Chapter 4
Physical, Cognitive and Affective Engineering

Abstract This chapter will assess the importance of physical, cognitive, and affective engineering in designing and developing technology for the user interface, device, and website. These aspects are essential in technology design, since they assist designers to examine the relationships between users and technology, and to improve users' performance when dealing with this technology, in order to reduce errors and increase satisfaction and users' acceptance of the system. These aspects should be part of sustainable technology design to ensure the users' acquiescence, reduce their frustration, and ensure that the new smart technology design will meet user, society, and community needs simultaneously.

4.1 Introduction

In this chapter, the authors explore the physical, cognitive, and affective aspects of engineering. Physical engineering examines how users' physical abilities will interact with and affect the ways in which users perform tasks using technology; cognitive engineering applies knowledge of cognitive attitude in the development of interactive systems. Finally, affective engineering explains how and why users cooperate with technology and how this can be applied to design. This chapter provides to designers and users clear guidelines regarding these concepts, and indicate how and why these concepts are essential in technology design; furthermore, it explains how designers can measure and evaluate physical, cognitive, and affective engineering features in terms of users' requirements.

This chapter is organized as follows: physical engineering, cognitive engineering, GOMS (Goals, Operators, Methods, and Selection rules), Norman's Model, and affective engineering.

4.2 Physical Engineering

This study aims to combine human body mechanics and physical limitations with industrial psychology to facilitate the interaction between human and devices in order to improve people's job performance and cater for users' needs.

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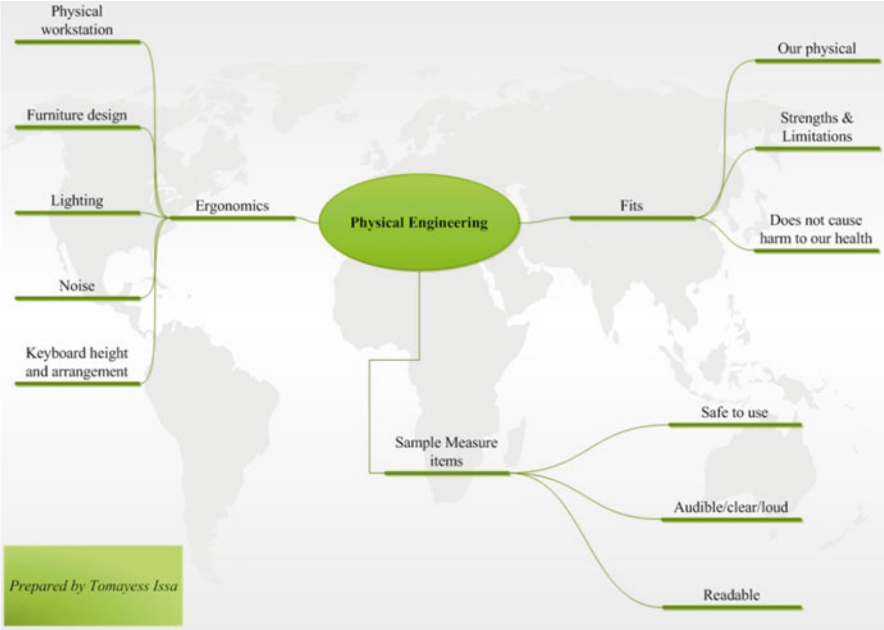

Fig. 4.1 Physical engineering (Prepared by Tomayess Issa)

Physical Engineering aims to improve users' performance ability by handling the work load in the workplace, as improved performance is concerned with reducing errors, improving quality, reducing the time required to complete tasks and ensuring and ascertaining users' acceptance of the system (see Fig. 4.1).

The physical engineering aspects of human computer interaction come into play principally in the process of input and output devices. The main objective of using input devices is to control the system's operations and input data, an example of input devices, mouse, joystick, text, numeric, graphic data, drawing, voice and touch. On the other hand, output devices are machines used to represent data from other devices i.e. monitors, printers, auditory output, synthesized speech, visual display, wearable devices, wireless devices, and haptic devices.

Physical engineering is also concerned with the ergonomics of information systems. It is concerned with things such as the physical workstation and furniture design, lighting, noise, and keyboard height and arrangement. These are all physical aspects of human engineering within an information systems context.

Currently, devices in general are being increasingly used to assist people to improve their job and work performance and productivity. This includes individuals with hearing, vision, or other physical impairment(s). Designers of new smart technologies should consider ways by which to improve the quality of life of people with disabilities, and encourage them to be part of the society and community.

