8

Modeling Behavioral Decision Making: Creation and Representation of Judgment

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8.1 Introduction

There are different perspectives in the field of judgment and decision making. For example, Gigerenzer (2004, p. 62) suggests, "If you open a book on judgment and decision making, chances are that you will stumble over the following moral: good reasoning must adhere to the laws of logic, the calculus of probability, or the maximization of expected utility; if not there must be a cognitive or motivational flaw."

The processes of judgment and choice, which are the core of behavioral decision making, are interconnected, but they have been researched separately by different groups of psychologists (Goldstein and Hogarth 1997). On the one hand, studies on preferential choice assume it is rational to maximize expected utility, so evaluating deviations from expected utility theory is at the center of this research (Goldstein 2004). This line

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of research, which includes deviances from Bayes' theorem, evolved into the heuristics-and-biases approach informed by Tversky and Kahneman's research (Goldstein 2004). On the other hand, studies on judgment have focused on accuracy rather than rationality, evaluating accuracy of judgment, e.g. individual intuitive predictions, with respect to simple statistical models (Goldstein 2004; Goldstein and Gigerenzer 2009). This area is called *Brunswikian*[1] research on judgment (Goldstein 2004). Basically, it suggests people infer or construct a percept from a collection of sensory cues that deliver incomplete and imperfect information (Goldstein 2004).

This chapter presents a model which uses Brunswikian principles to represent human behavior. The model reflects behavior classified as *fast and frugal heuristics* (Goldstein and Gigerenzer 2009) or *simple rules* (Sull and Eisenhardt 2012).

8.2 Research on Judgment: Brunswikian Principles

Goldstein and Hogarth (1997) suggest three basic principles of Brunswikian research. First, humans function in an environment they need to understand even though it is ambiguous and uncertain. Thus, adaptation to the environment can be described using deterministic models. Second, the human perceptual system combines information from different cues in order to generate a perception of the environment. However, this process is not perfect, and it needs to learn the correct interconnections between, or weights of, the cues. The process is interactive and uncertain over time, which may make it look incoherent to an outsider, as well as highly contextual. Third, it is important to study tasks and behavior in their natural environment. Thus, the manipulation of experimental factors deliberately destroying the interconnections established from learning processes can result in either misperception of the experimental stimuli or disoriented behavior. Brunswikian principles (Goldstein and Hogarth 1997) can provide a better approach to understanding and modeling behavioral deci-

[1] The term comes from the psychologist Ergon Brunswik. His main work is related to the area of perception and functionalization in the psychology field. A key article is "Representative Design and probabilistic Thoery in a functional psychology" published in 1955 by Psychological Review 62 (193–217).

sion making than preference choice when behavioral decision making needs to be embedded in OR models.

8.2.1 Considerations on Behavioral Experiments from a Brunswikian Perspective

The research on preference choices, heuristics-and-biases research is based on experiments consisting of an activity performed in highly elaborated situations; for an example see Tversky and Kahneman (1974). One-time activity implies an important restriction: participants cannot identify clear causality from their judgment. Learned causality originates only from multiple interactions, i.e. learning processes, which makes the results obtained from behavioral experiments potentially not realistic. The basic arguments supporting a learned-causality perspective are:

(i) Human beings, like any organisms, are adaptive systems whose behavior is a result of a process of evolution affected by social, educational and genetic factors. Consequently, their behavior has to be observed considering long-time horizons rather than hypothetical, snapshot situations.
(ii) Heuristics and biases are behavioral rules which originate from a process of evolution. Consequently, the origins of these heuristics and biases are related to a broader context, paying special attention to the relationship between heuristics and biases within the context where people use them.
(iii) Humans are controlled by goal-seeking feedback processes. The goals reflect the information necessary to balance our internal processes with the external environment. *Satisficing* (Winter 2000) rather than *maximizing* reflects the behavioral processes of goal attainment in an optimal way because it describes humans as minimizing the levels of energy employed to achieve their goals. Thus, the goal attainment process, as the selection of the first alternative encountered that meets minimal criteria for acceptability, cannot be considered non-optimal in this prespective. However, for an external observer this behavior may be considered non-rational, since it does not pursue the best alternative, and biased; but it may be an effective way to filter the environmental information necessary to reach the goals in an efficient manner.

