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Cognitive Process-based Design Implications for Mobile User Interfaces

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ABSTRACT

This study addresses the importance of understanding the cognitive aspects of a user in the mobile user interface design process. Cognition consists of several inter-linked processes, including attention, thinking, memory, perception, learning, planning, and decision making. In order to establish design guidelines for a mobile user interface model, the intended users should first be identified, followed by defining their cognitive strengths and traits, as well as their requirements. The users in this research are identified as the aging population, and their health limitations characterize this population; their social problems from a cognitive perspective are highlighted. The findings of the study are used to provide design implications for interactive products, as it is highly important to design any system with consideration of the strengths and limitations of the potential users. We observe that in contrast to unified modeling, the design and layout of a user interface should take into account the mental and physical strengths of its users, as these factors affect the performance of users in handling, perceiving, learning, and memorizing tasks.

Key words: Human–computer interaction, cognitive process, user attributes, design implications, aging population.

1. INTRODUCTION

Cognition is a concept of self-identity that differentiates a living being from its surroundings. It involves non-impulsive behavior, i.e., a process that allows acquiring knowledge through observation, analysis, planning, and decision making. At the highest level, it includes the imaginative ability to bring together apparently unrelated facts and propose a unique plan for future action or to create a novel solution [1]. In describing cognition, defining the context in which it takes place, the interfaces used, the tools employed, and the types of users involved is important. Humans' perceptual, cognitive, and motor abilities decline with age as a natural phenomenon, and this has negative effects on their capabilities to perform different tasks. The psychological and physiological changes occurring as a result of aging affect humans' potential to deal with technology, in general, and the control of user interfaces, in particular [2].

For a robust and intelligent human–computer interaction, the future generation of computer-based systems will require that user interfaces adapt to users' cognitive behavior. A unified interface model that treats the users of the same age group as one category would be infeasible because every single human thinks and acts in a different way [3]. Some people decide intuitively, whereas others consider the pros and cons of the situation and then make a decision. Thus, user interfaces should accept the input of the user adaptively, and the interface and the user must complement each other. User diversity is an open research challenge for real-world systems.

United Unions (UN) estimations show that by 2050, every fifth person in the world will be aged 60 or above [4]. The UN Department of Economic and Social Affairs states that between 2015 and 2030, the number of aging persons will increase from 901 million to 1.4 billion, and by 2050, it will reach 2.1 billion [5]. Aging is a natural phenomenon that causes several physical issues, such as hearing impairment, sight deterioration, and motor complications, as well as several psychological issues, such as cognitive deficit, memory loss, and linguistic impairment [6]. Physical and social functions strongly reflect a healthy lifestyle and healthy aging. According to the World Health Organization, the state of being healthy is not just the absence of disease or infirmity but is a state of complete mental and physical health [7]. Another critical factor that could worsen the quality of life with advancing age is the decline in self-confidence, which hinders persons from performing even the basic routine tasks of daily life, so they are forced to rely on external help [8]. The above problems related to physical and mental weaknesses result in a lack of social interaction in aging people, which leads to complete social isolation and depression.

Being social, i.e., interacting with other people, is a fundamental aspect of a healthy life, as humans are inherently social. They live, work, learn and play together and update one another about their activities, events, and everyday happenings. This interaction takes place in two different ways: face-to-face interaction and remote interaction [9]. Face-to-face interaction involves people working or studying together and updating one other about their plans, projects, meeting deadlines for assignments, upcoming events, and so on. Remote interaction, which is interaction through technology, is communication through the Internet using a variety of applications, such as Skype, Facebook, Instant Messaging, Yammer, and other online learning tools. The young generation experience both methods of interaction and enjoy playing with technology, but the aging population, by contrast, consists of the members of society who are retired from their jobs, with most of them spending their lives at home because of health issues, so they have minimal face-to-face interactions with other people. Therefore, the only way to improve their quality of living in order to create their virtual social circle is through remote interaction.

The age-related health decline issues highlighted above need continuous monitoring and support that are not feasible at times because of the high cost of healthcare, which constitutes a significant financial burden for families. In this regard, emerging assistive technologies for smart healthcare provide helpful resources to improve people's lifestyle through cognitive skills training. These assistive technologies include personal assistants, such as robots or mobile agents, and a collection of cognitive exercises to promote the mental stimulation of aging people [10]. Cognitive training methods supported by computerized and electronic systems provide remarkable advantages [11]. For instance, video games create a direct positive impact on concentration, attention, and reflex control by stimulating the nervous system. Such games enhance visual processing speed and involve people of different age groups, helping them to socialize and make new friends.

