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Identification of Common Heuristics and Cognitive Biases in Product Development: Initial Findings from the Literature

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Abstract: *Product development, especially in the era of mass customization, is complex, requiring extensive collaboration, information exchange, and unbiased decision-making which is often suboptimal due to several factors. This study examines the impact of heuristics and cognitive biases on product development. Through a systematic literature review, the research identified 14 common heuristics and 36 cognitive biases associated with the product development process. Additionally, we categorized heuristics and cognitive biases into three perspectives: cognitive biases are the result of heuristics; cognitive biases and heuristics are either effect, and cognitive biases can be generated from the source of information.*

Key Words: ***Product development, cognitive bias, heuristics, decision-making, mass customization***

1. INTRODUCTION

Product development is a complex and uncertain process that requires collaboration and the exchange of information between different participants (Antioco et al., 2008), especially in the era of mass customization (Suzić, Forza, et al., 2018; Suzić, Sandrin, et al., 2018). Mass customization (MC) refers to an organization's capacity to deliver customized products that meet the needs of each customer without substantial compromises in cost, delivery, and quality (Suzić, Forza, et al., 2018), based on Pine (1993), Liu, Shah, and Schroeder (2006) and Squire et al. (2006). To meet individual needs, MC seeks to leverage the cognitive abilities of product designers while considering consumer interests. However, no research has explored the interplay between MC and designer's behavioral reasoning, though attempts have been made to study reasonings for product development. Hence, after a preliminary review revealed a lack of relevant literature in the MC research field, we decided to focus on the connection between designers' behavioral reasoning and product development in general.

Although it is challenging to condense them all, product development processes generally follow six stages: strategic planning, idea development and screening, business and market opportunity analysis, technical development, product testing, and product commercialization (Song and Montoya-Weiss, 1998). The success of each product development activity relies on confronting the challenges and using opportunities, requiring a careful and strategic decision-making process (Ruelas et al., 2021).

Recent reviews (Cossette, 2014a; Teleaba and Popescu, 2018) indicate that decision-making in product development is often suboptimal and prone to errors. These errors can stem from various factors, such as the patterns of communication or information (Antioco et al., 2008; Gilovich et al., 2002);

employees' personalities, academic backgrounds, and experience (Antioco et al., 2008); the need to meet customer expectations, and environmental considerations (Yilmaz et al., 2015; Zheng and Miller, 2019). Several authors (Alkhars et al., 2019; Calle-Escobar et al., 2016; Martín and Valiña, 2023) noted that these decision-making errors are primarily due to design heuristics.

Currently, the application of design heuristics or cognitive strategies is playing a crucial role in the product development process under uncertain conditions (Calle-Escobar et al., 2016; Yilmaz et al., 2010). Design heuristics are mental shortcuts and simplified decision-making strategies used when facing uncertainty (Yilmaz et al., 2015). They involve selectively ignoring some information or retrieving much information to speed up decisions, which can result in cognitive bias. Cognitive biases are systematic deviations from rationality that stem from the reliance on judgmental heuristics (Tversky and Kahneman, 1974). Numerous studies have identified various cognitive biases in different fields, but little is known about the common heuristics and cognitive biases in the product development process (Alkhars et al., 2019; Ruelas et al., 2021). Identifying these biases is important to understanding their association with the product development process.

This study presents the common types of heuristics, and cognitive biases involved in the product development process, considering prior findings. Specifically, by applying a systematic literature review, the present study aims to identify these typologies within the domain of product design and mitigation approaches.

The remainder of the paper is structured as follows: Section 2 presents the notion of heuristics and cognitive biases in product development; Section 3 outlines the methodology; Section 4 identifies the typology of heuristics and biases; and finally, Section 5 presents the discussion, conclusions, and future research directions.

