, we conducted the first study in order to validate this algorithm. To do that we tested coherency between a set of pictures, which were supposed to evoke particular emotions with an emotional reaction from the participants, to be detected by Facereader while the participants were looking at those pictures.

The study had two parts. Based on the first part (pilot study) we selected pictures for the second (main) part of the study 1. The pilot was conducted on an Internet research platform. In the research we evaluated 100 pictures coming from the Internet, which based on the evaluation of two judges were supposed to evoke one of the six basic emotions: happiness, disgust, fear, anger, sadness or surprise. Participants ($n = 100$) had to watch pictures presented on the computer screen (one picture at a time) and they had to point out from the six Ekman's basic emotions which one they felt most while watching each picture.

For the main study we chose 18 pictures expressing only three very distinctive emotions: happiness, disgust and sadness (six pictures for each emotion). Moreover, pictures with the highest consistency were chosen—at least 70% of the respondents pointed to the same emotion that was evoked by the picture and the other five emotions were pointed out very rarely.

One hundred nineteen respondents participated in the main study (99 women and 20 men; average age—22.5 y.o.). The study had different subject designs with pictures of different emotional loading. In each condition six pictures were

Table 20.1 Declaration of emotions (happiness, disgust and sadness) in three experimental conditions presenting pictures with different emotional loading

	Emotional loading of presented pictures						Oneway Anova	
	Happiness		Disgust		Sadness			
Declaration of felt emotion	M	SD	M	SD	M	SD	F	p
Happiness	**63**	21.83	**10.85**	14.3	**9.44**	13.7	126.29	0.001
Disgust	**3.46**	7.76	**55.36**	24.02	**18.6**	17.18	92.04	0.001
Sadness	**2.82**	3.55	**19.93**	17.42	**56.33**	25.9	90.53	0.001

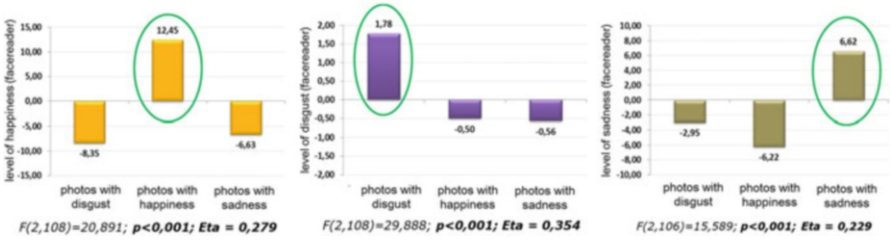

Fig. 20.2 Facial expression of emotions depending on emotional loading of the pictures

presented. Each picture was presented for 6 s with a 4 s break between them. The order of the pictures in each condition was rotated. During picture exposure the faces of the respondents were recorded on a high quality CCTV camera. After that a Facereader algorithm was used to decode the facial expression of emotions and a new computational algorithm for data processing (of Neuroidea company). After the application of this computational method the indicator of each emotion had a value between 100 (the strongest arousal of emotion compared to the neutral level) to −100 (the strongest decline of emotion compared to the neutral level—no expression of this emotion).

After the presentation of pictures the respondent had to answer questions about the emotions they felt while watching each picture. They got a questionnaire where the same pictures were presented as were presented on the computer screen and they had to describe in each case, for each picture, to what extend they felt each of the six basic emotions while watching the picture. A 1–100 point scale was used to describe their emotions where only peripheral values were described: 1-I didn't feel this emotion at all and 100-I felt this emotion extremely intensively.

In the first analysis we compared the emotions declared as felt by the participants while watching the pictures, in order to control the emotional loading of the pictures presented. We assumed that the declared felt emotion will be consistent with the emotional loading of pictures. The analysis confirmed this (Table 20.1). In the case of all three analyzed emotions the participants declared their higher intensity in the condition where pictures with the same emotional loading were presented. In all cases the difference was significant.

As a second step we analyzed data from Facereader showing the facial expression of emotion. Data presented in Fig. 20.2 confirmed that the emotions detected

by Facereader from the face of the respondent are consistent with the emotions expressed in the pictures. A comparison of the level of happiness expressed in these three conditions showed the highest level of this emotion in the condition where pictures expressing happiness were presented and it was significantly higher than the expression of two other emotions (Oneway Anova: $F[2108] = 20{,}891$; $p < 0.001$; $Eta = 0.279$. The level of facial expression of happiness in the condition with pictures expressing happiness was significantly higher than in the condition with sad and disgusting pictures ($p < 0.001$). Similar results were obtained for the facial expression of sadness ($F[2106] = 15{,}589$; $p < 0.001$; $Eta = 0.229$) and disgust ($F[2108] = 29{,}888$; $p < 0.001$; $Eta = 0.354$). In each case it was observed that there was a significant difference (on the level $p < 0.001$) between the condition where the expressed emotions were coherent with the facial expression of emotions (e.g. a facial expression of disgust while watching pictures showing disgusting objects) than when the emotions were not coherent (e.g. facial expression of sadness while watching pictures showing disgusting objects).

The conducted study confirmed the validity of the new algorithm for Facereader data processing, developed by Neuroidea. Therefore in the next studies this algorithm was used for testing shock advertising.

20.4.2 Automatic Emotional Reaction (Facial Expressions) Toward Controversial Advertising—Differences Between Men and Women (Study 2)

The goal of the second study was to test reactions toward controversial advertising referring to sexuality. We expected a discrepancy between the explicit measures (declaration) and the implicit—automatic facial expression of emotions (Facereader). Moreover, in the case of the majority of studies exploring "shockvertising" issues, the conclusions about their effectiveness were based on declarations (Dahl et al. 2003; Manchanda et al. 2002; Parry et al. 2013), in our study we decided to use an indirect measure of ad effectiveness, as used in marketing research practice (Maison 2005)—brand image shifting—the difference with the brand image was measured before (pre-test) and after ad exposure (post-test).

In the study we asked three main questions:

- What influence does a controversial ad exposure have on a brand image?
- What is the difference in emotional reaction between an explicit (declaration) and implicit (Facereader) measure?
- What is the difference between men and women in reacting to shocking advertising showing a woman as a sexual object?

Participants. Seventy-six respondents participated in the study: 40 females and 36 males, aged between 19 and 34. The study was conducted at the University of Warsaw, Poland.

Materials. For the study we chose eight existing shocking ads of two brands Dolce&Gabbana and Sisley, which evoked a lot of controversy (four ads for each brand). Pictures were downloaded from the Internet.

Measures. In the study an emotional reaction on two levels was measured: (a) Facereader—measured during the presentation of the ads (the same way as in study 1); and (b) declaration—after the ads' presentation respondents described what emotions they felt during each ad presentation. Six basic emotions: happiness, sadness, anger, fear, disgust and surprise were evaluated on a 100-point scale (from 1-does not fit with what I felt; 100-definitely fits with what I felt). Moreover respondents evaluated each ad by choosing one of four descriptions (I like it, it is attractive, it is an ad for me, it encourages me to buy the brand) and on a 4-point scale (1-totally disagree; 4-totally agree). The last measure was about brand image. Each brand was evaluated using nine dimensions (e.g. exclusive brand, strong, distinguishing, brand for me) and on 1-100-point scale (1-it does not fit at all; 100-it fits perfectly to the brand). This measure was repeated twice: before the ad exposure and after it.

Procedure. The procedure of the study was as follows: (1) first measure of the brand image (pre-test); (2) ad exposure with the Facereading recorded; (3) declared emotional reaction toward the presented ads—for each ad separately; (4) second measure of the brand image (post-test).

Results. The comparison of the brand evaluation before advertising exposure (pre-test) and after advertising exposure (post-test) showed significant differences for both tested brands. In the case of the Dolce&Gabbana brand, after the ads exposure the brand image decreased: in the case of six variables the difference was statistically significant, in the case of four dimensions the difference was not significant but still showed the same direction—after the ad exposure the brand was evaluated lower (Table 20.2). Likewise in the case of the Sisley brand, after the ads exposure the brand image deteriorated: in the case of nine variables the difference was statistically significant (or on the level of tendency)—in the case of eight variables evaluation after ad exposure was lower but in the case of one variable (distinguishing brand) evaluation after ad exposure was higher (Table 20.3).

Because in the case of Dolce&Gabbana brand, ads chosen for the study showed scenes suggesting sexual violence, we decided to observe the emotional reactions toward the tested ads separately for men and women. The comparison of the means of advertising evaluation and the declared emotions after the ad exposure didn't show significant differences in the reception of ads between men and women. The same was observed for the averaged automatic emotions detected by Facereader—no difference between the reactions of men and women. However, observation of traces of emotions felt during ad exposure showed differences between the facial expression of emotional reactions of men, to that of women, while watching the ads. For example one of the tested Dolce&Gabbana ads suggesting a collective rape scene evoked different emotions among men and women. The dominating automatic emotion among women was anger (Fig. 20.3—red line), but among men

Table 20.2 Dolce&Gabana brand image—comparison of measures before (pre-test) and after ad exposure (post-test)

	Pre-test (n = 76)	Post-test (n = 76)	T	p
I like this brand	53.26	51.89	–	n.s.
It is a nice brand	56.49	52.25	2.82	$p < 0.041$
It is worth recommending	64.55	60.71	–	n.s.
It is a trustworthy brand	68.57	60.14	3.57	$p < 0.001$
It is a good quality brand	77.45	71.68	3.12	$p < 0.005$
It is a strong brand	80.47	74.76	3.38	$p < 0.001$
It is a distinguishing brand	74.29	71.09	–	n.s.
It is an exclusive brand	78.37	73.28	2.13	$p < 0.036$
It is the brand for me	45.64	41.57	–	n.s.
I would like to have a product of this brand	49.53	45.92	2.32	$p < 0.023$

Table 20.3 Sisley brand image—comparison of measures before (pre-test) and after ad exposure (post-test)

	Pre-test (n = 59)	Post-test (n = 59)	t	p
I like this brand	46.16	38.61	1.99	$p < 0.051$
It is a nice brand	46.90	38.12	2.32	$p < 0.024$
It is worth recommending	53.85	42.68	3.81	$p < 0.001$
It is a trustworthy brand	55.81	43.64	3.88	$p < 0.001$
It is a good quality brand	58.17	50.86	2.41	$p < 0.01$
It is a strong brand	55.10	52.07	–	n.s.
It is a distinguishing brand	49.68	62.20	−4.16	$p<0.001$
It is an exclusive brand	56.29	49.56	1.99	$p < 0.051$
It is the brand for me	41.71	29.61	3.45	$p < 0.001$
I would like to have a product of this brand	41.10	30.93	2.96	$p < 0.005$

was disgust (Fig. 20.4—purple line). The analysis of declared emotions didn't show such a difference.

Information under the Figure:

The chart shows the changeability of facial expression of an emotional reaction in time. If the line on the chart is above the "0" line it means that the level of arousal of emotional reaction is above the baseline (stimuli induced this emotion). If the line on the chart is under the "0" line it means that the level of arousal of emotional reaction is under the baseline (stimuli induced decline of this emotion).

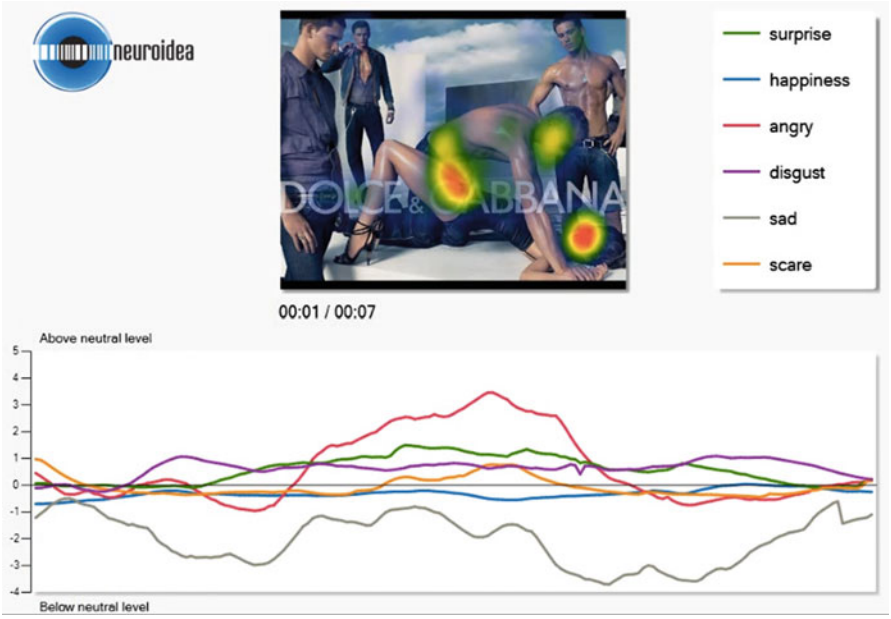

Fig. 20.3 Facereader—emotional reactions toward the ad and visual attention (eye-tracking) - WOMEN

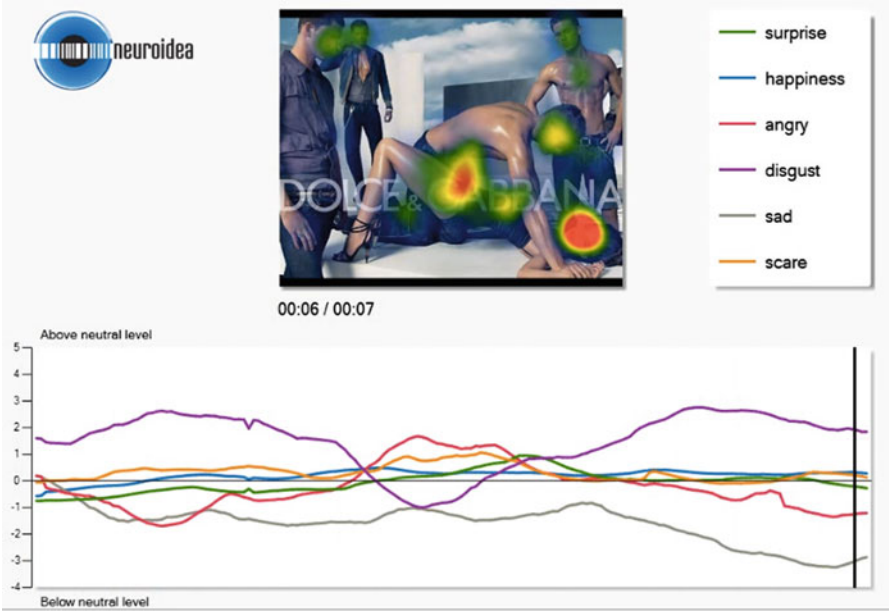

Fig. 20.4 Facereader—emotional reactions toward the ad and visual attention (eye-tracking) - MEN

20.4.3 *Differences Between Declared and Automatic Emotional Reaction Toward Controversial Advertising Referring to Homosexuality (Study 3)*

In the third study we tested again the automatic emotional reactions toward controversial ads by using Facereader, however this time we chose ads referring to homosexuality—promoting the legalization of partnership relations (expressing the idea that unmarried couples can have the same rights under law). This was at the time of conducting the study a very hot topic in Poland and was the subject of political discussions, especially within the context of homosexuality. Therefore we chose this issue as an exemplification of controversial advertising.

Participants. In the study 131 respondents participated: 68 females and 51 males (12—missed information), aged between 12 and 32. The study was conducted at the University of Warsaw (Poland).

Materials. For the purpose of the study some new printed ads were created. This was a social ad (public service announcement) promoting partnership relations. The ad had three versions with characters of different gender embracing each other in the picture: (1) man and woman; (2) two women; (3) two men. We assumed that apart from the first ad (man and woman—which functioned as the control condition) the two other ads had a controversial character because of the implicit suggestion of promoting a homosexual relationship (which was verified in the pilot study)—Fig. 20.5.

Measurements. The study had experimental between subject design—each participant saw one version of the ad randomly prescribed. Similarly in study 2, also here the emotional reaction on two levels was measured: a) Facereader—measured while presenting the ad; and b) declaration—after the ads' presentation respondents

Fig. 20.5 Examples of materials used in Study 3: (**a**) control condition; (**b**) men homosexual condition

described what emotions they felt during each ad presentation. There were six basic emotions (the same as in Facereader): happiness, sadness, anger, fear, disgust and surprise that were evaluated on a 100-point scale (from 1-does not fit with what I felt; 100-definitely fits with what I felt). Additionally the respondents also: (a) evaluated the ad using eight dimensions (e.g. interesting, trustworthy) on a 4-point scale (1-totally disagree; 4-totally agree); (b) evaluated the campaign using five dimensions (e.g. trustworthy, should be more of such campaigns) also on a 4-point scale (1-totally disagree; 4-totally agree). After that we measured the respondents' tolerance levels and attitudes toward homosexuality. In the case of both scales (ad evaluation and campaign evaluation) for the analysis we used aggregated indicators based on an average of answers for each question.

Results. The results showed that the two campaigns suggesting homosexual relationships (with two men or two women) were explicitly evaluated more negatively than the campaign with a neutral condition (the average evaluation in the control condition was 3.25, but the campaign in both experimental conditions was evaluated on the level of 2.81 (two women) and 2.80 (two men) (Oneway Anova $F = 4.34$; $df = 2130$; $p < 0.015$). In the explicit ad evaluation there was no significant difference between the conditions. Differences between declared emotions were significant only on one dimension (disgust) from 6. In the condition with two men, respondents declared the highest level of disgust ($x = 18.52$), higher than in the control condition ($x = 4.12$) and the condition with two women ($x = 9.02$; $F = 6.33$; $df = 2130$, $p < 0.002$).

In contrast to the declarations, the Facereader showed much more significant differences in the emotional reactions toward the three tested ads. First of all in the automatic emotional reaction toward the ad with the two men the feeling of disgust dominated (similar to the declaration) and in the lowest level of positive reaction—happiness. Secondly (which was different from the declarations), we discovered a strong emotional reaction toward the ad with the two women. It evoked the highest level of anger (higher than in the control condition), surprise and fear (Table 20.4).

20.4.4 Using Facereader Combined with Eyetracker to Better Understand Emotional Reactions Toward Controversial Advertising (Study 4)

In the last study we wanted to check the automatic emotional reaction toward a controversial ad, however this time in the context of an eye-tracking measurement (Jankowski et al. 2016). Eyetracking is measuring the visual attention toward an object. By combining data coming from Facereader with the data from eyetracker we can better understand which part of the picture evokes which emotional automatic reaction.

Table 20.4 Automatic emotional reactions (Facereader) toward three versions of social ads promoting partnership relations

	Version of advertising			Oneway Anova		
	(1)	(2)	(3)			
Emotions detected by Facereader	Girl and boy	Two girls	Two boys	F	p	[a]
Happieness	0.16	0.015	−0.027	7158	0.001	1/3; 2/3
Surprise	0.0004	0.006	−0.001	4406	0.016	1/2; 2/3
Anger	−0.008	−0.024	−0.003	3.066	0.053	1/2; 2/3
Fear	−0.0002	−0.007	0.00008			1/2; 2/3
Disgust	−0.001	−0.004	0.012	4016	0.022	1/3; 2/3

[a]Groups with significant difference on the level $p < 0.05$

Fig. 20.6 Research materials—study 4

Participants. In this study 76 respondents participated: 40 females and 36 males aged between 18 and 33. The study was conducted at the University of Warsaw (Poland).

Materials. For the purpose of this study some new printed ads were created. We used two pictures showing two people of the same sex kissing. The pictures were acquired from the Internet, showing people in controlled, similar poses. A brand logo was added to the pictures, in order to create the feeling for the respondents that they are participating in an advertisement testing situation (Fig. 20.6). The Bruno Banani brand logo was chosen, because at the time it was an unknown brand in Poland, and we wanted to avoid the influence of a brand image on the ad's perception (what might be the case in the study 2).

Measurements. Each participant saw both versions of the ad. Similar to study 2 and 3 the emotional reaction toward the ad was measured using Facereader while presenting the ad. Additionally visual attention was measured using eyetracking (SMI RED 4.2). Thanks to this it was possible to detect emotions evoked by different parts of the ad.

Results. In this study we used qualitative analysis in order to understand the reaction toward different elements of the ad. The analysis of the eye-tracking data didn't show any significant difference between men and women's visual attention (eyetracking) to ads showing two women kissing each other. The path of visual attention showed that participants (both men and women) were first looking at the faces and later at the breasts. Heatmaps also showed that those were the two elements of the ad that attracted most attention.

The analysis of the facial expression of emotions (Facereader) show that in all cases the ad evoked positive reactions—for both men and women the line of happiness is above the baseline, but the positive reaction for men is much stronger than for women, especially during the first 3 s of looking at the stimuli (Fig. 20.7).

We can observe a different pattern of results in second version of the ad—two kissing men. The line illustrating the emotional facial reaction (Facereader) of men toward the ad showed that the dominating emotion in this group was disgust. However, in the case of women respondents the lines look more flat which can be interpreted as a lower emotional engagement. Although we can observe an increase of anger among women after a period of time watching the ad (Fig. 20.8).

Analysis of the Facereader data combined with eyetracking gives a better understanding of the results. The pattern of visual attention provided by eyetracking showed first (and the strongest) a concentration of attention on the faces, and after 5 s visual attention is concentrated on the wedding ring on one man's hand—at the same moment anger arose in the group of women. Probably the wedding ring on the man's hand was associated with betrayal (the man is betraying his wife for another man) and not with the marriage of the two men shown in the picture (this was confirmed in the qualitative interview conducted after the ad presentation). In the men's group, looking at the wedding ring evoked mostly a feeling of happiness and surprise, however this emotion was not strong.

It is also worth taking a look at the facial expressions of the emotions appearing in the first few seconds of the participants looking at the ad with two kissing men, when visual attention was concentrated on the kissing faces. Among the men a very strong feeling of disgust dominates, but we don't observe this reaction among women, who express a slight emotion of happiness.