A well-designed computer interface must take into consideration human limitations, since those with disabilities must be considered as members of the community and society in general. Therefore, HCI experts and designers must include these categories of people in their agenda in order to serve them and provide the necessary facilities allowing them to become self-determining and independent. Examples of physical human limitations include (Te'eni et al. 2007; Zhang et al. 2005):

- ***Sensory limit***: what and how much our senses can perceive
- ***Responder limit***: reach and strength
- ***Cognitive limit:*** reaction time, accuracy
- ***Other limitations:*** vision, audition, touch, and motor-related activities

Furthermore, HCI experts and designers should provide the necessary guidelines and principles for accessibility, especially in the new smart technology devices. These guidelines and principles are specified in (Dix et al. 1993; Gerlach and Kuo 1991; Issa and Turk 2010; Te'eni et al. 2007):

- ***Standardize Task Sequences:*** allow users to perform tasks in the same sequence and manner across similar conditions
- ***Ensure the embedded links are descriptive:*** using embedded links, the links text should accurately describe the link's destination
- ***Use unique and descriptive headings:*** use headings that are different from one another and conceptually related to the content they describe.
- ***Use radio buttons for mutually exclusive choices:*** provide a radio button control when users need to choose one response from a list of equally exclusive options.
- ***Non-Text Element:*** provide a text equivalent for every non-text element
- ***Synchronize:*** for any time-based multimedia presentation synchronize equivalent alternatives
- ***Color:*** information conveyed with color should also be conveyed without it
- ***Title:*** title each frame to facilitate identification and navigation

Furthermore, Smith and Mosier (1986) offer five high level goals for designing user interface software including the new smart technology and devices for human beings in general:

- ***Consistency of data display:*** formats, colors, capitalization and so on should all be standardized and controlled by use of a dictionary of these items.
- ***Efficient information assimilation by the user***: format should be familiar to the user and should be related to the tasks required to be performed with the data
- ***Minimal memory load on the user:*** users should not be required to remember information from one screen for use on another screen
- ***Compatibility of data display with data entry:*** the format of displayed information should be linked clearly to the format of the data entry
- ***Flexibility for user control of data display:*** users should be able to obtain the information from the display in the form most convenient for the task on which they are working

Furthermore, Shneiderman and Plaisant (2010) establish several guidelines for HCI experts and designers so that their technology design engages users' attention by effectively using features such as intensity, marking, size, fonts, video, blinking, color and audio.

- ***Intensity:*** use two levels only, with limited use of high intensity to draw attention
- ***Marking:*** underline the item; enclose it in a box; point to it with an arrow.
- ***Size:*** use up to four sizes to draw attention
- ***Fonts:*** use up to three fonts
- ***Video:*** use opposite coloring
- ***Blinking:*** use blinking displays or blinking color changes with great care and in limited areas.
- ***Color:*** use up to four standard colors, with additional colors reserved for occasional use
- ***Audio:*** use soft tones for regular positive feedback and harsh sounds for rare emergency conditions

Therefore, HCI experts and designers should adopt these guidelines in their agenda and design technologies in order to minimize user frustrations and obstructions and to support disabled people who use devices ranging from workstations to new smart technologies such as iPads or iPhones.

Furthermore, to measure physical engineering, designers must measure safety, audible, and readable. By following these measurements, designers will ensure that the new smart technology meets users' requirements (Shneiderman 1986; Card et al. 1983; Preece et al. 1994).

Finally, several studies (Card et al. 1983; DePaula 2003; Dix et al. 1993; Gerlach and Kuo 1991; Olson and Olson 2003; Preece et al. 1994; Te'eni et al. 2007) indicate that technology and devices are being used more and more to assist users and disabled individuals to accomplish tasks; however, this technology can cause major health risks involving vision and muscular problems, and this can lead to inflammation, disc problems and painful muscles. Therefore, designers should initiate an awareness campaign for the new generation (called internet generation), since these people depend to a great extent on technology for their study and work. This awareness should be available on various media including websites, Facebook and the devices' packaging.

4.3 Cognitive Engineering

Cognitive processes involve user activities including thinking, reading, writing, talking; remembering, making decision, planning, solving problems, and understanding people (see Fig. 4.2). Norman (1993) distinguishes two types of cognition, namely: experiential and reflective. The Experiential mode reflects perceive, act, and react, as it needs a certain level of motivation and enthusiasm, i.e. driving a car, reading a book playing a video game or having a conversation. On the other hand, the reflective mode involves thinking, comparing, and decision-making. This mode leads to creativity and innovation such as writing a book, designing, learning (Isaias and Issa 2015).