However, assisted technologies have also age-related constraints. For instance, an aging person suffering from Alzheimer's disease needs the continuous support of caregivers, and he/she cannot be treated by assisted technologies at home. However, people with mild stages of cognitive impairment need less support and can be targeted as the intended users of assistive technologies [12]. Another important factor is knowledge about technology; the big gap between the technology skills of the young and the aging is well known. Because of natural physical and cognitive impairment, the aging community is usually less motivated to learn newer technologies; they feel comfortable with their previously learned methods, as cognitive impairments adversely affect memory functions [13].

Acilar claimed in his survey that the adoption rate of information and communication technology (ICT) components and tools, such as computers, mobile phones, and the Internet is significantly higher among the young generation than among senior citizens [14]. The primary reasons behind this include fear of using technology, lack of knowledge on how to use smart devices, and unfamiliarity with modern electronic tools on the part of aging individuals. In this modern, busy, and expensive world, ICT is the best way to support healthy aging, so age-specific user interfaces should be designed to create a simple and easy-to-use environment for seniors [15].

Another challenge in the above context is the growing complexity of computer-based systems, which puts forward an ever-increasing demand for intelligent and robust interactive systems in contrast to the existing generation of human–computer interfaces. As technology flourishes rapidly, highly capable smart devices are coming to the market with sophisticated applications requiring highly complex interactions that involve combinations of voice and gesture [16]. Such emerging technologies usually attract young users but make aging people uncomfortable, as they find such technologies confusing to work with. For instance, regarding voice-based mobile user interactions, speech comprehension errors, unreliable voice activity detection, and user confusion are the issues that make the accurate interpretation of users' intentions challenging and difficult. These issues related to the cognitive process can only be handled through intuitive user interfaces that take into consideration users' abilities and weaknesses [17]. A simple and easy-to-use user interface with valuable feedback attracts the users and enhance their learning skills [18]-[19].

The rest of the paper is organized as follows. Section 2 discusses the existing literature. Section 3 discusses the cognitive functions that deteriorate with age and the desired characteristics of cognitive user interfaces. Section 4 provides the cognitive process-based design implications for user interfaces, and Section 5 concludes the paper.

2. LITERATURE REVIEW

One of the fundamental factors in designing usable interfaces is obtaining a clear understanding of users' mental models. The accurate prediction and estimation of users' preferences and desires are not possible, and there exist conceptual and cognitive differences between designers and users, which are widened during the design process. Therefore, in contrast to ordinary users who use ordinary sense-making, interface designers use professional sense-making [20]. However, designers cannot work on their own, and they should have a set of guidelines to follow and address accessibility issues; much research also needs to be done in order to address this challenge.

In [21], the authors implemented a cognitive game on a multi-touch surface to support users suffering from memory decline problems. The multi-touch surface supports both audio and visual input and serves as a natural interactive medium. The authors first identified the requirements of aging users and proposed and implemented a design that was found to have a positive impact on users' perception. The authors stated that the effectiveness of cognitive games depends on a thorough understanding of the cognition processes of learning, thinking, and decision making. Such games can also enhance the memory of potential users if it is adaptive to the cognitive level of these users.

The interaction of humans with technology takes place through interfaces. Granata et al. created a graphical interface supported with voice interaction to facilitate aging users' interaction with robots [22]. For the linguistic part, rules were set to choose vocabulary words with respect to their frequency of usage, syntax, ordering, and semantics to avoid any ambiguities. The authors claimed that audio support in the interface enhances the usability of the product.

In [23], the authors proposed a navigation system based on user context that moved through a sequence of well-known steps to reach the desired content. They provided a practical technological solution that showed the landmarks or location of familiar points along the selected route in addition to the user-related information. Users' activities were monitored and guided in case they lost control of the system.

In [24], the authors proposed solutions regarding the design of mobile user interfaces to address the needs of the aging population. Considering visual impairments, memory-related issues, speed, and coordination of mental activities, they provided a set of guidelines for easy access to mobile interfaces. The authors highlighted that understanding accessibility issues should be the first goal of developers and must be addressed in the early design phase.

In [25], the authors confirmed that elderly people faced difficulties in adapting to the use of mobile applications because of the rapid change of technology. The authors proposed guidelines based on a mental model for designing mobile user interfaces for the elderly. They emphasized the need for developers to create a mobile application with an interface design that meets the requirements of the aging population.

All the above cases are examples of how researchers integrate the cognitive aspect in the design of user interfaces. However, mapping the cognitive process to user attributes and defining the design implications for the identified user are not specified.