20.5 Conclusions

The results of the four above-presented studies gave interesting insights in four areas: (a) knowledge about the shocking ad's effectiveness; (b) differences in reaction toward shocking ads between women and men; (c) differences in reactions

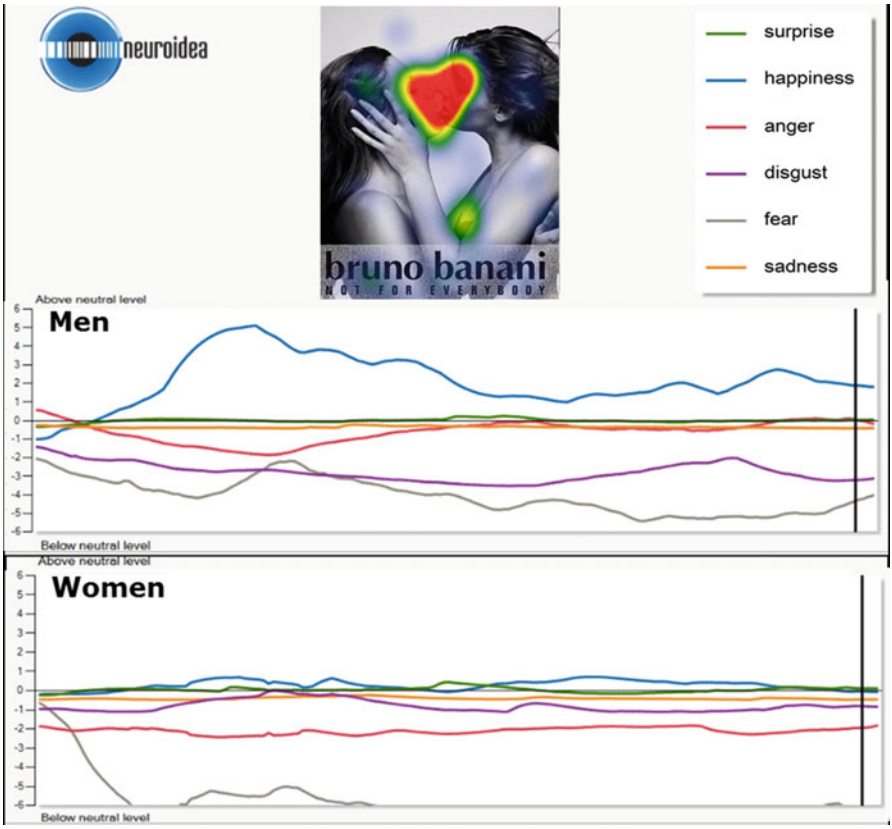

Fig. 20.7 Visualization of emotional reaction (Facereader) combined with eyetracking of men vs. women participants' reaction toward the ad showing two kissing women

toward ads showing women (lesbian) and men (gays) homosexuality and (d) the usefulness of such biometric methods as Facereader for testing advertising.

The results of the second study showed that the effectiveness of shock advertising is very questionable. It might attract attention (consistently with results of previous research), but it can at the same time destroy a brand image. In the case of the ads of two existing brands: Dolce&Gabbana and Sisley, that showed very sexual, pervasive and violent scenes, after the ads' exposure both brands appeared less attractive, less trustworthy, less exclusive, and were also perceived as of lower quality and they activated a lower willingness to possess the brand. In the case of both brands, the brand image after the ad exposure decreased compared to measures before the ad exposure. This result showing a negative reaction toward this type of ad is confirmed by the automatic facial emotional reaction of participants on

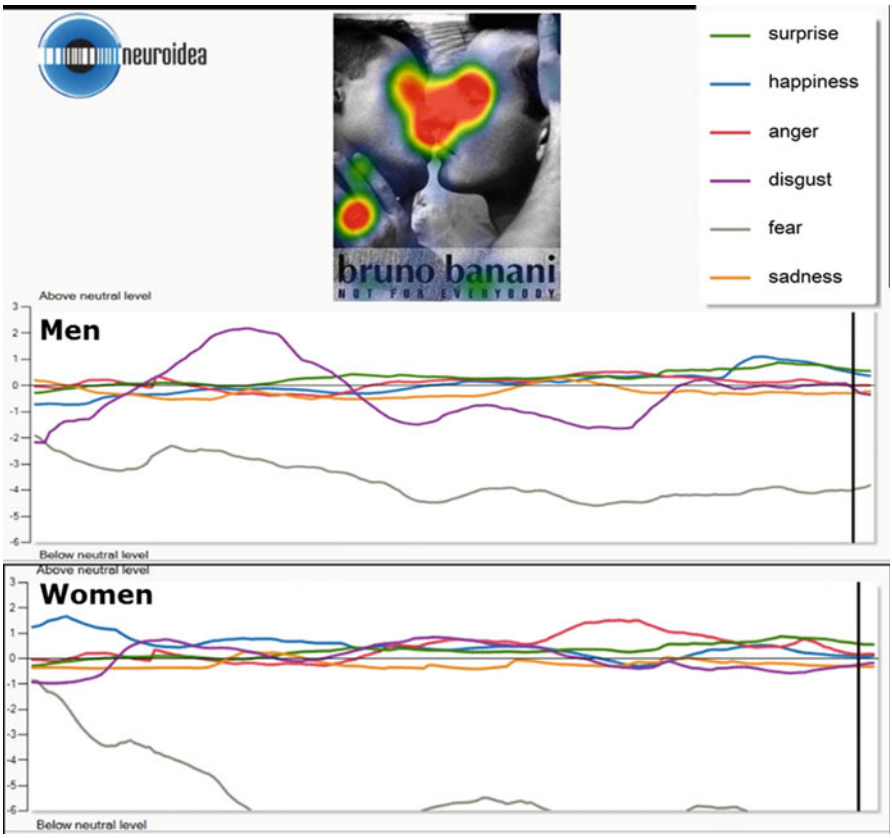

Fig. 20.8 Visualization of the emotional reaction (Facereader) combined with eyetracking of men vs. women participants' reaction toward the ad showing two kissing men

exposure to the ad (coming from Facereader). The investigated ad of Dolce&Gabbana suggesting collective rape evoked negative emotional reactions, however in the case of women the emotion of anger dominated, and in the case of men the dominating feeling was one of disgust. However we can ask if the long-term effect of this advertising would also be so negative. Many brands are choosing this way of advertising and their position on the market remains stable. Probably shock ads can be accepted in the case of brands which intentionally create images that are provocative and controversial.

The results of the third study showed that reactions toward social ads promoting the legalization of partnership relations were much more negative when showing two men (the gays' condition) rather than the two women (the lesbian condition) or the control condition. This might suggest the most negative reaction was toward

men's homosexuality. The highest level of the declaration of disgust in this condition supports this. However Facereader showed a more complex emotional reaction toward the homosexual ads. The men's ad evoked disgust on an automatic level and the lowest level of happiness. The ads with the two women evoked anger, surprise and fear.

The result of study 4, which also referred to homosexuality, showed slightly different results. In this case the ad with two kissing women didn't arouse a facial expression of any negative emotion, even more than that, the men's reaction was very positive. The difference might be connected to different types of ad. In study 4 it was a commercial ad where the picture of kissing people was only visualization creating a brand image. In the case of ads shown in study 3 it was a social ad referring to a controversial social problem promoting the legalization of same-sex marriages. From other studies we know that Polish people are much more tolerant toward homosexuality than to same-sex marriages, which is closely associated with the right to adopt children by homosexual couples that is even less acceptable (Pawlikowska and Maison 2015). The results presented in studies 3 and 4 are probably very much dependent on culture. We can imagine that if those studies were repeated in other countries where homosexual marriages are legal and common, the emotional reaction toward them would be very different.

Facereader seems to be very useful as an instrument for testing advertising and for understanding automatic (sometimes unconscious) emotions. It can provide additional information in testing advertising (both in practice and in scientific research) and helps to better understand communication in advertising. Because it catches more automatic and less conscious emotional reactions than the traditional measures based on declaration do. It is more sensitive and can detect more subtle emotional reactions. Another advantage of Facereader, compared to traditional advertising measurements, is that it detects reactions in the actual moment of looking at the ad (and not after, as in the traditional methods based on declarations). Therefore, especially when combined with eye-tracking, it can give information about each emotional reaction toward each element of the ad. This has very important practical implications for testing advertising methods in market research. Firstly, they should rely not only on the declaration but go beyond that by also using methods based on physiological reactions. Secondly, using such methods as Facereader, they can deliver very detailed information, which helps in the construction of advertising. Thirdly, this method seems to be especially useful for testing controversial ads, where we can expect a distinction between the declaration and what Facereader is able to capture.

Acknowledgment We would like to thank students from the University of Warsaw for their help in conducting the study: Przemysław Siewior—Study 1, Małgorzata Łozińska—Study 2, Paulina Wojsznis—Study 3.

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Chapter 21
The Implementation of Cognitive Neuroscience Techniques for Fatigue Evaluation in Participants of the Decision-Making Process

Kesra Nermend

Abstract The development of neuroscience techniques in the recent period as well as their application in various areas of knowledge has allowed us to understand cognitive processes related to the human brain functioning. Such techniques may be implemented in decision-making experiments for modeling preferences of decision makers. This study refers to the experiment participants' examination during the selection of the product according to their preferences by means of modern neuroscience techniques. In the experiment, data required to analyze the experiment participants' preferences will be registered by means of electroencephalogram (EEG), the measurement of galvanic skin response (GSR) and heart rate (HR). Additionally, web-tracking and eye-tracker methods will be implemented. Moreover, the study will verify how quickly the experiment participants become subject to fatigue in the course the decision-making process and the decision analysis. In relation to the above mentioned, the study presents how neuroscience may contribute to enhancing work effectiveness and to how analysts may support multi-criterion decision-making process.

Keywords Fatigue • Cognitive neuroscience • Decision-making support • EEG • GSR • Experiment • Multi-criterion methods • Behavioral aspects

21.1 Introduction

Each person starting their days undertakes dozens or even hundreds of decisions, choosing clothing every morning, deciding whether to drink tea or coffee, selecting the mug, food articles, the way to work, house to buy, selecting the service company or school for children. Every day, we choose various types of goods and services related to everyday functioning. The number of such choices or related to them

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_21

decisions is increasing correspondingly to the number of activities conducted by a given person. We perform some of such activities automatically in a routine manner, while, some of them require us to conduct certain analysis before we take them. Depending on the level of their complexity, the need to support them occurs. The decision maker searches for appropriate mechanisms, operating procedures or tools and methods enabling to make the right choice on the basis of many criteria, especially as in majority of cases decision makers are manipulated by manufacturers and sellers, which hinders rational decision taking. The use of decision-making methods may help decision maker to make a choice in the most rational manner. There are two main areas of supporting decision making, processes that is, multi-criterion decision analysis and multi-dimensional comparative analysis. Within the scope of the first area, one may distinguish two schools dealing with decision-making methods: the European school (comprising also national schools) as well as the American school. Creators of those schools include B. Roy (French school), J. Brans (Belgium school), T. Saaty (American school). The French school elaborated for instance ELECTRE group of methods (described more fully in works of Duckstein and Gershon (1983), Grolleau and Tergny (1971), Karagiannidis and Moussiopoulos (1997), Mousseau et al. (2001), Roy (1968), Vallée and Zielniewicz (1994)). The Belgium school, supported by the French school, is known for PROMETHEE method (Scharlig 1996), whereas, the American school is known for the AHP method (Saaty 1980), and ANP method (Saaty 2005). Representatives of the Polish school include professors: Gubała, Trzaskalik, Słowiński, Kacprzyk, Kaliszewski, Nowak and others. This school has elaborated such methods as BIPOLAR (Konarzewska-Gubała 1991), GRIP (Figueira et al. 2009), INSDECM (Nowak 2006), WINGS (Michnik 2013), and MARS (Roszkowska and Wachowicz 2016). Multidimensional Comparative Analysis—MCA is related mainly to representatives of the Polish school which focuses on taxonomic methods intended mainly for objects arranging. Polish taxonomy was started in 1909 by Prof. J. Czekanowski, whereas, in 1957 prof. Fierich refocused on the method of Czekanowski. Subsequently, the taxonomy was developed by Zdzisław Hellwig, in particular with regard to line arranging of objects. The work of 1968 entitled: "The application of the taxonomic method for typological division of countries with regard to their development level, resources and structure of qualified personnel" (Hellwig 1968) is the pioneer work in the field of applications and development of taxonomy in economic sciences. MCA methods are dedicated mainly to study social and economic development of regions and countries (Bartosiewicz 1984; Binderman 2011; Binderman et al. 2008; Borys 1984; Cieślak 1974; Dittman and Pisz 1975; Grabiński et al. 1989; Kompa 2014; Młodak 2006; Nermend 2006, 2012; Nowak 1990; Strahl 2006), assessment of financial attractiveness of the stock exchanges (Tarczyński 2004; Tarczyński and Łuniewska 2006; Kompa and Witkowska 2010), examination of banks functioning effectiveness (Witkowska 2010), assessment of companies activities (Pluta 1977) and the similar. Those methods are applicable in the situations where there is a necessity for the selection of one variant out of many possible. They are very popular with regard to solving various types of decision-making problems on

various levels of management in organizations (Wątróbski et al. 2016a; Jankowski et al. 2016). They are intended for subjective assessment of decision-making variants and informed choice of the best of them according to the adopted criterion, which is preceded by the analysis of potential alternatives. One of the groups of such methods uses pair wise comparison, and such comparison may refer both to qualitative as well as quantitative features (Wątróbski et al. 2016b). Variants are compared with each other (each variant is compared with all the others) with the implementation of various scales of assessment depending on the method used (Ziemba et al. 2016). If there are n variants for disposal, then the number of comparisons will be $n(n-1)/2$ (all of them which are compared with each other). In case when the number of variants is $n = 3$, and there is one criterion then we obtain 3(3–1)/2 comparisons 3. A far better solution refers to comparing two given decision-making variants with the implementation of one criterion. The number of comparisons may, however, considerably increase in such situation. For instance, while considering 100 variants with the implementation of four criteria one needs to conduct 6 for comparison criteria, and while comparing decision-making variants with the implementation of one criterion there will be 4950 comparisons. As above presented, this process is very labor-intensive and it requires extensive concentration from the decision maker with regard to expressing their preferences while selecting the product. Conducting the comparison the $n \times n$ matrix is created. Filling in the matrix, one shall remember that the values are related with each other in the matrix. For instance, in case of the AHP method, a ten-step comparative scale is implemented, whereas, in case of the REMBRANDT method a five-step comparative scale is implemented. In the course of research conducted with the implementation of such methods a human factor is of a considerable importance (Faizi et al. 2017). This is a participant of the decision-making process that conducting the assessment exerts the influence on the final result and depending on his/her actions there is a hazard of wrong undertaking of the decision. In order to avoid such situations, the cohesion of criteria and alternatives assessment matrixes is examined, which in case of complex decision-making problems may be still problematic. The more decision-making variants and criteria, the higher number of comparisons occur, which results in bigger engagement of the participant of the study and consequently higher fatigue of such participant.

The decision-making process may be potentially enriched by various less formal factors. One of them refers to experience allowing for making choices on the basis of situations that have taken place so far. Moreover, intuition, common sense as well as elaborated practical rules are implemented in numerous decision-making situations. The aspects regarding the brain functioning, mechanisms of human thinking, including the role of intuition and experience in undertaking decisions have been subjected to detailed research carried out with collaborators, among others, by Kahneman (2012) (Noble prize winner in 2002), and Aronsona et al. (2007). Those studies reveal that choices and decisions made by people depend on mechanisms of thinking, so called quick thinking (unconscious, automatic) as well as free thinking (controlled). Quick thinking does not require any efforts as it is based on thought patters (life experience) or heuristics (so called thinking shortcuts,

automatic reactions to stimuli from the environment). Quick thinking allows for almost immediate undertaking of concrete decisions, however, it is burdened with a risk stemming from the lack of analysis of a given situation. In case of free thinking, that is, human-controlled thinking, considerable intellectual efforts related to the analysis of possessed information are required. The above mentioned concerns the verification of quick thinking (automatic thinking) as well as controlling choices occurring. Informal techniques of supporting decisions refer, among others, to tossing a coin, professing by a future-teller or astrologist, although they do not constitute methods of any significant practical importance. All those approaches may be helpful, however, they will not replace a competent analysis which enables an in-depth consideration of decision making variants as well as their assessment with regard to determined preferences of decision makers. The chapter presents studies intended to verify how quickly participants of the study face fatigue in the course of the study. The study will be based on observance of the brain activity within the process of undertaking decisions. Data will be registered by means of the electroencephalogram (EEG), the measurement of galvanic skin response (GSR) as well as heart rate (HR). The methods of web-tracking and eye-tracker will be implemented.

21.2 Experiment Design

For the purpose of examining fatigue of the decision-making process participants during the selection of a given product, a research experiment has been designed in the form of the selection of one out of six (decision-making variants) vehicles of German production. All the vehicles were Sedans of the same class with regard to the size. Vehicles were compared with regard to six criteria (price, look, fuel consumption, the trunk space, maintenance cost and insurance cost). For the purpose of the research experience execution a web-tracking system has been designed enabling to track all the activities of the decision-making process participant. The system registers all the important events such as pressing the button, mouse clicking, time for each screen changing, etc. as well as the time of their display with the fraction of the second precision (Fig. 21.1).

Additionally, the brain neuroimaging technique was implemented by means of electroencephalogram (EEG) for the purpose of the brain activity observation in the decision-making process. The EEG device focuses on the measurement of the brain electrical activity registered by means of electrodes placed on the scalp in determined places. Due to a very high time resolution, this method is usually applied to examine changes in the brain activity over some period of time as well as to analyze reactions to external stimuli.

Moreover, psychophysiological techniques have been applied in order to examine correlations between the brain functions and physiological sensations regarding the influence of emotions on activities and cognitive functions of the examined. For that purpose the measurements of galvanic skin response (GSR) as well as heart rate

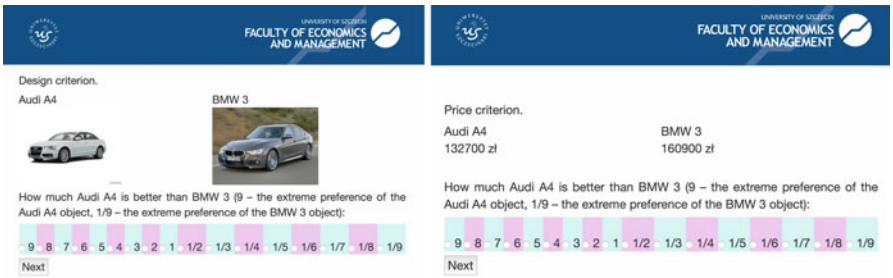

Fig. 21.1 Exemplary screens of the web-tracking system

(HR) were applied. Figure 21.1 presents exemplary screens of the web-tracking system in the course of the examination.

As the figure presents, the majority of screens were assisted by photos of vehicles chosen by participants of the experiment, in order to avoid the situation when a given participant does not know how a given vehicle make looks like, which might affect his/her decision.

For the purpose of data registration by means of electroencephalogram (EEG), electrodes have been installed in compliance with guidelines of the 10–20 system, which determines places for inserting individual electrodes on the scalp. In the area of the frontal part of the frontal lobe only seven electrodes have been taken into consideration (Fp1, Fp2, F7, F3, Fz, F4 and F2). In compliance with findings of neuroscience, the brain areas related to higher cognitive functions which are accountable for thinking, memory and assessment of emotions are located there (Jaśkowski 2009).

Thirty-three persons from there age groups: 20–24 years of age (students), 30–40 years of age (researchers, administration personnel), and above 40 years of age (administration personnel, researchers) took part in the study. Participants of the experiment included persons having the knowledge of the AHP method.

21.3 Experiment Results and Discussion

On the basis of the registered time of the event occurrence from the web-tracking system, the average time for the selecting the alternative for individual criteria was calculated for each participant of the decision-making process (Fig. 21.2a). At the beginning the time for the criterion of the price was above 2 min. The average time decreased for the criterion of the look, and increased for the criterion of cost-effectiveness. For the criterion of the trunk space it dropped down to 1.5 min and for other criteria it was more or less similar. The above mentioned could stem from higher skills with regard to filling in the questionnaire by the person examined as well as from decreased interest of the person examined which might lead to random responses.

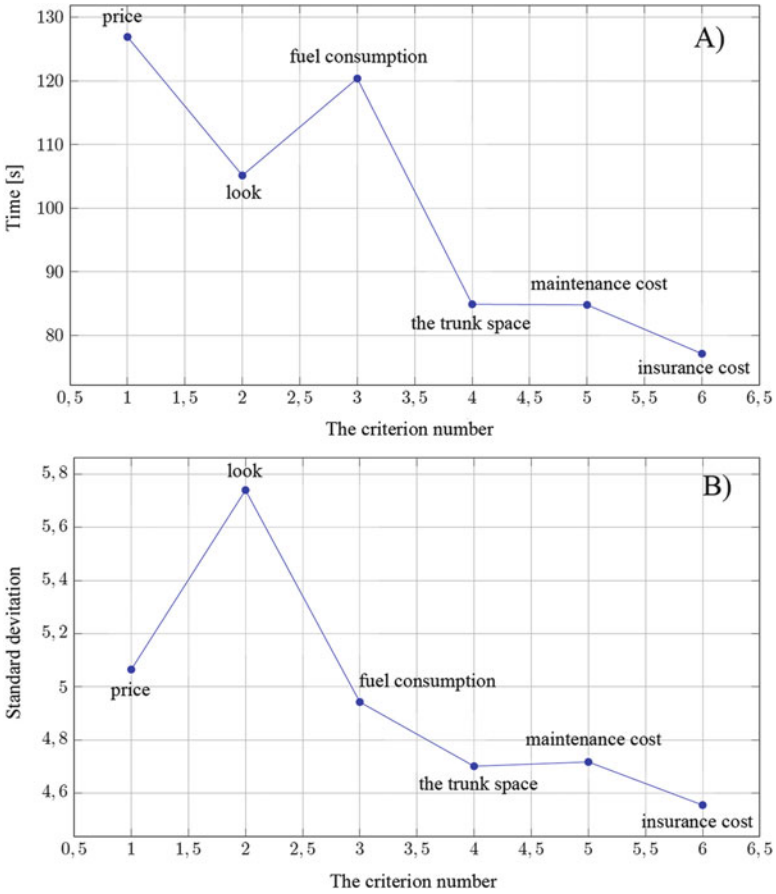

Fig. 21.2 Data from the web-tracking system: (**a**) the average time of fulfilling the questionnaire for individual criteria (without reading the question); (**b**) the average standard deviation of the response

Subsequently, the average standard deviation of the experiment participants' responses was calculated (Fig. 21.2b). The highest diversity in responses referred to the first three questions (price, look, cost-effectiveness). The above mentioned fact confirms that there was no interest in the study commencing from the half of the experiment, that is, after forty-five comparisons. After such number of pair wise comparisons with the AHP method, participants started to select responses automatically without thinking. The biggest diversity in responses occurred for the criterion of the look. This may prove that this criterion raised most interests. The above mentioned may be related to the fact that this criterion was illustrated with photos of vehicles.