(iv) Every organism including humans, tries to maintain a balance between internal processes and environment by adapting to changes. Therefore, the process always starts from a previous balanced situation—which is the existing anchor—and moves toward attaining the new goal defined by the environment—the adjustment behavior. Consequently, the main driver of behavior is a process of anchor-and-adjustment which can be observed only from the behavior and their components—heuristics and biases—within a specific context and over time.

8.3 Modeling Behavioral Decision Making

The behavioral decision making model presented here is based on Brunswikian concepts, which are integrated in a model called "Brunswick's lens model" (Goldstein 2004). Brunswik is considered a *functionalist* because he suggested the goal of psychology was to explain how humans managed to function in their environments (Goldstein 2004). Thus, Brunswik proposed that people face complex environments (focal object) which they perceive through sensory activities (cues). The percept (perception of the object) must be accurate enough (judgmental accuracy) to let them perform related activities and ensure their survival and well-being. Survival and well-being depend on the abilities to bring (i) perceptions into line with focal objects and (ii) focal objects into line with their desires (Goldstein 2004). However, the degree of correspondence between the focal object and its perception is mediated by proximal events and processes (means) (Goldstein 2004). The mediation process is encompassed under the concept of *vicarious functioning,* which refers to the multiplicity, flexibility and intersubstitutability of ways of using cues and means (Goldstein 2004). In Fig. 8.1, the process of selecting the cues to recombine into the perception of the focal object is captured by the weights for each cue (r_n). Over time the selection of cues and means may vary so the resulting perception is stable only after a large number of trials (Goldstein 2004). Judgmental accuracy can be measured by the correlation between the characteristics of the focal object and the judgment (perception of the object). One of the key issues in this model is how to understand the complexity of the environment (focal object), which determines the identity of the

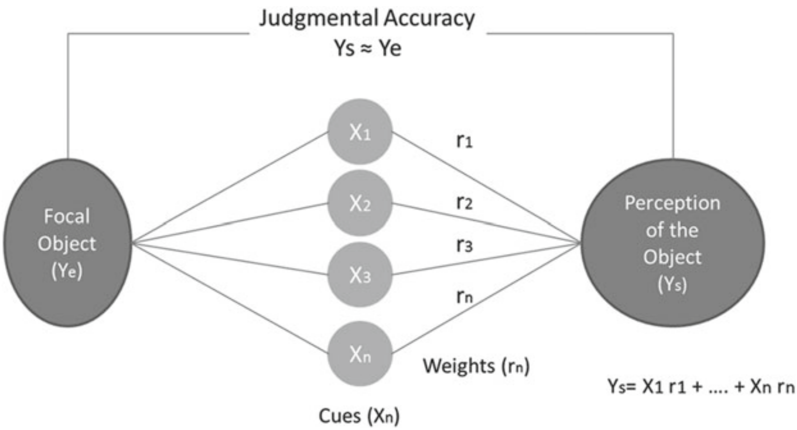

Fig. 8.1 Brunswick's lens model

features that define the object, the strength in the descriptions between the features and the cues, and the interrelationships (weights) in the descriptors between the cues (Goldstein 2004). The research employing this model has demonstrated people's sensitivity to task environments and the process of learning as a way of adaptation to new environments (Goldstein 2004).

The model starts describing the process from basic learning about cues until it reaches more complex functionality yielded by a heuristics-and-biases approach.

8.3.1 Basic Process of Knowledge Creation

Consider for a moment the task of a manager who is controlling the level of inventory. The manager does not have any idea about the inventory level, so their knowledge (the perception) about the inventory is updated as they receive information over time (cues and weights). A first model describes the basic process of learning that controls the degree of knowledge (inventory level) as Fig. 8.2 presents. The variable *perceived inventory level* represents the subjective representation (the manager's knowledge about the level of inventory) of the environment (the real level of the inventory). The representation is increased by new information (daily readings of the inven-

