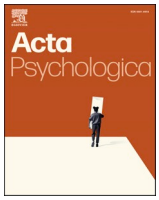
Acta Psychologica 260 (2025) 105622

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy



Identifying communal user needs for quality of experience (QoE) evaluation and improvement focused on user-centered design

Beom-Su Kim, In-Seok Heo, Krishna Sahithi Karur, Sang-Ho Kim *

Kumoh National Institute of Technology, Department of Industrial Engineering, Gumi, 39177, South Korea

ARTICLE INFO

Keywords:
Quality of experience
Communal user needs
User-centered design
Topic modeling

ABSTRACT

The rise of intelligent systems has led to the emergence of new types of interactions and diverse purposes of technology use. As a result, the importance of Quality of Experience (QoE) is becoming increasingly important in fulfilling user needs and ensuring high satisfaction. However, current measurement and improvement methods of QoE are primarily based on objective QoS metrics rather than the highly subjective nature of user needs. Additionally, evaluation models are developed separately for each technological domain, focusing just on domain-specific parameters, leading to inconsistencies when applied to other domains. To address this, the present study selected ten technological domains and employed BERTopic and thematic analysis to identify user needs. By identifying patterns in shared aspects, the study defined eleven common dimensions referred to as "communal user needs." To verify the reliability of these communal user needs, three researchers independently evaluated 1000 reviews to determine which communal user need each review corresponded to. The resulting Krippendorff's α was 0.805, indicating a sufficient level of inter-rater reliability. The findings suggest that, while user needs may be expressed differently at the individual technology level, they align toward communal user needs at an abstract level. Furthermore, the variation in the number of times the user needs appeared across different technological domains in a similar pattern suggests that a more universal QoE model could be constructed. This could be done by incorporating the dynamic nature of user needs through relative importance adjustments. The proposed methodology of identifying communal user needs for QoE measurement is expected to serve as a reliable evaluation tool that can effectively respond to the rapidly evolving technology market.

1. Introduction

Since the beginning of the Fourth Industrial Revolution, highly advanced intelligent systems have provided users with innovative experiences through new types of interaction. Furthermore, the purpose of technology use has increasingly emphasized not only pragmatic aspects like efficiency and accuracy but also hedonic aspects such as enjoyment and fun (Hassenzahl & Tractinsky, 2006; Zhong et al., 2017). These trends highlight the complex and diverse characteristics of user satisfaction with technology use. Therefore, Quality of Experience (QoE), which measures user satisfaction from various perspectives, is increasingly becoming a more important evaluation tool (Seufert et al., 2021; Shin, 2017). QoE was proposed by the ITU-T in 2007 to overcome the limitations of the conventional Quality of Service (QoS), which did not sufficiently account for users' psychological and contextual conditions (Kalibatienė et al., 2023; Pornpongtechavanich & Daengsi, 2019). The currently most widely accepted definition of QoE is as follows (Le Callet et al., 2013):

> "QoE is the degree of delight or annoyance of the user of an application or service. It results from the fulfillment of his or her expectation with respect to the utility and/or enjoyment of the application or service in the light of the user's personality and current state."

From this definition, it is evident that QoE aims to fulfill user needs and maintain a high level of user satisfaction (Bao et al., 2016; Fizza et al., 2021; Yang et al., 2018). In other words, the timely incorporation of user needs throughout the design process is essential for maintaining positive user experiences and advancing functionality from a user-centered perspective.

As defined above, QoE is a concept that integrates technological aspects and user needs, and this perspective is expected to facilitate the effective application of user-centered design (UCD), which reflects user needs in the design and improvement process (Seufert et al., 2021). However, experiential aspects such as user needs are subjective and

* Corresponding author at: Department of Industrial Engineering, Kumoh National Institute of Technology, 61 Daehak-ro, Gumi, Gyeongbuk, 39177, South Korea.
E-mail address: kimsh@kumoh.ac.kr (S.-H. Kim).

https://doi.org/10.1016/j.actpsy.2025.105622
Received 1 March 2025; Received in revised form 21 August 2025; Accepted 22 September 2025
Available online 30 September 2025

difficult to measure (Chen & El Zarki, 2011; Laghari et al., 2018). Therefore, current QoE evaluations still heavily rely on conventional QoS parameters that are easy to measure, rather than on subjective user needs (Baraković & Skorin-Kapov, 2015; Kalibatienė et al., 2023). This trend is also reflected in the ITU-T recommendations that first proposed the concept of QoE. Recommendation ITU-T G.1031, which provides guidelines for developing opinion models for web browsing QoE, includes certain influencing factors related to users' perceptual dimensions and usage contexts. However, it places greater emphasis on system influencing factors such as servers, content, networks, and clients (ITU-T, 2014). The recommendation concerning VR services likewise emphasizes system influencing factors, such as content, media/codecs, networks, and hardware, more prominently than other influencing factors (ITU-T, 2022). Although QoS remains an important component in assessing QoE, it does not capture subjective aspects such as user satisfaction and experience (Kougioumtzidis et al., 2022). For example, in the context of video streaming, even if throughput is reported as low in terms of QoS, it doesn't always disrupt the viewing experience, so it doesn't necessarily lead to low QoE (Nam et al., 2016; Pimpinella et al., 2022). In the study by De Moor et al. (2010), an experiment using mobile web applications showed a statistically significant correlation between the QoS metric Received Signal Strength Indication (RSSI) and QoE. However, the study also demonstrated that QoE evaluations varied across users despite having the same RSSI, thereby empirically showing that QoS does not necessarily determine QoE (De Moor et al., 2010).

In this context, some studies have posited that perceived dimensions of user needs should be considered for a deeper understanding of QoE. Shahid Anwar et al. (2020) presented perceived quality, presence, and cybersickness as the main perceptual dimensions of QoE in a 360-degree video environment. Suznjevic et al. (2019) proposed immersion, responsiveness, fluidity, and challenge as the main perceptual dimensions in an MMORPG game environment. Likewise, Wu et al. (2009) presented a theoretical model related to the formation of QoE in a distributed interactive multimedia environment, revealing that concentration, enjoyment, presence, usefulness, and ease of use are key factors determining behavioral outcomes.