Figure 21.3 presents charts of GSR signals for the criterion of the trunk space for two participants of the experiment. The events of mouse-clicking at the radio-

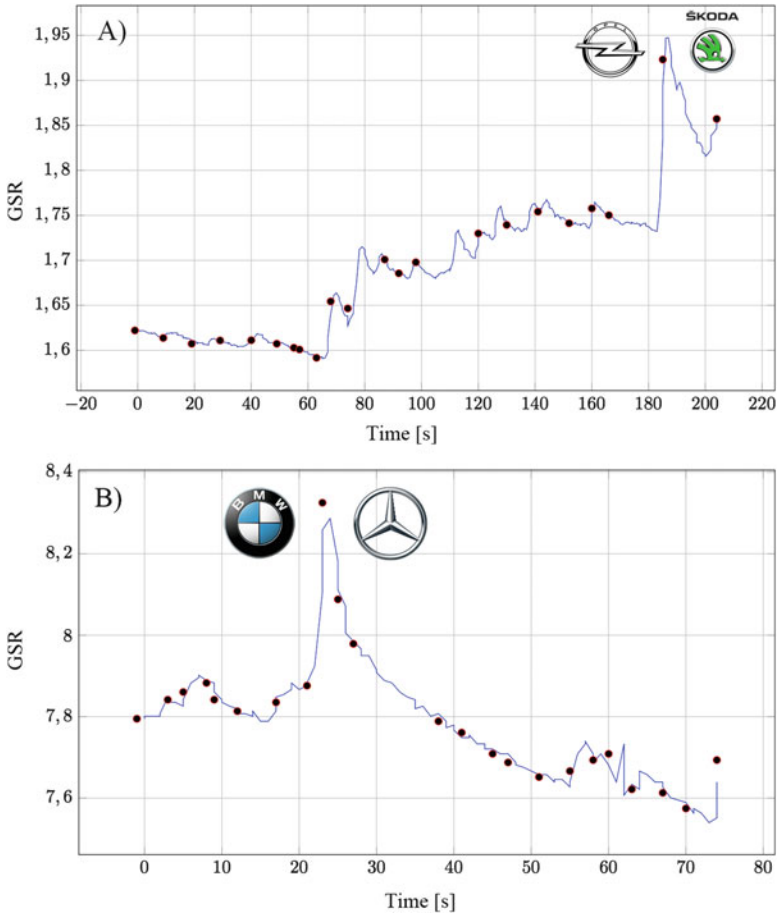

Fig. 21.3 GSR signal for the criterion of the trunk space for two participants of the experiment

button referring to the selection of one of two alternatives according to the Saaty scale are marked as points.

The galvanic skin response occurs with a delay ranging within 2–6 s depending on the participant of the experiment. The signal registered presents the levels of emotions of the person examined in the course of the experiment. Figure 21.3a presents that in case of the first participant the biggest emotions were raised at the moment of comparing the decision-making variant of Opel Astra to Skoda Octawia with regard to the criterion of the trunk space. The time for the selection of the decision-making variant was very long which reveals that the participant of the experiment hesitated for long before undertaking the decision. Figure 21.3b presents that the biggest emotions of the second participant of the experiment could be observed during the comparison of the decision-making variant of BMW 3 to Mercedes C class with regard to the same criterion.

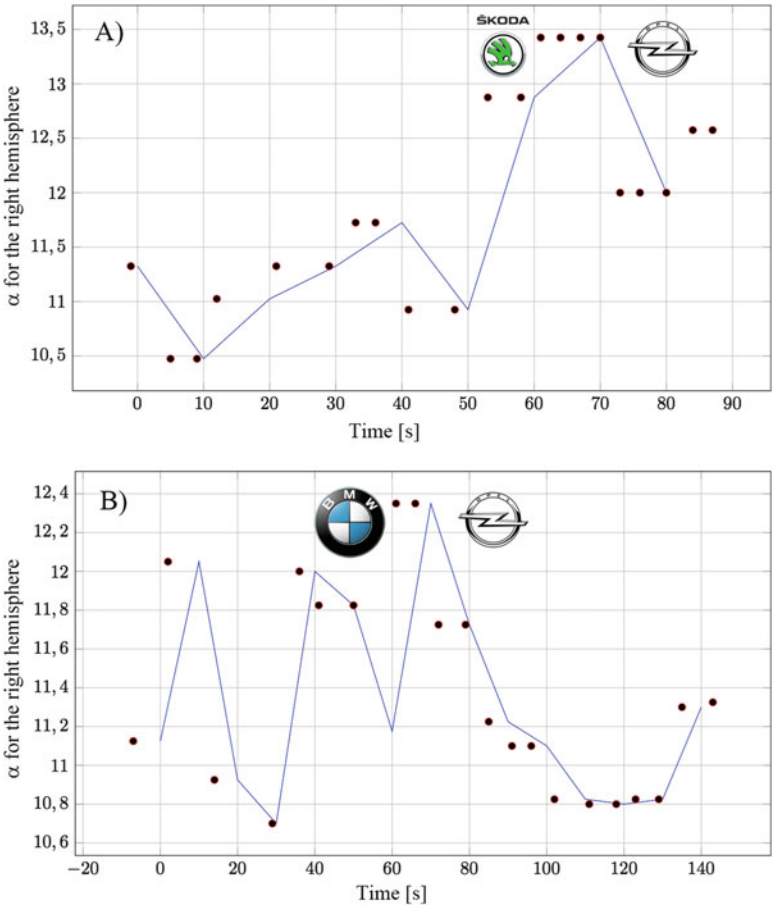

Fig. 21.4 The EEG signal for the participant of the experiment with regard to the criterion of: (**a**) the trunk space; (**b**) fuel consumption expressed as the number of liters consumed per 100 km

Figure 21.4 presents charts of α signals for the right hemisphere of the participant of the experiment, during the pair wise comparison of the decision-making variants with the AHP method with regard to the trunk space and fuel consumption.

In the course of the study, the participant of the experiment demonstrated the highest activity of the α signal while comparing the decision-making variant of Skoda Octawia to Opel Astra with regard to the criterion of the trunk space (Fig. 21.4a). For the criterion of the fuel consumption, the highest activity of the α signal occurred while comparing the decision-making variant of BMW 3 to Opel Astra. This fact may reveal the interest of the experiment participant in Opel Astra.

21.4 Conclusions

Cognitive neuroscience techniques in the field of undertaking decisions (not only management decisions) demonstrate a tremendous research potential. In part it has been already utilized; however, still there are many possibilities which have not been verified yet. The main difficulty in preparation of the appropriate study refers to the necessity of having knowledge in various fields—neuroscience, psychology, economy and IT. In that context, it seems natural to establish inter-disciplinary teams which thanks to the knowledge and skills of individual researchers could design and conduct successful experiments with the implementation of techniques and tools of neurocognitive sciences.

The study the suggestion of which has been presented in this chapter is intended first of all to present the potential of neuroscience and its techniques with regard to taking decisions. Further works that will be conducted after the completion of data collecting according to the depicted scenario focus on the use of results obtained for the purpose of the elaboration of the management decisions supporting system operating on the basis of the analysis of neurophysiological signals of the decision-maker. The conducted studies reveal that the longer the study lasts the more fatigue is experienced by participants of the experiment as presented on Fig. 21.2a and b. Such effect was visible approximately after 45 responses. In such situations one shall consider whether it would not be better to apply other methods, as for instance the PVM method, for a high number of decision-making variants. This method is adjusted to perform rankings of decision-making variants. In the first stage of the method, the values allowing for initial arrangement of objects are calculated and then one may precisely compare only variants with the highest values of the importance coefficient with consideration of additional subjective criteria. This manner will limit the participation for the experiment participant in the decision-making process to the minimum, which may help avoiding the phenomenon of fatigue in the experiment participants. The application of cognitive neuroscience techniques for the registration of the brain activity in the experiment participants may be very helpful for monitoring their real preferences as participants not always undertake decisions in compliance with declared by them preferences.

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Chapter 22
Cognitive Neuroscience Techniques in Examining the Effectiveness of Social Advertisements

Mateusz Piwowarski

Abstract Advertising broadcast within the scope of conducted social campaigns is usually intended to shape certain attitudes about important social challenges. One of the manners for verifying the effectiveness of advertisements refers to the examination of recipients' reactions, verification whether a certain threshold for means of expression has been achieved. With that regard the advertisement promoting electrical energy saving and its supplier has been analyzed. Cognitive neuroscience techniques, such as EEG, GSR and HR have been used. Individual shots of the advertising spot were verified with regard to their impact on interest, remembering and emotions of the recipient.

Keywords Social campaign • Advertisement • Social advertisement • Cognitive neuroscience • EEG • GSR

22.1 Introduction

The social campaign is defined as an organized effort of a group of persons focused on convincing recipients to adopt, change or abandon certain conducts, attitudes or perceptions (Kotler et al. 2002). As Prochenko adds (2017), this effort and those activities shall be organized within a given timeframes, and their purpose shall refer to the increase of knowledge, change of perception or conduct with regard to a given social problem which prevents realization of common benefits. Social campaigns promote certain positive attitudes and conducts or negate those inappropriate. Thus, their purpose is often of an informative and educational nature explaining or encouraging to undertake certain determined actions referring to the public interest. An effective social campaign is often a complex undertaking and it may be conducted in various manners as well as it may consist of various numbers of

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_22

stages. Daszkiewicz (2011) extinguishes seven stages of that process, namely: the initial analysis, market segmentation and the selection of the target market, studying target recipients, setting goals, planning of social marketing-mix, formulating the creative strategy and elements of the social campaign, as well as communication activities drafting. Tarczydło (2013) distinguishes eight stages, whereas, for instance Bazan (2011) enumerates only four of them. Irrespective of the approach to social campaigns creating applied, the final goal refers always to a change of attitudes with regard to crucial social challenges. For the purpose of introducing such changes, social campaigns make use of various advertising tools and techniques. Social advertising and social marketing are mentioned in that context. Advertisement is in that case the element of the social campaign and a part of social marketing (Kozłowska 2008). Social advertising is discussed in the context of various information, educational and persuading campaigns whose goals refer to important social issues, conducts which are a perceived by a majority of the society as proper ones (Scheffs 2015). There are various types of the social advertising intended to achieve various goals (Porochenko 2007). Some of them are intended to popularize the activity of social organizations, others to solicit funds, whereas, the aim of some others refers to persuading people to adopt certain pro-social conducts, or care about safety and health (Scheffs 2015).

In order to reach recipients and achieve goals planned by creators of the advertisement, various techniques of influencing human sub-consciousness awareness and control are implemented. They include, among others, influencing the memory, emotions, sub-consciousness. Additionally, various techniques of the sociological advertising and social engineering techniques are implemented.

It is a human nature that people remember better images than words. The above mentioned is caused by transferring visual information, without all the details, from the short-term memory to the long-term memory. Thus, words that may be reflected in the form of images are memorized better than words with a conceptual nature. Our memory saves better ideas than the verbal message. The advertisement becomes effective in case when a certain threshold of means of expression is achieved. On the other hand, it is ineffective, when such means are too weak to be saved in the memory. That is why, the advertisement shall attract attention, and in order to achieve the above mentioned various techniques are adopted, as for instance, influencing through contrast, the application of the appropriate scale of stimuli, or evoking associations (Kuśmierski 2000). Moreover, emotions play a significant role in the perception of the advertising message. The above mentioned refers both to the recipient as well as the level of saturating the message with emotions (Doliński 2000). Emotions exert the influence on the perception and remembering of the advertisement message, as well as they account for the level of satisfaction and triggering the intention of possession, or implementing changes (Laszczak 2000). Each emotional process is characterized by three features which exert the influence on evoking emotions in recipients of the advertisement message. This is the value of the emotion which may be positive (pleasant stimuli, e.g. joy, love) or negative (unpleasant stimuli, e.g. fear, aversion). This is also the intensity of the emotion (the ability for experiencing emotions under the influence of a given

stimulus) as well as the content of the emotion which depends on the type of the stimulus (Nowacki 2011; Falkowski and Tyszka 2009). Emotional conducts may be triggered by verbal and non-verbal stimuli, however, the latter ones exert a bigger influence on conducts of the advertisement message recipients (Jankowski et al. 2016a). The advertisement may influence the sub-consciousness being presented below the consciousness threshold (sublimal advertising) (Jankowski et al. 2016b). In such situation, the recipient is not aware of the hidden message, which may refer to both visual as well as audio stimuli which last for too short to be consciously registered (Jankowski et al. 2016c). Such a hidden message, however, is not registered by memory. Such type of advertising is legally forbidden in many countries of the world. In fact, however, various weaker forms of the advertising influencing the sub-consciousness are implemented and in order to obtain better results the advertising is repeated with a given frequency. Short advertising films may serve as the example, where in spite of the lack of recipient's attention, the advertisement broadcasted many times leaves traces in the memory (Williams et al. 2006). Thus, in case of the sociological advertising we experience open and transparent actions, however, their purposes are executed in a concealed manner. Recipients do not contemplate the source of the experienced intention or satisfaction. Basing on certain social conditionality related to the intention of possessing, or striving for something, various techniques oriented on, for instance, success, or other values are implemented in advertisements (Kuśmierski 2000). Advertising campaigns often adopt various social engineering recommendations, assisted by various techniques and means with the implementation of which planned goals are supposed to be reached (Wątróbski et al. 2016). Such activities may include, for instance, the technique of the preparing (introducing) advertisement or the technique of accompanying (reminding) advertisement. In the first case the advertisement is intended to provide information on certain qualities, assets or create the atmosphere of awaiting the product, service, etc. The other technique is related to maintaining the interest of the already known and recognizable products. In compressively planned advertising numerous social engineering techniques are constantly applied (Grzegorczyk 2010).

Social campaigns as well as commercial campaigns are based on similar principles and techniques in spite of the fact that their goals are different. The aim of commercial advertising refers usually to advertising products or services whose sale will bring measurable benefits and profits. On the other hand, the aim of the social campaign refers to providing, widening of social knowledge, engaging in social affairs, or sensitizing to certain issues (Bogunia-Borowska 2004).

A change of social attitudes evoked by social campaigns requires conducing complex and difficult studies of social conducts. The examination of the manner of the advertisement perception, its understanding, or evoked impressions of recipients is a less complicated task, but not trivial (Rasińska et al.). For such research to be objective and not based only on questioning recipients of the advertisement (questionnaires, etc.) one shall analyze reactions taking place in the human brain, or other parts of the body. We shall verify what emotions have been evoked by the advertisement, what elements of the advertisement have been noticed by individual

groups of recipients, whether the construction of the advertising spot has brought expected effects. Conducting such studies requires the application of modern research techniques and methods allowing for the reading and analyzing impulses generated by the brain, heart muscles, skin surface, etc. These are so-called cognitive neuroscience techniques. The aim of this chapter is to present options for the application of selected cognitive neuroscience techniques (EEG, GSR, HR) to examine the efficiency of the social advertising. Such efficiency is understood as achieving of a certain threshold of expression means supporting interest, remembering or evoking emotions in the recipient.[1]

22.2 The Description of the Experiment and Research Methods

The development of good habits with that respect brings concrete benefits both for household budgets (lower invoices for energy), as well as for the natural environment (our environment and the environment of future generations). Electrical energy saving refers to the protection of our health, saving forests, waters, air, the whole nature. Saving methods are not very problematic as it is enough to develop certain habits of proceeding. They concern the appropriate exploitation of household devices such as switching off the light in rooms left by householders, switching off the computer, TV set, and radio when not used, using energy-saving bulbs, filling in the whole washing machine, dish-washer, etc.

Social campaigns constitute one of the main methods for informing and promoting environmental awareness. Advertisements are broadcasted in TV ensuring a wide group of recipients. It is, however, not clearly known how people perceive such type of advertisements, whether they evoke any emotions, interest in the subject, what is remembered? The advertising spot lasting 30 s has been analyzed. The purpose of the advertisement referred to increasing awareness with regard to the need for a rational use of the energy as well as to highlight pro-ecological nature of ENERGA business (energy supplier). The concept was based on engaging unconventional actors—the dog, canary and cat, teaching proper habits, among others, by encouraging to switch off the light, TV set or computer.

The course of the experiment was as follows. A fragment of the film was broadcasted (title: "The birth of a man, the thinking being"), which was divided by two advertising breaks. Each break consisted of six advertisements. Advertisements referred to various aspects, including among others, various social problems. The total time broadcasting time of the film together with advertisements was 32 min and 2 s. The analyzed advertisement (broadcasted one time) was broadcasted during one advertising breaks. Figure 22.1 presents 30 shots of that advertisement selected

[1]The project was financed with the NCN funds allocated according to the decision DEC-2016/21/B/HS4/03036.

Fig. 22.1 Film frames of the analyzed advertisement

over 1 s periods. Additionally, theme frames comprised in the advertising spot have been marked.

Having seen the film, persons fulfilled the questionnaire based on questions about their preferences, approaches to various aspects of life and the content remembered by them from the advertisements watched. Results of the questionnaire were later on compiled with results obtained from measurements. Such measurements included the examination of the brain activity by means of electroencephalography (EEG), the measurements of galvanic skin response (GSR) and heart rate (HR).

EEG (electroencephalography) constitutes one of the neuroimaging techniques. With the use of the electroencephalograph the recording of the bioelectrical activity of the brain (neurons) is read. An important part of this examination refers to electrodes placed on the head of the examined person and registering the electrical potential in a given place. It is a resultant of potentials of all the sources of the electrical field, that is, apart from the electrical activity of the brain, also the external activity is considered. The record of the EEG results refers to rhythms and waves of various frequencies and amplitudes. We differentiate various types of waves. Alfa waves (with the frequency of 8–13 Hz, amplitude of about 30–100 μV) are for instance related to a low level of cognitive activity and the condition of relaxation. Beta waves (12–30 Hz, up to 30 μV) demonstrate how much the cerebral cortex is engaged in cognitive activities, their slight amplitude is visible during the attention focusing. Theta waves (4–8 Hz) are related for instance with the cognitive activity, and first of all they refer to memory processes. Delta waves (up to 4 Hz) appear mainly while sleeping, and gamma waves

range within the frequency from 26 to 100 Hz (Bear et al. 2006; Jaśkowski 2009). For the needs of the examination, electrodes have been installed on the scalp in compliance with the guidelines of the 10–20 system (Jaśkowski 2009). In the area of the frontal part of the frontal lobe only seven electrodes were taken into consideration (Fp1, Fp2, F7, F3, Fz, F4 and F2).

The measurements of the galvanic skin reaction (GSR) were conducted by means of the galvanometer measuring the skin conductivity changing depending on the general simulation of the sympathetic nervous system. The activation of the autonomic nervous system is related to the physiological stimulation and thus, changes in electrical resistance of the skin may mean experiencing emotions or a spontaneous reaction to the stimulus (Boucsein et al. 2012; Dawson et al. 2007).

The measurements of the heart rate (HR) are registered for the purpose of establishing the frequency of heart beats per minute (Dulleck et al. 2014). The measurement was taken at the wrist of the left hand, but it may also be taken on the chest.

In order to ensure synchronization of the readings from individual devices, the system registering the timeframes of the occurrence of the event with the precision of the fraction of a second has been elaborated. Tests were conducted in 2017 for a group of 20 persons of different ages, from 20 to 50 years old.

Emotional conditions evoked by the film broadcasted to the persons examined (including the advertising spot) were analyzed on the basis of obtained EEG, GSR and HR signals as well as established on their basis indexes of memorization, interest and emotions.

Memorization Index (MI) is established in compliance with the formula:

$$MI = \frac{1}{N_Q} \sum_{i \in Q} x_{\theta_i}^2(t) = Average\ Power_{\theta_{left,frontal}}, \tag{22.1}$$

where: x_{θ_i} represents the i-th EEG channel in the theta band that has been recorded from the left frontal lobe, Q is the set of left channels, N_Q represents its cardinality.

The increase of the MI value is related to enhanced memorization (Werkle-Bergner et al. 2006; Summerfield and Mangels 2005; Vecchiato et al. 2014).

Index of interests - Approach-Withdrawal (AW) Index is calculated on the basis of the formula:

$$\begin{aligned} AW &= \frac{1}{N_P} \sum_{i \in P} x_{\alpha_i}^2(t) - \frac{1}{N_Q} \sum_{i \in Q} y_{\alpha_i}^2(t) = \\ &= Average\ Power_{\alpha_{right,frontal}} - Average\ Power_{\alpha_{left,frontal}}, \end{aligned} \tag{22.2}$$

where: x_{α_i} and y_{α_i} represent the i-th EEG channel in the alpha band that have been recorded from the right and left frontal lobes, respectively, P and Q are the sets of right channels and left channels, N_P and N_Q represent their cardinality.

The value of the AW index is related to the increase of interest, its drop together with the decrease of interest. The AW signal measured has been transformed and

averaged in such a manner so as to obtain the averaged course (Davidson 2004; Vecchiato et al. 2014).