3. THE COGNITIVE PROCESS AND COGNITVE USER INTERFACE

The use of an effective interactive technology is a daunting proposition. The collection and organization of valuable content will not be beneficial unless the designers of user interfaces create these interfaces in such a way that they facilitate users' access to content [26]. Cognitive compatibility is the key component of a human-centered system design, which means that there should exist a perfect match between the cognitive styles of the user and the user interface. The processes involved in cognition that specifically deteriorate with age are discussed below.

i. Attention

It is a process that involves auditory and visual senses to select the things that need to be focused on at a point in time. For instance, a patient sitting in a room and is waiting for his/her name to be called out to go see the doctor requires auditory attention. Similarly, scanning the match results online to see whether a team is winning needs visual attention. The important factors involved in this process are the clarity of goals and the extent to which the required information exists in the environment.

ii. Perception

Perception is the process of using one's sense organs, such the ears, eyes, and fingers, to acquire information from the environment and then transform this information into experience. For an interactive design, it is highly important to present the information in a readily perceived and recognizable way. Perception is a complex process, as it involves other cognitive processes, such as attention, memory, and language.

iii. Memory

Memory is a versatile process that involves recalling or remembering different kinds of knowledge in order to act appropriately, for instance, remembering someone's name or recognizing someone's face. It is not humanly possible to remember everything we hear, see, touch, or smell, as the brain would be overloaded, and the situation is even more complex for aging persons who suffer from common diseases of old age, such as Alzheimer's and dementia. Therefore, we need to filter out the relevant and desired information to be memorized. Moreover, different kinds of information require different levels of effort to remember, for example, remembering a phone number is more difficult than memorizing tunes.

iv. Learning

It is a natural phenomenon that learning through practical experience is far better and easier than learning by following a set of written instructions in a manual; the former also has a long-lasting effect. In this context, several interactive technologies are being used. Graphical user interfaces provide good environments to support active learning through exploration and by allowing users to undo or reverse their actions in case of any mistakes. E-learning, web-based learning, and multimedia are the technologies that enable users to interact with information and actively participate in the learning process, which are not possible alternatively through traditional methods, such as reading books.

Cognitive styles are the preferences or habits of an individual to process information. User interfaces should consider user attributes, such as cognitive processing capability, intellectual capability, and prior knowledge about the technology [27]. In [28], the authors proposed the Myers-Briggs Type Indicator tool to measure four dimensions of cognitive capabilities, i.e., the extent of being an introvert or extrovert, sensing, perception, and thinking. It was observed that understanding individuals' cognitive differences plays a vital role in enhancing human–computer interaction; an interface suitable for one user may not be good for another because of their inherent cognitive differences. Therefore, cognitive user interfaces should meet the following four essential characteristics in order to address the above-mentioned challenges of future human computer–interfaces [16].

i. Capability of planning under uncertainty:

One of the pillars of effective communication is having the ability to achieve specific goals even with incomplete knowledge. For this purpose, the goals need to be explicitly defined, and then the strategies should be optimized to efficiently meet the objectives.

ii. Capability of supporting reasoning and implication:

Human communication involves gestures, speech, and facial expressions that are imprecise analog gestures by nature. User interfaces must be capable of intelligently interpreting these inputs by resolving ambiguities and minimizing errors. This task involves viewing the input gestures as observations rather than commands so that the system can infer the users' intention.

iii. Capability of learning from experience:

A user interface should have the capability of learning from both its short-term and long-term experiences. The higher is the usage, the higher should be the smartness level achieved.

iv. Capability of autonomous adaptation to changing circumstances:

As the context and the environment change, the user interface must be adaptive by modifying its behavior in order to maintain a satisfactorily performance level.

Figure 1 illustrates the mapping between the cognitive process and the cognitive style of a user interface to help the designer adapt the cognitive process when designing the user interface for the defined user.

From the figure, it is clear that attention maps to the capability of planning under uncertainty, as both require the goal to be defend and clear. Perception maps to the capability of supporting reasoning and implication, as communication starts from the sensing process of the user; both require