2. THE NOTION OF HEURISTICS AND COGNITIVE BIASES IN PRODUCT DEVELOPMENT

Product development begins with ideation, often referred to as the fuzzy front end (Dahl and Moreau, 2002). In this stage, decision-making lacks distinct rules and is prone to cognitive biases (Lockton, 2012; Ruelas et al., 2021). Recent studies have highlighted the importance of heuristics and cognitive biases (Cristofaro et al., 2022; Zhang et al., 2020), emphasizing the need to consider these factors in product development, which can be crucial for mass customization where customer-specific preferences are vital (Da Silveira et al., 2001).

Dahl and Moreau, (2002) preferred terms like cognitive psychology and cognitive strategy over heuristics and cognitive biases to describe biased decisions resulting in the product development process. Their study revealed that far analogy is more effective than near analogy. Dahl and Moreau (2002) assert that far analogies require identifying similarities between the base domain (i.e., transferring information from existing categories) and the target domain (i.e., using the information in constructing new ideas), particularly when these domains share few similarities. Near analogies, characterized as "literal similarity," involve smaller conceptual distances between old and new ideas, potentially diminishing innovation. Conversely, Åstebro and Michela (2005) observed that involving experienced external bodies, such as inventor assistance programs (IAPs), during the ideation phase in design domains with few similar ideas can mitigate unrealistic optimism among inventors, thus ensuring long-term product success. This finding contrasts with studies emphasizing the importance of considering a few similar ideas.

Antioco et al. (2008) proposed a cognitive opportunity to counteract professional culture bias among design teams, rather than directly considering heuristics. The study indicated that employees, more than senior managers and engineers, are prone to cognitive biases due to consistent interactions with customers. To reduce ongoing product design decision-making bias, the authors suggested distributing information overload from gatekeepers to senior managers. The study implies that customer information, filtered through employees, influences both designers and engineers.

In 2010, Yilmaz et al. utilized cognitive strategy to foster creativity, and facilitate common understanding among design teams to mitigate perception differences. The perception difference can come from ambiguous design problems, potentially hindering efficiency. In fact, Kurz et al. (2024) and Alzayed et al. (2022) attempted to mediate this difference using an empathy approach. Yilmaz et al. (2010) also emphasize that heuristics, as cognitive strategies, enhance product development ideation. Later, Yilmaz et al. (2015) further developed the previous finding by demonstrating that design heuristics are valuable at every stage of product development, particularly during concept generation. The authors proved that considering multiple design heuristics with working instructions enhances creativity among designers and engineers, despite (Dahl and Moreau, 2002) missing this point. However, Yilmaz et al.'s(2015) finding is not always valid. For example, despite engineers and designers following the same instructions and facing the same design problem, design outcomes varied significantly (Calle-Escobar et al., 2016). This difference was attributed to time limitations during the design process, which resulted in cognitive bias.

Cognitive bias arises from either implicit (intuitive reflection) or explicit (analytical thinking) decision-making systems (Cristofaro et al., 2022; Reinhardt et al., 2024). While implicit decision-making empowers professionals in product creativity, it is not significantly correlated with explicit decision-making (Cristofaro, 2022). Reinhardt (2024) argues that implicit decision-making influences the explicit system, depending on the type of products developed. This argument is supported by a case study focused on product concept selection, revealing an inherent preference for premium innovation or new product over economic product.

Some authors, including (Lockton, 2012) argue that cognitive bias and heuristics are either effect that influence participant's behavior from a design perspective. Lockton (2012) identified some biases such as confirmation, status quo, and Cialdini's biases; and integrated them into design domains that previous findings had overlooked. The either effect concept is, in fact, supported by Kahneman (2011).

Meanwhile, it can also be seen that different authors use different terms for the same heuristics. For example, Belvedere et al., (2013) and Ruelas et al. (2021) referred to anchoring bias, termed anchoring heuristics by Tversky and Kahneman (1974). We can observe not only different terms but also the introduction of new cognitive biases based on the research problem, such as high-end bias (Reinhardt, 2024) and try-new bias (Teleaba and Popescu, 2018) as shown in Table 2.