Emotional Index (EI) is established according to the dependency:

$$EI = 1 - \frac{\beta}{\pi}, \tag{22.3}$$

where:

$$\beta = \begin{cases} \frac{\frac{3}{2}\pi + \pi - \vartheta}{\frac{\pi}{2} - \vartheta} & if\ GSR_Z \geq 0, HR_Z \leq 0 \\ & otherwise. \end{cases}, \tag{22.4}$$

GSR_Z, HR_Z represent the Z-score variables of GSR and HR respectively; ϑ- arctang (GSR_Z, HR_Z). The angle β is defined in order to obtain the EI varying between $[-1, 1]$.

According to (22.2) and (22.3) negative $HR_Z < 0$ and positive$HR_Z > 0$ values of the EI are related to negative and positive emotions (Astolfi et al. 2008; Mauss and Robinson 2009; Vecchiato et al. 2014).

22.3 The Analysis of Results

In the course of the experiment, signals of EEG, GSR and HR have been registered. Such signals were subjected to processing, including filtration and extraction of features. In the first step, the MI and AW indexes were established on the basis of the registered signal of EEG. Then, on the basis of GSR signal, the emotional index was established.

Memorization index (MI) was established for each second of the broadcasted advertising spot, for each of the participants of the experiment. Subsequently, the averaged values for all the persons examined have been calculated. Figure 22.2 presents the chart of the averaged values of memorization index for all the persons examined.

The curve of the signal reflecting the MI values visibly presents that three shots, in which the animals switch off electrical receivers (the bird and cat) or intend to do so (the dog) were memorized in particular. The first considerable increase of the signal refers to frame 8 (the bird's switching off the TV set by a remote control), frame 15 (the dog's climbing up the cabinet) and frame 26 (the cat's closing of the laptop). They are very characteristic shots, in which household animals conduct certain not typical for them activities. As it is presented on the chart, the memorization index value for frames with the logo of the electricity supplier is low about which the advertiser may be concerned as its intention is to promote the brand.

As the next step, the index of interest (AW index), was calculated for all the persons taking part in the experiment and its averaged value was calculated. Figure 22.3 presents values of the index of interest for all the participants of the experiment. Analyzing the curve of the chart one may come to the conclusion that

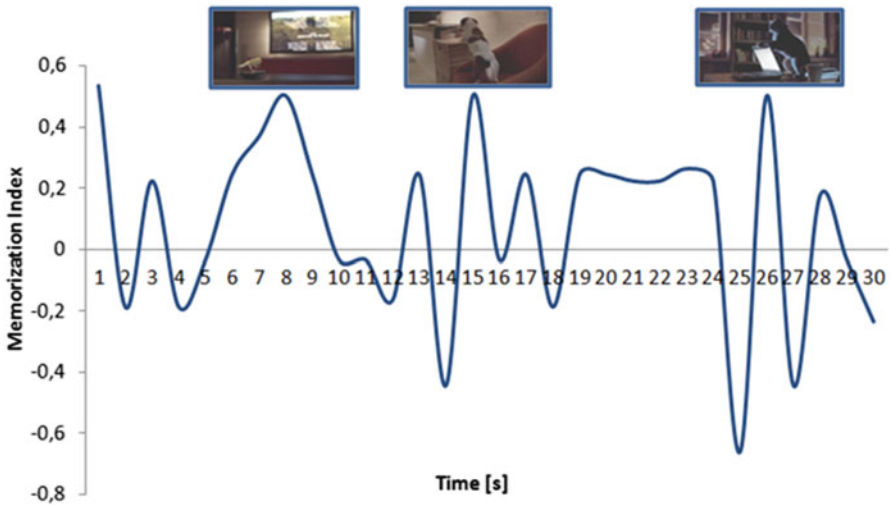

Fig. 22.2 Averaged values of the memorization index (MI) for all the participants of the experiment

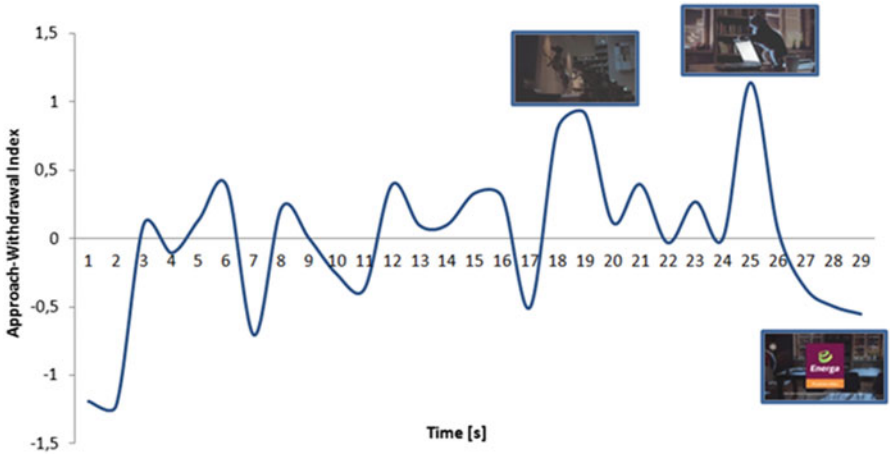

Fig. 22.3 Averaged values of the index of interest (AW index) for all the participants of the experiment

in the course of broadcasting the advertising spot, the interest in the spot was slowly increasing. On the other hand, there were moments when the value of the AW index was dropping down, however the tendency was increasing. There were two key moments with regard to the AW value (two peaks on the chart). The first one (frame 19), namely, when the advertisement presents the shot of the dog switching off the light and the second one (frame 26) when the cat closes down the laptop. From the

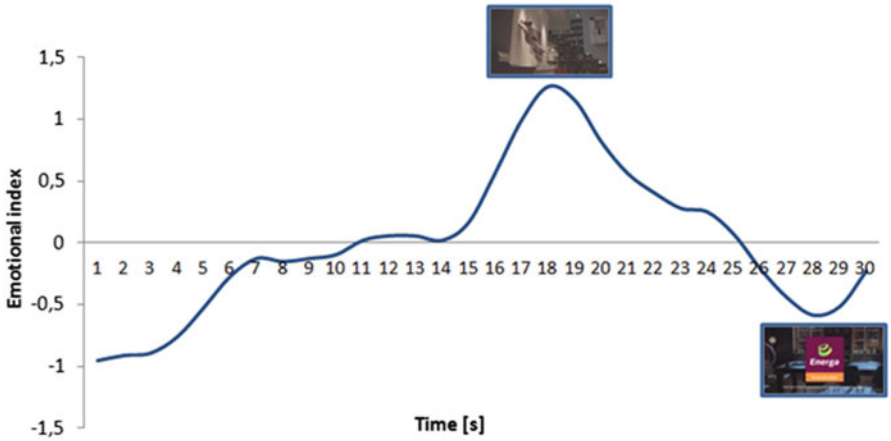

Fig. 22.4 Averaged emotional index (EI index) for all the participants of the experiment

next frame there is a clear decline of the interest, including the presentation of the logo of the energy supplier.

Moreover, emotions evoked by the advertising spot regarding energy saving were examined. The above mentioned was executed on the basis of registered GSR and HR signals. The GSR signal was standardized and it was analyzed for individual persons taking part in the study, together the averaged value. This signal has been presented in Fig. 22.4.

From the beginning of the advertising spot broadcasting there was an increase in the value of the GSR signal. At the beginning it was very low. It maintained on more or less the same level between frames 7–14. These are scenes when the bird switches off the TV set with a remote control, and then the dog rises from the bed and watches the lights tuned on. A significant increase in the value of the signal appears with the scene when the dog switches of the light pressing the switch with its paws (frames 18–19). A further part of the advertisement demonstrates a considerable decline in the level of the signal, with a short moment of maintaining that level at the moment of the cat's approaching to the open laptop (frames 24–25). Interestingly, the last scene of the film in which the logo of the energy supplier appears (frames 28–29) demonstrates a relatively low value of the signal; however, it prevents the value from declining. On the basis of the analysis of the GSR signal one may conclude that the biggest emotions among recipients were evoked by the scene in which the dog standing on its rear paws switches off the light. Similar conducts of other animals (the bird and dog) did not evoke such emotions, although it is visible that the emotional level in such scenes was maintained for a while.

22.4 Conclusions

The effectiveness of the advertising campaign may be influenced by numerous factors. One of them refers to the elaboration of the appropriate message for recipients. For that purpose advertisements are commonly used, and they are broadcasted in mass media, including, television. Usually advertisements evoking certain emotions and the interest in the subject are memorized and successful. The examined advertisement with the social message on energy saving (ENERGA supplier) turned out (according to the potential assumptions of the advertiser) to be a good production. The engagement of animals for promoting proper conducts of humans turned out to be effective. The above mentioned is confirmed by results of the examinations which were conducted with the use of cognitive neuroscience techniques, such as EEG, GSR and HR. Registered and processed signals allowed for the final designation of three indexes (MI, AW, EI) reflecting the conditions of the human, namely memorization, interest and emotions. The scene with the dog (switching off the light) turned out to be highly effective demonstrating high values of all the examined indexes: MI, AW and EI. In case of the scene with the cat (closing of the laptop) high values were reached with regard to MI and AW indexes. On the other hand, the scene with the bird (switching off the TV set with a remote control) was admittedly memorized (MI), but it did not evoke any particular interest or explicit emotions of the persons examined. The analysis of the advertising spot, conducted with the implementation of cognitive science techniques, considerably (however, not fully) covers the results of the questionnaire conducted among examined persons (after the completion of the examination). The persons remembered scenes with the animals, in particular with the dog, other scenes were less remembered. It may seem interesting that at the moment of broadcasting the logo of the energy supplier, MI and AW indexes demonstrated low values (declining tendency). In case of the EI, the declining tendency was reversed, although still the values of the index remained negative.

Thus, the presented techniques for studying social campaigns, including broadcasted advertisements, are effective. The techniques presented have proved that the analyzed advertising spot has been well prepared and it meets its objective.

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Chapter 23
Measuring the Impact of Intrusive Online Marketing Content on Consumer Choice with the Eye Tracking

Malwina Dziśko, Jarosław Jankowski, and Jarosław Wątróbski

Abstract Persuasive messages within online advertisements are some of the key factors in making marketing content noticed by potential consumers. In order to attract more and more attention in a very competitive environment, various techniques are used with observed evolution toward higher intrusiveness. The question is how an intrusive content is affecting consumer decisions and choices. While aggressive techniques are affecting user experience negatively, it is worth searching for a compromise between expectations of marketers and web users The main goal of the presented research was to verify the relation between the level of intrusiveness of marketing content and the consumer choice within an online environment, with the use of eye tracking to show if products with more noticeable advertisements used are less or more frequently when selected by affected consumers.

Keywords Interactive marketing • Consumer choice • Eye tracking • Online advertising

23.1 Introduction

Increased competition on the online markets is resulting in the need for searching for new ways to attract consumers' attention and distinguishing from other offers available online. In order to counteract this, marketing campaigns increasingly encourage potential consumers to purchase the products. Such campaigns are based on different theories and ideas, such as consumer perception (Andreasen 1995; World Health Organization 1997), and are affecting consumers with persuasive messages (World Health Organization 1997). A special role is played here by the theory of consumer choice, which describes the specific market behavior of individual consumers, and explains the operation of the market mechanism (Bigné et al. 2016). In

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_23

order to better address the consumer needs, the campaign planning includes consumer preferences, specification of target group and advertising content (Andreasen 1995; Jankowski et al. 2016), among others. Preferences are based on consumer tastes that influence the choice of products. The consumer mostly chooses products with the purpose of maximizing their utility (Rogers 1983). Within strategies based on the use of the Internet, the interactive commercials in various forms and formats are taken into account (Rogers 1983). Features of advertising components, like the intensity (Petty and Cacioppo 1986) and persuasiveness of the message, are the key elements to attract potential consumers' attention (Borawska 2016; Vecchiato et al. 2014). Previous studies show key parameters related to effectiveness of advertising content that affect consumer choices, including animation (Coyle and Thorson 2001), vividness effect (Bigné et al. 2016) and intrusive forms, such as pop-up windows, which are blocking access to editorial content and interrupting the cognitive process (Rogers 1983). Research which analyzed the impact of intrusiveness of advertising content and methods of influence on customer behavior is limited. In order to investigate the impact of the content intensity of consumer choice, an experiment was planned and conducted, with the main purpose being to determine whether the level of intrusiveness of advertisements is influencing the decision whether to choose an advertised product or not. In order to facilitate the detection of the factors that influence the effectiveness of a marketing campaign, eye tracking was used on experimental advertising content with varying influences on target user. The results of these studies were analyzed, so as to determine the degree of interest in advertising and how it supports the final consumer choice. Chapter is organized as follows: Sect. 23.2 includes a review of literature, Sect. 23.3 presents the experiment design, Sect. 23.4 presents results of an empirical study and this is followed by conclusions.

23.2 Literature Review

Consumer choice can be determined by the intensity and persuasiveness of the adverting message or the combination of these two elements (Laskey et al. 1995; Matin 2006). In the case of interactive advertising, we have to deal with specific consumer attitudes to advertising. For the behavior resulting from viewing the advertisement of a particular product, M. Salomon identifies a positive or negative reaction to stimuli (Motluk 2006). D. Wilson argues that customer response to advertising is caused by emotions, which are formed inside the mind of a client while watching advertising content (Hesse-Biber et al. 2006). It causes the formation of mood and positive or negative interest in advertising for the consumer. Thus, the behavior and reaction when watching the ad are affected by a proper selection of components. And the way advertising is designed (Lease et al. 1976; Watróbski et al. 2016). Previous studies of D. Stayman show that there are four specific consumer attitudes resulting from watching ads (Aaker et al. 1986). The first attitude is the transfer of emotions, which shows that the response to advertisement influences the attitude toward the advertised brand and product. The second

reaction is a so-called double mediation, which first stimulates the client to get acquainted with the brand, and then results in a reaction related to the product. The third reaction is mutual mediation, which describes the mutual influence—attitude toward the advertisement and attitude toward the brand can influence each other. The last customer response to advertising is the independence of the impact of response to the advertising and brand for the purchase of the brand. According to J. Edell the client's emotions add to the described above behavior of the customer, with the greatest impact on product selection (Johnson et al. 2007). Excitement in the formation of attitudes toward products through interactive advertising shows that while watching the ad, the client evaluates the presented advertisement, especially on an emotional level. According to the above theory, the reaction of potential customers and emotional assessment of the ad refers to a pleasant mental state that advertising causes (Nermend 2016; Bettman 1979). This has a very big impact on the different reactions of consumers in relation to the same ad and the response to the product, and ultimately to the product selection. The presented and briefly described models of consumer behavior identify possible sources affecting the attitude toward the brands. They include knowledge of advertisement, brand knowledge and attitude toward advertising. J. William shows that the reactions of the customer, which were based on direct experience, are more durable than the reactions generated through advertising (Williams 2012). Such behaviors of potential customers have greater accessibility, and affect immediately the customer's response in the context of a situation in which the purchase is carried out. Eyewitness and verbal information about the products included in advertising have different effects on attitudes in relation to the product. The most effective ads are those that contain an attractive content, both verbal and visual. To a large extent, they stimulate the consumer to imagine the possibilities of using the product and recall their associated emotions and beliefs. Successful advertising content has to be properly presented to the consumer and consciously read, then interpreted in the way intended by the designer, and it is finally remembered. If advertising components are properly designed and developed, the customer will enjoy the various pleasures and emotional satisfaction (Franz et al. 2009). As a result, many consumer reactions, including purchase decisions, are conditioned by the good qualities of advertising, which include attractiveness and aim to attract the attention of the customer; suggestiveness with care about customers' confidence toward the advertised product; clarity of product, so closely linked to remembering it; conciseness or reference to the most significant advantages of the presented product and originality being a way to distinguish advertising from other media. Messages should be durable and useful for a long time. Also, the advertising message should be persuasive, because advertisements affect customers before making a purchase and has weak effects compared to other factors, such as its actual usefulness or price. The most important element of advertising is its form. In principle, the form of advertising should be easy to understand by the potential consumer content and consist of only the most important information. Content advertising should provide information to the client, thus sparking interest, and this will result in the intended reaction, which is usually the purchase of the product. The essence of the content of

the ad is also a good slogan, which should summarize the contents of the entire advertising message and communicate clearly to the customer. In preparing marketing campaigns based on interactive advertising, in order to build a competitive advantage, advertisers should keep in mind the behavior of potential customers. It can be tracked with the eye-tracking studies investigating the interests of these consumers (Sałabun and Pietrzykowski 2016), so that through interactive advertising can increase the effectiveness of marketing campaigns (Franz et al. 2009). The basis for the construction of advertising is therefore a good knowledge of theory related to the marketing and use of the latest technology.

23.3 Experiment Design

The review of the literature shows that, even though many areas were investigated, the influence of the advertising content on consumer choices showed that the role of intrusiveness of was not deeply analyzed. The main goal of the presented research and the problem of these considerations is the role of content invasiveness in consumer choices. To realize this study, several theoretical assumptions were determined, upon which research experiments were performed. The system was created for measuring responses from interactive advertising messages. With the aim of measuring this effect, an eye tracker was used and combined with dedicated software, through which the advertisement with varying degrees of aggressiveness were displayed, along with a questionnaire which enabled the selection of one of the three advertised product after viewing the advertising content. On the research website, it was possible to move between subsequent articles and a test was used at the same time to display each article. The time to display a single article was set to 30 s, which is sufficient to become familiar with the presented article and advertising content. If the time is too long, this would cause aimless wandering of the user on the screen, which also would provide unnecessary noise making up the heat map of a given article. An advertisement located on the text was displayed with three levels of aggressiveness, and each of the levels of aggressiveness was assigned to one of the three advertised products. Ads were repeated in every third article, which gave three ads appearing within the duration of a single test. During the second module, the system used was eye-tracking software. Along with it, we collected and analyzed the data to specify what actions were performed within the specified time by the person being investigated. The diagram represented in Fig. 23.1 shows how the experiment was conducted. During the experiment, information about the movements of the eyeballs was collected, along with the current picture representing gaze paths. The last element that completes the survey system comprises the selection of one of the three products by the person tested. The diagram represented in Fig. 23.1 shows how the experiment was conducted. Within experimental space E represents the version of advertisement viewed by respondents, P represents the display order of the product, AG stands for degree of aggression of displayed ads for a particular product, T represents the total time viewing of the product by the respondents, FL represents the first look time at the advertisement.

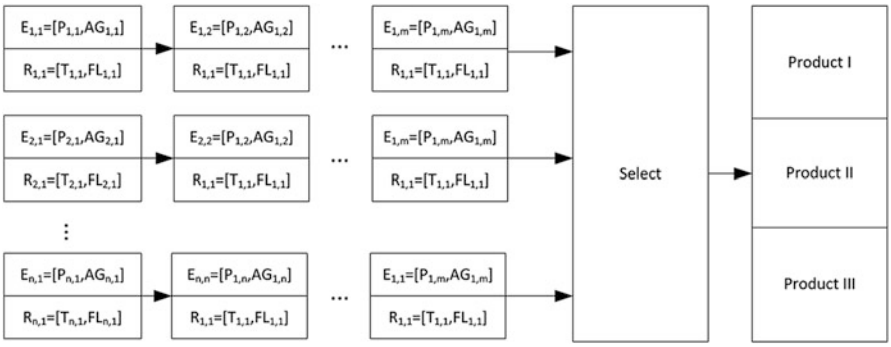

Fig. 23.1 Generalized model of the experiment

Advertising content was presented to the respondents, along with texts, and they were viewing all the presented subpages. Products were selected and advertised from the set (Product I, Product II, and Product III). After seeing all the ads, subjects were making their choices as consumers and selecting preferred products. The results of the study were analyzed with the Logit model. For the purpose of statistical verification, coding variables for flickering advertisements were used as follows: no aggression—1, average aggression—2, strong aggression—3. The results, which were subject to analysis, include the number of users interested in advertising, the time of the first look, the watch time and re-look in the direction of advertising content. The assumed confidence level is set at 0.95 and the significance level at 0.05.

23.4 Results

The results of an experiment performed on 20 subjects are presented in Table 23.1. The table includes data acquired with the use of eye tracking, and shows data registered for the selected product and its ID, as well as the relationship between the first look (FL) and the degree of aggressiveness of advertising content (AG), and watch time (T) by the subject for non-selected products as well. The study was designed to test whether aggressive advertising affects the first look, watch time and product selection.

Results of the experiment were registered with eye-tracking with a sampling rate of 60 Hz. Table lists the aggregate level of aggression of content showed to the users during the experiment. In the Selected product section, parameters of the products selected by the respondents are presented. The first column represents the ID of a selected product, the second represents the level of aggression of displayed advertising, and it is followed by the column with the sum of the time looking at the advertisement of a selected product. The last column includes a first look tile in the direction of advertising. A similar layout is used in sections for unselected products

Table 23.1 The result of the study for selected and unselected products

Subject	ID	Selected product			Not selected A			Not selected B		
		AG	T	FL	AG	T	FL	AG	T	FL
1	1	6	10.8	2.41	3	11.89	6.34	9	15.56	1.46
2	2	6	15.44	7.62	3	2.18	9.84	9	14.37	4.06
3	2	9	8.41	3.75	6	7.49	9.02	3	8.23	5.55
4	1	6	6.34	0.92	3	6.24	3.86	9	6.13	2.13
5	1	9	10.86	10.37	3	9.01	5.43	6	17.24	1.88
6	3	6	8.9	2.18	9	8.52	3.1	3	5.66	3.21
7	2	3	8.9	7.49	9	9.93	11.83	6	7.85	14.51
8	2	6	12.64	7.8	3	3.9	11.94	9	18.33	3.07
9	3	6	5.12	1.98	3	4.55	3.89	9	7.41	0.67
10	2	3	11.01	2.34	6	6.85	7.52	9	11.01	6.16
11	1	9	4.85	1.12	3	5.47	2.2	6	3.73	0.78
12	3	6	6.67	4.37	9	5	7.91	3	9.85	5.63
13	3	6	7.18	2.59	3	4.04	6.85	9	6.06	7.08
14	1	6	1.98	1.17	3	4.34	6.29	9	5.7	5.9
15	2	6	4.04	10.22	9	7.18	2.59	3	6.06	7.08
16	2	3	2.9	10.74	6	2.65	9.81	9	3.15	6.25
17	1	6	1.91	3.48	9	2.96	7.69	3	4.35	7.31
18	3	6	5.8	5.27	9	5.8	9.01	3	3.5	11.55
19	2	6	4.04	8.84	2	6.53	7.32	9	2.46	7.33
20	1	9	5	11.99	3	3.97	9.41	6	5.35	10.01
	AVG	6.15	7.14	2.41	5.2	5.93	7.09	6.6	8.1	5.58

A and B. On the basis of the detailed data, a simplified Table 23.2 was created, in order to display the results of the average, minimum, maximum, lower quartile, upper quartile, variance, standard deviation, skewness, kurtosis, and statistical significance. In the last column, the table includes statistical significance from logistic regression, which shows that aggression of the advertising content had a significant influence on consumer choice.