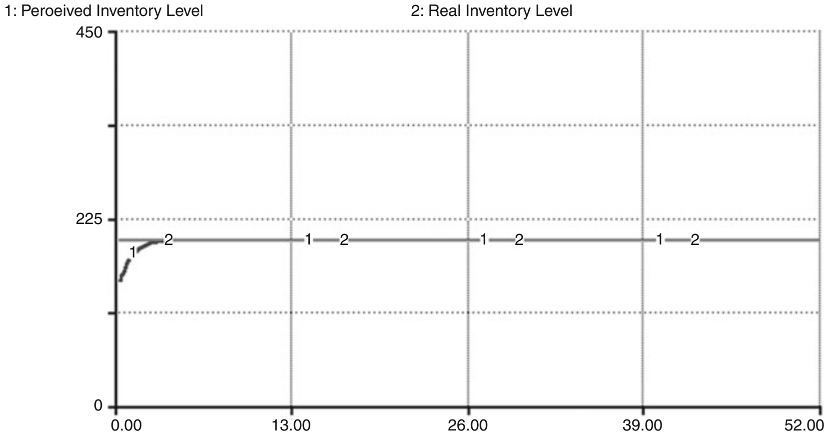

Fig. 8.2 Matching real with perceived inventory after updating information

tory), which is incorporated if it implies a change on the level of knowledge stored. Otherwise, the updating adjustment rate is zero (see Fig. 8.2).

Basically, the level of knowledge (perceived inventory) is represented as a stock or accumulation that can be observed over time. The process for knowledge updating is an inflow, which provides the information to update the level of accumulated knowledge. In this simple situation, the perceived inventory level increases over time until it reaches the true state of the environment, the real inventory level. The equations of this model are presented below.

```
Perceived__Inventory_Level(t) = Perceived__Inventory_Level(t- dt) + (Updating) * dt

INIT Perceived__Inventory_Level = 150

INFLOWS:

Updating = Updating_Adjustment

Real_Inventory_Level_ = 200

Updating_Adjustment = Real_Inventory_Level_-Perceived__Inventory_Level
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Proposition 1 In order to investigate and model decision making processes, a processual approach is required. The approach involves matching the level of knowledge of the person with respect to the task or the focus of the decision. Therefore, there are two important conditions to consider: how fast the person builds their knowledge and their initial level of knowledge.

8.3.2 Information Selection and Its Influence on Decision Making

The model is now expanded to capture the knowledge creation process based on the subjective interpretation process of the environmental information. The model keeps the basic functionality described in the previous section, but it is expanded to reflect two issues: (i) updating of accumulated knowledge becomes an external process and (ii) the subjective interpretation of the information is subject to internal feedback that represents the level of dissatisfaction between the internal knowledge level and the environment, i.e. judgmental accuracy.

