The Impact of Cognitive Biases on User Decision Making in Human-Computer Interaction: A Review of the Literature

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ABSTRACT

Human-Computer Interaction (HCI) is an interdisciplinary subject that studies the interaction between humans and computers. Cognitive biases are systematic errors in human reasoning and decision-making which is suggested to affect interactions of users with computers. This study aims to contribute to the bridge the gap in the literature by addressing the impact of cognitive biases on user decision-making in HCI and discuss the practical applications of the currently literature. Accordingly, a literature search was conducted using electronic academic databases. The reviewed papers were mainly focused to articles published in the last 10 years (2003-2013) to ensure the relevance of the literature to current research questions. Our research revealed four factors (the quantity of available and accessible information, the lack of meaning associated with the information, the need for quick action, and what information is remembered or recalled) that can trigger cognitive biases and how they can further impact decision making processes of users through common biases. An explored two common strategies (user research and digital nudging) for designing interfaces that minimize negative effects of cognitive reductions. Our findings provide a valuable contribution to the literature and aimed to lead a better user experiences and greater user satisfaction with technology.

Keywords: *Human-Computer Interaction, Cognitive Biases, User Experience, User Experience Research*

1. INTRODUCTION

Often referred to as HCI, Human-Computer Interaction is an interdisciplinary subject that studies the interaction between humans and technological artifacts, and their designs. [1]. HCI encompasses a wide range of subjects, including engineering, behavioural sciences, and design [2]. HCI aims to support human activities is intuitive, efficient, and effective [3]. It can also contribute to the development of new technologies and applications that address important societal challenges, such as healthcare, education, and environmental sciences [4].

As computers and other digital devices become increasingly ubiquitous in our daily lives, HCI plays a critical role in shaping the way people interact with technology through such user platforms as online shopping, social media, healthcare services etc. [5]. Accordingly, these platforms use the user interfaces (UI) serve as the primary means of interaction and communication between humans and computers on a technological device. An effective interface design can help to ensure that technology is user-friendly and accessible to a wide range of people, including those with disabilities or limited technical knowledge and can lead to improved productivity, better decision making, and increased user satisfaction [6] [7]

There are several ways how the research in the field of HCI contributes these outcomes: Such as developing methodologies that enable user experience (UX) designers and UX researchers to prototype and test machine interfaces even prior to their deployment to end-users or creating techniques that can produce "engineering models of human performance" which can predict human performance on computer tasks before they are carried out. John and Kieras [8] provide a detailed overview and comparison of these tools, which are similar to models used in the physical sciences [9]. As these and many other examples suggest studying and understanding human factors (cognitive processes and behaviours) and their effects on humans' interactions with the computers are significant parts of the HCI research for creating technology that is user-centred and able to meet the needs of users in diverse contexts [10].
Cognitive biases are one of the key human factors studied by HCI researchers which is initially defined by Tversky and Kahneman in 1974 as inherent flaws or systematic errors in human reasoning and decision-making [11] [12]. There are several explanations why cognitive biases occur however, the vast amount of literature tends to explain this phenomenon with dual-processing theories which suggest that mental processes can be divided into two categories as controlled and automatic processes [13]. Accordingly, controlled processes are initiated intentionally, require considerable cognitive resource, and operate within

conscious awareness. In contrast, automatic processes are initiated unconsciously, require minimal cognitive resources, and operate quickly. In his well-known book Thinking, Fast and Slow [14], Kahneman described these processes as System 1 (referring to automatic processes) and System 2 (controlled processes) and suggested System 1 can led to faster decisions, but it can be error-prone due to biases and heuristics. System 2 tends to be more reliable, but it requires more cognitive effort and slows down decision-making [15].

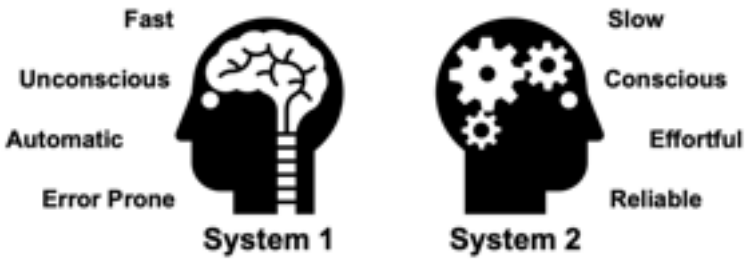

Figure 1. System 1 and System 2 demonstration based on Thinking, Fast and Slow [14]

Thereby, Cognitive biases can simplify decision-making by reducing the amount of information and uncertainty that needs to be processed [16]. Therefore, it is imported to note that although cognitive biases are typically assumed to have a negative impact, they can have positive impacts as well. On the other hand, the intensity of the biases can differ in people due to the combination of evolutionary, societal, and environmental factors, as well as individual differences in cognitive processing [17].