Analysis focused on parameters such as average, minimum, maximum, lower quartile, upper quartile, variance, standard deviation, skewness and kurtosis. Three variables are minimal: the first look, the total time of looking and aggression are at the level of 0.67; 1.91 and 1, and a maximum of 1.51; 18.33 3rd Quartile and the bottom of said variables in the table shows that, in the case of the first sight, 25% of the output is less than or equal to 2.83, just as in the watch time value of 4.19 and aggression first upper quartile is the following values: at first sight, 75% of the value is less than or equal to 8.37, and the same goes for the other two variables: time—8.9, and aggression—3. The variance for the first look is 11.95, for a total time viewing of 14.81 and 0.68 for aggression. The standard deviation shows that the results are obtained when the focus is not very far from the mean. As for the skew in the case of aggression is concerned, the distribution deviates from the ideal because it is equal to 0, so there is no asymmetry. The first look and watch time are

Table 23.2 Descriptive statistics and result of logistic regression analysis

ID	AVG	MIN	MAX	Quartile down	Quartile up	DVAR	STDEV	SKEW	KURT	p-value
FL	6.15	0.67	14.51	2.83	8.37	11.95	3.46	0.27	−0.79	0.41
T	7.14	1.91	18.33	4.19	8.9	14.81	3.85	1.1	0.87	0.97
AG	5.33	1	3	1	3	0.68	0.82	0	−1.53	0.01

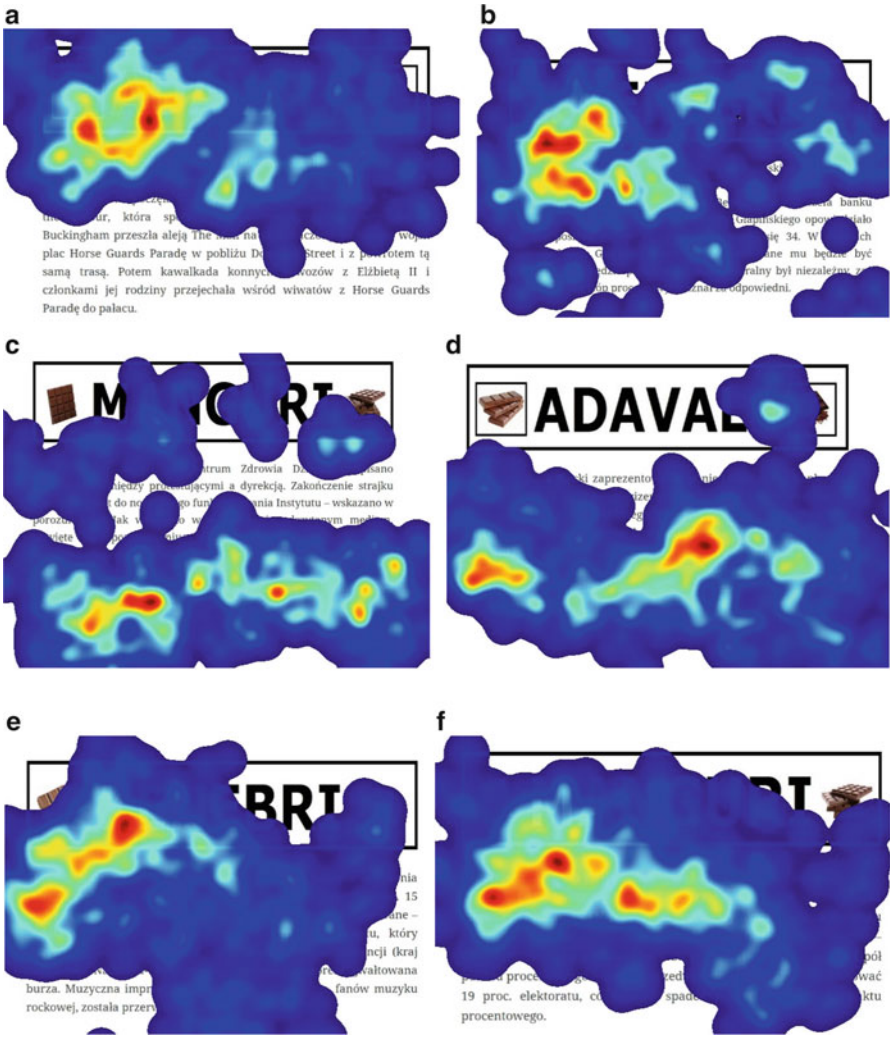

Fig. 23.2 (**a**) represents a heat map of the first product for all test users, (**b**) represents a heat map of the second product for all test users, (**c**) A heat map of the third product for all test users, (**d**) represents a heat map of the first product of all test users, (**e**) represents the second heat map product for all test users, (**f**) shows the heat map of the third product for all test users, (**g**) heat map shows the first product for all test users, (**h**) represents a heat map including a second product surveyed by all users, (**i**) shows a map of the thermal product placed third of all test users, (**j**) shows the result of LOGIT in the form of a graph

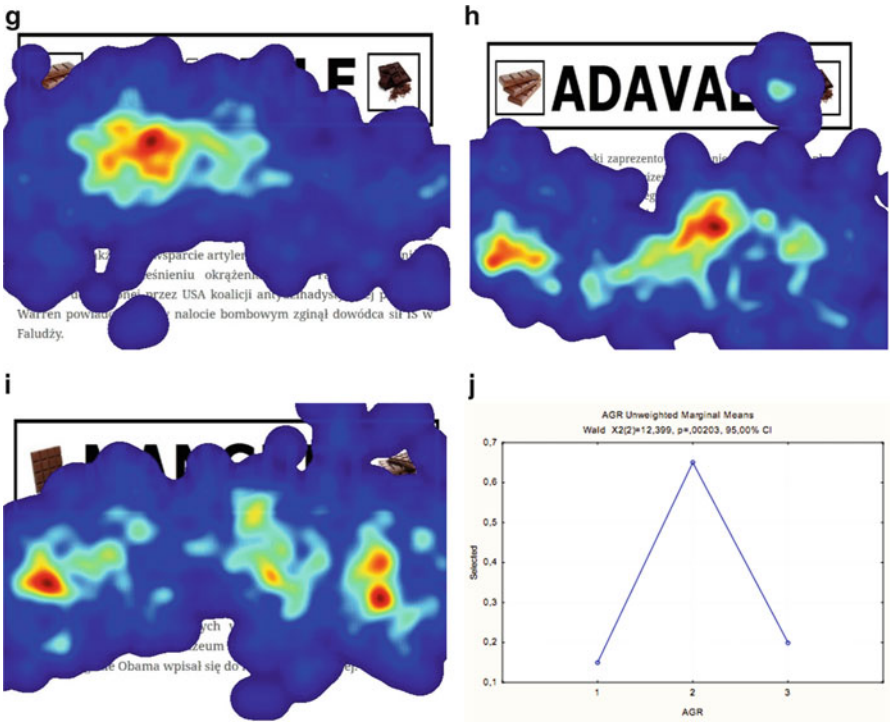

Fig. 23.2 (continued)

positive, which indicates that the system is skewed upward, which means that the values are lower than average. In two cases, after the results received negative kurtosis, however, they were not very far from 0 in terms of flattened distribution (first look and aggression); this indicates that there is a fairly tight cluster around the mean. In the next stage, a visual analysis of selected and heat maps generated during the experiment was performed, while results are presented in Fig. 23.2a–i.

When analyzing the heat maps it can be noted that the greatest interest of respondents to the display advertising was on Fig. 23.2a, b. These ads appear with an average degree of aggression, which coincides with the LOGIT analysis that the greatest interest in advertising was when the aggressive advertising was average (Fig. 23.2d). Another interesting phenomenon is that the interest in advertising, which has a very high degree of aggression is the least attracted users attention, even after heat maps, are Fig. 23.2c, d, and h. The rest of the figures show the indirect interest in advertising the test, and it did not have any degree of aggression. Upon analyzing Fig. 23.2j noted that, in the case study on the impact of the first look at the range of products, the average time for this product is 5.25, while the average total is 6.15. This result indicates that the average time to first look for the selected product is lower by 15%, since the initial sight occurred. The average time of seeing it amounts to 7.14 and is lower than the average time of looking at the chosen product

for 1.28 s, and the ratio of percentage is 27%. When analyzing the results of the impact of violence on product selection, it turned out that there is no statistical significance with a confidence level of 0.002917. It turns out that the ratio is 5.33 and is greater than the average aggression selected product, which is 5.25, and translates to a percentage scale of 0.02%.

23.5 Conclusions

In summary, through visual analysis and logistic regression, it can be noted that the largest number of viewers was attracted by advertising, which has the level of intrusiveness in the medium and the content that is the least eye-catching advertising is very aggressive. The conclusion is that aggressive advertising is annoying for the average person, and is resulting in a negative response to the brand in a form of lower interest. Examining statistical significance influence of individual variables, such as the first look, the time spent observing the aggression demonstrated that the statistical significance occurs when violence impacts on consumer choice. This may precisely be subject to the fact that the ad can be very annoying in the case of very aggressive advertising, too boring for static advertising, or attracting attention and interest in the case of advertising with an average level of aggression. Analysis with both visual and statistical approach showed that respondents chose the ad, which was fraught with an average degree of aggression, and which was justified above the ability to choose the advertised product. The results show that ads with a medium level of intrusiveness can be created, and customers are more likely to select the product with the use of highly intrusive contents. Future work assumes the use of a fuzzy inference model, through which it will be easier to choose the components of advertising, so as to effectively affect the potential consumer.

Acknowledgement This work was partially supported by the National Science Centre, Poland, Grant No. 2016/21/B/HS4/01562. Authors would like to thank Adrian Kokot, the student of Faculty of Computer Science and Information Technology at West Pomeranian University of Technology for his help during the experimental study.

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Chapter 24
Experimental Study of Color Contrast Influence in Internet Advertisements with Eye Tracker Usage

Wojciech Sałabun, Artur Karczmarczyk, and Piotr Mejsner

Abstract In the last decade, the number of practical applications that use eye tracker devices has significantly increased. Nowadays, eye tracking is a very important part of neuromarketing and experimental economics research. This chapter presents the experiment with eye tracking usage that was conducted to check how the contrast of advertisements influences their effectiveness. The main motivation for this research is the fact that it is very difficult to gain consumer's attention in online systems. The experiment was aimed to detect the relations between the contrast of advertising units, its location within the site, and the level of the recipient's interest based on absorption and attention. The results of the experiment are presented and discussed.

Keywords Eye tracking • Contrast • Advertising content

24.1 Introduction

Nowadays, economics develops at a rapid pace and is forced to introduce new technologies into its analysis. A good example of it is the experimental economics which combines the achievements of classical economics with the latest technologies such as eye tracking or electroencephalography (EEG) (Vecchiato et al. 2014). Eye tracking is a technology that allows to monitor the movement of the human eye. A dedicated software used in this type of research provides information on various types of fixations in the areas and thermal maps of the examined text or graphics which the person finds most interesting. Experiments with the eye tracker devices are successfully conducted in many areas.

Literature of the subject indicates the Internet as the most dynamically developing source of marketing content, as a result of which, many companies choose to

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_24

campaign for research that verifies their effectiveness (Ziemba 2013). Thus, it is possible to personalize the advertising message in a way that attracts the attention of the potential consumer most effectively (Koohang and Paliszkiewicz 2014, 2016). Consumer behavior and advertising related interdisciplinary research provides a look about influence of characteristics of ads placed online along with webs within which it is placed on the web user's attitude and behavior (Al-Augby et al. 2016; Jankowski et al. 2017; Nermend 2016). Research conducted within this field has considered diverse advertisement content characteristics such as colors with different visual aspects (Jankowski et al. 2016b; Wątróbski et al. 2016). The visual aspects are usually relevant about its effects in seeking people attention along with their attitude to advertisement. Though very prominent ads present on web pages can easily grab visitor's attention for a small time through the help of instant attention, the current research says that consumers are able to pass ads and such ads are usually irrelevant to the goals and tasks of consumers on website (Duff and Faber 2011; Resnick and Albert 2014). Consumers are also enough able to pay the visual attention in accordance with their goals by the top down control along with avoidance of paying attention on such online advertisement (Cho and Cheon 2004). Effective advertisement is not only supposed to gather attention but it also helps in getting hold of ad content elaboration (Radach et al. 2003). Studies focus on the format (Goodrich 2010), avoidance of ad along with user task (Resnick and Albert 2014), animation (Chtourou and Abida 2010) show very clearly that the research on effectiveness of online advertisement has produced uncertain results till now, along with that a lengthy argument on effectiveness of online advertisement is continued. Before advertisement, the research on the advertising had focused primarily on the effects that can occur after viewer is exposed to advertisement stimuli. Small research conducted to find out that how the contrast in between the advertisement as well as its components is going to affect the user behavior and how to separate it from different elements present within web (Jankowski et al. 2015, 2016a).

The purpose of this chapter is to use the eye tracking technology to determine the impact of the color contrast in advertising. It studies whether it is relevant to the consumers and if it influences their decisions about the products purchased. To achieve this aim, a simple experiment is designed with the usage of the eye tracking technology.

The chapter is organized as follows: Sect. 24.3 introduces the concept of eye tracking technology. Afterwards, Sect. 24.4 presents the plan and objectives of the proposed experiment. The discussion of results are presented in Sect. 24.5. Finally, Sect. 24.6 presents conclusions.

24.2 Literature Review

With large number of competitors online, it is very difficult to gain consumer's attention. Due to overload of information and advertisement mess, the customer's visual search has become more selective and it has been focused on attentive

resources particularly toward present task and they pay very small attention toward ads (Burke et al. 2005). As the click via rates and ads attention has been reduced, the media firms and marketers have turned toward new technologies including compulsory and conspicuous ad formats in order to gain customers attention toward advertisement (Franconeri and Simons 2003; Nielsen 2000). Previous researches have examined different aspects of effectiveness of online advertisement. It includes effects of ad repetition (Lee and Sundar 2002), animation (Bayles 2000), emotional response toward advertisement (Yoo and Kim 2005), top down and bottom up ads processing (Stenfors et al. 2003), colors role (Lothia et al. 2003). Still when the research on marketing studies the color functioning along with its role of attributes such as saturation or hue, the entire focus is usually on the single color (Westerman et al. 1993; Labrecque et al. 2013), while avoiding this fact that, on particular, the colors are seldom experienced within isolation (Schloss and Palmer 2011). The daily visual stimulus we observe has never been of single colored. Such is the case with objects we daily encounter as the customers. For example, in the environment of online shopping, the products are showed on different colored background of website (Bagchi and Cheema 2013). Moreover, the logos, walls of shopping malls, product packages (Labrecque et al. 2013) and many others, also consist mostly of different colors. As a result, there is so much to be discovered still regarding the response of consumers to the combinations of colors. Alternatively, consumers usually prefer the combinations of colors that consists of same colors (matching or closely related). On the contrary, the consumers like opposite color combination as well (Deng et al. 2010).

Understanding of mechanisms that are guidance to the consumers for selection of different interest points within an image (forecasting places of big interest and standards of attention) contains wide applications in business world (Zhao and Koch 2013). Research based on eye tracking provides information about which thing is more related to attention involvement as it is actually related to visual fixation pattern within different issues of marketing (Fiszman et al. 2013). Moreover, the eye tracking is also used with different equipments to measure the cognitive response, lead synergy for latest insights, specially, in accordance with marketing communication and consumer behavior. When it has been synchronized with facial coding, results have found visual activity precise measurement (exactly at the point to which people are focusing) linking specified emotional response with different components of stimulus (as how people are feeling about what they have saw). The study of sessions of recording can be the saccades and fixations based analysis. Fixation is devoted to a phenomenon that aims at retinas inner part toward object which is watched (Just et al. 1980). The action persists from 0.15 to the 1.5 s. The fixation measurement is referred toward area of interest (AOI) (Poole and Ball 2006), repeatability of fixation (Goldberg and Kotval 1999), time span (Jankowski et al. 2016a, b, c), spatial density (Cowen 2001) or fixation share within AOI (Albert 2002). The eye movement in between two fixations has been represented by the saccades and this occurs 4–6 times in a second and it will last from about 0.03 to the 0.06 s. Related to the fixation, the saccade can be easily interpreted differently as it is dependent on context (Jacob and Karn 2003).

When new challenged of research related to contrast role between marketing content elements with eye tracking ability are combined then it makes possible to find out component roles along with different contrasts within web and its ability to gain customer's attention.

24.3 Eye Tracker

An eye tracker is a device for measuring eye positions and eye movement. The most popular way to graphically display results gathered by eye tracker is the usage of heat maps. This type of results presentation collects information about fixations, which can be defined as the "permanent positions of the eyeballs" of the users, and uses colors to display them to the investigator (Jankowski et al. 2016a, b, c).

The Fig. 24.1 presents an example of heat maps, where colors indicate the number of fixations in the place. The red color indicates the high intensity, and the blue color represents low intensity. The colder the color, the less focused the eyesight is in that place. Individual software programs show the results differently, however, they do not often differ significantly from each other.

The abovementioned fixation number is usually used, but other variations are also the sum of the fixation times or the number of subjects. The disadvantage of such presentation is the lack of traceability of sight paths. Another interesting way to image data is saturation mapping (focus mapping). It works just like heat maps with the difference that a black saturation is used instead of colors.

The Fig. 24.2 depicts an example of saturation mapping, where the most obscured area was overlooked most often. The brightest areas are the ones that attracted the greatest interest. Eye tracking applications also offer maps of fixation showing the path of the respondent's eyes.

Figure 24.3 presents an example fixation map, where each colored circle means one fixation. The larger circles mean that the examined person looked longer at a given spot. The lines between them are called saccades and represent point-to-point jumps. However, for big samples the map is barely legible (Fig. 24.4), which may significantly increase the time required for its analysis.

24.4 Experiment and Results

A contrast is a sharp opposition between juxtaposed objects. Contrary to popular opinion, the contrast in advertising is not just a "dark–bright" difference. It consists of many elements that result in the marketing message gaining strength and originality. The complexity of the contrast phenomenon, as well as the need to incorporate selected IT factors in its analysis, led to the fact that the World Wide Web Consortium (W3C) normalized and formalized its main aspects. As the result of the W3C efforts, an algorithm has been developed, which gives the measures to

Fig. 24.1 An example of heat maps

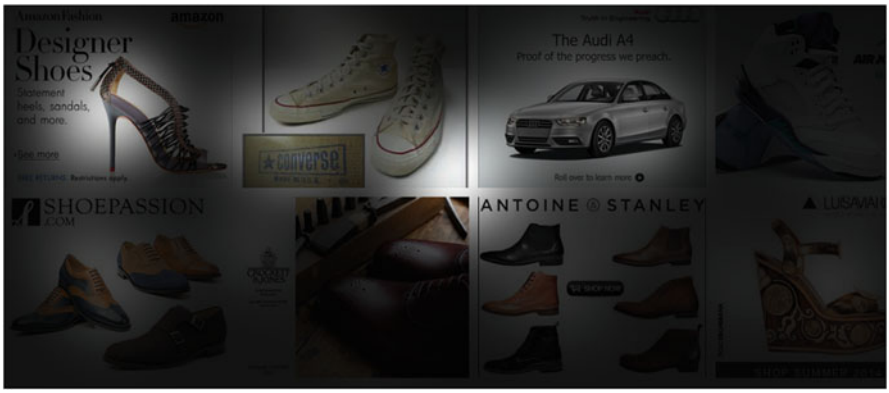

Fig. 24.2 An example of saturation mapping

Fig. 24.3 An example fixation map for one person (small sample)

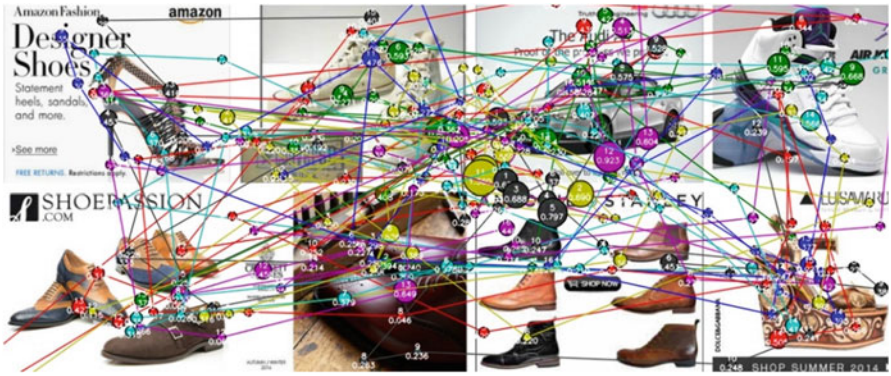

Fig. 24.4 An example fixation map for one person (big sample)

calculate the contrast coefficient—WCAG 2.0. In practical terms, WCAG gives us the accessibility guidelines for the content published on the Internet. The structure of the document is presented as four main points:

1. information and user interface components must be presented to users in a way that is accessible to them,
2. user interface components and navigation must be functional (should allow interaction),
3. the content and user interface must be understandable,
4. the content must be sufficiently reliable to be properly interpreted by many different customer users, including assistive technologies.