The updating process captures information from the environment, which is decoded into three possible interrelated cues. The person (manager) selects the weight for each cue (different sources for the daily readings of the inventory) that fits best with respect to the environment (real inventory level). The process of anchor-and-adjustment (Tversky and Kahneman 1974) starts with a certain level of knowledge (the variable *perceived inventory level*), which adjusts toward the environment (the variable *real inventory level*). People as adaptive systems are dominated by goal-seeking feedback processes. Thus, the determination of the adjustment to each cue is based on the level of dissatisfaction that the person has with their level of knowledge. Consequently, a *balancing feedback loop* exists between the level of accumulated knowledge and the weight of the cues employed to capture the environment, which is controlled by the level of satisfaction. (In this case, the aim is to reduce monthly dissatisfaction to zero.) This balancing feedback loop is also known as the *satisficing principle* (Simon 1979; Winter 2000). In other words, the model reflects the principles that people do not optimize but adapt their behavior within the limits of their rationality (bounded rationality) until they reach a satisfactory outcome (Simon 1979).

In this version of the model, the balancing process between knowledge and environment is exogenous, as the model is built as a game simulator and the person using the simulator must enter the weights for each cue. Figure 8.3 shows a stock-and-flow diagram where the broken line reflects the intervention of the person to update the weights.

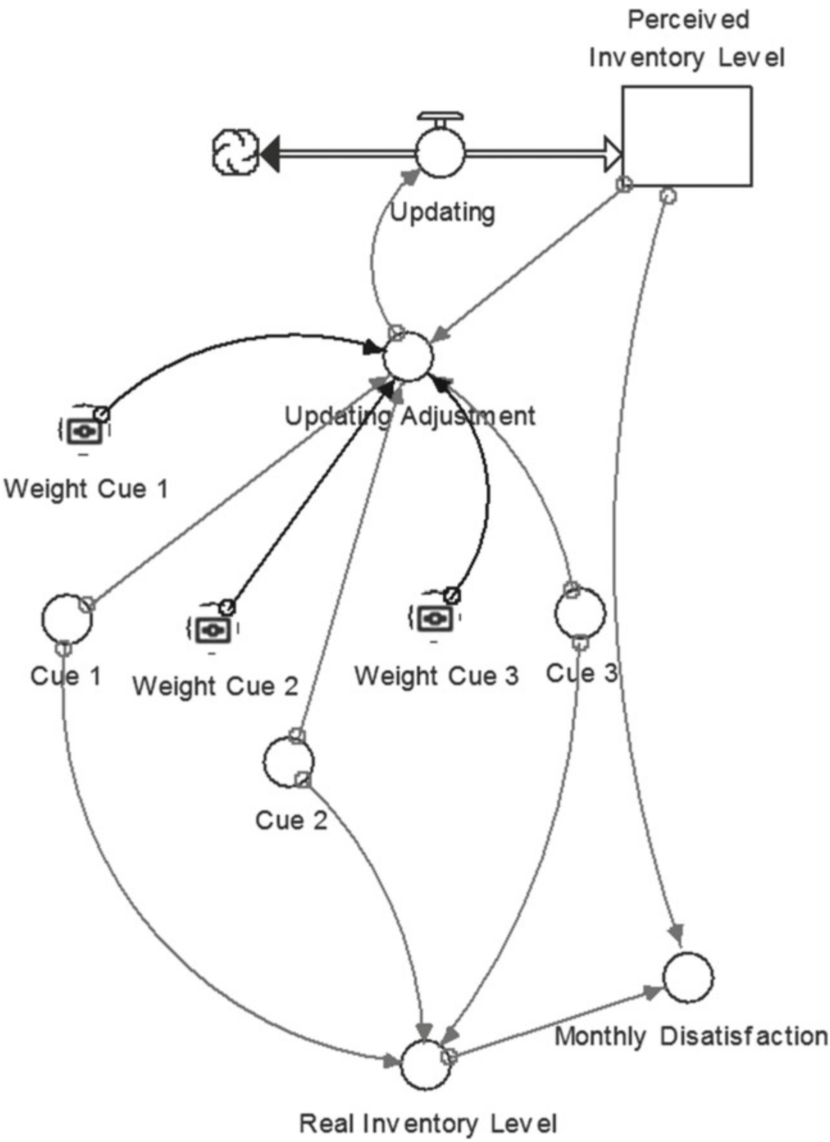

Fig. 8.3 Stock and flow diagram showing the Brunswikian principle on decision making

The equations for the model are presented below.