Like this, several studies have presented the scalability of models through a comprehensive approach that integrates QoE from a QoS-centric research trend to the user perspective. However, most studies have adopted a top-down approach, constructing models around a few predefined variables. This is advantageous for concise and efficient model development, but because it focuses only on the core values of a specific technological domain, it may not fully reflect diverse user needs (Koniuch et al., 2024; Norman & Spencer, 2019). Also, because they rely on deep domain knowledge (Khalili & Auer, 2013), it is difficult to generalize the models across different technological contexts. For example, Xu and Zhang (2019), who presented a non-linear mathematical QoE quantification model applicable to universal traffic types, pointed out that while network operations and management centers should be able to effectively evaluate the QoE of various types of network services, current QoE evaluation cannot be definitively applied to other network services. Chiariotti (2021) noted that when existing QoE metrics designed for still images and videos related to video streaming are applied to new types of technologies like immersive video streaming, they do not accurately align with actual human perception, show weak correlations, and make it difficult to evaluate the unique challenges of new technologies. The inability of QoE models to achieve cross-domain applicability is a significant constraint, leading to the inefficiency of having to develop a separate evaluation framework each time a new technology emerges. This makes it difficult to reflect user needs in the technology market in a timely manner.

In this regard, recent studies have emphasized the importance of user-generated content (UGC), such as online reviews, in identifying and reflecting user needs in a timely manner (Liu & Ma, 2024; Nasrabadi et al., 2024; Rathore et al., 2016). Rathore et al. (2016) emphasized that social media–based UGC offers a cost-effective and timely alternative to traditional methods, enabling comprehensive validation and responsiveness to user needs from the early stages of product development. Similarly, Liu and Ma (2024) demonstrated the importance of user needs-based research and development for systems with long production cycles, such as automobiles, and proposed a framework for predicting user needs based on the limited UGC available during the early stages of development.

If the communal attributes of user needs can be extracted from user-generated content (UGC) across various technological domains and applied to the design of a domain-independent, user needs–based QoE model, this would substantially reduce the cost and time associated with model development and validation. Furthermore, it would facilitate consistent QoE evaluation across heterogeneous technological contexts. Accordingly, this study adopts a bottom-up approach to extract user needs from online reviews across diverse technological domains, to identify common core elements, termed communal user needs, and to examine the feasibility of constructing a universal QoE evaluation model grounded in these elements. Communal user needs can serve as a crucial concept not only in QoE evaluation but also in various disciplines, such as psychology and behavioral sciences, where they contribute to explaining human behavior and satisfaction.

2. Literature review

2.1. Prior studies on identifying user needs

Since the success and purpose of design depend on the extent to which it satisfies people's needs, deriving, clearly understanding, and implementing user needs within the framework of user-centered design is essential throughout the entire design process (Desmet & Fokkinga, 2020; Xu, 2014). In the product design stage, most of the lifecycle cost is determined during the initial concept phase; therefore, an accurate understanding of user needs is critical to capturing appropriate product and service opportunities (Chang et al., 2019; Ulrich & Eppinger, 2015). Moreover, because users' interests and preferences change over time, comprehensive extraction of user needs is required for product optimization, alongside efficiency and accuracy (Liu & Ma, 2025; Pei et al., 2025). User needs are also a crucial element in the evaluation and management of user experience (Lee et al., 2009; Wiklund-Engblom et al., 2009). Based on the importance of the user needs mentioned above, this study conducted a literature review on identifying user needs to lay the theoretical foundation for the purpose of identifying communal user needs that are not limited to the technological domain. Specifically, the literature review focused on whether the research was conducted under a clear conceptual definition of user needs, along with the methodology used to derive user needs and whether various technological characteristics were considered.

The details of the literature selection process are summarized in Table 1. In brief, keywords were established according to the review objectives described above. Using the same set of keywords across

Table 1
Criteria for literature selection.

Category	Description	Documents
Search Keywords	(“Elicit user needs” OR “Identify user needs” OR “extract user needs”) AND (“quality of experience” OR “user experience”) AND (“intended use” OR “maturity”)	–
Search Engines and result	Google scholar, Science Direct, Springer, ACM Library, Taylor & Francis	366
First Screening	Duplicate removal Exclusion of inaccessible documents Limited to peer-reviewed journal articles or conference papers	127
Second Screening	Abstract review to exclude studies not directly related to the derivation of user needs	12

multiple search engines initially yielded 366 documents. After removing duplicates, inaccessible sources, and materials that were not peer-reviewed journal articles or conference papers, 127 documents were retained. Next, by reviewing the abstracts, studies not directly related to the derivation of user needs were excluded. Finally, 12 documents were selected for full-text review and subsequent analysis.

Table 2 summarizes the results of the review of the 12 selected studies. First, from a methodological perspective, traditional methodologies such as interviews, questionnaires, and focus groups are still used in many studies, and recently, there has been a growing trend of utilizing methodologies like topic modeling based on UGC. Some studies have confirmed that user needs are being understood from multiple perspectives, considering various purposes of technology use through universal access methods, such as immersive technology and mobile applications. Although communal needs are expected to serve as an approach to characterizing diverse types of experiences (Wiklund-Engblom et al., 2009), current research remains largely concentrated on specific technologies. In terms of the definition of user needs, many studies either used the concept interchangeably with related notions or refrained from providing an explicit definition, instead distinguishing it from related concepts. In cases where user needs were defined, they were regarded as the outcomes of topic modeling or broadly conceptualized as expressed desires, needs, aspirations, and changing requirements. Since user needs share similar meanings with concepts such as wants, requirements, and demands, a clear definition is necessary. However, most studies have been conducted under a broad and inclusive interpretation.

Based on a literature review, this study conducted research utilizing UGC-based topic modeling, which has been frequently used in recent studies on user needs identification. In this regard, Section 2.2 explains the advantages of data-driven methodologies compared with traditional approaches. Furthermore, this study differs from prior research in some respects. First, by considering technological characteristics such as purpose of technology use and technological maturity, it derives user needs across various technological domains rather than from a single domain, thereby identifying their communal attributes. Section 2.3 elaborates on the necessity of accounting for diverse technological characteristics in the extraction of user needs. Second, this study derives user needs on the basis of a clear definition that distinguishes them from related concepts. Section 2.4 provides a detailed discussion of these definitions and conceptual relationships.