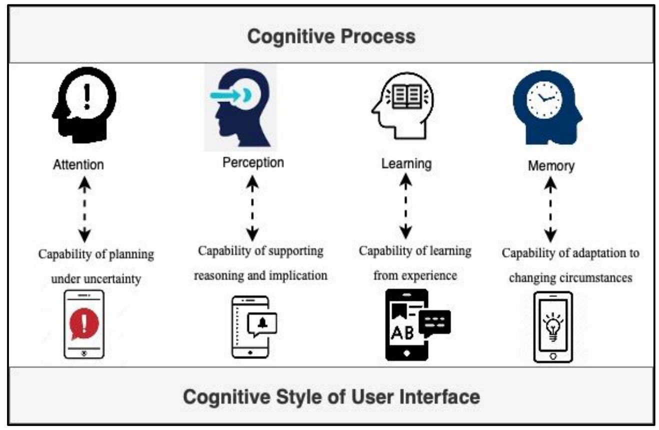

Figure 1 : Mapping the Cognitive Process to the Cognitive User Interface

information to be readily visible and capable of being intelligently interpreted with the minimum amount of time and error. Learning and the capability of learning from experience require users to acquire the needed learning style and interact with the information. Memory maps to the capability of autonomous adaptation to changing circumstances, as changing the context may affect the satisfaction of the user; the designer therefore needs to be aware of the user's characteristics.

4. COGNITIVE PROCESS BASED DESIGN IMPLICATIONS FOR USER INTERFACE

The user interface design is influenced by several factors, including usability aspects, the user's thought processes, the capabilities and types of programming tools, and the hardware environment. While providing advice and guidelines on interface design, technical communicators also take benefit from cognitive mapping techniques which aim to improve the user-interface interaction. These techniques are used to collect information on and understand users' demands about the interface, as well as to develop conceptual models for the user interface design, significantly enhancing the learning experience. The usability of an interface is severely affected if the model does not match users' expectations.

In this section, we focus on the design implications based on user requirements and user attributes. As stated in the above section, one of the key requirements in establishing design guidelines is to first define and identify the anticipated users and then obtain the requirements from the perspective of both the system and the users. Table I defines the user attributes of the aging population for the four cognitive processes explained in Section II, i.e., attention, perception, memory, and learning, and it also presents the design implications for the mobile user interface corresponding to each user attribute.

Table 1: User Attributes and Design Implications

Cognitive Process	User Attributes	Design Implications
Attention	Difficulty to access information	• Design the interface in such a way that the information can be easily accessed at a particular stage of a given task • Design the interface using graphics, underlining, spacing, and ordering of items
	Difficulty to focus because of a cluttered interface	• Design the interface with only the necessary colors and sounds, i.e., without decorative fonts, tricky gestures, and cluttered information • Design the interface with minimum distractions for users by avoiding a hotchpotch of media, as this may annoy users instead of being helpful for obtaining relevant information
	Difficulty to handle notifications	• Design the interface in such a way that allows users to set their preferences for notification (i.e., banners, a lock screen, or a notification center) during the registration process
Perception	Lack of navigation power	• Design the interface with icons and borders, as these are effective visual methods to group information into meaningful categories • Design the interface with minimum hierarchies, making it easy to perceive and trace the items
	Lack of capability to distinguish and understand input	• Design the interface with clear, audible, and distinguishable sounds, enabling users to understand the information presented and to differentiate between the spoken words • Design the interface in such a way that clearly differentiates the text from the background, such as using dark-colored text against a light background
	Lack of capability to handle errors	• Design the interface in such a way that it provides effective and informative tangible feedback, allowing users to identify errors and understand how they can resolve issues so that they can continue working • Design the interface with multimodal feedback, i.e., provide both auditory and visual responses
Memory	Difficulty to memorize irrelevant information	• Design the interface in such a way that it does not overload users' memory with complex procedures for performing common tasks
	Difficulty to remember the interface design and layout	• Design a simple and user-friendly interface that promotes recognition rather than recall • Design the interface in such a way that consistently positions the objects following established conventions
Learning	Difficulty to understand the interface layout	• Design the interface structure with an understandable layout in order to motivate users to explore and enhance their learnability
	Difficulty to handle complex tasks and functions	• Design a multi-layered user interface that allows users to start working with a reduced functionality layer and then shifting to higher-order functionalities after learning the basic functions

5. CONCLUSION

Designing user-specific interfaces is a challenging task. Before an interface is designed, the intended users must first be identified, and their cognitive traits must be surveyed to facilitate the users tasks and to conserve resources. The design of an interface significantly affects the cognitive process of a user to perform different tasks. These cognitive process include perception, attention, learning and remembering. Understanding the different directions of the cognitive can explain the user interaction and how to inform the designer to improve the user performance.

This article has reviewed the existing literature, addressed age-specific accessibility issues. The author proposed a model to map the cognitive process attributes to the cognitive style of the user interface to link the user's need to the user interface design. Then, apply this mapping by providing design implications in the mobile user interface context based on the user attributes. A well-designed user interface reduces the response time by minimizing unnecessary searching. However, this is not the responsibility of the designer alone; he/she should be provided with useful guidelines to address the physical and cognitive abilities of users, which is an open research challenge.

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