



A Systematic Review of User Mental Models on Applications Sustainability

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Abstract: In Human-Computer Interaction (HCI), a user's mental model affects application sustainability. This study's goal is to find and assess previous work in the area of user mental models and how it relates to the sustainability of application. Thus, a systematic review process was used to identify 641 initial articles, which were then screened based on inclusion and exclusion criteria. According to the review, it has been observed that the mental model of a user has an impact on the creation of applications not only within the domain of Human-Computer Interaction (HCI), but also in other domains such as Enterprise Innovation Ecology, Explainable Artificial Intelligence (XAI), Information Systems (IS), and various others. The examined articles discussed company managers' difficulties in prioritising innovation and ecology, and the necessity to understand users' mental models to build and evaluate intelligent systems. The reviewed articles mostly used experimental, questionnaire, observation, and interviews, by applying either qualitative, quantitative, or mixed-method methodologies. This study highlights the importance of user mental models in application sustainability, where developers may create apps that suit user demands, fit with cognitive psychology principles, and improve human-AI collaboration by understanding user mental models. This study also emphasises the importance of user mental models in the long-term viability and sustainability of applications, and provides significant insights for application developers and researchers in building more user-centric and sustainable applications.

Keywords: Human-Computer Interaction (HCI), user mental models, application sustainability, systematic review

1. Introduction

When it comes to an application, the mental model of a user is one of the most important factors in ensuring its sustainability. The Human Computer Interaction (HCI) topic of research encompasses the mental model that is used in application development. This field of study is essential since the mental model determines how the user interacts with the application (Payne, 2012). A mental model is the end-user's understanding of how an application functions and the outcomes that they should anticipate as a result of their interactions with it. This is an insider's look at how the

application works and the actions a user might take to accomplish their goals in using the application (Maier, Abdullah, McComb, & Menold, 2021).

A user's mental model is essential throughout the entirety of the application development process, beginning with the preliminary phases of user research and requirements collection and continuing all the way through the prototype and usability testing stages. When the designer understands the mental model of a user, they are more equipped to make decisions regarding which features should be included, how the interface should be arranged, and how the user should interact with the system. The mental model of a user is, in general, an essential component in the long-term viability of an application since it serves as a blueprint for the development of the system's user interface and interaction design. This helps to ensure that the application satisfies the user's needs and objectives, leading to a more satisfying overall user experience (Nourani et al., 2022; Wei, Xi, & Hou, 2020). Hence, the purpose of this study is to identify and evaluate the research that has been carried out in the field of user mental models and its link to the sustainability of applications. The discussion in this paper is expected to assist application developers in the process of designing a more sustainable application.

2. Methodology

The systematic review adopted PRISMA 2009 flow diagram published by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher D, Liberati A, Tetzlaff J, 2009). The presented flow diagram delineates the process of identifying, screening, and establishing the eligibility and inclusion criteria for the reports that pertain to the subject matter of the review. The details of each process are explained in the following subsections, while the summary of the process is illustrated in Figure 1.

2.1 Identification Process

By using thesaurus, dictionaries, encyclopaedias, and prior research, the first process involves the identification of keywords and the search for associated, related terms. Following the identification of all relevant phrases, search strings for the Scopus and Web of Science databases have been constructed (see Table 1). During the first phase of the systematic review procedure, this study was able to acquire 641 articles from both databases. The theme of this review is to identify the relationship between human mental model with application's sustainability. Since application development falls under 'computer' field of study and human mental model is closely related with HCI research area., the search string used for article identification is 'human mental model in HCI' with 'computer' as the subject area.

Table 1 - The search string

Scopus	Web of Science
TITLE-ABS-KEY (human AND "mental model" AND "Human Computer Interaction") AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "COMP")) AND (LIMIT-TO (LANGUAGE , "English"))	TS=((human AND "mental model" AND "Human Computer Interaction")) and 2013 or 2014 or 2015 or 2016 or 2017 or 2018 or 2019 or 2020 or 2021 or 2022 or 2023 (Publication Years) and Article (Document Types) and Computer Science (Research Areas) and English (Languages)
Date of access: March 2023	Date of access: March 2023

2.2 Screening Process

There were two screening process executed for this study. First was the preliminary screening stage where duplicate articles were eliminated. Second, inclusion and exclusion criteria established by the researchers were used to filter the articles as detailed in Table 2. The first criterion was the presence of relevant literature (research articles) as this is the most reliable way to obtain useful information. Publications in the forms of systematic review, review, meta-analysis, meta-synthesis, book series, books, chapters, and conference proceedings have also been excluded from the current study. Only completed publications in the field of computer science are considered for this review. In addition, the review was limited to works written in English. An important fact to keep in mind is that the publication period was limited to a period of ten years (2013–2023). After employing all inclusion and exclusion criteria (see Table 2) and eliminating seven (7) duplicate articles, the resulting articles were reduced to 50 in both databases. These 50 articles will be used for the next process of screening for eligibility.