```
Perceived__Inventory_Level(t) = Perceived__Inventory_Level(t - dt) + (Updating) * dt

INIT Perceived__Inventory_Level = 200

INFLOWS:

Updating = Updating_Adjustment

Updating_Adjustment = (Cue_1*Weight_Cue_1+Cue_2*Weight_Cue_2+Cue_3*Weight_Cue_3) -Perceived__Inventory_Level

Real_Inventory_Level_ =

a.   100*0.20+ 200*0.5+ SINWAVE(100,12.5)*0.3 → A cyclical inventory

b.   100*0.20+ 200*0.5+ 100*0.3 → A fixed inventory

c.   RANDOM(90,110)*0.20+ 200*0.5+ 100*0.3 → A random inventory

d.   RANDOM(90,110)*0.20+ 200*0.5+ 100*0.3 → A random inventory

Weight_Cue_1 = 0 (for scenarios b and c) and 0.20 (for scenarios a and d)

Weight_Cue_2 = 0.5

Weight_Cue_3 = 0.3
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As Fig. 8.4 depicts, the process of knowledge (perceived inventory level) and environment (real inventory level) matching is not instantaneous because it involves a process of adjustment between the original level of

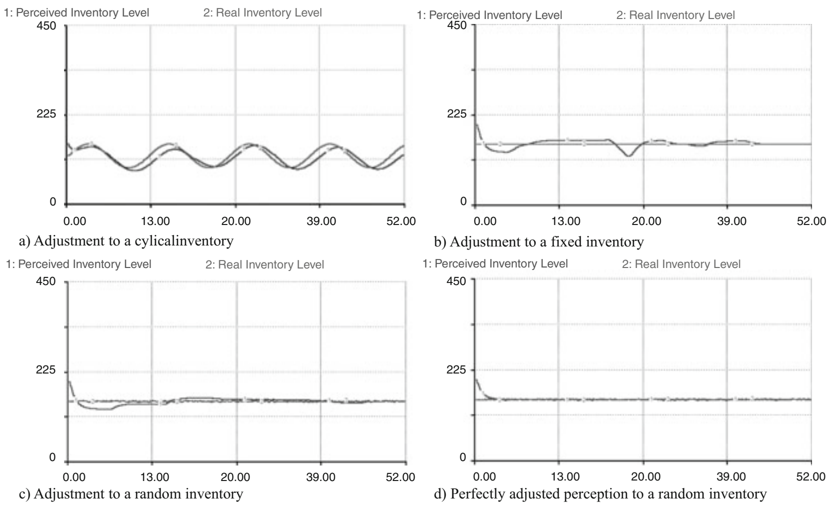

Fig. 8.4 Matching real with perceived inventory in diverse situations after updating information

knowledge (anchor) and the requirements from the environment. Fig 8.4. and 8.5 contain the four behaviors described in the equations of the model under the variable "Real Invertory level" and listed as a, b, c and d.

The level of knowledge adjustment involves a certain level of dissatisfaction as the person finds the correct weights (interconnections between different cues to create an image of the environment). Even finding the right weighting also takes time; because it is impossible to observe the future, updating processes are backward looking rather than forward looking (Gavetti and Levinthal 2000). Figure 8.5 displays this process.

Proposition 2 Behavioral decision making must consider the physical impossibility of updating knowledge before evidence is presented. Subjective perceptions are updated as evidence comes. Thus, decision making accuracy (as well as heuristics, like overconfidence or preference reversals) is improved over time once the subject is able to interpret the evidence presented.

A person who selects the correct initial combination (see Fig. 8.5d) between all the possible cues and achieves a perfect match between