Overall, while there is no consensus, the number of reported biases currently exceeds 180, with different categorizations of these biases proposed in the literature [18]. Moreover, cognitive biases are often unconscious and can be difficult to detect, making them a significant challenge in many fields, including HCI [19]. The presence of the bias can result with the adoption of the irrational beliefs and early inferences without following any objectivity [20]. As the concern of this paper, these biases not only affect the judgement of the users but can further dictate their decisions which is undesirable in a user-centred computer interface design [21]. Accordingly, this study aims to contribute to the bridge the gap in the literature by providing a review of the overall themes and trends in the literature regarding to the nature of the interaction between the two concepts. Accordingly, our research questions are: (22) How cognitive biases impact user decision making in HCI? (2) What are the practical applications suggested in literature for reducing the bias in HCI?

2. METHODOLOGY

A systematic literature search was conducted using electronic databases such as Google Scholar, ACM Digital Library, Frontiers, and Elsevier. The reviewed papers were mainly focused to articles published in the last 10 years (2003-2013) to ensure the relevance of the literature to current research questions. The following search terms will be used: "cognitive bias," "decision making," "human-computer interaction," "HCI," and "user interface." Articles will be screened based on their relevance to the research questions, with a focus on studies that address the impact of cognitive biases on user decision-making in HCI, identify common biases that users face while interacting with computers, and discuss the practical applications of the current literature. Nevertheless, studies were included in this review if they meet the following criteria: (a) published in English language, (b) conducted empirical research related to cognitive biases and their impact on users' decision making in HCI, (c) published in peer-reviewed journals, conference proceedings or books. Studies were excluded if they do not meet the inclusion criteria or if they are duplicate studies. The quality of the studies will be assessed using established quality assessment tools such as statistical reliability parameters. There were no ethical issues are anticipated for this literature review.

3. EMPRICAL REVIEW

3.1.How Cognitive Biases Impact User Decision Making in HCI?

Our research identified various factors can trigger cognitive biases and further impact decision making processes of users. These factors are: (23) the quantity of available and accessible information, (24) the lack of meaning associated with the information, (25) the need for quick action, and (26) what information is remembered or recalled. Based on the systematic review of Azzopardi [27] these factors as overall categories of biases can initially associated with search behaviour of users in various platforms including web-based user interface design. We conducted current review through this perspective for narrowing the scope of the study.

3.1.1.Quantity of Available Information

Social psychology theories suggest that various cognitive biases can affect human decision making based on their engagement and elaboration

with the available content [28]. Accordingly, information overload which is a situation where a person is presented with an excessive amount of information while attempting to perform a task or make a decision (IDF) which is commonly observed in various online environments [29]. In contrast, lack of information might lead users to make uninformed early interferences regarding the information. On both situations, it is found that individuals tend to make decisions based on emotions, simple rules, or social cues due to the reduced motivation and reduced use many cognitive resources which induce cognitive biases [30]. Therefore, the amount of available and accessible information in a user interface of a platform such as a social media channel can lead users to notice paying attention and even favouring information that is already primed in memory or repeated overly in the interface [31].

Our research revealed the confirmation bias as the most common theme under this subject (e.g., [32] [33] [34] [35] [36] [37]). Confirmation bias refers to the tendency to seek, interpret, and remember information in a way that confirms one's pre-existing beliefs or hypotheses while ignoring or dismissing information that contradicts them (Nickerson, 1998). Accordingly, there are several situations that confirmation bias has studied in the HCI context. For example, Suzuki and Yamamoto [38] observed confirmation bias in the context of web search behaviour. They exemplified the process by referring to an imaginary health-conscious user (X), who watches a TV program claiming that genetically modified food Y is harmful to health. Subsequently, when X searches the web to gather more information about food Y's safety, X suggested more likely to focus on information that confirms his belief that food Y is harmful. This unconscious tendency to seek out information that supports pre-existing beliefs is known as confirmation bias. Even if the information that X finds is inaccurate or low-quality, they may still give it preference over information that contradicts their existing beliefs. Accordingly, their study with overall 300 participant showed that participants with poor literacy and negative prior beliefs about the searched topic spend significantly less time going through the web search results compared the ones with positive and neutral beliefs. Supporting this, the study by Pothirattanachaikul et al. [39] found that participants spent more time in searching through documents when they were presented with belief inconsistent documents.