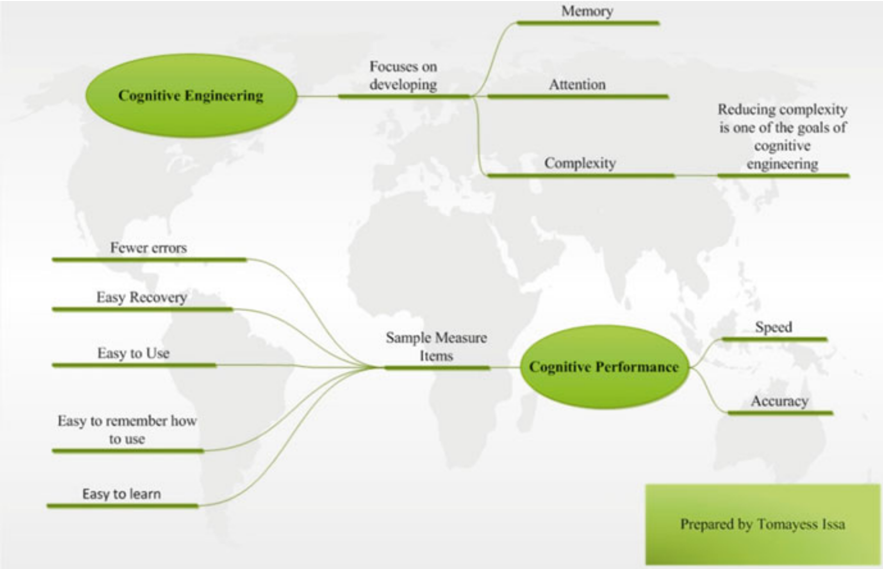

Fig. 4.2 Cognitive engineering (Prepared by Tomayess Issa)

Overall, both modes need specific technologies and are essential for everyday life.

Cognitive Engineering focuses on developing systems which support cognitive processes of users such as memory, perception and recognition, memory, learning, reading, speaking, listening, problem solving, decision making and attention are used in HCI. Difficulty is seen to represent the employment of rare cognitive resources and reducing complication is one of the goals of cognitive engineering (Isaias and Issa 2015).

The human information processing [HIP] model validates how cognitive resources such as memory and processors are employed. There are three types of processors, namely: (1) Perceptual: detects and accepts inputs from the external world and stores parts of the input in the working memory. (2) Cognitive: interprets, manipulates, and makes decisions about the inputs. (3) Motor: is responsible for translating cognitive decisions into physical actions such as using a keyboard. There are two types of memory, namely: working memory which is similar to the human brain's task, since information and data is coming to the human brain for processing and storage of complex cognitive tasks such as language, learning, comprehension and reasoning (Baddeley 1992); and long-term memory which permanently stores, manages and retrieves information for future use and life time (Goelet et al. 1986).

Generally, cognitive engineering takes a narrow view in relation to performance, automatic behavior, controlled behavior, processing of images, processing of verbal information and memory aids (Te'eni et al. 2007, p. 89–90).

- ***Performance:*** the speed and accuracy of the information-processing task

- ***Automatic behavior:*** fast and relatively undemanding of cognitive resources (i.e. entering 50 numbers into a spreadsheet would quickly become an automatic activity)
- ***Controlled behavior:*** slow and cognitively demanding (i.e. deciding to use the summation function and defining it parameters requires access to long-term memory, selection of appropriate functions and parameters and control to ensure correct operation)
- ***Processing of Images:*** processing characterized as spatial, graphic, and holistic
- ***Processing of verbal information:*** processing characterized as sequential, linguistic, and technical
- ***Memory Aids***
  - ***Heuristics:*** rules of thumb that depend heavily on the content and context of the task
  - ***Image:*** a cognitive process in which an experience is related to an already familiar concept
  - ***Mental model:*** a representation of the conceptual structure of a device or a system

Cognitive engineering focuses on development systems that support and assist designers to understand the interaction between the user and the technology (including computer). Similarly, Gersh et al. (2005) indicate that cognitive engineering developed in response to two reasons, first, to ensure that technologies including computers are well designed and meet users' needs; secondly, it introduced design principles in technology design to ensure that skilled technicians could operate them safely and efficiently.

Finally, in order to measure cognitive engineering, designers should consider the following measures in technology design, namely: fewer errors, easy recovery, easy to use, easy to remember how to use, easy to learn (Dix et al. 1998, 2004).