2.2. User needs in technological contexts

To fulfill user needs and deliver innovative experiences through technology, a UCD approach must be applied (Heo et al., 2024; Witteman et al., 2015). ISO 9241-210:2019 defines UCD as a design and development approach that focuses on system usage, applying ergonomics, usability knowledge, and techniques to create useful interactive systems. In addition to the effectiveness and efficiency mentioned in the definition, the goal is to improve factors such as human well-being and user satisfaction to create an effective and engaging user experience (Interaction Design Foundation - IxDF, 2016b; Lindblom & Alenljung, 2020). To create products and services that align with this approach, it is essential to understand user needs, preferences, and behaviors and translate these needs into technology, facilitating user-centered product design (Nguyen et al., 2022; Ten Klooster et al., 2022). In summary, it is imperative to consider a range of technological characteristics and to derive user needs that reflect desires for key technological properties in order to facilitate UCD and the development of a universal QoE model.

Technology is often developed by integrating existing technologies, resulting in a hierarchical structure and increasing the complexity of individual components (Arthur, 2009). In this regard, technology not only shapes human behavior but also affects lifestyles and even social conventions (Norman, 2005). As the complexity and societal impact of technology continue to grow, user needs have become increasingly diverse. Therefore, when deriving user needs from technology, a holistic approach is required, one that considers not only the specific characteristics of individual technological domains but also the overall structure and context of technology. In addition, technology and user needs tend to co-evolve (Walker et al., 2009). Variations in how user needs are expressed between established technologies and their emerging successors are closely linked to this co-evolutionary process. Technological advancement accelerates the pace of this co-evolution. Failing to capture and respond to such shifts in a timely manner may result in unsatisfactory improvements (Ravichandar et al., 2007). Accordingly, it is essential to reflect users' actual needs in technology design by accurately identifying requirement levels based on technological maturity and by actively involving relevant stakeholders throughout the development process (Lima et al., 2023; Spinuzzi, 2005).

Table 2
Summary of reviewed studies on user needs identification.

Studies	Technological domain	Methodology	Considered technological characteristics	Conceptualization of User Needs
Wang et al. (2024)	mHealth apps	Topic modeling	App characteristics	Mixed with related concepts
Sim et al. (2025)	Cross-platform game	Topic modeling	Each platform's unique characteristics	Considered topics as user needs
Brinkel et al. (2017)	Mobile phone-based IVR	Focus group discussion	Domain-specific technological characteristics	Mixed with related concepts
Chang et al. (2019)	Smart PSS	User analysis	Domain-specific technological characteristics	Distinguished related concepts without explicit definition
Huang et al. (2025)	Audio Training apps	Questionnaire, Interviews	Domain-specific technological characteristics	Distinguished related concepts without explicit definition
Apsey et al. (2024)	Mood and menstrual tracking app	Interview, co-design workshop	Domain-specific technological characteristics	Distinguished related concepts without explicit definition
Børøsund et al. (2018)	Stress management mobile app intervention for cancer survivors	Interview, consultation	Domain-specific technological characteristics	Mixed with related concepts
Ali and Hong (2019)	Smartwatch	Opinion processing based on UGC	Domain-specific technological characteristics	Mixed with related concepts
Liu and Ma (2025)	NIO EC6	Topic modeling	Domain-specific technological characteristics	Defined clusters of product features as user needs
Yi et al. (2024)	Immersive technology	Interview, questionnaire, focus group	Purpose of technology use	Mixed with related concepts
Veling and Villing (2024)	Assistive robotics	Authentic citations process	Purpose of technology use	Clearly defined the concept
Dawar et al. (2017)	Mobile application	Questionnaire, Interviews, Affinity analysis	Purpose of technology use	Concept encompassing demands from diverse dimensions

2.3. Approach to identifying user needs

Traditional methodologies for eliciting user needs include methods such as surveys, interviews, and focus groups (Adams & Cox, 2008). These methodologies are commonly used for data collection, but they have several limitations. First, because it takes a long time and is expensive, it is not possible to gather opinions from a wide range of users, and only a limited amount of data can be collected (Timoshenko & Hauser, 2019; Wang, Liu, & Kara, 2022). Secondly, the time required to collect, analyze, and apply needs for evaluation and improvement is long, making it difficult to keep up with the rapidly changing level of technological advancement (Hao et al., 2023). Finally, it is mentioned that existing methodologies collected based on knowledge are highly subjective and rarely lead to the derivation of new product concepts (Bu et al., 2020). In light of the limitations of traditional methodologies, a data-driven approach that extracts user needs from online reviews has recently gained prominence (Wang, Zheng, Li, and Chen, 2022). Because users describe and evaluate products from their perspective in online reviews, this approach is considered more user-oriented and reliable than conventional methods (Bickart & Schindler, 2001; Chen & Xie, 2008; Chevalier & Mayzlin, 2006). Moreover, it offers the advantage of collecting large volumes of user feedback in a short timeframe (Kim et al., 2022; Lee, 2007). As a result, various studies are being conducted to extract user needs from online reviews (Chen et al., 2022; Cong et al., 2023; Han & Moghaddam, 2021).

2.4. Definition and concept of user needs

When expressing their opinions in reviews, users do not clearly distinguish between their needs, goals, and other related aspects, which makes it challenging to extract user needs from such user opinions. Moreover, prior studies have often identified user needs differently even for the same technology. Therefore, it is necessary to derive user needs systematically on the basis of a precise definition.

Terminologies related to user needs and associated concepts are primarily defined in the standards belonging to the Systems and Software Quality Requirements and Evaluation (SQuaRE) series, established by the International Organization for Standardization (ISO) under ISO/IEC 25000. The core concept, user needs, is defined in these standards as "prerequisite identified as necessary for a user, or a set of users, to achieve an intended outcome, implied or stated within a specific context of use" (ISO, 2013, 2016, 2019). This definition underscores the gap between the current state and the desired state, indicating that user needs are ultimately converted into user requirements by accounting for contextual factors such as the usage environment and priority. From this definition, it is clear that user needs are conceptually associated with two related notions: intended outcome and user requirements. First, the intended outcome is defined as a "goal" (ISO, 2013, 2016, 2019. It refers to the goals users seek to achieve when interacting with a product or service, and the prerequisites that users identify as necessary for attaining such goals constitute user needs. Additionally, user requirements are defined as a "set of requirements for use that provide the basis for the design and evaluation of interactive systems to meet identified user needs," encompassing the means, extent, and capabilities by which these needs are to be addressed (ISO, 2013, 2016, 2019).