Table 2 - The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2013-2023	< 2013
Literature type	Journal (Article)	book chapter, conference proceeding.
Publication	Final	In press

2.3 Eligibility Process

In this process, the eligibility of the 50 screened articles were examined thoroughly. During this third step of the review process, the titles and primary content of each article were evaluated to see whether the inclusion criteria had been met and whether the articles were pertinent to the current study on ‘user mental models on applications sustainability’. There are a total of 28 articles that do not meet the criteria, leaving 22 articles for the analysis process as illustrated in Figure 1.

2.4 Data Extraction and Analysis Process

An integrative analysis, which is one of the assessment strategies used to analyse and synthesise multiple research designs, was carried out in this study. This technique was among those used in qualitative, quantitative, and mixed methods studies (Bazeley, 2012; Cronin & George, 2023; Loewenstein, Barroso, & Phillips, 2019). The primary focus of the study was on the formulation of pertinent subjects and subtopics. The phase of collecting data was the initial step in developing the theme that was being worked on. The authors have gone through a set of 22 papers very thoroughly in search of remarks or information that responded to questions raised by the current investigation (see Fig. 1). For the second step, the authors and the expert then conduct an analysis on the significance of user’s mental model used in the application development field.

The approach used resulted in the establishment of three key topics, which may be split down into the following categories: *mental model study issues*, *method employed*, and *significance of user’s mental model in application sustainability*. The authors went back and reviewed every developed theme from this point on, including any themes, thoughts, or ideas that had any kind of connection. The corresponding author of this study collaborated with the other co-authors to construct themes based on the findings of the study within the context of this research. In this instance, a log was kept during the process of analysing the data in order to document any analyses, opinions, puzzles, or other thoughts that were pertinent to the data interpretation.

Also, the authors compared their data to resolve any differences in the process of theme generation. Notice that if any inconsistencies in the themes arise, they were resolved by the authors in conjunction with one another. Finally, the themes were modified to maintain their coherence. The assessments were conducted by two Information Technology (IT) professionals to guarantee the veracity of the problems. By demonstrating domain validity, the phase of expert review assisted in ensuring each subtheme's clarity, significance, and adequacy. Changes were made at the author's discretion in response to expert opinion and feedback.

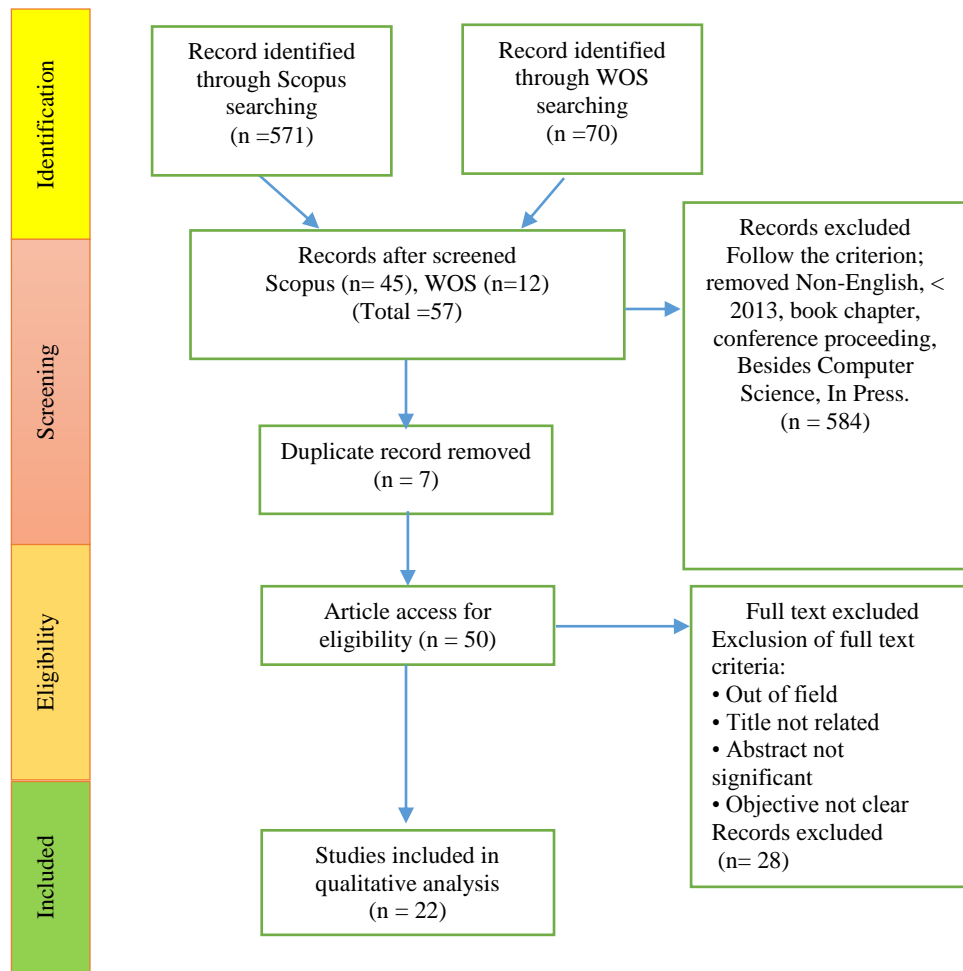


Fig. 1 - Flow diagram of the proposed searching study
 Source: (Moher D, Liberati A, Tetzlaff J, 2009)