4.4 GOMS (Goals, Operators, Methods, and Selection Rules)

The GOMS (Goals, Operators, Methods, and Selection rules) model was created by Card et al. (1983). This model aims to present the knowledge of determined human computer interaction (HCI), and how users can interact with computers and the implications for designers. This model endeavours to reduce the complexity in the interface as well as in the cognitive resources and engineering. This model has specific elements that describe purposeful HCI:

- ***Goals*** specify what the user wants and intend to achieve.
- ***Operators*** are the building blocks for describing human-computer interaction at the concrete level.
- ***Methods*** are programs built with operators that are designed to accomplish goals.
- ***Selection rules*** predict which method will be used. For example, "If the mouse is working, select 'point to an item on screen', if not select 'choose OPEN option in file menu'".

Finally, the GOMS model (Goals, Operators, Methods, and Selection rules) is based on levels of interaction that bridge the gap between the abstract (psychological) task and the concrete (Physical System).

4.5 Norman's Model

To understand the interaction between human and computer, Norman developed a model of user activity (Norman 1986). Before discussing Norman's model, we need to understand the principles of human behavior in order to enhance users' performance in terms of an effective design and technology. These principles are divided into gulf of execution which handles the interruption between the user's goal and aims and its device implementation, and the gulf of evaluation that relates to the gap between device implementation of the user's goal and its evaluation by the user (Te'eni et al. 2007).

Norman's model has eight steps intended to assist users to complete and accomplish a task when using a specific technology:

- ***Goals:*** create a goal that needs to be accomplished
- ***Intentions:*** develop an intention that will accomplish the goal
- ***Action Specification:*** identify a sequence of actions to implement the intentions
- ***Execution:*** execute the action
- ***Perception:*** understand the system outcomes from the action
- ***Interpretation:*** interpret the system state
- ***Evaluation:*** evaluate the results and compare it with the goals

Figure 4.3 shows the steps that are jointly required the user goals for a particular goal. Generally, these steps will allow users to identify their goals: what is done to the world, the world, and to check the world. In general, these steps have three majors components: identify the goals, do something and evaluate at the end.

4.6 Affective Engineering

Affective engineering focuses mainly on emotions, moods, affective impressions and attitudes; it concentrates on integrating product design and consumers' feelings for a product into design elements (Jordan 2002; Rosson and Carroll 2001; Hewett et al. 1992).

Affective engineering is essential in Human Computer Interaction to balance and integrate the affective and cognitive aspects in the technology design; cognitive engineering interprets and makes sense of the world, while affective engineering evaluates, judges and provides some warning to the users out of possible hazards and risks.

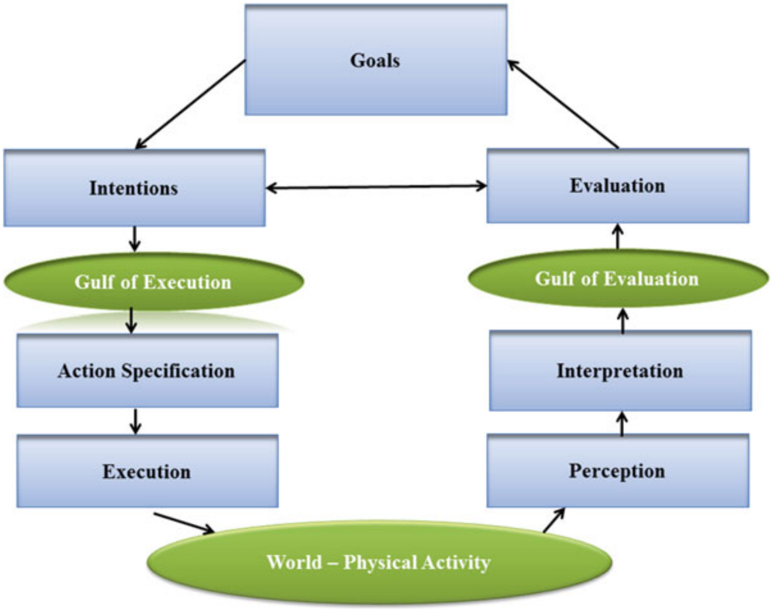

Fig. 4.3 Norman's seven-stage (Adopted from Norman (1986). Prepared by the authors)