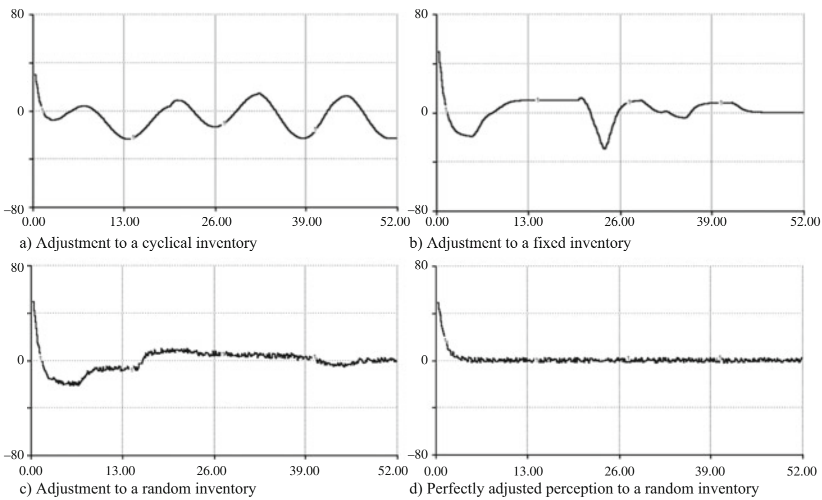

Fig. 8.5 Dissatisfaction during adjustment processes in diverse situations

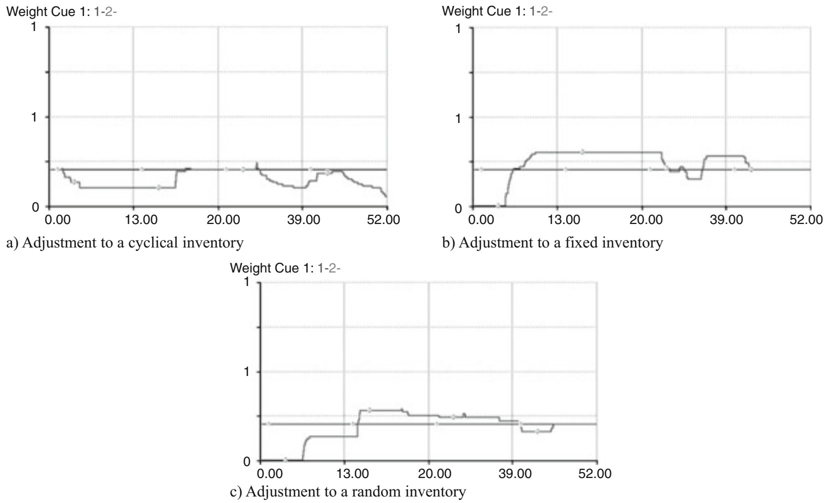

Fig. 8.6 Cue adjustment processes in diverse situations

knowledge and environment has to be considered lucky. The person also needs to be patient, because they have to wait until the initial gap between perceived and real knowledge declines over time, which may create anxiety, leading to changes in the cues and weights. After reaching a satisfactory level, a person stops updating his/her knowledge and his/her performance can be considered *rational* (as well as *functional*) in the sense that is perfectly adapted to the requirements of the environment.

The behavior depicted in Fig. 8.6 reflects the process of cues (weights) adjustment through oscillations, which is a common goal-seeking feedback process with delay, until the person reaches a satisfactory situation.

This process of gradual adjustment in the coding of environmental information is generated because a natural process of action-result-reaction occurs. However, this process may work fine for some individuals but not for others. Thus, changes in internal adjustment processes influence the subjective perception of the environment. From this consideration, we suggest the next proposition:

Proposition 3 Behavioral modeling of decision making must consider the diversity in environmental perception processes among subjects. Subjective perceptions of the same event may be completely different due to structural differences.

8.3.3 Environmental Influence on the Process of Information Selection and Its Consequence on Decision Making

To capture the effects of more complex and dynamic environments, the environment is changed to cyclical (scenario a) and random situations (scenarios c and d) to compare with & fixed invertory situation (scenario b). One of the main arguments against anchoring-and-adjustment processes is that the adjustment is insufficient (Tversky and Kahneman 1974). The model used in the previous simulations showed that this argument is erroneous if the person's percept is well calibrated (the cue's weights are correct) and the environment is stable. However, if the environment is dynamically complex, the anchoring-and-adjustment process will clearly be insufficient. One of the reasons is that people require more time to understand and learn the signals from a changing environment: the *calibration process*. A second reason is the nature of the updating process: it usually is backward oriented and has delays. Thus, dissatisfaction oscillates, as can be observed in Fig. 8.5a, following changes in the environment, because the existence of a delay between the reception of the information from the environment and the adjustment in the knowledge.

Proposition 4 Anchoring-and-adjustment processes are powerful heuristics, which may seem to represent basic decision making processes. However, anchoring-and-adjustment is affected, like any heuristic, by the level of complexity of the environment. Modeling of decision making may need to consider complexity as well as ambiguity in the environment. Subjective perceptions of events take time to calibrate and obtain a reasonable image of the environment.

8.4 Final Considerations

The Brunswik model has been a cornerstone in *social judgment theory* and functionalism models (Goldstein 2004). Indirectly, functionalism has illuminated many areas of research in behavioral OR. For example, it demonstrated that learning from outcome feedback is slow and limited, leading to the development of the concept of *cognitive feedback* (Todd and Hammond 1965), which is at the core of behavioral experimentation related to misperceptions of feedback processes (Kunc 2012) and implies the importance of providing task information to subjects in experiments rather than simply informing them of the outcomes from trials. Another important finding is that the root of interpersonal conflicts may be cognitive, as people have shared goals but differ in their assessment of the situation (diverse cues and weights) and of the action consequently required to remediate it (perception) (Goldstein 2004). An example of this finding can be observed in Chap. 17, by Huh and Kunc (2016). A key contribution is to the area of heuristics in terms of computational speed (fast) and information requirements (frugal), in which Gigerenzer and colleagues evaluated the accuracy of judgment based on simple heuristics and their appropriateness in diverse environments (Goldstein 2004). Gigerenzer and colleagues propose that heuristics are tools employed by our minds to take advantage of the structure of the information existing in the environment to arrive at reasonable decisions, rather than unreliable aids limiting decision making performance (Gigerenzer and Todd 1999).