Taken together, the relationships among *user needs* and related terms as defined in the standards suggest that, in order to achieve improvements aligned with what users genuinely desire, user needs must be satisfied. To do so, it is essential to first identify the relationship between the *intended outcome*, what users aim to achieve through interaction, and the *user needs*, which represent the prerequisites for achieving that outcome. Within this framework, it is further implied that *user requirements*, which pertain to the technical specifications a product or service must possess or fulfill, should be defined based on the identified user needs and their corresponding intended outcomes.

In summary, intended outcome and user needs are core concepts related to user problems or needs, while user requirements are about addressing identified user needs from a system perspective. This summary indicates that the relationship between intended outcomes and user needs is more directly rooted in the user's perspective. This relationship is also directly related to the user needs statement, which identifies problems and needs from the user's perspective between these two concepts and presents them in structured sentences (Nielsen Norman Group, 2019; Interaction Design Foundation - IxDF, 2016a). A user needs statement typically consists of three components: a user (a specific individual), a need (aligned with the standard definition of user needs), and a goal (corresponding to the intended outcome). It emphasizes that user needs should be expressed not as specific solutions stated in nominal form, but as goals or desired end states to be achieved.

3. Method

To explore whether communal user needs, those observed across diverse technological domains, exist independently of domain-specific characteristics, it was deemed necessary to consider a broad range of technological features. Accordingly, online review data were collected from ten distinct technological domains, selected based on two key characteristics: the intended purpose of technology use and the level of technological maturity. To derive both domain-specific and communal insights, the collected review data were divided into two separate datasets. The first dataset consisted of original reviews collected from each domain, which were then analyzed independently. The second dataset was constructed by extracting an equal number of reviews (20,000) from each domain and combining them into a single, merged dataset.

The two datasets were analyzed using a combination of topic modeling and thematic analysis. Topic modeling has proven particularly effective for analyzing large volumes of textual data (Vayansky & Kumar, 2020; Yang et al., 2023). However, to derive meaningful insights from the resulting topic models, human interpretation is often required (Bao & Datta, 2014). As a result, an increasing number of studies have integrated the strengths of both approaches by combining topic modeling with thematic analysis (Blasco-Arcas et al., 2022; Delgosha et al., 2022; Schmiedel et al., 2019).

In this study, BERTopic, which incorporates embedding and clustering as core processes, was employed to identify topics related to user needs from large-scale review data, with the aim of detecting common patterns across diverse technological domains. Subsequently, thematic analysis was conducted to interpret the topic models in depth. Based on this analysis, intended outcomes and user needs were coded, and a set of communal user needs was ultimately defined and labeled. The overall research procedure is illustrated in Fig. 1.

3.1. Data gathering

To account for diverse technological characteristics and types, this study selected ten technological domains based on purpose of technology use and technological maturity, as illustrated in Fig. 2. Online reviews were collected and analyzed for each domain. Intended use can be categorized into pragmatic technologies that support task performance and hedonic technologies designed for enjoyment (Taylor, 2024). Technological maturity distinguishes between relatively immature ones and well-established technologies (Choi, 2024). These characteristics, such as intended use and maturity, can influence user needs at the level of specific technologies.

For example, in terms of intended use, pragmatic technologies mainly reflect user needs related to functionality and performance, while hedonic technologies tend to emphasize emotional aspects. Changes in user needs with respect to technological maturity may be caused by co-evolution between technology and users or by differences in completeness between existing and emerging technologies. Nevertheless, if the communal attributes of user needs can be identified across