Several studies (Alkhars et al., 2019; Ruelas et al., 2021; Teleaba and Popescu, 2018) argue that heuristics are sources of cognitive biases. For example, representativeness heuristics generate biases such as insensitivity to the prior probability of outcomes, misconception of chance, and illusion of validity (Alkhars et al., 2019), as first pointed out by Tversky and Kahneman (1974). Taking these biases, Alkhars et al. (2019) applied the cognitive reflection test (CRT) to reduce biased decisions and found high cognitive reflection exhibited less cognitive bias among design engineering students. Differently, Zheng and Miller, (2019) focused only on the effect of overdesign bias on creativity, neglecting its association with heuristics. The study revealed that design engineers avoided ownership bias in centralized teams when idea value was not considered but showed bias when selecting their ideas regardless of quality.

Cognitive biases can also originate from the source of information (Cossette, 2014), potentially leading designers to interpret it in the wrong way (Feiler and Tong, 2022). For example, overconfidence and optimism, common biases among inventors due to misinterpreting information, have attracted researchers' attention (Cossette, 2014; Feiler and Tong, 2022). Other findings relate biases to users' emotional experiences. For instance, Wei Sun and Ping Sun (2008) emphasized customers' psychology and emotional experience during product use to maintain their attention consistently. Wang et al. (2021) provided supporting evidence for the study of Wei Sun and Ping Sun (2008) through redesigning office chairs. The study revealed cognitive biases due to uncertainties in understanding user needs, affecting the designer's accurate perception of user emotional experiences. Whether the decision-making results are positive or negative, the perception difference between designers and customers can lead to bias. Overdesign, resulting from these perception differences, is a common example (Kurz et al., 2024; Belvedere et al., 2013). Kurz et al. (2024) also added that such biases occur when designers highly empathize with customers' needs.

More recently research has highlighted the positive impacts of cognitive biases. Zhang et al. (2020) observed that biases from availability and representativeness heuristics, as shown in Table 2, generally boost inventors' performance. Similarly, Cristofaro et al. (2022) indicated that biases like impact bias and exclusivity bias positively contribute to employee creativity and product performance, reshaping manager mindsets. These findings challenge the belief that cognitive bias is always detrimental.

3. METHODOLOGY

This study employed a systematic review to identify and refine the literature on cognitive biases and heuristics in product development. Systematic literature reviews currently play a vital role in consolidating knowledge in a specific research field, as demonstrated by Fettermann & Echeveste (2014), Dresch et al. (2015), and Suzić et al. (2018). Specifically, it helped us to consolidate the common types of heuristics and cognitive biases in the product development process.

An initial search was conducted using specific keywords *("new product develop*" OR "product develop*" OR "product design*" OR "product innovat*") AND ("cognitive bias*" OR "cognitive bias and heuristic*" OR "decision-making bias*" OR "behavioral bias*" OR "decision-making processes*" OR "judgment bias*" OR "decision strateg*" OR "human decision-making" OR "psychological factor*" OR "cognitive psycholog*" OR "problem-solving heuristic*" OR "decision-making psycholog*" OR "behavioral decision* *theory*" OR "cognitive processes*" OR "decision-making model*" OR "bias* in innovation")* retrieving a total of 735 potential articles. These articles were then refined to include only relevant subject areas such as engineering, business, and management; social sciences; decision sciences, and economics resulting in 389 documents. Subsequent steps involved screening the titles and abstracts to focus on articles addressing product development, innovation, cognitive biases, and heuristics, leading to a selection of 80 articles. Finally, full-text reading was conducted to methodically examine the interplay between product development or innovation, heuristics, and cognitive biases resulting in a final selection of 21 relevant articles.

3.1. Distribution of Article Sources and Affiliations in Research Dataset

The dataset includes a total of 19 journal articles, 1 conference proceeding, and 1 book chapter. These articles are categorized by journal quartile: 15 in Q1, 1 in Q2, and 1 in Q3, with 4 articles in an unknown quartile. The majority of articles (5) originate from the USA, followed by Canada (3) and China (3). Other contributing countries include Italy (2), Germany (2), and various single-document contributions from the UK, France, Switzerland, Saudi Arabia, Romania, and Colombia.