3. Results of Review Work

The term "application" in this article refers to the program that incorporates both a website and a mobile platform. Only 20 of the 22 articles were chosen as the most relevant to be analysed and reported on in this study after a review of their respective contents. In addition to the field of Human Computer Interaction (HCI), other areas of study such as Enterprise Innovation Ecology, Explainable Artificial Intelligence (XAI), Information Systems (IS), User Experience (UX), Cognitive Science, social behaviour, Internet of Things (IoT), Computer-Mediated Communication (CMC), Information Science, Human Factors and Ergonomics, Human-Robot and natural interaction with smart homes have also addressed a user's mental model in relation to application development.

The issues that prompted every researcher to conduct their study are an additional factor that is reviewed. Acknowledging the issues raised by the researchers are essential to advancing our understanding of the core cause of the need for user mental model research and how to deal with it. Following this, the methodology that was used to carry out the studies was examined and assessed so that it might serve as a guide for future researchers. After that, the results of the studies were analysed in order to determine the significance of knowing users' mental models on the process of application development. Table 2 provides a summary of the content of the journal, and the next section provides an explanation of the discussion of the results and findings.

Table 2 - Summary of journals' content

Authors & Year	Title & Journal	Field of study	Issues	Method	Significance
1. (Dong, 2023)	Title: Philosophical Research on Enterprise Innovation Ecology Based on a Human-Computer Interaction Mental Model Journal: Sustainability (Switzerland)	Enterprise innovation ecology and Human Computer Interaction (HCI)	Business managers are too busy coming up with new ideas and making their structures as efficient as possible to pay attention to actual innovation and ecological construction, while they are not concerned about the difficulties with real construction.	Conceptual analysis, model design	It increases ecosystem construction, algorithm performance, cognitive psychology, creative ecosystem understanding, and business growth.
2. (Li & Luximon, 2023)	Title: Navigating the Mobile Applications: The Influence of Interface Metaphor and Other Factors on Older Adults' Navigation Behavior Journal: International Journal of Human-Computer Interaction	Human Computer Interaction (HCI)	The interface metaphor was suggested to aid mental model building when navigating; however, its efficacy among older persons is unknown.	Experimental	This study can help HCI researchers understand how interface metaphors effect older users' phone use.
3. (Martín & Macías, 2023)	Title: A Supporting Tool for Enhancing User's Mental Model Elicitation and Decision-Making in User Experience Research Journal: International Journal of Human-Computer Interaction	Human Computer Interaction (HCI) User Experience (UX)	The problems with the way card sorting is done now and what needs to be done to make it better so that UX study and decision-making can get more quantitative and complete information.	Card sorting incorporate with advance statistical analysis and machine learning technique	Mental model study helps UX researchers create useable designs and improve existing products by revealing how people perceive and understand a system or product.
4. (Tamas, O'Brien, & Santana Quintero, 2023)	Title: Evolving interaction: a qualitative investigation of user mental models for smart thermostat users Journal: Architectural Science Review	Human Computer interaction (HCI), User Experience (UX)	We looked at manual and programmed thermostats to see how the way people think the device works affects how they use it more than how it actually works.	Case study	Understanding mental models in smart thermostats optimizes user engagement, energy outcomes, and usability. It helps researchers and designers detect user misconceptions, address complexity concerns, and create interfaces that match users' mental models, increasing user experience and boosting effective usage.