3.1.2.Lack of Meaning Associated with the Information

Experiencing certain events without lack of attached meaning or explanation may lead false attributions and errors in decision-making such as stereotyping or generalising a situation based on prior knowledge or beliefs causing positive inferences to familiar things [2]. Our research found that this commonly leads to the bias which is known with the names of bandwagon effect, group thinking and herd behaviour [2]. The bias occurs when individuals tend to adopt a particular behaviour, style, or attitude because they observe others doing so [19]. The greater the number of people adopting the trend, the more likely it is for others to follow suit [4]. This effect has found its reflection in decision-making process through various computer interfaces that allows content creation, product reviews, peer recommendations and question-answering (Q&A) [9]. Accordingly, Kelly et al. [15] asked 128 participants to use a computer-based search engine to find information about four topics while their interactions with the engine were recorded. During the task, search engine provided query suggestions that varied in popularity and quality. Although researchers found both popularity and quality of query suggestions significantly affected the participants' selection of queries, popularity had a stronger effect on the participants compared to quality of the queries. The findings suggest that users may be biased due to the bandwagon effect, even at the expense of quality and accuracy of the information. Another study by Lewandowsky et al. [19] with over 1,000 social media users showed that users tend to share articles that have already been widely shared by others, which is another indication of bandwagon effect in HCI context.

3.1.3.Need for Quick Action

Time pressure in decision making can lead to biased thoughts such as preferring simple options over complex ones or/and prioritizing preservation of autonomy and group status as well as avoiding irreversible decisions to prevent any mistake [2]. Accordingly, combination of time pressure and user interface design may trigger decoy effect in participants which might lead faulty decisions. The decoy effect is a cognitive bias where an option becomes more attractive when it is presented alongside an unattractive option (decoy). In the study conducted by Tietz et al. [37], when 96 participants were presented with the choice of receiving an e-book for a $10 pledge (Competitor) or both an e-book and a hardcover book for a $20 (Target) pledge, most of them chose the former (69%). However,

when a decoy option was introduced that offered only the hardcover book for $20, most of them chose to pledge $20 to receive both books (68%). The decoy option nudged backers towards the more expensive option, resulting in more pledges. Table 1 presents an overview of the choice sets of the two scenarios.

Table 1: Choice sets for the book scenario [37]

Option	Baseline Condition	Decoy Condition
Option A	PAY $10 – GET an eBook	PAY $10 – GET an eBook
Option B (Decoy)		PAY $20 – GET a hardcover book
Option C	PAY $20 – GET an eBook and a hardcover book	PAY $20 – GET an eBook and a hardcover book

Further studies by Wu and Cosguner [40] and Sherlin et al. [41] also reported decoy effect on real online shopping settings which suggest the possible use of decoy pricing to increase sales and revenue by strategically pricing their products in a way that influences user behaviour. However, some researcher caution that the use of decoy pricing may not be suitable for all product categories and may have ethical implications that should be carefully considered since users may not be aware that their decision is being influenced by the presence of the decoy option. [42].

3.1.4.What to Remember or Recall

To cope with the need to retain information selectively from the available content, people tend to select and store certain elements of events and lists. They may also edit and reinforce memories based on how they were experienced [43]. Nevertheless, we found that most bias which were considered under this group showed challenging results in the scope of HCI. For instance, priming effect which is commonly suggested to influence over the attitudes and experience toward technology [45] [46] [47]. For example, the study by Ferreri et al. [48] found that the according to their primed expectations (negative, positive, or neutral) toward the technology in online scavenger hunt, participants (N=42) showed significantly different attitudes in their responses to failures in digital technology.

In contrast, further study by Hawes and Arya [49] with 51 participants conducted to understand whether virtual environments can be created in a way that boosts participation and proficiency in various cognitive tasks. Accordingly, participants were assigned three different conditions (virtual reality learning spaces) as animation studio (primed condition), theatre with animation artifacts (primed condition) and theatre without animation artifacts (no-primed condition) while receiving a seminar with same educational content. Although results found an increase in general user-experience as well as academic performance, no significant difference found between the groups.

3.2. What are the Practical Applications Suggested in Literature for Reducing the Cognitive Biases in HCI?

Reducing the negative effects of cognitive biases in user experience is another important topic in HCI since they can lead errors, decrease performance, and reduce user satisfaction [50]. In addition to its general impact, it is also suggested that HCI systems can be designed more inclusive, as certain biases may disproportionately affect certain groups [51] [52]. However, Adams et al. [53] discovered that the majority (94%) of behavior change technologies featured in HCI publications target the reflective mind (System 2), which is the deliberate and conscious decision-making process, rather than the fast and automatic mental processes (System 1) that govern an estimated 95% of our daily choices which suggests the technology is produced information-centric rather than user-centric [3]. In other words, users are left frail toward cognitive biases in their interactions with computers which possibly affect their decision-making. Nevertheless, there are several practical applications suggested in the literature for reducing cognitive biases in HCI including (1) user research and (2) digital nudging.