The Brunswik model can also illuminate future research in behavioral OR. For example, it shows that experimentation should follow representative design rather than systematic design[2] (Goldstein 2004). Representative design implies that the design of experiments should reflect the natural environment (stimuli and conditions) of the subjects in the experiments to reveal issues in judgment accuracy, known as ecological validity (Goldstein 2004). In other words, experiments using OR models need to be consistent with the potential use and users of the models, e.g. experimenting with optimization models dealing with issues

[2] Systematic design refers to the design of experiments where investigators define different stimuli to generate uncorrelated independent variables to test hypotheses about behavior.

in a supply chain should include subjects who are experienced in supply chain management and more importantly on the issue the optimization model is meant to solve. Behavioral OR without ecological validity may be useless. However, if the intention of the experimentation is to observe adaptation, then the manipulation of the environment and observation of learning will be a valid design (Goldstein 2004). This is one of the suggestions in Gary et al. (2008) regarding the use of System Dynamics in behavioral strategy. Another example is the Multi-Criteria Decision Analysis (MCDA) process (Figueira et al. 2005), which encompasses some of the tasks described in the Brunswick model: identifying cues and weights. Researchers in MCDA can employ the research techniques from functionalist psychology to evaluate the effectiveness of the method and uncover behavioral factors affecting the outcomes.

Finally, the following phrase summarizes the main distinction between functionalism and heuristics-and-biases research, with profound implications for behavioral OR practitioners:

> *"One can be accurate without being rational (e.g. "right for the wrong reason") and one can be rational without being accurate (e.g. holding a coherent world-view that is out of touch of reality)".*
>
> Goldstein 2004, p. 55

References

Figueira, J., S. Greco, and M. Ehrgott. 2005. *Multiple criteria decision analysis: State of the art surveys* (Vol. 78). Springer Science & Business Media: New york.

Gary, S., M. Kunc, J. Morecroft, and S. Rockart. 2008. System dynamics and strategy. *System Dynamics Review* 24: 407–430.

Gavetti, G., and D.A. Levinthal. 2000. Looking forward and looking backward: Cognitive and experiential search. *Administrative Science Quarterly* 45: 113–137.

Gigerenzer, G., D.J. Koehler, and N. Heroes. 2004. Fast and frugal heuristics: The tools of bounded rationality. In *Blackwell handbook of judgment and decision-making*, 62–88. Chichester: Wiley.

Gigerenzer, G., and P.M. Todd. 1999. Fast and frugal heuristics: The adaptive toolbox. In *Simple heuristics that make us smart*, ed. G. Gigerenzer and P.M. Todd, 3–34. Oxford: Oxford University Press.

Goldstein, W.M. 2004. Social judgment theory: Applying and extending Brunswik's probabilistic functionalism. In *Blackwell handbook of judgment and decision-making*, ed. D.J. Koehler and N. Harvey, 37–61. Chichester: Wiley.

Goldstein, D.G., and G. Gigerenzer. 2009. Fast and frugal forecasting. *International Journal of Forecasting* 5: 760–772.

Goldstein, W.M., and R.M. Hogarth. 2004. Judgment and decision research: Some historical context. In *Research on judgment and decision making*, ed. W.M. Goldstein and R.M. Hogarth, 37–61. Cambridge: Cambridge University Press.

Huh, K., and M. Kunc. 2016. Supporting strategy: Behavioral influences on resource conceptualization processes. In *Behavioural operational research: Theory, methodology and practice*, ed. M. Kunc, J. Malpass, and L. White, 337–356. Basingstoke: Palgrave-Macmillan.

Kunc, M. 2012. Teaching strategic thinking using system dynamics: Lessons from a strategic development course. *System Dynamics Review* 28: 28–45.

Simon, H.A. 1979. *Models of thought*. New Haven: Yale University Press.

Sull, D., and K.M. Eisenhardt. 2012. Simple rules for a complex world. *Harvard Business Review* 90: 68–75.

Todd, F.J., and K.R. Hammond. 1965. Differential feedback in two multiple-cue probability learning tasks. *Behavioral Science* 10: 429–435.

Tversky, A., and D. Kahneman. 1974. Judgment under uncertainty: Heuristics and biases. *Science* 185: 1124–1131.

Winter, S.G. 2000. The satisficing principle in capability learning. *Strategic Management Journal* 21: 981–996.