5. (Le Guillou, Prévot, & Berberian, 2023)	Title: Bringing Together Ergonomic Concepts and Cognitive Mechanisms for Human-AI Agents Cooperation Journal: International Journal of Human-Computer Interaction	Artificial intelligence, explainable AI, human-robot interaction, human-computer interaction, cognitive science	Real-world applications of artificial intelligence (AI) and the need to contemplate the social aspects of human-computer interaction	Article Review	The paper highlights that artificial agents need an appropriate mental model of their behavior to communicate with humans.
6. (Nourani et al., 2022)	Title: On the Importance of User Backgrounds and Impressions: Lessons Learned from Interactive AI Applications Journal: ACM Transactions on Interactive Intelligent Systems	Explainable Artificial Intelligence (XAI) and Human-Computer Interaction (HCI)	Explainable Artificial Intelligence (XAI) methods aim to promote human-AI collaboration by clarifying models and improving mental models. Users' experiences can pose unexpected issues for system designers.	Experimental Observation Questionnaire	The study helps AI designers understand how user impressions and backgrounds can prejudice XAI systems. This understanding can help XAI build more effective and user-centered techniques to increase human-AI decision-making and model transparency.
7. (Mattyasovszky-Philipp, Putnoki, & Molnár, 2022)	Title: The Unrepeatable Human Mind—Challenges in the Development of Cognitive Information Systems—What Makes a Machine Human? Journal: Electronics (Switzerland)	Cognitive Science, Information Systems (IS), Human-Computer Interaction (HCI)	The lack of full understanding of human cognition and the incomplete synchronization of Information Systems (IS) with humans.	Article Review comparative study	Understanding the human mental model can lead to the development of more effective CISs, improved HCI, and a better integration of information systems with human cognitive processes
8. (Zancanaro, Gallitto, Yem, & Treccani, 2022)	Title: Improving Mental Models in IoT End-User Development Journal: Human-centric Computing and Information Sciences	Human-Computer Interaction (HCI) with a specific focus on End-User Development (EUD) in the context of Internet of Things (IoT)	End-user development (EUD) for IoT systems, notably trigger-action (TA) rule programming, lacks understanding of naïve users' mental models.	Experimental, Questionnaire	Understanding and improving users' mental models in EUD of IoT systems have the potential to enhance user performance, accuracy, and comprehension, leading to more effective and efficient programming of TA rules
9. (Chen, Tu, & Wu, 2022)	Title: User-Defined Foot Gestures for Eyes-Free Interaction in Smart Shower Rooms Journal: International journal of Human computer interaction.	Human-Computer Interaction (HCI)	Foot-gesture-based interfaces are an underexplored field, particularly in scenarios where users' hands are occupied with other duties that require preferences and guidelines.	Experimental Questionnaire	When designers and developers know how people think when they use foot gestures, they can make better, more user-centered interfaces that meet users' needs, preferences, and expectations. This improves the entire user experience.

10. (Maier et al., 2021)	Title: A Query Conundrum: The Mental Challenges of Using a Cognitive Assistant Journal: SN Computer Science	Human-Computer Interaction (HCI)	Cognitive assistants have been widely studied, but their effects on humans have not, especially on mental workload, frustration.	Card Sorting. Interviews	Maintaining a clear, simple, and intuitive mental model of the cognitive assistant is important to reduce the mental effort required for interacting with during work tasks.
11. (Shera et al., 2021)	Title: Blind and visually impaired user interface to solve accessibility problems Journal: Intelligent Automation and Soft Computing	Human Computer Interaction (HCI) focused on blind and visually impaired (BVI)	The interface accessibility problems faced by blind and visually impaired (BVI) users while using mobile applications.	Article Review Model Design Experimental Observation Questionnaire	Blind people liked the app's design. The presentation and organization of the content pleased participants. Understanding user mental models enabled this.
12. (Lee & Malcein, 2020)	Title: Users' mental models for computer-mediated communication: Theorizing emerging technology and behavior in eHealth applications Journal: Human Behavior and Emerging Technologies	Computer-mediated communication (CMC), Human Computer Interaction (HCI), social behavior	The importance of gaining a better understanding of users' mental models in order to inform the design and evaluation of intelligent systems	Theoretical review	Understanding users' mental models improves intelligent system design, assessment, and optimisation, facilitates user adaption, complements technological models, and redefines humans' roles in developing technologies.
13. (Anderson et al., 2020)	Title: Mental Models of Mere Mortals with Explanations of Reinforcement Learning Journal: ACM Transactions on Interactive Intelligent Systems	Intelligent user interfaces Human Computer Interaction (HCI)	how reinforcement learning (RL) agents can effectively explain themselves to humans who are not trained in artificial intelligence (AI)	Experimental Model Design Questionnaire	Understanding the mental model is crucial for developing effective explanations of RL agents to individuals without AI training.
14. (Conrad & Tucker, 2019)	Title: Making it tangible: hybrid card sorting within qualitative interviews Journal: Journal of Documentation	Information Science	The need for qualitative researchers and information practitioners to investigate underlying mental models, nuanced perspectives, emotions, and experiences of their target populations	In-depth interviews, Hybrid card-sorting	Understanding mental models with hybrid card sorting deepens participants' perspectives, creates rich data sets, and offers a fresh qualitative research approach.
15. (Beimel & Kedmi-	Title: Improving the identification of functional system requirements	Information systems (IS);	The difficulty of planning an information system (IS),	Experimental, Observation	Understanding a mental model able to help inexperienced IS analysts understand the