Two success categories can be found in the WCGA documentation—AA and AAA. The first one is the result of the minimal contrast and the second is the result of the enhanced contrast. The rules that the service must meet to achieve these success categories are described in greater detail in the official documentation[1].

The purpose of the study was to determine whether the contrast affects the message success. GazePoint v3.2.1 was used to perform the experiment. The software allows to design and show a multimedia presentation to the investigated individuals and to record the path of their eyes. Twenty respondents participated in the experiment. Their average age was 21 years. None of the examined individuals had any visual impairments that could have a negative impact on the measurement results. The experiment started with a short users' introduction into the theoretical part describing how the equipment was used and how the test would run. The purpose of the study was explained after its completion, because any premature explanations could have suggested a specific behavior on content display. The eye tracker has been pre-configured for each participant individually to determine the individual position of the track. Then, each of the 20 people were shown a

[1] http://www.w3.org/TR/

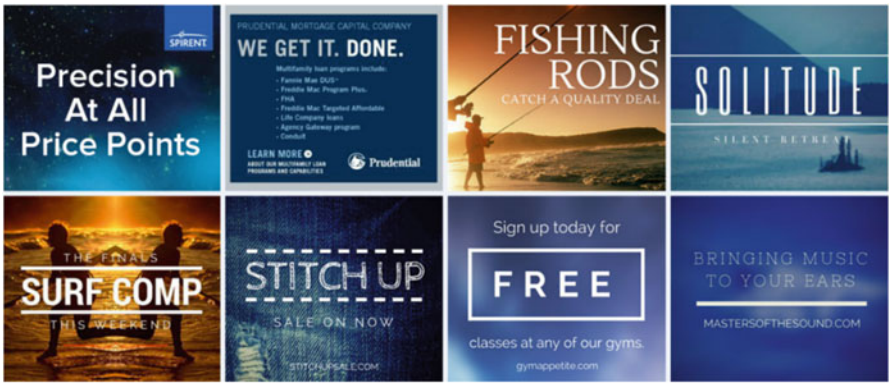

Fig. 24.5 An example of eight advertisements with the contrast colors (*orange* and *blue*)

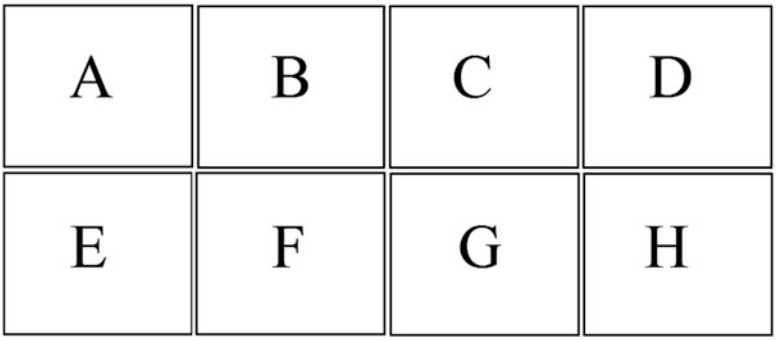

Fig. 24.6 Split screen area

multimedia presentation consisting of 21 slides, each containing eight advertisements. Each slide was displayed for 5 s. An example slide is presented in Fig. 24.5.

The Fig. 24.6 shows how the screen area is divided into eight parts, which are named from A to H. On the basis of this experiment, the following parameters are obtained:

- viewers—people who have visited the whole area of sight,
- watched time (s)—time spent by the user, expressed in seconds,
- watched time (%)—time spent on given area, expressed in percent,
- revisits—revision factor; calculated using the arithmetic mean of each user,
- revisitors—the number of people on the entire test that returned to the area,
- first view (s)—time elapsed in seconds before the area was noticed for the first time.

A part of the results is presented in Table 24.1, where the ratio of orange and blue advertisements is 2:6. The discussion of the obtained data is presented in Sect. 24.4.

Table 24.1 Results of the experiment for two orange and six blue advertisements

2:6	Viewers	Viewed time (s)	Viewed time (%)	Revisits	Revisitors	First view (s)
A	16/20	0.38	7.66	2.0	2/20	2.01
B	18/20	0.62	12.41	1.5	12/20	1.06
C	18/20	0.57	11.38	1.6	12/20	1.12
D	9/20	0.3	6.01	1.0	2/20	2.67
E	17/20	0.47	9.41	1.0	3/20	2.2
F	15/20	0.7	13.97	1.5	10/20	1.76
G	15/20	0.31	6.14	1.6	5/20	2.82
H	12/20	0.56	11.12	2.0	2/10	3.09

Table 24.2 Mean values for the main results of experiment for each box

	A	B	C	D	E	F	G	H
Viewers	17.85	18.00	18.86	14.28	15.86	16.57	15.86	11.86
Viewed time (s)	0.47	0.59	0.62	0.39	0.51	0.47	0.41	0.39
Revisits	1.34	1.69	1.69	1.20	1.10	1.50	1.37	1.07
Revisitors	4.43	12.71	12.71	2.71	3.86	6.29	6.00	1.71
First view	1.93	0.74	1.10	2.82	2.32	1.99	2.40	3.08

24.5 Discussion

Based on the data obtained, we can make a few simple statistical analyses and draw conclusions. First of all, the most impressive result is the number of return visits. The highest values for this parameter were obtained by the ads placed in the upper part of the slide, in boxes B and C (see Fig. 24.4). Regardless of the experiment hypothesis, the data shows that these were the places the users were most likely to return to. The mean value for boxes B and C is 12.71 for other boxes 4.17. This difference was significant with p-value equal to 2.9E−16. The first view parameter has also been an impressive result for boxes B and C with the mean equal to 0.92 s. For all other boxes the mean of the first view is 2.43 s (significance of the difference with p-value 1.04E−13). The examined contrast of color had no significance. The most attractive boxes B and C are quite similar and have the same number of revisitors and very similar mean of viewed time (p-value 0.67). However, the box B has 0.74 second to first view, on the other hand mean value for the box C is equal 1.10 s. The difference is statistically significant with p-value 0.0106.

The content shown in the corners was the least effective—they achieved the smallest revision rate and in most cases they were noticed at the latest, which can be easily observed in the Tables 24.2 and 24.3, presenting the means for all parameters in all groups and exemplary matrix of statistical significance. Probably, it results from the habits of the users. For example, the mean number of revisitors for boxes A, D, E and H (corner boxes) is equal to only 3.18, whereas for the rest of the boxes it is equal to 9.43. This difference is significant with p-value 7.06E−10. The same situation can be observed for the first view, where for corner boxes the

Table 24.3 Statistical significance (p-value) of difference between mean values in the group A–H for viewers parameter (the value smaller than 0.05 means that difference is statistically significance)

	A	B	C	D	E	F	G	H
A	–	0.0040	0.0019	0.2032	0.1934	0.0688	0.0132	0.0100
B	0.0040	–	0.4677	0.0000	0.0001	0.2706	0.2577	0.0000
C	0.0019	0.4677	–	0.0000	0.0001	0.1243	0.0859	0.0000
D	0.2032	0.0000	0.0000	–	0.1714	0.0035	0.0001	0.0811
E	0.1934	0.0001	0.0001	0.1714	–	0.0049	0.0004	0.1676
F	0.0688	0.2706	0.1243	0.0035	0.0049	–	0.6961	0.0001
G	0.0132	0.2577	0.0859	0.0001	0.0004	0.6961	–	0.0000
H	0.0100	0.0000	0.0000	0.0811	0.1676	0.0001	0.0000	–

mean value is equal 2.54 s, and for the rest of the boxes it is 1.56 s. This difference is statistically significant with p-value 8.2E−7.

The following conclusion can be drawn: websites-literate respondents focused their attention on the center of the presentation, as the content of web pages is usually placed there. Also, according to the results of the research on banner positioning on pages (Nielsen 2000), those placed at the top of the site yield better results. On the other hand, the low visibility of the various ads can be attributed to the assumption of the respondents that no significant content will be displayed there, as online ads are usually located there.

24.6 Conclusion

The main purpose of the chapter was to introduce an eye tracker device in the study of the effect of contrast on advertising messages and their intensity. The analysis of the obtained data shows that the contrast does not significantly affect the effectiveness of online advertising, which can be due to a number of factors, such as the individual preferences of the respondents or the small sample of respondents. The sum of the visual fixation time of the participants in the study was evenly distributed without showing any tendency toward specific behaviors. An interesting observation is that the eye-catching ads were not so much striking compared to ads located in specific parts of the screen. The ads that attracted the most interest were the ones located in the central part of the slide.

The studies conducted show that the eye tracking combined with the effectiveness of advertising messages can be a powerful tool in analytical economics and, in particular, in the acquisition of valuable information about the preferences of the marketing content recipients. An advertiser with the knowledge of what and how to advertise is able to generate a personal targeted advertising, reaching out to users with a personalized content.

Research has also identified areas for improvement and an extension of the research. For example, the next research experiment design should include an increased sample of the respondents, as well as the content of the displayed items should be analyzed in detail.

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Chapter 25
The Use of Experiment in Simulation of Debt of Local Government Units

Beata Zofia Filipiak

Abstract The chapter presents the use of shock analysis in the measurement of the financial stability of the local government units. This approach is based on the use of the experiment in forecasting the debt of local government units. The aim of the study is to demonstrate the possibilities of applying the experiment with the use of the shock analysis in monitoring the financial stability of the local government units, which is particularly important in the situation of having these debt units. In the first part of the study, the importance and the need for multi-variant approach to the assessment of the level and the possibility of borrowing of local government units are presented. Then, the importance and use of the plane of the experiment as a tool to support decision-making process of local government indebtedness is discussed. The last part of the study presents of the use of the shock analysis as an expression of the experiment supporting the decision-making process of local government units indebtedness. The importance of this experiment in maintaining the financial stability of local government unit by selecting the appropriate approach to the conduction of the experiment was also indicated.

Keywords Debt • Debt management • Shock analysis • Experiment

25.1 Introduction

Financial stability is not only an integral factor in the financial management of local government units (LGU), but it has a significant impact on the implementation of the tasks of these units and their public perception. Financial stability is a condition in which the local government units perform their basic functions continuously, efficiently, maintaining liquidity and fulfilling resulting from the Act fiscal rules, regardless of all kinds of perturbations and disturbances in the environment. Financial stability is determined by the provisions of the law, and the factors

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_25

affecting its formation are: the size of local government debt and balance of the current budget.

Although the statutory indications regulate the maintenance of financial stability, it is the primary factor in determining it, which is the size of local government debt, that is subject to risk and demanding to take wider action concerning the estimation of its effects. In the literature it is indicated not only on the need to move away from the legal approach to the problem of estimating the effects of the risk associated with the level of local government debt. This approach is not only criticized from the point of view of statutory construction, but also is pointed out that does not work both from the theoretical point of view and practice. It is also called on the need to use different approaches and methods for estimating the effects of debt on the stability and liquidity (e.g. Filipiak 2009, 2016a, b; Poniatowicz et al. 2010; Buiter 2011; Kamiński 2012; Denek and Dylewski 2013; Buiter and Sibert, 2016; Cichocki 2016).

One of the most important approaches from the point of view of the potential risks of local government units' financial instability is the use of an experimental approach to modeling the level of debt (to determine the financial model, or often called in practice, the financing model) to simulate decision situations allowing to get to know the factor (or factors) interacting on the level of debt in order to eliminate the risk associated with the loss of ability to meet its obligations.

It was assumed that the critical observations relating to the existing practice in the Polish local government approach to estimate the debt level will provide the basis for recommending the use of the shock analysis (stress tests) in building financial stability of the local government units. The aim of the study is to demonstrate the possibilities of applying the experiment with the use of the shock analysis in monitoring the financial stability of the local government units, which is particularly important in the situation of having these debt units.

In the first part of the study, the importance and the need for multi-variant approach to the assessment of the level and the possibility of borrowing of local government units are presented. In this part it has been demonstrated that the debt is the primary factor of the loss of stability of the local government units.

In the next part, the significance of the experiment and its applicability in the local government units is presented. Then, the importance and use of the plane of the experiment as a tool to support decision-making process of local government indebtedness is discussed.

The last part of the study presents of the use of the shock analysis as an expression of the experiment supporting the decision-making process of local government units indebtedness. It tells in detail how the experiment should be conducted using the shock analysis. The importance of this experiment in maintaining the financial stability of local government unit by selecting the appropriate approach to the conduction of the experiment was also indicated.

Implementing the set objective assumes the use of a theoretical approach to the shock analysis as the object of an experiment aimed to design its use in the practice of local government. In addition, the analysis of the legal sources will be used, allowing to determine the scope and possibilities of using the shock analysis. The

considerations will be supplemented with a theoretical discussion based on literature of the subject. Descriptive analysis method was also used in pursuing the aim and the method of deduction as well.

25.2 The Need for Multi-variant Approach to Assess the Level and Possibilities of Indebtedness of the Local Government Units

Issues related to the formation, purpose and meaning of public debt, arouse not only the controversy, but debt is repeatedly indicated to be a problem or a limiting factor (Kiyosaki and Lechter 2001; Poniatowicz et al. 2010; Bartkowiak-Marchewka and Korolewska 2011; Wiśniewski 2011; Dylewski 2016b). The basic problem stems from the approach to understanding the essence of debt management. Practice shows that it is the business of "shaping its structure so that with the existence of the debt were associated the smallest costs at an acceptable level of risk" (Ministerstwo Finansów 2016). This is one of the most important aspects of debt management, but not the only one. Much more comprehensive from the point of view of methodical and pragmatic is an indication that debt management is a process that must be considered in terms of short and long term, consisting in determining the ability of local government units to secure incurring debt, possibilities of its repayment and the most efficient use of available instruments of financing it (Cichocki 2013). This process is derived from decisions of constitutive organs and executive local government units and is part of the debt management strategy, which should lead to achieving the desired model of local development of the given local government unit from the point of view of the specifics of its financial economy, as well as in the context of the socio-economic situation in the region and individual legal, political, organizational and cultural conditions (Filipiak 2008; Poniatowicz et al. 2010; Kamiński 2012). Objectives of debt management are associated with satisfying the demand for money, choice of optimal development path under given conditions, ensuring tasks at a level acceptable by the society, creating conditions providing a secure and complete financing of the tasks which do not cover the income of local government units, reducing the transaction risk (in particular the financial risk: exchange rate, refinancing, interest rate, loan), cost optimization of the use of debt, including the optimal distribution of debt servicing costs over time and minimizing risk of liquidity loss by the unit.

Debt, although it is a category burdened with considerable risk (as indicated by the challenges to the process of debt management), can positively influence the functioning of the local government units in the long and short term, increase the flexibility of financial decisions, affect the achievement of financial stability, as well as accelerate the socio- economic development.

The challenge for local government units is undoubtedly the skillful use of indebted categories in the financial economy of local government in order to

preserve the financial liquidity, minimize the risk (especially of financial losses, the source of financing must be covered in the budget), or undertake development activities. The optimal solution is not to eliminate the debt, but to skillfully turn it into the financial management of the local government units in certain situations arising from the real needs and premises, and creating an optimal structure of capital and assets. In addition, the legislature requires that the decision-making government bodies to comply with existing regulations in terms of limiting debt. Applicable law in Poland introducing quantitative limits and qualitative information on incurring debt obligations by local government units (Wiśniewski 2010; Dylewski 2016b). To quantitative regulations are included (Filipiak 2010):

- the limitation resulting from the basic fiscal criteria (limiting) applicable in EU countries, which concerns the procedure for excessive deficit occurring in the given country, when the actual or planned public sector deficit exceeds 3% of GDP or the ratio of government debt to GDP exceeds 60%,
- the limitation relating to the achievement a value greater than 55% and lesser than 60% of the relation of the amount of public debt to the gross domestic product resulting in the introduction of remedial actions under the law on public finances,
- reduction of contracting loans, granting guarantees and financial sureties resulting in the public debt exceeding 3/5 of GDP (Internetowy System Aktów Prawnych. Sejm RP (1997)) and the ban on exceeding the relation of 60% of total debt of a local government unit to the income of this unit during the financial year (Internetowy System Aktów Prawnych. Sejm RP (1999)),
- the prohibition on the issuance of securities at a discount of more than 5% of nominal value,
- limits of the maximum absorption of the debt (incurring and its service) based on the individual indicator, which refers to the realized current income, property income and current expenditure in terms of ex-post for the last three years

  (*It is a relation introduced by the Article. 243 of the Act of 27 August 2009. Public Finance. OJ No. 157, item. 1240 with amendments. d .. The method of its calculation is as follows:*

$$\left(\frac{R+O}{D}\right)_n \leq \frac{1}{3} * \left(\frac{Db_{n-1}+Sm_{n-1}-Wb_{n-1}}{D_{n-1}} + \frac{Db_{n-2}+Sm_{n-2}-Wb_{n-2}}{D_{n-2}} + \frac{Db_{n-3}+Sm_{n-3}-Wb_{n-3}}{D_{n-3}}\right)$$

  where: R—the total amount of repayment of the loans installments and buyouts of securities issued or incurred to finance, planned for the financial year: the planned budget deficits; repayments of earlier liabilities incurred due to the issue of securities and loans and borrowings; O—interest on loans and interest and discount on securities—incurred or issued on the same objectives as set out above and the repayments of the amounts resulting from sureties and guarantees planned for the financial year; D—total income of the budget for the financial year; Db—current revenue; Sm—income from the sale of assets; Wb—current expenditure; n—the year when the relation is established; n-1—the year preceding the year when the relation is established; n-2—the year preceding the year for two years; n-3—the year preceding the year for three years.)

- the limitation on the incurrence of obligations specified by statute titles above planned amounts in the budget resolution of the local government units.

Quality regulations formulated regarding the possibility of incurring debt obligations by local government units include[1]:

- the obligation to bear the costs of debt service at least once a year,
- the prohibition of capitalization of interest on debt obligations,
- the need to obtain the opinion of the regional Accounting Chamber relevant to the given local government unit concerning the possibility of repayment or repurchase of debt obligations,
- the use of indebted instruments only provided by law (loans and credits, issued securities, public-private partnership, leasing transactions hire purchase type of, loans and trade credits, insurance services, sureties and guarantees, hedging transactions (such as underwriting), hybrid instruments[2]),
- the prohibition of incurring debt obligations whose nominal value to be paid on the due date, expressed in zloty, has not been determined on the date of the transaction,
- the necessity of estimating transactional risk and making its audit.

Despite the restrictions imposed by the legislature, it should be noted that the size public debt of the local government is considerable. Incurrence of debt obligations requires the creation of appropriate managerial and decision-making instrumentarium, which will allow of the local government units authorities to make the right decisions, allowing to achieve the desired objectives in time, and above all, will ensure the financial stability of the local government units (including the maintenance of liquidity), with an acceptable level of social and economic development.

The level of local government's debt over time is presented in Fig. 25.1. In recent years, a systematic increase in the debt of the entire local government subsector can be observed, although it must be emphasized that the very high growth dynamics of debt, which took place in 2008–2011, has been significantly slowed down. It was influenced by several factors, including the introduction of the individual limitation of debt, which some local government units while preparing it limited further growth of debt.

A slowdown in the growth of debt was also associated with the completion of the financial perspective of the EU. During the period 2008–2012 local governments from the EU funds co-financed investment assignments of significant value. The

[1]This is indicated by Article 68, 92, 93 of the Act of 27 August 2009. Public Finance. OJ No. 157, item. 1240 with amendments.

[2]For the purposes of ESA'95 (The European system of national and regional account - ESA'95), and in accordance with EUR-Lex (2015) Commission Regulation (EU) 2015/2406 of 18 December 2015. amending Regulation (WE) No 1126/2008 adopting certain international accounting standards in accordance with Regulation (WE) No 1606/2002 of the European Parliament and of the Council as regards International Accounting Standard No. 1. EUR-Lex (2015)

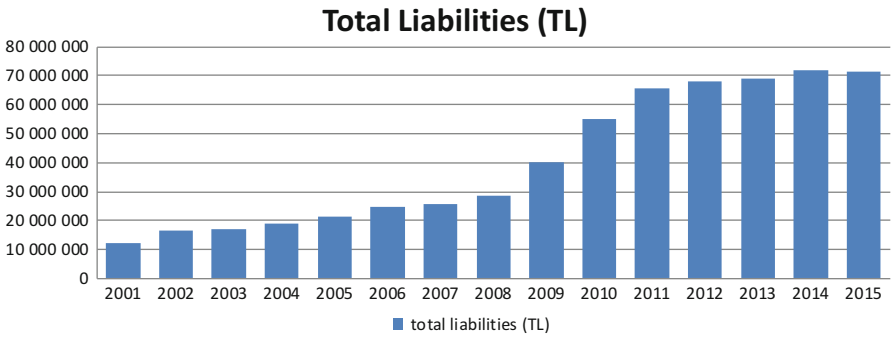

Fig. 25.1 Total debt of local government units in a billion PLN (own study based on data (Krajowa Rada 2002–2016))

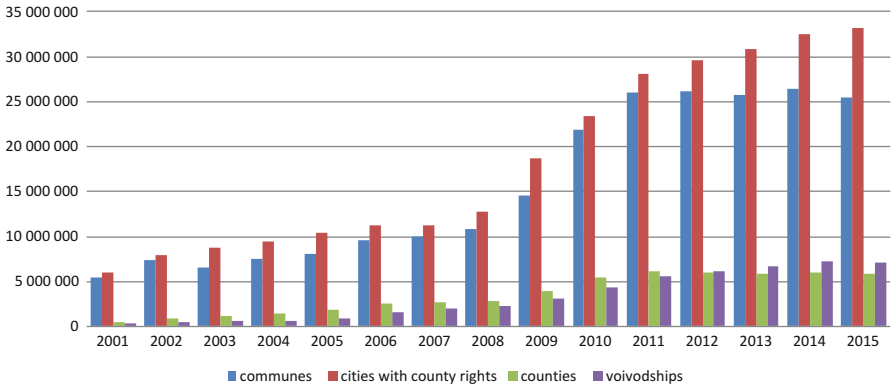

Fig. 25.2 The debt of local government units divided into types of units in billion PLN (own study based on data (Krajowa Rada 2002–2016))

new financial perspective starting in 2013 brought a delay in decisions concerning the directions and priorities for the use of EU funds, which resulted in reduced absorption of both the EU funds and reducing loan needs.