4. THE COMMON HEURISTICS AND COGNITIVE BIASES IN PRODUCT DEVELOPMENT

Tversky and Kahneman (1974) initially theorized three key heuristics: representativeness, availability, and anchoring, used in assessing probabilities and forecasting events under uncertain conditions. While these heuristics are important, they can lead to systematic errors, referred to as biases. Following Tversky and Kahneman's (1974) notable work, additional heuristics and biases have emerged. Table 1 identifies potential heuristics, and Table 2 recaps cognitive biases in product development from 2002 to 2024. Although there is a lack of clear consensus on the type of heuristics and cognitive biases (Cossette, 2014), we have summarized their relevance to product development.

Table 1. *Different Types of Heuristics in product development and their definitions*

References	Heuristics	Definition
(Cossette, 2014; Lockton, 2012; Teleaba and Popescu, 2018)	Availability heuristics	If something is easily recalled in people's minds, they overestimate its likelihood; if not, they underestimate it (Tversky and Kahneman, 1974)
(Alkhars et al., 2019; Cossette, 2014; Teleaba and Popescu, 2018)	Representativeness	The probability of an event occurring is assessed based on its similarity (implicit or explicit) to other events as if they belong to the same class (Tversky and Kahneman, 1974).
(Cossette, 2014)	Anchoring and adjustment	The initial value is used as a starting point and then adjusted before the final decision (Tversky and Kahneman, 1974).
(Teleaba and Popescu, 2018; Belvedere et al., 2013)	Recognition heuristics	Ability to reach or recognize the correct solution rapidly.
(Alzayed et al., 2022)	Ten design heuristics	- Disposal: causes physical material disposal - Salvage: enables recovery of discarded physical material - Recycling: uses or supports the recycling of physical materials - Remanufacturing for reuse: supports renewing materials for reuse or update - Reuse as is: allows the transfer of ownership - Longevity of use: allows long-term use by a single owner - Sharing for maximal use: allows use by many people through dynamic ownership - Heirloom status: creates long-lasting appeal motivating preservation and transfer - Wholesome alternatives: eliminates the need for physical resources while improving quality of life - Repair of misuse: targets repairing harmful effects of unsustainable use with sustainable alternatives, referring to Eli Blevis, (2007)

Table 2. *Different Types of Cognitive Biases in product development and their definitions*

References	Biases	Definition
(Alkhars et al., 2019; Åstebro and Michela, 2005; Cossette, 2014b; Ruelas et al., 2021; Zhang et al., 2020)	Unrealistic optimism, or Illusion of control or Illusion correlation	Predicting personal future outcomes as more favorable than the suggested value.
	Hindsight bias	People are much more optimistic about trusting the previous result than they admit now.
(Lockton, 2012)	Serial position effect	Overweigh or underweigh the evidence based on order, results from the primacy effect (the earlier a piece of information is presented, the more influential it is) or the recency effect (the more recently a piece of information is presented, the more influential it is).
(Lockton, 2012; Ruelas et al., 2021; Teleaba and Popescu, 2018)	Salience bias	Decisions due to distinctive stimuli or reasons that might not be relevant.
	Loss aversion or Endowment effect or Sunk cost fallacy	Prefer to take risks to avoid losses (segregate gains, integrate losses).
	Framing effect	People understand the same situation differently, which results in different decision-making.
(Lockton, 2012; Ruelas et al., 2021)	Confirmation bias	People overweigh the evidence that supports their point of view.
(Cossette, 2014; Lockton, 2012)	Status quo bias	Make a decision based on default values (present state).
Valeria (2013) referring to Lovallo and Sibony (2010) biases	Action-oriented bias	Excessive optimism often leads to decision-making.
	Interest bias	The tendency of employees to interpret information and make decisions in ways that align with their interests rather than corporate interests.
	Pattern recognition	It is the tendency to identify patterns or trends based on experience.
	Stability bias	The tendency to prefer what people have on hand today.
	Social bias	Just accept the group's decision rather than encountering or justifying the argument.
(Cossette, 2014; Feiler and Tong, 2022; Ruelas et al., 2021; Teleaba and Popescu, 2018; Zhang et al., 2020)	Overconfidence	The tendency to overestimate one's abilities, to predict future outcomes.
	Law of small numbers or Avoidance of information	The tendency to generalize from small samples (data).
(Lockton, 2012; Ruelas et al., 2021; Teleaba and Popescu, 2018)	Anchoring bias	Consider a reference point that people have already in their minds (so less likely to try other means).
(Teleaba and Popescu, 2018)	Bandwagon effect	People tend to adopt certain behaviors simply because others are doing so.
	Choice overload	People prefer to choose by not choosing.
	Try-new bias	The higher the frequency of introducing a new product, the higher the satisfaction and loyalty of customers will be.
(Alkhars et al., 2019)	Insensitivity to prior probability of outcomes	Due to the representativeness heuristic, people may ignore the prior probability information.
	Insensitivity to sample size	If the parameter highly represents the population, people believe that the parameter is often given a high probability.
	Insensitivity to predictability	When people are asked to predict things, they refer to a description they received beforehand.
	Misconception of chance	People assume a random outcome from a random process both locally and globally.