Shahar, 2019)	when novice analysts create use case diagrams: the benefits of applying conceptual mental models Journal: Requirements engineering	Human-computer interface (HCI); Cognitive psychology	especially for inexperienced analysts like students. Defining the future system's needs, a vital step in any IS project, is tough.		future system's functional requirements, relations, and actors using cognitive psychology and human-computer interaction.
16. (Furlough & Gillan, 2018)	Title: Mental Models: Structural Differences and the Role of Experience Journal: Journal of Cognitive Engineering and Decision Making	Human factors and ergonomics	The examination of how the structures of mental models differ among video game players with varying levels of experience.	Interview Questionnaire	Understanding mental models, especially in video games, improves user experience, training programme design, game design, cognitive psychology, and research.
17. (Zhu, Ma, Chen, & Liang, 2017)	Title: Tripartite Effects: Title: Exploring Users' Mental Model of Mobile Gestures under the Influence of Operation, Handheld Posture, and Interaction Space Journal: International Journal of Human-Computer Interaction	Human-Computer Interaction (HCI), Interaction Design	The investigation of the effects of various factors (types of operations, handheld postures, and interaction spaces) on users' mental models in the context of user-defined mobile gestures	Elicitation study	User-defined mobile gestures' nature, steps, and spatial utility mirror users' mental models. Understanding users' mental models improves usability, user experience, and responsiveness to users' demands.
18. (Brown, Fercher, & Leitner, 2017)	Title: What I Tell You Three Times Is True: The S.N.A.R.K Circuit Journal: Building an Intuitive Multimodal Interface for A Smart Home: Hunting The SNARK	Human Computer Interaction (HCI) natural interaction with smart homes	The limitations of current voice-based interaction systems	Multi-modal interaction techniques	Understanding mental models and embracing multi-modal communication makes smart home interactions more successful and intuitive. Designers can improve user experience and accuracy by adding gestures and other natural cues to voice commands.
19. (Xie, Zhou, & Wang, 2017)	Title: How Influential Are Mental Models on Interaction Performance? Exploring the Gap between Users' and Designers' Mental Models through a New Quantitative Method Journal: Advances in human computer interaction	Human-Computer Interaction (HCI), Cognitive Science	the effect of the gap between two different mental models on interaction performance	Model Design Card sorting Observation	Practitioners can increase interaction performance and build user-centered systems or processes by understanding users' mental models and bridging the gap with designers'.

20. (Cristian, Gabriela, & Dan, 2014)	Title: Use case of cognitive and HCI analysis for an e-learning tool Journal: Informatica (Slovenia)	Human Computer Interaction (HCI)	Development of a tool that improves the educational process by assisting professors in forming accurate mental models of students' performance	Experimental	Understanding mental models helps create a high-quality user interface for an Intelligent Tutoring System that personalises learning and improves usability for professors and students.
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4. Findings Related to The Objective of The Review

In order to understand how user mental model influences the sustainability of application, the findings of this review are discussed in the next subsections. It addresses on three primary elements that are derived, 1) concern and issues, 2) method employed, and 3) the significance of user's mental model on application sustainability.

4.1 Derived Concern and Issues

Varied issues were found to be the trigger to a mental model study. The issue emphasised in an article by Dong (2023) is that business managers are frequently preoccupied with generating new ideas and optimising organisational structures to the detriment of innovation and ecological considerations. They may overlook the practical obstacles inherent in implementing actual construction initiatives. This issue can be linked to business managers' mental models. A mental model is a cognitive framework that people use to comprehend and interact with the environment. In this instance, the mental models of business administrators are centred on efficiency, idea generation, and organisational structures. Their mental models may not prioritise innovation, ecological sustainability, or the practical aspects of innovation construction. Whilst, in Li & Luximon (2023) article, they discuss the use of interface metaphors to facilitate mental model construction, specifically in the context of navigation in mobile application. However, the effectiveness of this strategy with older individuals is dubious. It indicates that older individuals may have distinct mental models or may have difficulty adapting to new interface metaphors, which could hinder their ability to navigate effectively. On the other side, Tamas et al. (2023) found that understanding mental models in smart thermostats maximizes user involvement, which in turn improves energy outcomes and usability. It assists researchers and designers in identifying user misconceptions, addressing concerns about complexity, and creating interfaces that match users' mental models, which in turn improves the user experience and increases effective utilization. As Le Guillou et al. (2023) stress, the mental model is equally crucial in the field of artificial intelligence. In order for artificial agents to communicate with humans, they need an acceptable mental model of their behavior. Then, Nourani et al. (2022) emphasized that it is important in enhancing human-AI collaboration and clarifying models. This problem highlights how important it is for people and AI systems to communicate and comprehend one another clearly. This can be accomplished by providing explanations and insights into AI models and their decision-making processes.