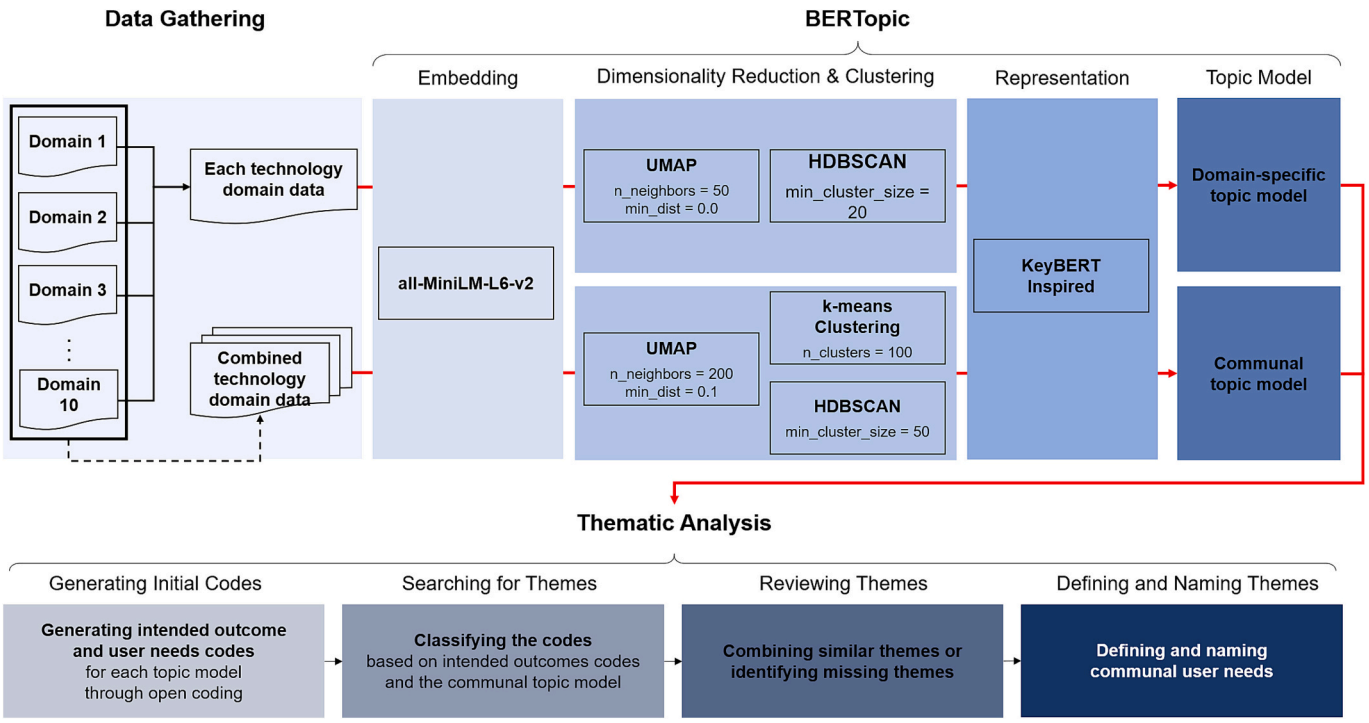


Fig. 1. Overall research process.

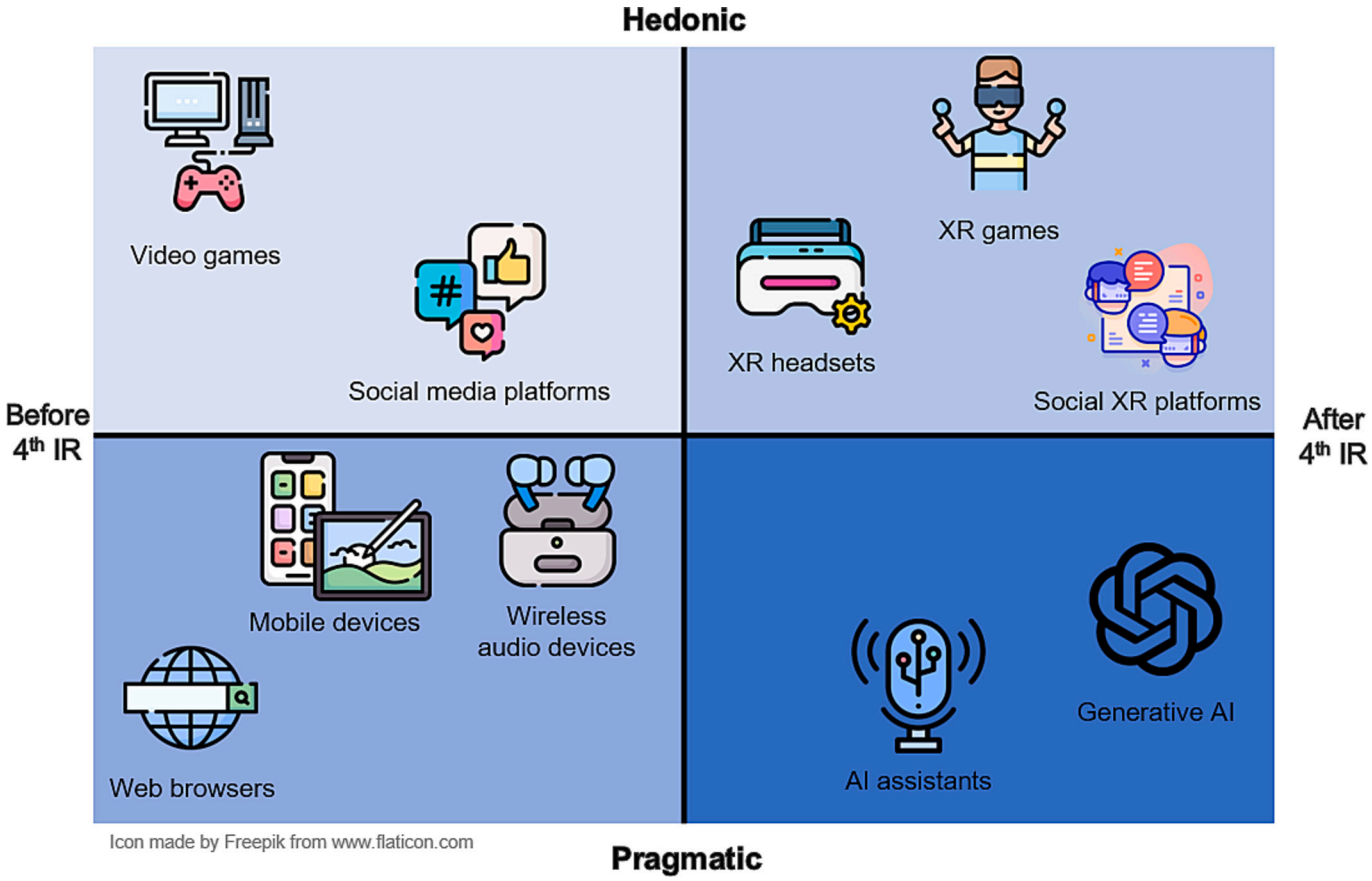


Fig. 2. Technology selection criteria.

heterogeneous technologies, these findings can contribute to meeting user needs more effectively and facilitating technology adoption (Saunders et al., 2011).

In addition, this study aimed to ensure that hardware and software domains are included in each of the four categories defined by technological maturity and purpose of technology use in a balanced manner. For example, a comprehensive range was secured in each category, including technological domains such as XR headsets, XR games, and XR social platforms. Efforts were also made to prevent the overrepresentation of any single specific technology within each domain, thereby capturing a broad spectrum of products and services. This approach was intended to ensure that the findings reflect domain-level user needs rather than the characteristics of individual technologies. For example, in the web browser domain, user reviews were collected from five distinct platforms, such as Chrome, Safari, Firefox, Microsoft Edge, and Opera, to identify user needs representative of the domain as a whole.

Specifically, the pragmatic technologies selected were web browsers, smartphones, and Bluetooth audio devices, which were developed before the Fourth Industrial Revolution and are still in use, and generative AI and AI assistants, which began to be primarily used after the Fourth Industrial Revolution with the advancement of artificial intelligence. All five techniques mentioned above share the common goal of effectively and efficiently helping users achieve their specific objectives. Among these, generative AI and web browsers share the similarity of being designed to help users easily find or receive the information they want, while smartphones and AI assistants share the commonality of enabling users to achieve their desired goals through various applications.