Figure 25.2 shows the evolution of the level of indebtedness divided into four types of units occurring in the Polish territorial division. The observed trend is the presence of a significant level of indebtedness in communes and cities with county rights. In cities with county rights and voivodeships government indebtedness shows a continuous upward trend since 2008. In communes since 2011 indebtedness tends to stabilize. However, in the counties since 2012 it has been a slight trend in limiting debt.

Analysis of the data indicates that the largest loan needs show a communes and cities with county rights. At a similar level report borrowing needs counties and voivodships. It can therefore be concluded that in Poland there is quite a wide variation in level and dynamics of local government units of indebtedness.

Taking into account both the existing restrictions (especially the limitation level and repayment of debt obligations) in incurring debt obligations, the existing tendency and significant size of the already incurred debt obligations (Figs. 25.1 and 25.2) and the challenges associated with the possibility of occurrence of new loan needs, decision-making bodies of local government units should base their decisions on multi-variant approach and financial simulations aimed at reducing the risks associated with the already incurred and potential debt.

Proper (optimal) decision should never be made randomly, without considering the complete information, without specifying options including the potential impact and risk of planned decisions. The optimal decision is the result of deliberate efforts of intellectual executive bodies and of constituting local government units. It must take into account the risk and uncertainty associated with the decision situation, because the existing legal provisions require consideration of potential risks. The key issue in the decision analysis is application of proper technique of quantitative consideration of the decision variant description and its likely outcomes under conditions of uncertainty. This is possible in particular through the description of uncertainty in terms of mathematical probability theory, capturing the probability (adoption by random variable some values) in numerical terms. Very useful development is to use a simulation approach. It allows to consider many variants of decision making in actual system, (which leads to the assessment of trends in the area of indebtedness from the past and forces the determination of the most optimal level of indebtedness, or a proceeding path in an uncertain future in terms of financial situation). Another argument in favor of the use of simulation methods for optimal predicting from the point of view of risk and financial stability of the local government units is the ability to conduct a sensitivity analysis of indebtedness, which allows to make changes in selected parameters of simulated model of indebtedness and the controllable variables (eg. interest rates, or financial parameters describing a debt instrument), observing of the model the reaction to these changes and registration of indicators showing the degree of their optimality. Through carrying out (based on previously prepared variables) a number of experiments it can be concluded about the relation between variables of model and above all to make an initial verification of a number of alternative strategies around indebtedness (in a relatively short period of time), and choose from them the most appropriate (Law and McComas 2001).

25.3 Experiment as a Tool to Support Decision-making Process of Indebtedness of Local Government Units

As it is indicated the simulation is associated with modeling the system and performing experiments involving observation of the model in time. Predicting (estimation of consequences) the results of individual variants of decision through a series of virtual (aimed at improving the predictions) experiments (conducted on

the basis of the representation of the developed model and not the real system or situation). = (Swain 2003; Findeisen et al. 1978). The experiment is a series of experiences enabling the identification and optimization of the analyzed object or model (Mańczak 1976).

The gradual popularization and implementation of the practice of public sector economics of the experiment is associated with the person of Vernon Smith, who sought explanation to the many issues microeconomic, and in particular studied the mechanism for delivering public goods (Smith 1979, 1980).

In experimental studies the basic step is to establish the plan of the experiment, the effect of which is the acceptance of the value or category of independent variables (independent variable) which are to be compared. Also people are selected, objects or subjects for research. at the same time there are procedures in place, to which are allocated individual values or categories of the independent variable and specifies what type of observations and measurements will require a study of the given phenomenon or problem.

Determination of the value or category of independent variables is to determine the specific experiences (not necessarily conducted at the same time). Set of experiments creates a series. In the individual experiments the values of variables may change, while the set of variables does not change. Repeating a series of experiments using the same values of variables is used in order to estimate the description parameters of the studied phenomenon (or object) with the assumption of the presence of factors not included in the mathematical description of the object.

The planning procedure forces of the experiment (Czarny 1979; Zabawa 2005):

- decision on the nature of the experiment (active or passive, continuous or discrete),
- determination of the parameters of the experiment (forecast accuracy, the duration of the experiment),
- undertaking the activities aimed at elimination of anomalies in the results of experiments and make of filtration of the results,
- taking action of the actual design of the experiment (for an experiment active),
- decision on the technique of the experiment.

The biggest advantages of this experiment is the possibility of reproducibility. Replica of the outcomes of the study confirms the results of the first experiment. The experimenter should be tempted to re-run their project in order to compare the results (Brzeziński 1999; Jabłońska 2013).

Experiments have an advantage over the other research methods that allow under controlled conditions to track the impact of each factor on a particular model or a decision variant. In addition, they allow to test different solutions, which are to serve the optimal financing of implemented tasks (both of a current and investment character), and therefore they seem an essential tool for research and solutions seeking (Marwell and Ames 1981; Dawes and Thaler 1988; Jakubowski and Kuśmierczyk 2008, 2013).

The outline of the approach to conducting experiments in economics presented above, allows to place question about the applicability of this approach to the

assessment of debt of local government units. Considering the same phenomenon, reference may be made to the use of the experiment on two levels:

- The first level will create the possibility to use the experiment to assess the adopted model or models of debt and determine the effect of (estimation of the consequences, effects) the adopted model of indebtedness (models) on financial stability and ability to maintain the liquidity of local government unit.
- The second level includes the possibility of conducting the experiment referring to the assessment on the based on the adopted changing decision behaviors of the local authorities reaction) on the model of debt.

While the first level applies to the appropriate motivation of the respondents to make considered decisions, to know their potential effects and to reduce the risk, it is the second level that refers to the impact of the behavioral factor on decision making process on the indebtedness (choice of a specific model of debt). The results of the experiment concerning the first level will be aimed to take decisions in terms of choice of the optimal construction model or verify the existing model of debt. They will allow to get to know the effects of the most important factors (variables) on financial stability and liquidity of local government units in time.[3] This is a very important aspect of the (even critical) decisions made by local government's authorities, taking into account presented conditions and restrictions associated with incurring debt obligations. Limitations on the possibilities of incurring debt obligations and the unconstrained shaping of the debt repayment are important variables in the construction model. Their inclusion in addition to other market elements of shaping the model of indebtedness (in particular: instruments, interest rates, currency) is essential in the construction of the model.[4] Moreover, the variables that must be taken into account are the size of income and expenditure, as variables affecting the development of the individual debt ratio (IDR) (Filipiak 2016a).

The results of the second level will be an important informing factor about the tendency of local government authorities (decision making) to make decisions including the risk factor. This tendency will be examined on the basis of the experiment and its results will have indeed an effect on the choice of the model of debt.

The answer to the question about the possibility of using the experiment to assess the indebtedness is positive. But the potential to use the experiment in the decision-making process should also be positively assessed, because the results of the experiments will allow not only to estimate the inclination to take risks concerning the decisions taken by the local authorities. The results of the experiments will increase the accuracy of the used debt model, change its parameters, increase the

[3]More about the factors determining financial stability and liquidity in the studies: Kamiński (2012), Poniatowicz (2014), Filipiak (2016a, b), Dylewski (2016a, b).

[4]Component elements and approach to the construction of model variants indebtedness presented Filipiak (2008), and studies in this area were carried out by Kamiński (2012).

flexibility of the model, and thereby this approach will contribute to the maintenance of financial stability and increase the ability to control liquidity of local government units.

As indicated above, an important function of the planning procedure of the experiment is the technique of the experiment and approach to the modeling. From the perspective of the development of experimental approach in economics, popularization of computer technology should be emphasized, as a kind of specific platform for the efficient organization of the experiment. For the use of the organization of the planning process and conducting the experiment has already been indicated by V. Smith (1998). From the point of view of development of the approach are important the works of Nehrebecka and Dzik (2012), Guszczyński (2012). With regard to the public finances about the importance of the techniques in conducting the experiment Jakubowski and Kuśmierczyk (2008, 2013), Czekaj and Nawrocki (2012), Filipiak (2016b), Cichocki (2016) are discussing in their work.

25.4 The Use of the Shock Analysis as an Expression of the Experiment Supporting the Decision-Making Process of the Local Government Units' Indebtedness

One of the research problems that can be solved using the planning technique of the experiment is to seek answers to the question about the value of decision variables to optimize the level of debt. As has already been argued, the values of these variables are not only important from the point of view of the statutory of quantitative restrictions related to the level of debt, but also an important aspect of the policy of maintaining liquidity and financial stability of the local government units. These are therefore relevant variables from the point of view of the decision-making process by the local authorities.

In order to determine the value of decision variables in the planning process of the experiment shock analysis can be used. Shock Analysis (stress test) lead to the assessment of the level of resistance of the local government units' financial economy (in particular parameters describing it, and one of them is the level of indebtedness resulting from the adopted model of debt) to negative events (Painchaud and Stučka 2011). This aspect is very important, because it allows to determine the values of decision variables, which can be the basis for the destabilization of the unit consisting of the loss of liquidity, or the initiation of the restrictions specified in the applicable law and of exceeding the statutory restrictions on incurring or repayment of debt obligations. Shock analysis allows to answer two main questions (Filipiak 2016b):

1. what is the financial stability of the local government units at given time on a given level of debt?
2. what factors affect this stability, taking into account the adopted parameters of (values of decision variables) the debt model?

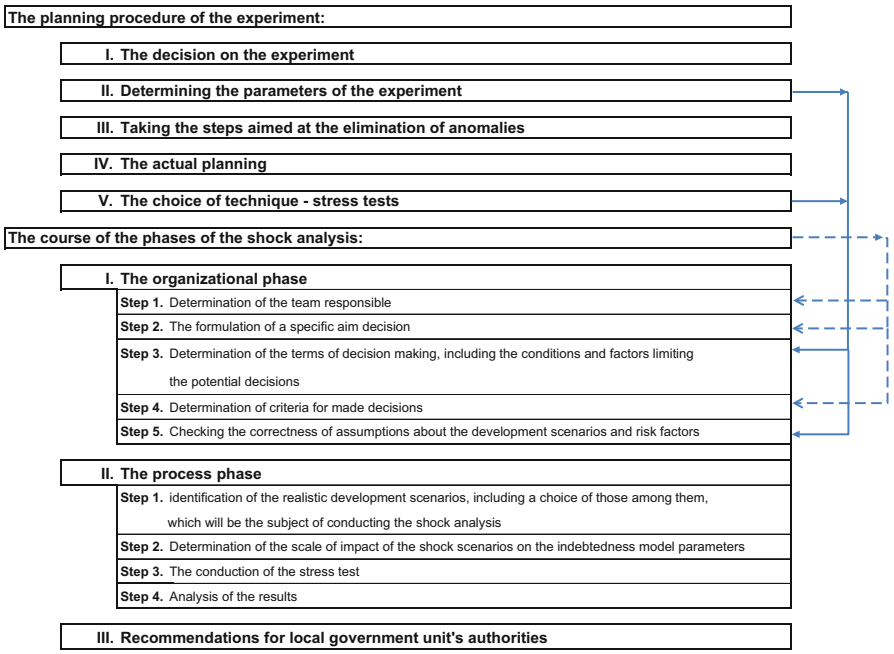

Fig. 25.3 Flowchart of the experiment with the use of the shock analysis (own study)

From the above reasons, one should call for the introduction of stress tests as an instrument for monitoring the potential impact of changes in financial position due to many factors (called decision variables). For the financial stability of local government unit the knowledge of the factors destabilizing it is also important. Relation of planning stage of the experiment to the course of the phases of shock analysis shows Fig. 25.3.

The first phase of shock analysis (organizational) starts by the appointment of the team responsible for carrying out the experiment, assigning team members to tasks and determining responsibilities for the execution of specific tasks. The next step in the first phase of shock analysis starts by formulating the specific decision aim, which will answer the question which decision taken by the local authorities will bring the most benefit and minimize the loss. In mathematical terms, the set of all variants of the decision is marked as (A) and takes the form (Nawrocki 2015):

$$A = \{a_1, a_{2,\ldots}a_n\} \tag{25.1}$$

A sought result of a solution (R_{KL})m is the result (r) of a decision (K) by the development scenario[5] (L) takes the form:

$$R_{KL} = \mathrm{r}\left(\mathrm{a_k}, \Theta_\mathrm{l}\right) \tag{25.2}$$

In practice, decisions relating to the size and parameters of the debt comes down to choosing at least several decision options. The aim, which local government unit can put itself can maximize the use of debt financing (maximum parameter), the minimization of debt, minimizing the cost of debt service (minimum parameter), connecting options to minimize the cost of debt service with maximizing or minimizing the debt (minimum parameter), increasing the limits in the applicable statutory limitations (increasing the potential possibility of incurring the debt in the future) (maximum parameter), acceleration ability of debt repayment (maximum parameter).

In the next step (third) in the first phase, determination of the conditions of the decision making is carried out, including the conditions and factors limiting the potential decisions that must be satisfied during the implementation of the taken decisions. They may belong to a independent group from the decisions of the local government unit, but also may be dependent factors. Among the conditions limiting the potential decisions of the organs of local government must be included the statutory debt limits (i.e. SGL that in this step must be calculated in accordance with applicable law[6]), legally acceptable debt instruments, acceptable parameters describing the transaction debt (these parameters are important variables of the stress test). In this step the fiscal space is also projected.[7] Can also be accepted additional parameters (which is in practice very often used and reflects the individual policy of local government authorities to shape debt). An example of a parameter can be to determine the percentage diversification of the use of funding sources (Czekaj and Nawrocki 2012; Nawrocki 2015; Filipiak 2016b).

In addition, the criteria for decision making must be specified. Each decision must have a direct relation to the adopted criterion, and be closely associated with the specific decision aim. In this phase it is assumed that the scenarios of development based on the task of the local government unit will affect the model of debt (consisting on a given indebtedness model debt instruments with describing them debt parameters, or steerable variables, also called components of the debt portfolio) (Painchaud and Stučka 2011).

The second phase of shock analysis, called the process phase, is carried out to identify all realistic scenarios, those that may negatively affect the scheduled

[5]Development scenario of local government units, is a method of presenting a possible future serving the choice of a variant of development policy, apart from the planned tasks are included the sources of financing, including the planned debt (funding source return).

[6]The method of calculation is given in the footnote 1.

[7]This term is synonymous with the concept of operating surplus, understood as the difference between current revenues and current expenditure of the local government unit.

parameters of the debt model. It is also where one choose from a number of them, which will be included in the shock analysis. The ones that can bring the most negative consequences are usually assumed. Please note that the decision is taken in terms of risk, that is, when even one of the decision possibilities involves more than one consequence, where set of possible consequences and the probability of their occurrence is known. For this reason, it is necessary to determine what risks will start various development scenarios (Nawrocki 2015; Filipiak 2016b).

The set of identified scenarios, in mathematical terms, is designated as: (Nawrocki 2015)

$$\Theta = \{\Theta_1, \Theta_1, \ldots, \Theta_n\} \tag{25.3}$$

The optimal scenario is a set one piece, characterized by the best decision under the given circumstances. It can be represented by the formula (Nawrocki 2015):

$$\Theta = \{\Theta_0\} \tag{25.4}$$

Taking into account the realities, it should be emphasized that this scenario is unattainable, because in practice we are dealing with the impact of the risk factors, which usually involve more than one consequence. The occurrence of risk factors makes it impossible to achieve the best result. Considering that the decision on the indebtedness is taken in specific risk conditions and the set of consequences and the probability (P) of their occurrence is known, the result of an optimum decision can be expressed by the formula (Nawrocki 2015):

$$R_{opt} = r(a_{max/min}, \Theta_0) \tag{25.5}$$

Probability (P) is expressed by the formula:

$$\mathrm{P} = \{\mathrm{p}_1, \mathrm{p}_2, \ldots, \mathrm{P}_n\} \tag{25.6}$$

The sum of the results of a given decision (k) for all approved development scenarios can be expressed by the formula (Nawrocki 2015):

$$\mathrm{R}(\mathrm{a_k}) = \sum_{l=1}^{m} r_k * p_l \tag{25.7}$$

An optimal decision, which will be either the maximum value (max) or minimum (min), which can be expressed by the formula:

$$R_{opt} = R_{max/min} \tag{25.8}$$

It should be noted, however, that in practice there may be situations where the decisions of the local authorities will be taken in conditions of uncertainty, when probability of the consequences of the decision is not known. In this situation, one must accept the safest scenario from the set, which guarantees the determination of

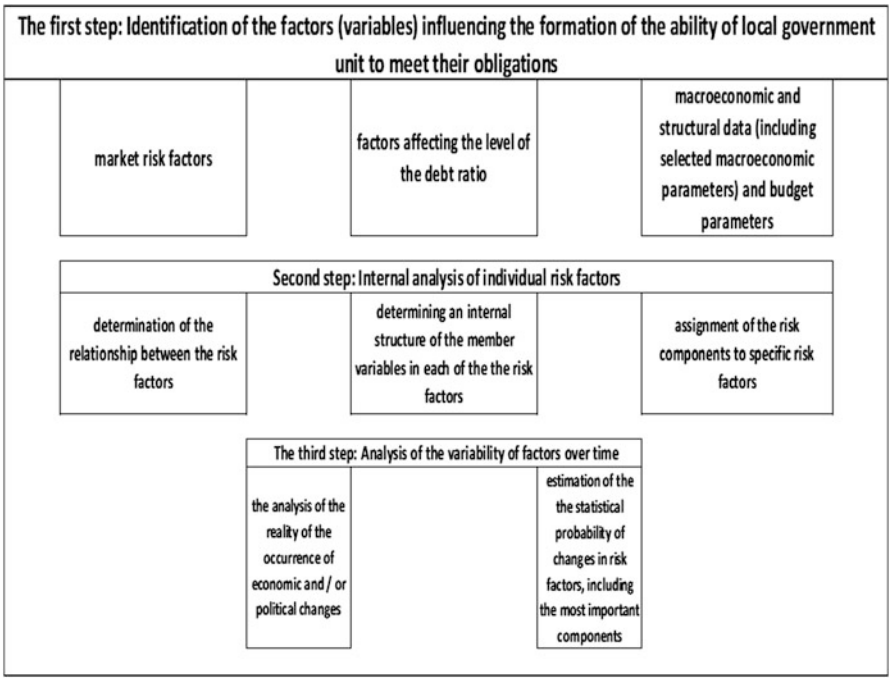

Fig. 25.4 Schematic approach of the proceedings in order to identify the groups of the risk factors that may affect the aim decision (own study)

the probability of the specific consequences by the formation of the given decision parameters.

Figure 25.4 shows the groups of the risk factors that may affect the agreed aim decision. These factors can be put in two groups: market risk factors[8] (in particular the interest rate, fluctuations of exchange rates, the refinancing risk, the situation on the domestic and foreign financial markets) as well as factors affecting the level of the debt ratio (i.e. restricting limits). The macroeconomic parameters and budget should also be subject to the assessment, affecting the basic risk factors of the portfolio. In the analysis the fact that one risk factor may consist of several or dozens of components (variables) should also be taken into account. Then, each component (variable) must be assigned to one or more risk factors. Unquestionable decision problem which is to solve, is the number of risk variables and estimation of the statistical probability of its occurrence (Czekaj and Nawrocki 2012; Filipiak 2016a, b).

As part of the process phase of the shock analysis, the next step the scale of the impact of the shock scenarios on the parameters of debt model (i.e. debt portfolio) is

[8]These factors have a direct impact on the increase or decrease in the cost of debt service, or on its level.

determined. An important decision one need to make is to choose the methods for estimating the volatility of risk factors. It should be emphasized that the practice would indicate the two approaches in this area. The first recommendation is to use the VAR method (Value at Risk)[9], which spread in the banking system. The second approach is a scenario analysis and building the maximally negative scenarios of states based on the historical development of selected risk factors (ie. scenario analysis[10]). This does not change the fact that in the literature it is indicated on the legitimacy of building a deterministic models with adopted assumptions of shaping variable parameters (reflecting the volatility of the risk factors), conducting analysis of the variability of time series and the use of methods of analysis of probability with regard to the occurrence of a particular risk factor. The choice of method does not change the basic postulate, which is, that this analysis should be focused on the negative approach (i.e. upheavals of the negative impact on the behavior of financial stability) (Kamiński 2012; Czekaj and Nawrocki 2012; Filipiak 2016b).

Before the final step is physical conduction of the shock analysis, as an experiment. The last step of the process phases of the shock analysis includes conducting an analysis of the results achieved (results). The analysis of maximally unfavorable variant (scenario) is conducted here, which will indicate the occurrence of the so-called financial gap (or the demand for money) resulting from the occurrence of extremely adverse impact of the risk factors on the financial position of the local government unit. This means that there a scenario is determined, that is characterized by such portfolio of risks that threaten the current fulfillment of the obligations and will prevent the implementation of the records concerning the SDL, causing disturbances in the tasks in the accepted qualitative and quantitative standard. The result of the last group of activities should be to determine the resistance of the financial management of local governments unit on the occurrence of negative financial phenomena.

In this step the assessment of the level of probability of the shock scenarios is also carried out. This allows to determine the probable scenarios that will become the recommendations for the construction (including adopted criterion in decision phase 1) or correction of the existing debt model.

Despite the fact that the results of the stress test may be prone to errors (due to the estimated nature of the parameters that describe a particular debt instrument, also known as the steerable variables, as well as due to the estimated intake of macroeconomic and budget parameters) should not diminish the fact that this analysis validates the ability to fulfill the obligations of the local governments unit, indicate the possible changes and their effects on the adopted financial model, identify a safe (and not statutory) debt limit through made simulations of the adopted scenarios.