3.2.1.User Experience Research

User experience research or user research (UXR) refers to the process of understanding the needs, behaviours, motivations, and pain points of users through various research methods such as user interviews, surveys, and usability testing [54]. User research is an effective method to reduce cognitive biases in HCI. Study by Olson and Olson [55] suggested that user research helps in reducing assumptions and biases by providing insight into users' mental models and cognitive processes. This information can be used to design. user interfaces that are more intuitive and aligned with user needs [56]. As noted by Preece et al. [57], user research helps designers to "develop empathy with users and design for their needs, rather than designer or business needs."

Table 2: Definitions of common UXR methods [58] [59]

Research Methods	Definition
User Interview	A one-on-one conversation with a user to gather information about their thoughts, feelings, and behaviours
Surveys	A questionnaire designed to gather data from a large group of users in a structured way.
Usability Testing	An evaluation of a product or prototype with real users to identify usability issues and areas for improvement.
Contextual Inquiry	An in-person observation of a user in their natural environment to understand how they interact with a product or service.
Heuristic Evaluation	An expert evaluation of a product or prototype based on a set of usability principles or heuristics.

User research can be classified into two categories: exploratory research and evaluative research. Exploratory research aims to understand the users' needs, preferences, and behaviours, while evaluative research evaluates the usability and effectiveness of a product or service [60]. User research can help to evaluate the effectiveness of design solutions in reducing cognitive biases in both stages. For instance, before coming up with any design solution, detailed interviews with users may reveal established cognitive biases of users like stereotyping, whereas researchers may conduct usability testing to observe how users interact with the further design solution and identify potential sources of cognitive bias or other usability issues in testing process. This gives opportunity to stakeholders, engineers, and designers to come up possible solutions that reduce observed biases in final product.

3.2.2.Digital Nudging

Nudging is a technique that involves subtly influencing people's behaviour without taking away their freedom of choice [61]. Nudging can be used to

encourage people to make healthier choices or engage in environmentally friendly behavior [62]. For example, supermarkets places certain items like snacks, gums, or drinks next to the checkout services to nudge their customers into making unplanned purchases. Alternatively, nudges are not only used in physical environments. Accordingly, digital nudging refers to the use of user interface design and other digital tools to influence the behaviour of users in a predictable and positive way [63].

There is a considerable number of studies regarding the effect of digital nudges where a systematic review by Caraban et al. [64] identified 23 distinct mechanisms of nudging that affect user behaviour in various levels through analysing 71 articles from 13 prominent HCI venues. For example, they referred to the NewsCube which is an innovative online news platform that designed to address media bias including confirmation bias. The platform gathers articles from diverse sources, removes irrelevant information, and clusters the content into balanced sections, while highlighting unread sections to nudge users to explore all viewpoints [65]. Another example for digital nudging comes from Lee et al. [66] who utilized the decoy effect to encourage healthier snack choices on a website where users could order snacks. They placed a picture of a large and visually appealing Fuji apple next to a small and unappealing apple to increase the likelihood of users choosing the fruit over a cookie.
Overall, it has been showed that digital nudging has been applied in various contexts such as e-commerce, digital platforms for education, health, and wellness to promote positive behaviour change, improve decision-making, and increase engagement with digital platforms [67] [68]. However, ethical concerns around the use of digital nudging, particularly around issues of privacy, autonomy, and informed consent should be considered in practical use as well as being studied as a significant research topic in HCI.

4. CONCLUSION

Overall, this study aimed to examine the impact of cognitive biases on user decision-making in Human-Computer Interaction (HCI) and explore practical applications of the current literature. Our research identified factors such as the quantity of available information, the lack of meaning associated with the information, the need for quick action, and what information is remembered or recalled, which can trigger cognitive biases and impact

user decision-making. Furthermore, we discussed two common strategies, user research and digital nudging, which can minimize negative effects of cognitive biases in interface design. Our findings not only contribute to the literature but also have practical implications, such as improving user experiences, productivity, and satisfaction with technology.

The limitations of this study include the reliance on academic databases, which may not capture all relevant literature, and the potential for publication bias, as studies with significant findings may be more likely to be published. Additionally, the review will be limited to articles published in English and may not capture non-English literature on the topic. Nevertheless, our literature review highlights the need for designers and developers to be aware of the impact of cognitive biases on users' decision making in HCI. By designing interfaces that consider the influence of cognitive biases, we can create systems that are more user-friendly and effective. Further research is needed to explore the effectiveness of different design strategies in mitigating the impact of cognitive biases on users' decision making in HCI.

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