In addition, the lack of a comprehensive comprehension of human cognition and the insufficient synchronisation of Information Systems (IS) with humans pose an additional challenge (Mattyasovszky-Philipp et al., 2022). This suggests that there is a disconnection between how humans think and process information, and the design and functionality of information systems. Thus, a comprehension of the human mental model is required to solve the problem. In the context of IoT systems, specifically trigger-action (TA) rule programming, this issue highlights the need to consider the conceptual models of novice users (Zancanaro et al., 2022). Lack of comprehension of these users' mental models suggests that intuitive and user-friendly interfaces for IoT devices may be difficult to design, impeding their adoption and usability. Next article mentions that studies of mental models are particularly important in the development of smart shower rooms because they help designers and developers understand foot gestures for eyes-free interaction. This is necessary for the creation of user-centered interfaces that are tailored to users' requirements, preferences, and expectations and are able to enhance the overall quality of the user experience (Chen et al., 2022).

In addition, the study by Maier et al. (2021) brings to light the fact that the impacts of cognitive assistants on humans have not been thoroughly researched, particularly in terms of the mental effort and the level of dissatisfaction they cause. This highlights how important it is to evaluate the impact that AI assistants have on human users in order to ensure that they successfully support and augment the cognitive processes of human users rather than overpowering or frustrating them. Another intriguing aspect found in one article is the interface accessibility issues that blind and visually impaired (BVI) mobile application users face (Shera et al., 2021). It represents the difficulties in designing interfaces that accommodate the requirements of all users. This fact underlines the significance of considering diverse user perspectives and designing accessible interfaces that accommodate individuals with varying abilities.

According to an article by Conrad & Tucker (2019), it is critical to obtain a deeper knowledge of users' mental models while designing and evaluating intelligent systems. This highlights the importance of academics and information practitioners delving into their target communities' underlying mental models, nuanced perspectives, emotions, and experiences (Conrad & Tucker, 2019). The following article initiates the study of video game participants. The authors of the article found that there is a need for research examining how the mental model structures of video game users with varying levels of experience differ (Furlough & Gillan, 2018). Essentially, examining whether a person's familiarity with and expertise in a particular domain can influence their mental models. This knowledge can be used to inform game design and customise participant experiences. The final article examines the effects of various factors on the mental models of users in the context of user-defined mobile gestures (Zhu et al., 2017). It stresses on the significance of investigating how various elements, such as types of operations, handheld postures, and interaction spaces, affect the mental representations and comprehension of the system by the user.

In conclusion, the issues raised in the reviewed articles are closely associated with the necessity of mental models, ranging from the difficulties faced by business managers in prioritising innovation and ecological considerations, to the

need for understanding users' mental models to inform the design and evaluation of intelligent systems. It emphasises the significance of incorporating diverse user perspectives, cognitive abilities, and experiences into interface design, application development, and AI application. Figure 2 presents the total number of issues that have been addressed in accordance with the field of research.

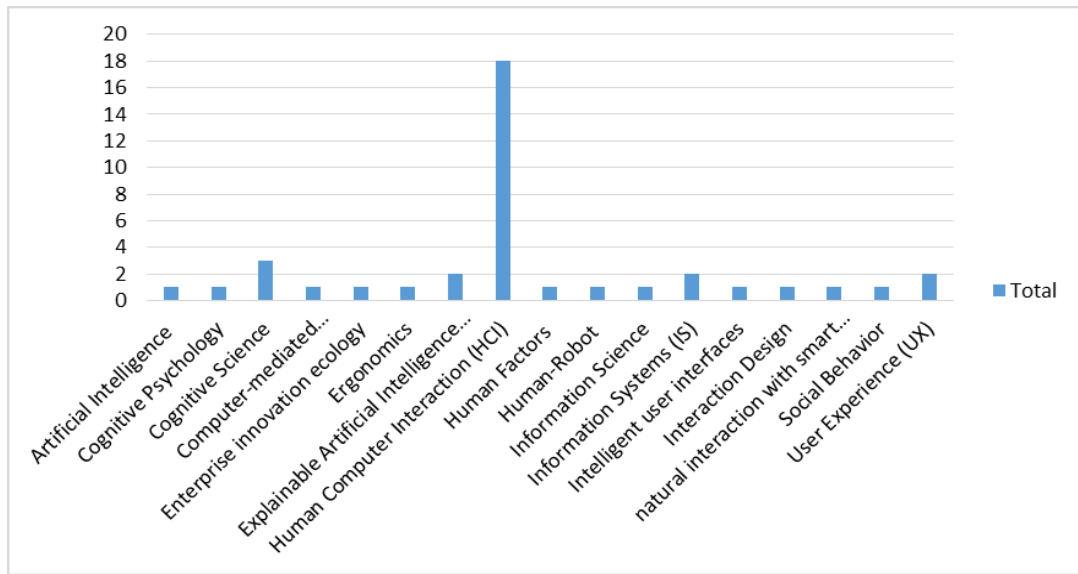


Fig. 2 - Total number of issues in accordance to the field of study

4.2 Method Employed

As shown by the information depicted in Figure 3, thirteen methodologies were utilised in the reviewed articles. Among these methodologies, experimentation ranks first with eight occurrences, followed by questionnaire with six occurrences. Typically, the experimental method is used to test hypotheses or specific statements regarding the relationship between variables, whereas questionnaires are useful for obtaining self-reported data (Mcleod, 2023; Nourani et al., 2022).