In terms of hedonic technologies, the study included five domains: video games and social media platforms, which predate the Fourth Industrial Revolution, and XR games, XR social platforms, and XR devices, which have emerged in tandem with the development of eXtended reality (XR). The goal of delivering enjoyment unites these technologies. Videogames and XR games are centered around entertainment through gameplay, whereas social media platforms and XR social platforms emphasize enjoyment through social interaction.

Although differing in both maturity and purpose, Bluetooth audio devices (pragmatic) and XR devices (hedonic) share the characteristic of being wearable technologies. A summary of the technological domains and merged dataset is provided in Table 3.

Table 3
Dataset overview.

Technological domain	Object of analysis	Data source	Specific technology	Sampling size
Wireless audio devices	Domain-specific user needs	UCSD Amazon review dataset	Occiam, TOZO	21,674
Mobile devices		Bestbuy	Apple, Samsung (Smartphone, Tablet, Laptop)	64,459
Web browsers		Google playstore	Google chrome, Safari, Firefox, Microsoft Edge, Opera	58,193
AI assistants		Bestbuy, Google playstore	Google assistant, Amazon Alexa	59,938
Generative AI		Google playstore	Chat GPT, Microsoft Copilot, Google Gemini	26,787
Social media platforms		Google playstore	Facebook, Whatsapp, Instagram, X	74,986
Video games		UCSD Amazon review dataset	A collection of 20 games, such as GTA, Fallout 4, and Minecraft, etc.	79,845
XR games		Meta	Beatsaver, Bonelab, Ghosts of tabor, Gorilla tag, Jobsimulator, the walking ead	49,962
XR headsets		Bestbuy	Meta Quest, Oculus series	42,341
XR platforms		Steam	VR Chat	82,466
Merged Dataset	Communal user needs	Randomly extracted 20,000 samples from each of the 10 technological domains		200,000

3.2. BERTopic

Topic modeling is commonly employed to efficiently process large-scale textual data or to extract latent variables from datasets (Vayansky & Kumar, 2020; Yang et al., 2023). Among these methods, Latent Dirichlet Allocation (LDA) has long been widely used to identify user needs (Cong et al., 2023; Xuan et al., 2024). However, there are several limitations to LDA. First, the quality of the generated topics is highly sensitive to preprocessing procedures and hyperparameter adjustments, both of which are complicated (Oh et al., 2023; Sreejith & Sinimole, 2024). Second, its performance tends to decline when dealing with short documents (Vayansky & Kumar, 2020). Third, because it does not account for word order or contextual information, LDA has limited capacity to accurately capture the semantic meaning of texts (Oh et al., 2023; Vayansky & Kumar, 2020; Yang et al., 2023). To address these limitations, BERTopic has recently gained attention for its relatively robust performance. In this study as well, BERTopic was adopted in place of LDA due to its simpler and more systematic process, as well as its strength in handling noisy and unstructured data such as online reviews.

BERTopic proceeds in three main stages: document embedding, document clustering, and topic representations based on class-based TF-IDF (Grootendorst, 2022). In this study, the same BERTopic pipeline was applied to both datasets. However, since one was analyzed from a domain-specific perspective and the other from a communal perspective, the stopword removal strategies and hyperparameter settings were adjusted according to the purpose of each analysis. The algorithms and hyperparameters used at each stage are summarized in Table 4. In the preprocessing stage, standard text processing procedures such as duplicate removal, tokenization, lemmatization, and the removal of unnecessary characters and stopwords were performed. Stopword removal, in particular, was applied differently depending on the nature of the dataset. For the domain-specific datasets, commonly used stopwords (e.g., “a,” “the,” “about”) as well as general terms unrelated to user needs were manually removed to better capture fine-grained, domain-specific user needs. In contrast, for the merged dataset, which aimed to identify more generalized user needs, domain-specific terms closely tied to particular technologies were also manually excluded, in addition to the general stopwords.

The first step in topic generation, document embedding, involves converting text-based documents into high-dimensional vector representations. In this study, we used the all-MiniLM-L6-v2 model, which is widely adopted in BERTopic for its strong ability to capture semantic similarity. Subsequently, to enable effective clustering of the document embeddings, UMAP was applied as a dimensionality reduction technique. UMAP has two key hyperparameters, n_neighbors and min_dist. The n_neighbors parameter balances global structure and local structure preservation, and min_dist determines how densely clustered data points are in the low-dimensional space (McInnes et al., 2018). In general, the larger the values of these parameters, the better the preservation of the entire data structure. Accordingly, in the domain-specific dataset, n_neighbors = 50 and min_dist = 0.0 were set to capture the detailed characteristics unique to the technology, and in the merged dataset, to reveal a wider pattern, n_neighbors = 200 and min_dist = 0.1 were set to obtain a more generalized perspective.

Table 4
Summary of BERTopic modeling configuration and hyperparameters.

Topic Model	Documents Embedding	Documents Clustering						Topic representation
		Dimensionality reduction			Clustering			
		Algorithm	Parameters		Algorithm	Parameters		
Communal user needs (kmeans)	All-MiniLM-L6-v2	UMAP	n_neighbors	200	k-means	n_cluster	100	KeyBERT Inspired model
Communal user needs (HDBSCAN)			min_dist	0.1	HDBACAN	min_cluster size	50	
Domain-specific user needs (HDBSCAN)			n_neighbors	50			20	
			min_dist	0.0				

To cluster the reduced document embeddings into groups of similar vectors, HDBSCAN was applied to both the merged dataset and the domain-specific datasets. HDBSCAN is effective in capturing structures with varying densities and improves clustering accuracy by assigning outliers to a separate noise cluster. However, during this process, a large number of reviews may be classified as outliers, which can make HDBSCAN less suitable in certain cases (de Groot et al., 2022). This issue becomes more pronounced as the dataset size increases. To complement the aforementioned issues and mitigate potential biases associated with a single clustering algorithm, this study additionally applied k-means clustering to the large merged dataset. This was done to examine whether clustering results similar to those produced by HDBSCAN could be obtained from a communal perspective. For the primary clustering algorithm, HDBSCAN, the key hyperparameter is min_cluster_size, which defines the minimum number of points required to form a cluster. A smaller value allows for the formation of a greater variety of clusters. In the domain-specific datasets, min_cluster_size = 20 was set to explore a wide range of user needs expressions. In contrast, in the merged dataset, the value was adjusted to min_cluster_size = 50 to focus on extracting only the most essential clusters. Additionally, since k-means clustering was also applied to the merged dataset, the number of clusters was set to n_clusters = 100. After clustering was completed, class-based TF-IDF (c-TF-IDF) was used to extract topics from each cluster. This method enables more accurate topic representation by calculating the relative importance of terms within a specific cluster compared to the entire corpus. The KeyBERTInspired model, showing excellent performance among the available methods, was adopted to represent the extracted topics.