[9]Indicates a recommendation to use this method: Pritzker (2001); Pera (2008); Czekaj and Nawrocki (2012), Nawrocki (2015), Filipiak (2016b).

[10]This approach is recommended particularly in the study of the effects of political, economic and financial factors on the costs of debt service in Filipiak (2008), Kamiński (2012); Czekaj and Nawrocki (2012).

25.5 Conclusions

Analysis of statistical data concerning the level of the formation of local government units' debt obligations indicates not only on the gradual, and in some years even abrupt increase of debt obligations. On this situation imposes the significant effect on the financial stability of the business cycle factors, affecting the income level of local government units. Volatility of macroeconomic developments, their speed and fierceness cause problems in the correct estimation of the income. A financial gap appears, which on the one hand, requires the search for sources of external financing (i.e. indebted), and on the other hand, there is a problem with the limitation of the indebtedness and restricting concerning the formation of the size of the repayment on an annual basis debt obligations. The presented situation confirms the necessity of making impact analysis the risk factors on preserving the financial stability, and thus the impact of risk on the level of debt obligations and the costs of their service. From the point of view of preserving the financial stability multivariant approach to explore new critical factors and to determine the most critical scenarios becomes important.

From the point of view of the needs of local decision authorities, and especially to ensure financial stability and liquidity in the long term, the experiment that allows to explore the critical multi-variant development scenarios, considering the specific financing model gains importance. The experiment allows to know the impact of risk factors associated with debt financing, the risk effects burdening the use of selected debt instruments and parameters describing them (eg. Foreign exchange rates, interest rates) in the given model.

Through the use of the experiment increases the area of local government decision authorities, as well as preparing specific scenarios allows for the elimination of extremely unfavorable scenarios (of particular value is here the use of the shock analysis). It is important that the experiment allows to determine the optimum decision, taking into account the optimal choice of parameters for the indebtedness model. This means that, through the experiment there is achieved an optimal decision from the viewpoint of the decision criterion ($R_{opt} = R_{max/min}$).

The undeniable advantage of the experiment is the ability to find answers to the question of financial stability and financial liquidity by local government units at a given level of indebtedness and existing or potential model of debt. This advantage of the experiment is undeniable in terms of making decisions by the local authorities. Against this there is a slight difficulty in conducting the experiment. It is the human factor. Employees of the local government must not only have the knowledge to carry out the experiment, they must be able to interpret the obtained results from the point of view of the risk, but also must want to use experimental approach.

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Chapter 26
Reflections on Research Process: Online Experiments on Allegro Platform

Aleksandra Grzesiuk and Jacek Cypryjański

Abstract Purchases made through auction platforms reflect many aspects of behavioral features of decision-making processes. The roots of purchases on auction platforms in Poland go back to the pricing policy and the pursuit of customers to buy at the lowest price. However, contemporary mainstream research indicates that the buyers' behavior is strongly conditioned behaviorally. Therefore behavioral aspects of decision making on online auctions are in the center of interest in this chapter. Allegro platform is the key transaction website in Poland. The scope of this marketplace and its recognition mean that it is a perfect place to conduct field experiments in the context of online auctions. The chapter focuses on experiments in the context of online auctions carried out in real conditions on Allegro platform. The background for field experiments is presented in general, followed by an extensive discussion on the determinants of field experiments online. The Authors report on their experiences with online field experiments as research methodology and present some insights and advice for conducting such studies. Finally, they review the possibility of using Allegro platform as a space to conduct market experiments online.

Keywords Economic experiments • Field experiments • Online auctions • Allegro

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K. Nermend, M. Łatuszyńska (eds.), *Neuroeconomic and Behavioral Aspects of Decision Making*, Springer Proceedings in Business and Economics,
DOI 10.1007/978-3-319-62938-4_26

26.1 Introduction

The Authors are interested in different aspects of buyers' behavior in online auctions and managerial recommendations. This problem is fairly widely analyzed in the international literature, which provides a number of valuable research and analysis. However, as for the Polish market, the knowledge in that field is limited.

The purpose of this chapter is to present the opportunities to conduct field experiments online for e-business purposes. In the past, market experiments in real conditions (field experiments) have not been widely used in business, but the Internet creates a special space for their implementation. The chapter focuses on experiments in the context of online auctions carried out in real conditions on Allegro platform. Research interest in online auctions is due to their key role for the Polish e-commerce.

In this chapter, the background for field experiments is presented in general, followed by extensive discussion on the determinants of field experiments online.

The structure of online auction market in Poland is presented, followed by the thesis that the market share of Allegro platform on the online B2C and C2C market in Poland is so important that Allegro can be regarded as an independent marketplace.

Thus, the Authors formulate the hypothesis that the field experiments conducted on Allegro platform can verify the behavior of online buyers in Poland. However, the concept of field experiments online as a research method is poorly recognized in Poland. In this chapter, the Authors report on their experiences with online field experiments as research methodology and present some insights and advice for conducting such studies. Thus, the other aim of this chapter is to review the possibility of using Allegro platform as a space to conduct market experiments online. The Authors are going to create a catalog of the conditions of this kind of research.

26.2 The Idea of Field Experiments

Field experiments represent the conjunction of two methodological strategies, experimentation and field studies (Gerber and Green 2011).

Experimentation (experimental research) is commonly used in sciences such as sociology, psychology, physics, chemistry, biology, medicine, etc. Today, there is also widespread use of experimental research in political science. Experimentation is a form of research known for a long time. Rousmaniere (1906) described it over a century ago. He classified the difference between observation and experimentation. In experimentation, the investigator consciously and voluntarily alters the conditions of the phenomena studied. As Oehlert (2010) described, an observational study also has treatments, units, and responses as in experimentation. However, in the observational study, we merely observe which units are in which treatment

groups; we don't get to control that assignment. The comparison between manipulated and basic groups is the key feature of experimentation.

According to the Authors of this chapter, above definition is a classic perception of the experiment and it clearly reflects the essence of this research method and its use in economic sciences.

In the broad sense, experimentation is a form of investigation where the researcher manipulates one variable and control the rest of the variables. As two groups are investigated: the control group and the manipulated group, the units have been randomly assigned to the groups. The researcher tests one effect (manipulated variable) at a time. An independent variable (the cause) is manipulated and the dependent variable (the effect) is measured. A hypothesis is scientifically tested. Any extraneous variables are controlled.

However physical sciences tend to define experiments more narrowly than social sciences, for the purpose of this chapter we will focus on this wide context of understanding experimentation. In the following parts, we will focus on the use of experiments in customer buying behaviors' research and these, in turn, are classified within social sciences.

As mentioned, field experiments combine experimentation and field studies. There are three types of experiments: laboratory/controlled experiments, field experiments and natural experiments. Laboratory experiments are conducted in a well-controlled environment. The researcher decides where the experiment will take place, at what time, with which participants, in what circumstances etc. Natural experiments are conducted in the everyday environment of the participants (real life), and the experimenter has no control over the variables as it occurs naturally in real life. Field experiments are also done in the everyday environment of the participants. However the experimenter still manipulates the independent variable, but in a real-life setting (so cannot really control extraneous variables). The literature review and the review of research practice tend us to the conclusion that researchers identify natural experiments with field experiments. For the purpose of this study, strict separation of these concepts is not necessary. Therefore the Authors assume that laboratory experiments are conducted in the well-controlled environment while field/natural experiments—in everyday, real-life environment.

As Harrison and List (2004) indicate, lab experiments in isolation are necessarily limited in relevance for predicting field behavior, unless one wants to insist a priori that those aspects of economic behavior under study are perfectly general in a sense that we will explain.

Thus, in the center of our interest are field experiments. Their main advantage in business and management is the ability to study the customer behavior in the real-life. According to the Authors, the implications of such research are particularly valuable for managers (managerial recommendations).

Although the field experiment may give more construct validity and greater external validity than lab experiments, there are also disadvantages. The field experiment may lack external, construct, and internal validity. Furthermore, field experiments may be unethical, and demand more time, researchers' involvement and costs. The time and costs perspectives may limit its use in economic research.

Of course, we can list examples of organized processes of research in different areas of the business conducted as field experiments. An example is a market test as a kind of commonly used experiment in marketing when introducing a new product on the market.

Another example, at the macroeconomic level, is basic income experiment in Finland. The experiment will take place in 2017–2018 (Kangas and Kalliomaa-Puha 2016). Through this experiment, the government wants to explore how to diminish, and possibly abolish, the work disincentives and income traps which it thinks weakens the present social transfer system in Finland. The experiment in basic income covers unemployed participants. As officially published 2000 randomly selected citizens will be given a guaranteed basic monthly income of €560, even after they've found work. Total costs of the payment of this allowance (basic income) will exceed €26,8 millions plus organizational, administrative and research design costs.

Due to the costs of conducting such experiments, they are feasible only with the support of the e.g. state budget. At the microeconomic level, for the business purpose, decision-making process of the company, the most common limitations like costs and time are so significant that prevent conduct extensive field experiments. However, the development of communication technologies, including the Internet, has created a new environment for the business activity. In the next section, we will consider the possibility of conducting online field experiments.

26.3 Field Experiments Online vs. Offline

Field experiments conducted over the Internet have several distinct characteristics compared to those conducted in a real environment, beyond the virtual space, offline. Of course, the main difference relates primarily to the specifics of the buyer's behavior. The nature of customer behavior is often unique to the online environment; even through the underlying behavioral principles might be the same.

Online auctions combine the conventional auction model with information technology. However, information asymmetry within such online auctions causes risks and uncertainties that influence consumer purchase intentions and generally, customer behavior.

There have been intensive studies of online shopping attitudes and behavior in recent years. Many factors of the buying process have been discussed to have a great impact on consumers' online auction purchasing intention. The most important are: price, product information, brand, seller reputation, the number of bidders and auction time (Wu et al. 2011). It is claimed that a customer's search online goods cheaper than they can buy them offline. The argument for online shopping could be a price. The price is often cited as an important criterion in purchase decision-making process. But online its importance is much larger because the customers receive in a very short time summarized comparison of prices from different suppliers.

Due to uncertainty and impersonal nature of online transactions, perceived risk can be viewed as a critical element of online decision-making process. Wu et al. (2011) show that e-retailer reputation has a more significant influence on general risk than product price does.

By following the online field experiment, the researcher has the possibility to verify these relationships in the real environment of the buyer.

Online auctions have attracted emotional buyers through exciting shopping processes such as searching and bidding (Min-Young et al. 2013). Buyers offline usually have to pay more time and effort for searching, and in spite of all, their possibilities to review the offers on the market are smaller than online.

Bo-Xu et al. (2010) show that buyer's purchase behavior and usage of risk relief service for a transaction in buy-it-now auctions are determined by the perceived risk, which is influenced by the buyer's risk attitude, seller online reputation, and the product price and type.

Online auction platforms are well-organized markets. The operators of these websites implement systems to assess the reliability of both sellers and buyers. Hence, the buyer may reduce the perceived risk.

For research perspective, conducting online field experiment could result in interesting conclusions and recommendations in the field of reputation management.

26.4 Online Auction Markets as Separate Markets

One of the research questions verified in this study is the question of market structure. Analysis of statistical data in different national markets shows a structure generally dominated by a single website/online platform, with a very high market share, close to a monopolistic or oligopolistic structure. Reasons of such a market structure are not studied in this chapter. However, the Authors emphasize that it represents an interesting area of research of economic theory, market structures, and competition structures. Observation of the market structures of online auction websites in different countries indicates a dominant position of eBay worldwide (see Table 26.1).

In 2016 the number of eBay total active buyers reached 165 million users and 25 million active sellers. A maximum number of eBay live listings at one time account for one billion. In 2013, fixed price trading generated 70% of eBay's total gross merchandise volume. This means a significant increase against 2009 when the figure was 53%. According to eBay statistics, 81% of goods on eBay are new (Table 26.2).

It is undisputed that eBay is the key online auction website. However, in some countries the market structure is different and eBay market share is quite marginal. Market leader in China is Alibaba Group. Alibaba is not the only auction website, it covers trading platforms, online payment service, e-logistics and e-marketing, IT support for online retailers. Alibaba Group dominates the Chinese B2C

Table 26.1 Global statistics of online auction websites (http://aukcjostat.pl/id3_en/global_statistics.html)

	Market leader—online auction website	No of online auctions per day (estimated)
UK	eBay UK	147 million
Belgium	Delcampe	74 million
USA	eBay US	60 million
Germany	eBay Deutschland	55 million
Australia	eBay Australia	53 million
Poland	Allegro	49 millions
Austria	eBay Austria	44 million
Switzerland	eBay Switzerland	43 million
Italy	eBay Italy	37 million
France	eBay France	37 million

Table 26.2 Facts on eBay worldwide (https://www.statista.com/topics/2181/ebay/ Accessed 24 Jan 2017)

	2013	2014	2015
eBay's annual net revenue	$8257m	$8790m	$8592m
eBay's annual net revenue in US	$3419m	$3525m	$3624m

e-commerce market having an online store Tmall, with 57.7% market share in 2015 and the leading C2C platform Taobao (Alibaba Group 2017).

In 2016 the number of active users of Alibaba Group online auction websites (several different platforms) reached 423 million and 12.7 billion annual orders. Alibaba's share in China's mobile shopping account for 86.2%.

Data on the number of executed transactions relate to the potential of the internal market. Comparative analysis of national markets requires, among others, comparison of the potential of internal markets. Selected criteria for evaluating market attractiveness include population, economic environment, market capacity, buyers' behavior and perspective trends. In this context, the potential of the Chinese market is much larger than the combined potential of the European markets. However, in this chapter, we focus on the specific features of the online auction market, not exactly on the size of internal markets.

Following this observation, in Poland, the market leader is online auction website Allegro with over 84% market share (Aukcjostat 2017). The second position holds Lekki Koszyk website with 6,7% market share. The market share of eBay is marginal—less than 1%. If worldwide eBay brand became synonymous to online auctions, in Poland this is synonymous with Allegro. Table 26.3 shows the scope of transactions on Allegro (app. 48,8 million online auctions daily). Some marketing indicators support the leading position of the company: 75% of respondents asked about an online store name Allegro as first, prompted awareness of the brand is as much as 98%. And finally, for 81% of Internet users in Poland Allegro is the first choice for online shopping.

Table 26.3 The share of each category in the total market on Allegro (Allegro, Accessed 28 Sep 2016)

Products category	Total No. of auctions (in million)	Total No. of auctions (% of total)	Types of online auctions						
			Buy-it-now (%)	Bid auction (%)	Bid auction with BIN option	Announcement (%)	New items (%)	Used items (%)	Undefined (%)
Home and health	5.7	12	83	1	0	16	71	2	28
Kids	2.6	6	90	6	5	0	77	18	5
Electronics	4.6	9	99	1	0	0	81	12	7
Company and services	1	2	99	1	0	0	47	6	47
Collectables and art	1.4	3	88	10	3	0	11	2	87
Entertainment	6	12	97	1	1	0	60	38	3
Fashion and beauty	5.7	12	89	7	4	0	85	13	2
Motors	19.5	40	99	0	0	1	33	66	1
Sport and leisure	2	4	98	1	1	0	72	4	24

In addition, it should be noted that the predominant position of Allegro is maintained since the introduction to the market in 1999. According to the marketing theory, it can be stated that Allegro has created C2C auction market in Poland. Developing competitive advantage of the first company in the market, Allegro consistently evolved its strategy, in order to maintain its leading position with a majority market share (over 80%).

This analysis positively verifies the hypothesis regarding the identification of the Allegro website around the online auction market in Poland (Allegro as online auction marketplace). Thus, experiments and other research methods related to online auctions conducted on Allegro may give rise to the inference general population.

26.5 Allegro Platform as a Space for Conducting Market Experiments

Literature review in the field of marketing, management and e-commerce does not provide much evidence for the use of Allegro transaction platform (Poland) as a space to conduct market experiments. Contrary, other studies in the context of online auctions field experiments reported on the results of researches conducted on eBay internationally. To some extent, eBay is a popular marketplace for online auction field experiments. As indicated in previous parts of this chapter, the position of eBay on the Polish market is marginal. Therefore, it is more appropriate to use Allegro—market leader as a marketplace for experimentation.

However, the Authors did not find examples of accurate research projects on Allegro. It proves the unexploited potential of this space to conduct experiments. There are some examples of online auctions field experiments conducted in Poland (El Haji et al. 2016). But the experiment was conducted using Veylinx, an online experimental auction platform.

The advantage of experiments on Allegro lies in the fact that they can be carried out in a real environment, not on the platform created exclusively for scientific purposes. Thus, the research on Allegro would form a typical field experiment.

It is possible that such experiments and observations are conducted in Poland. It would be justified, among others, free access to the platform and small formal constraints, which should encourage researchers from different disciplines. However, there are no scientific publications in peer-reviewed literature on the subject.

In the previous papers, the Authors reported on several research projects focused on online auction experiments that they conducted on Allegro (Cypryjański et al. 2015, 2016).

Experiences and recommendations of these projects form the basis for creating a catalog of the possible use of Allegro website for scientific experiments, focused on customers' behavior in online auctions. Some conclusions from these experiments can also be implemented for other areas of e-commerce.

Allegro transaction platform is available to every individual, 18 years of age and has full legal capacity and for legal persons. Users may be persons who are at least

13 years of age but less than 18 as far as they can acquire rights and assume obligations in accordance with the common law. Such a broad definition of the users resulting from the Allegro Regulations means that potential participants of research (experiments) conducted online on Allegro can be a very diverse population demographically, geographically, socially and culturally. This results in higher accuracy and representativeness of research and results, that their results can be boldly generalized to the wider population. However, the observed dependence refers only to the Internet users.

According to the Allegro Group in 2016, the community portal had approx. 14 million users, of which approx. 2.9 million were active users per month. Thanks to this scale experiments conducted on Allegro can reach a large research group. Additionally the scale of online experiments does not entail a proportional increase in the costs of their implementation. In accordance with the theory of statistics, larger sample size does not necessarily mean greater reliability of the research. However, for the purpose of experimentation, it enables watching of the actual market transactions on the example of a very diverse population, at the same time without interfering with the observations by attending a moderator or interviewer.

The rules of online auctions on Allegro are described in detail in the Allegro Regulations, which is a critical factor in conducting experiments. Mandatory application of the principles in the document limits the "freedom" to conduct transactions on the platform and at the same time significantly reduces the possibility of designing experiments. Formation of independent variables in experiments conducted market (see Table 26.4).

For the design of online experiments on Allegro the important are regulations on pricing policy. Entrepreneurs on Allegro have to follow established rules. The seller, in addition to the price for goods, can also charge the buyer only indicated in the offer costs of delivery. It is not allowed to add anything else. It is not allowed

Table 26.4 Examples of combinations of dependent and independent variables in online auction experiments conducted on Allegro (own elaboration)

Examples of dependent variables:	Final price Duration of online auction Total highlights of auction site Number of transactions Number of items sold/sales volume
Examples of independent variables—limited opportunities for free development of the variables:	Delivery costs Seller reputation Buyer reputation Position of the auction on a displayed list
Examples of independent variables—unlimited opportunities of shaping variables:	Auction title Presentation of the auction title (e.g. auction title written by small letters vs. capital; highlights) Description of the item Delivery time Method of payment

overcharging for shipping. Since it is not permitted drive up the price for delivery, the experiments for which the controlled variable is the cost of shipping/delivery can be carried out only within the limits of Allegro Rules. As an example, online experiment in which independent variables would be the relationship: the low price of the product—higher delivery costs vs. higher product price—lower delivery costs, have to include limitation of delivery costs. At the same time, costs of delivery cannot be freely determined by the seller (and in the online experiment—researcher). These costs must reflect the current price lists of postal and courier services. It is not allowed to add to the final price costs associated with the preparation of the items for shipment (packaging, service). Final price has to include these costs.

To sum up, conducting research on Allegro requires accepting the limitations of the platform. For this reason, the researcher does not have "freedom" in manipulating variables to verify research hypothesis. The Allegro regulations limit the design of online experiments for which the independent variables are shipping costs, a method of calculating the final price, the way of exposure the final price on the auction site and the potential components of a final price.

Rules for Allegro users also restrict the ability to create additional costs that will be added to the final price. To the final price cannot be counted Allegro commission or fee for credit card payments.

Allegro runs well organized and consistently implemented program to assess the reliability retailers. Therefore the platform is the appropriate place to conduct online field experiments in the context of perceived risk.

The customer can enter any of the seller's offers. This way the customer obtains access to information on the average of the ratings of sales and a link to a page where other customers have put their opinions on transactions with the user. Among the comments from the buyers is, among others, information: is it easy to get in touch with the seller; quality of products; if the goods are shipped quickly; if the seller carefully packaged goods; if the seller is reliable—indeed it exists and execute the transaction in accordance with the contract.

The Allegro rating system is universal, which builds customer trust. Thus it allows conducting complex online field experiments on the impact of seller's reputation on customer behavior and the impact of customer comments on the activities of online auction sellers.

Other aspects that should be considered when designing an online auction experiment on Allegro is the issue of confidentiality of customers' personal data, but also some stereotypical perception of space online as ensuring anonymity, which can seriously impede the scope and credibility of the declaration of the experiments participants. The mentioned confidentiality of personal data limited ability to identify the buyer, its demographic, economic and psychographic features. Therefore, the study of relations taking into account such variables should rather be implemented within the lab experiments, where the bidders are aware of the participation in the experiment. And therefore they could more willing to provide information on these sensitive issues. At the moment the design of Allegro platform does not permit obtaining this information in the form of field experiment.

26.6 Conclusions

Allegro is a valuable space to conduct online experiments. Given the limitations to the unconstrained development of the variables studied in the experiment, which result from the Regulations platform, an interesting experimental studies design can be designed and conducted. The conclusions of these studies increased knowledge on the online buyers' behavior and operators of online auction business. The chapter reflects on experiments conducted on Allegro which are important because of the importance of online auctions in the Polish e-commerce market.

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