Then, model design, observational, and card sorting followed with a total of four occurrences each. Model design refers to the creation of a model that can be used to collect data from participants (Dong, 2023; Shera et al., 2021; Xie et al., 2017). Observation, on the other hand, is a method of data collection that involves observing behaviour, events, or physical characteristics in their natural environment (Kiv & Shyshkina, 2020; Nourani et al., 2022; Sharifuddin, Nasrudin, & Ahmad Junid, 2020). While the card-sorting method requires users to organise information into logical groups, it is commonly used in technology-related research, such as gathering user requirements (Nurmuliani, Zowghi, & Williams, 2004), website design (Conrad & Tucker, 2019), and mental model (Martn & Macas, 2023).

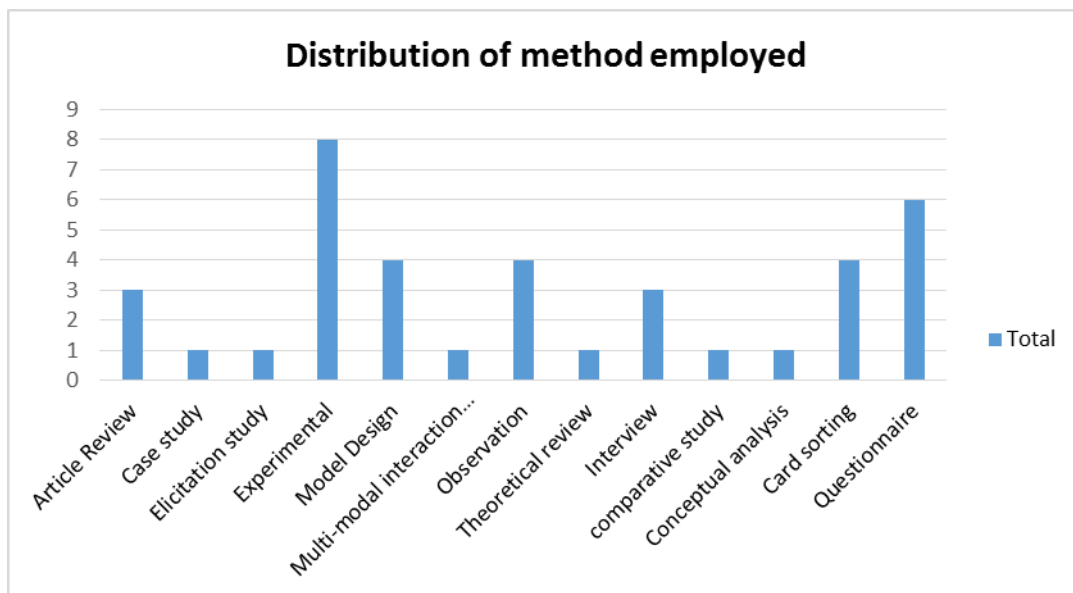


Fig. 3 - Method used in mental model study reviewed articles

The next most frequent methods are article review and interview, with three (3) occurrences each. Article reviews are commonly used to provide cutting-edge critical analyses of particular topics by referencing and contrasting prior research (Balon, 2022). In addition, Shera et al. (2002) found that the article review method could be used to determine the design and development requirements and characteristics of a model. Interviews, on the other hand, are a common qualitative research method for collecting in-depth information and participant perspectives (Nasiru, 2021).

In addition, the findings also identified case study, elicitation study, multi-modal interaction techniques, theoretical review, comparative study, and conceptual analysis as other methods employed in the mental model study. Each of these methodologies has appeared once in the reviewed articles. Majority of the studies do not rely on a single method for obtaining data from participants, as found by the review process. For instance, Zancanaro et al. (2022) combine experimental and observational methods to address the lack of comprehension of the mental models of novice users in trigger-action (TA) rule programming.

Indirectly, it implies that researchers must be inventive when selecting a research method. Each methodology has its own strengths and generates distinct data and insights categories. Using a variety of methodologies, every researcher can obtain a comprehensive understanding of a topic and sound conclusions based on diverse data sources. To conclude; a combination of qualitative and quantitative methods were used to investigate the mental model topic, with experiments and questionnaires being the most prevalent methods.