	Misconception of regression	If an extreme outcome occurs, then people expect the same outcome to repeat subsequently.
(Alzayed et al., 2022; Zheng and Miller, 2019)	Ownership bias, opposite to Social bias	An individual's tendency to prefer one's own ideas over others during the design process.
(Zhang et al., 2020)	Base-rate fallacy	This bias occurs when people neglect base-rate statistics in favor of unimportant personal information.
	Regression fallacy	This bias occurs when people explain statistical phenomena with causality instead of recognizing natural fluctuations around the mean.
(Ruelas et al., 2021)	Bounded awareness	Systematic and predictable ways in which people fail to notice obvious information available in a situation prevent them from seeing the full picture.
	Search type	When looking for a solution, options, information, and so on, people tend to use their default search strategy with little or no consideration of its effectiveness.
	Inconsistency	Some experiment results show more cognitive errors in the control phase, with errors evenly spread, indicating inconsistent value assignment.
	Redundancy	The false belief that adding redundant inputs will linearly increase system reliability.
(Cristofaro et al., 2022)	Impact bias	The inclination to outline ongoing methods, solutions, and processes as suboptimal.
	Exclusivity bias	The tendency to value more the work where others are less likely to succeed.
	Novelty appreciation bias	The tendency to recognize novelty under extremely positive lenses.
	Efficacy of tenacity bias	The prediction positively considers and continues effort and commitment as a way to overcome difficulties.
	Malleability of social norms bias	The possibility of being involved in an environment where the normative rules are dynamic and changeable rather than rigid.
(Reinhardt et al., 2024)	High-end bias	"The tendency of employees and managers to favor premium (high-end) over economy (low-end) products, all else being equal."

5. CONCLUSIONS

As of recently, heuristics and cognitive biases are being studied related to product development. Our study recorded 14 heuristics and 36 cognitive biases relevant to the product development process. However, depending on the research problem, the heuristics used and the resulting cognitive biases vary in type and content. This has generated different understandings of heuristics and cognitive biases in the research literature.

The present study marks the first attempt of the research team to systemize the latest knowledge on heuristics and cognitive biases that occur throughout product development with an eye toward its application in the context of mass customization, an area previously unexplored. Our work underscores the importance of identifying common heuristics and biases in product development, as they significantly shape decision-making processes. Moving forward, informed judgment, decision-making strategies, and negative bias mitigation approaches are crucial for enhancing product development effectiveness. Considering this insight, future work could explore empirically the effect of each heuristic and cognitive bias on product development stages, outcomes, and its implication for mass customization.

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