In the BERTopic process, the number of topics is not predefined, so it often results in multiple overlapping topics. To support more consistent and interpretable analysis, this study manually performed topic merging and refinement. BERTopic calculates a hierarchical structure based on distance matrices derived from c-TF-IDF or topic embeddings, which can be visualized as a dendrogram. In this study, topic merging was conducted based on the semantic similarity reflected in the hierarchical structure and a comprehensive review of the core terms and representative reviews for each topic. This approach improved the clarity and appropriateness of topic representation (Li et al., 2024; Tang et al., 2024).

Finally, the quality of the two communal topic models derived from the merged dataset using HDBSCAN and k-means was objectively evaluated. Although there is no universally established standard for evaluating the quality of topics generated by topic modeling, topic coherence and topic diversity are most commonly considered (Austin et al., 2024; Tan & D'Souza, 2025; Wu et al., 2024; Zhou et al., 2023), and in some cases, topic similarity is additionally taken into account (Papadia et al., 2023; Seo et al., 2025).

Topic coherence, which evaluates the semantic relatedness among words within a topic, is widely used to determine whether a topic model is interpretable and meaningful (Abdelrazek et al., 2023; Cheddak et al., 2024; Seo et al., 2025; Tan & D'Souza, 2025). In this study, we used two representative metrics: the Cv coherence score and the UMass coherence score. The Cv coherence score measures the semantic similarity of words within a topic to indicate how well they form a cohesive theme (Hiniduma et al., 2025; Röder et al., 2015). By contrast, the UMass coherence score evaluates coherence based on the probability of words co-occurring in the corpus (Hiniduma et al., 2025; Mimno et al., 2011). Although no absolute benchmark exists, topic quality is generally interpreted as higher when the Cv coherence score approaches 1 and the UMass coherence score approaches 0.

Topic diversity is an index that evaluates how varied the top words within each topic are, measuring whether topics are distinguishable from one another without overlap (Seo et al., 2025; Tan & D'Souza, 2025). In this study, for each of the 15 topics generated by each topic model, the top 10 keywords were extracted to form a set, after which duplicate words were removed. The proportion of unique words among all extracted words was then calculated to assess topic diversity. Although no absolute benchmark exists, a diversity value closer to 1.0 indicates fewer overlaps and, thus, higher diversity.

Topic similarity measures the proximity of the top words assigned to specific topics and assesses the degree of similarity in word distributions and meanings between topics, thereby determining the likelihood of overlap (Seo et al., 2025). In this study, cosine similarity was computed to evaluate semantic similarity, and Jaccard similarity was employed to assess the overlap of top terms across topics, with the results visualized accordingly.

3.3. Thematic analysis

Based on the topic model derived from each domain-specific dataset and the common topic model extracted from the merged dataset, the subject analysis was performed to identify communal user needs by first extracting the corresponding intended outcomes and user needs and then analyzing the relationship between them. Thematic analysis is an established qualitative methodology for systematically analyzing data, which includes the procedure of generating codes from individual data items and organizing them into meaningful topics through iterative processes (Braun & Clarke, 2006). Code refers to the basic unit of analysis that captures the characteristics of data perceived by the researcher to be relevant and provides analytical meaning to a given phenomenon (Boyatzis, 1998). A theme represents a patterned meaning across the dataset, reflecting conceptually structured and recurrent ideas (Braun & Clarke, 2006; Delgosha et al., 2022). In the context of this study, codes correspond to individual user needs and intended outcomes, while themes are defined as the communal user needs derived from them. The following section describes the step-by-step thematic analysis procedure employed to define and label the communal user needs.

First, the keywords and representative reviews provided by each topic model were carefully examined and thoroughly understood. During the coding phase, prior studies were reviewed and found to commonly adopt an open coding approach (Gamage et al., 2022; Liu et al., 2024; Yang et al., 2023). Accordingly, this study applied the same method to identify intended outcomes and user needs from the topic models generated by BERTopic, based on both the domain-specific datasets and the merged dataset. Three researchers independently engaged in an inductive coding process, referencing topic-specific keywords and representative reviews. From the domain-specific datasets, they extracted codes corresponding to domain-specific intended outcomes and user needs as lower-level categories. From the merged

dataset, generalized intended outcomes and user needs were derived as top-level categories. Throughout the entire process, disagreements among the researchers were continuously compared, discussed, and coordinated to ensure consistency in the coding system. Specifically, all intended outcomes and user needs were expressed as verb-based statements rather than nouns, following the best practice of focusing on user goals and desired end states rather than pre-defined solutions (Nielsen Norman Group, 2019). Subsequently, the domain-specific code was categorized according to semantically similar intended outcomes, and these categories were further abstracted into higher-level common intended outcomes. Through this multi-layered categorization, potential themes were derived, ultimately leading to the definition and naming of common user needs.

The topic labeling process is related to the topics derived from the topic modeling results performed earlier. Topics are composed of words or phrases, and manual labeling, which identifies and labels the subject matter based on the top words, is primarily used (Silva et al., 2021; Yau et al., 2014). This study also manually labeled each topic by comprehensively considering representative reviews, focusing on the top words. Specifically, domain-specific user needs can be identified more concretely and precisely within each technological context, so they were labeled as nouns. On the other hand, more comprehensive and high-level common user needs that exist across multiple technical domains were primarily defined by considering the quality characteristics outlined in ISO/IEC 25010, the international standard for software product quality and evaluation, and they were labeled using adjectives. This method of naming with adjective forms is also consistent with the previous practice of describing user needs using verb-based expressions, and it better captures the experiential responses of users to the emotional and sensory aspects of products and services (Nagamachi, 2002). Additionally, various stakeholders can use it to evaluate product quality and define requirements (ISO, 2023).