4.3 Significance of User's Mental Model on Application's Sustainability

The reviewed articles' research findings for the study of mental models were found to have several implications in the context of application sustainability. By gaining insights into users' mental models, developers are able to design applications that promote ecosystem construction, improve algorithm performance, align with cognitive psychology principles, foster creative comprehension of ecosystems, and support business growth (Li & Luximon, 2023). Understanding the mental models of users facilitates the development of applications that meet their needs, preferences, and cognitive processes in a sustainable manner.

The following article found that its research findings could aid HCI researchers in comprehending how interface metaphors effect the phone usage of older users. By analysing their mental models and analysing how interface metaphors influence their usage patterns, researchers can identify design strategies and alter the user interface so that older users can utilise mobile applications effectively. This comprehension contributes to the development of more inclusive and user-friendly interfaces, thereby fostering the sustainability of technology use by ageing populations. The findings of another article, however, was able to assist AI designers in comprehending how user impressions and origins can prejudice Explainable AI (XAI) systems. This knowledge can assist XAI designers in developing more efficient and user-centric techniques to enhance human-AI decision-making and model transparency.

The mental models of users are also crucial to the design of XAI systems. By comprehending how the impressions and experiences of users influence their interpretation of AI outputs, designers can create more transparent and user-centric techniques. This comprehension helps bridge the gap between humans and AI, fostering sound decision-making and increasing confidence in AI systems. By aligning XAI with the conceptual models of users, it is possible to establish human-AI collaborations that are dependable and long-lasting. Understanding the human mental model is crucial for aligning CIS design with the user's cognitive processes, resulting in more effective and efficient systems. Incorporating users' mental models into interface design can also enhance HCI, resulting in interfaces that are intuitive, user-friendly, and promote the sustainable use of information systems.

End-User Development (EUD) of Internet of Things (IoT) systems has demonstrated the significance of comprehending users' mental models so that developers can design EUD interfaces that improve user performance, accuracy, and comprehension. This comprehension facilitates the programming of Trigger-Action (TA) principles, which are central to Internet of Things (IoT) systems. By aligning EUD interfaces with user mental models, it is possible to achieve sustainable and efficient programming, thereby enhancing the overall usability and efficacy of IoT applications. Understanding a user's mental model has led to the development of cognitive assistants that are user-friendly and straightforward to comprehend. By minimising the mental effort required to interact with the assistant, users are able to utilise the application more effectively, resulting in increased productivity and potentially long-term sustainability. The reviewed article also addresses the mental models of blind users, so that designers can create applications that cater to their specific requirements. This finding emphasises the significance of inclusive design, which ensures that people with disabilities can access and benefit from digital applications, in the context of application sustainability. By taking into account various mental models, applications can be designed to accommodate a larger user base, thereby promoting their long-term viability and efficacy. In the context of intelligent system development, designers can also tailor their systems to meet user requirements and inclinations by understanding how users perceive and interact with technology. Incorporating mental models into the design process enables the development of more efficient, effective, and sustainable applications that are consistent with the cognitive processes and expectations of users.

Next, video games frequently rely on the player's mental representation of the game world and its mechanics. Understanding how players develop these mental models can inform the creation of engaging and long-lasting gaming

experiences. By harmonising game mechanics with the mental models of users, designers can create immersive and pleasurable experiences, resulting in sustained engagement and game usage. Moreover, designing mobile applications with gesture-based interfaces reveals the significance of understanding the mental models of users. Additionally, harmonising gesture interactions with the mental models of users may assist designers in creating intuitive and natural interactions that improve the application's usability and longevity. In the context of an Intelligent Tutoring System that personalises learning and enhances usability for professors and students, it is necessary for designers to comprehend the mental models of both professors and students in order to create intelligent tutoring systems that cater to their specific requirements. Personalised learning experiences that align with the mental models of the users increase engagement and promote the system's long-term adoption. In turn, this improves the durability and efficiency of instructional applications.

In a nutshell, these findings highlight the importance of understanding users' mental models in the context of application sustainability by aligning application design, interfaces, and interactions with these models. Designers may then anticipate the development of applications that are more likely to be adopted, utilised, and maintained over time because they are more usable, inclusive, and engaging.

5. Conclusion

The articles that were reviewed examined the importance of recognising user mental models and their influence on the sustainability of applications. The articles explored a range of topics pertaining to mental models, including the difficulties encountered by company managers when it comes to prioritising innovation and taking into account ecological factors. The results of the conducted research have noteworthy significances for the long-term sustainability of application. By comprehending the mental models of users, developers will have the ability to develop programmes that prioritise the needs and preferences of users, promote inclusivity, and optimise efficiency. This comprehension enables the development of interfaces and interactions that are in accordance with users' cognitive processes, resulting in sustained use and acceptance. In summary, it is imperative to comprehend user mental models in order to develop sustainable applications that effectively address users' requirements, preferences, and cognitive capabilities. The integration of varied user viewpoints and the utilisation of a range of research methods have the potential to enhance the effectiveness and ease of use of applications.

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