Affective engineering is used in any technology design ranging from user interface, technology or websites to color, animation, layout, structure, text, images and menu. For example, using pastel colors for e-commerce sites will leave users feeling calm and will foster a more accepting attitude and readiness to buy and interact further with the site. Additionally, affective engineering focuses on technology design, which is pleasing, engaging, enjoyable, fun, attractive, beautiful satisfying and entertaining. These attributes will encourage the user to accept and use the new smart technology to achieve his/her goals and aims (Fig. 4.4)

Furthermore, user attitudes to combined cognitive and affective engineering are used to evaluate devices including computers, mobiles, and other devices. The evaluation aims to identify errors and problems in order to ascertain whether or not the devices are successful. This is evaluation is based on users' perceptions and opinions and should be taken into account by designers in order to resolve any problems and meet user needs.

Attitudes can be shaped and managed to some extent by training users to examine the devices' performance in general in order to reduce anxiety. Furthermore, a very important step in the design process is the management and involvement of users, as this will promote user satisfaction and acceptance of devices, further reducing user frustration.

Finally, to ensure that users will accept devices, satisfaction is considered the most commonly used in the HCI and information systems field, since users will either confirm or not confirm their satisfaction with the device.

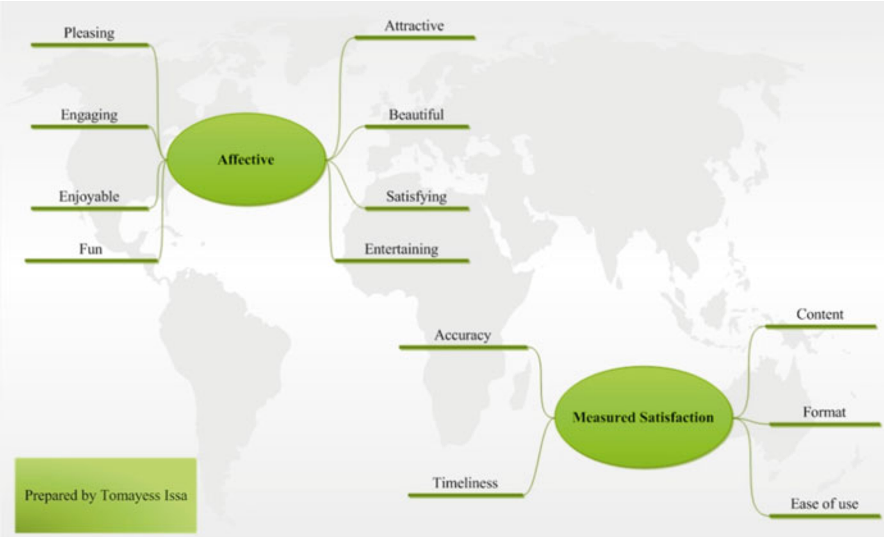

Fig. 4.4 Affective engineering and satisfaction (Prepared by Tomayess Issa)

Doll and Torkzadeh (1988) proposed the most popular measure of satisfaction called End-User Computer Satisfaction. This measure is constructed of five sub-factors namely: content, accuracy, format, timeliness and ease of use.

According to Doll and Torkzadeh (1988, p.268), the five sub-factors include the following aspects:

Content

- Does the system provide the precise information that the user needs?
- Does the information content meet user needs?
- Does the system provide reports that meet user needs?
- Does the system provide adequate information?

Accuracy

- Is the system accurate?
- Is the user satisfied with the system accuracy?

Format

- Is the system output presented in useful format?
- Is the information clear?

Ease to Use

- Is the system user-friendly?
- Is the system easy to use?

Timeliness

- Does the system provide the information that you need in time?
- Does the system provide up-to-date information?

The End-User Computer Satisfaction instrument is a significant development, as it will assist designers to measure user satisfaction with a technology design. This evaluation and measurement will assist designers to identify any errors and problems in their design, making it easier for them to tackle these problems in order to improve users' satisfaction and acceptance.

4.7 Conclusion

This chapter discussed and examined several features, which are required for technology design including sustainable design. These include physical, cognitive and affective engineering. Physical engineering is mainly concerned with the user's ability to handle the load or demands of the work situation, job performance (i.e. reduce errors, enhance quality, and reduce time required to complete specific tasks) and acceptance of the system. Cognitive engineering involves user activities including thinking, reading, writing, talking, remembering, making decision, planning, solving problem and understanding people. This engineering is mainly intended to reduce the complexity between users and devices. Finally, effective engineering works alongside physical and cognitive engineering to examine and assess users' emotions, moods, impressions and attitudes towards product design.

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