Finally, to assess the reliability and validity of the communal user needs identified through Thematic Analysis, Krippendorff's α was calculated. This statistical measure evaluates the degree of agreement among multiple coders and is widely recognized for its applicability across various data types, its support for multiple coders, and its robustness in handling missing values (Krippendorff, 2018). According

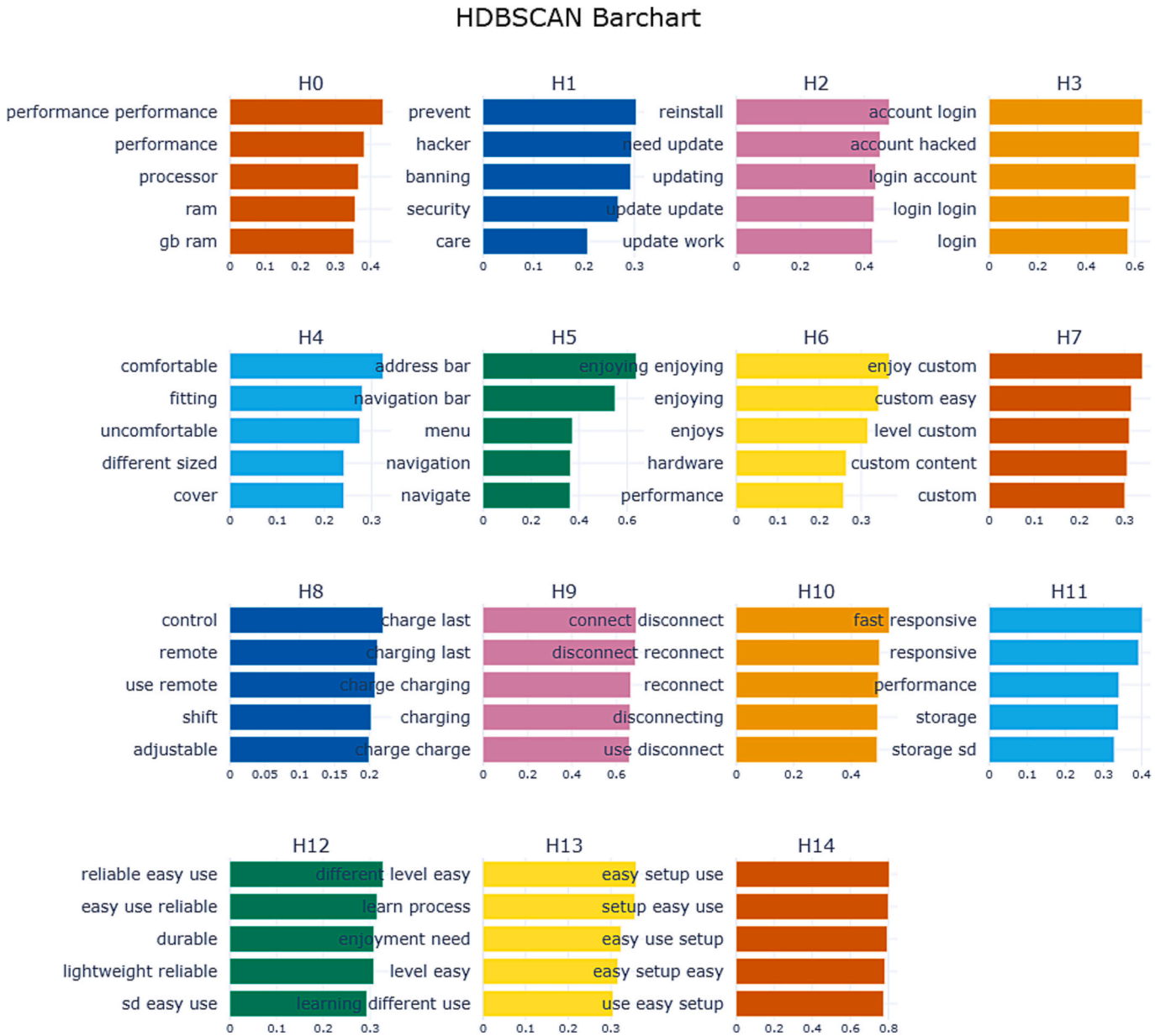


Fig. 3. Keyword distributions of topics derived from HDBSCAN-based BERTopic modeling.

to established guidelines, an α value of 0.800 or higher indicates acceptable reliability; values between 0.667 and 0.800 are considered acceptable for exploratory research; and values below 0.667 suggest insufficient reliability. Based on these thresholds, the present study evaluated the consistency of coding decisions and the overall reliability of the derived communal user needs.

4. Result

4.1. Construction of topic models using BERTopic

This section presents the final topic modeling results obtained by applying BERTopic to the two types of datasets, using hyperparameters tailored to each analytical objective, and performing topic merging to refine the outputs. Subsequently, the evaluation results for the communal topic models, derived from the merged dataset and representing the core findings of this study, are also presented.

The topic modeling results for each technological domain are summarized in Appendix A, which includes the Key Word column and the Count column indicating the number of documents associated with each topic. Each domain-specific model generated an average of 20 to 30 detailed topics. As shown in the sets of associated keywords for each topic, many of them were highly specific to their respective technological domains. Simultaneously, we discovered overlaps between some topics and those from other domains.

The topic modeling results based on the merged dataset are presented in Appendix B. As a result of applying BERTopic, 150 topics were initially generated through HDBSCAN and 100 topics through k-means clustering. Each communal topic model then underwent an independent merging process, ultimately resulting in 15 final topics for both models. The top keywords for each extracted topic were visualized using bar charts, with the HDBSCAN-based model shown in Fig. 3 and the k-means clustering-based model shown in Fig. 4. In addition, during topic modeling on the merged dataset, terms that were closely associated with specific technological domains were manually treated as stopwords. This allowed for the extraction of keywords that predominantly reflect

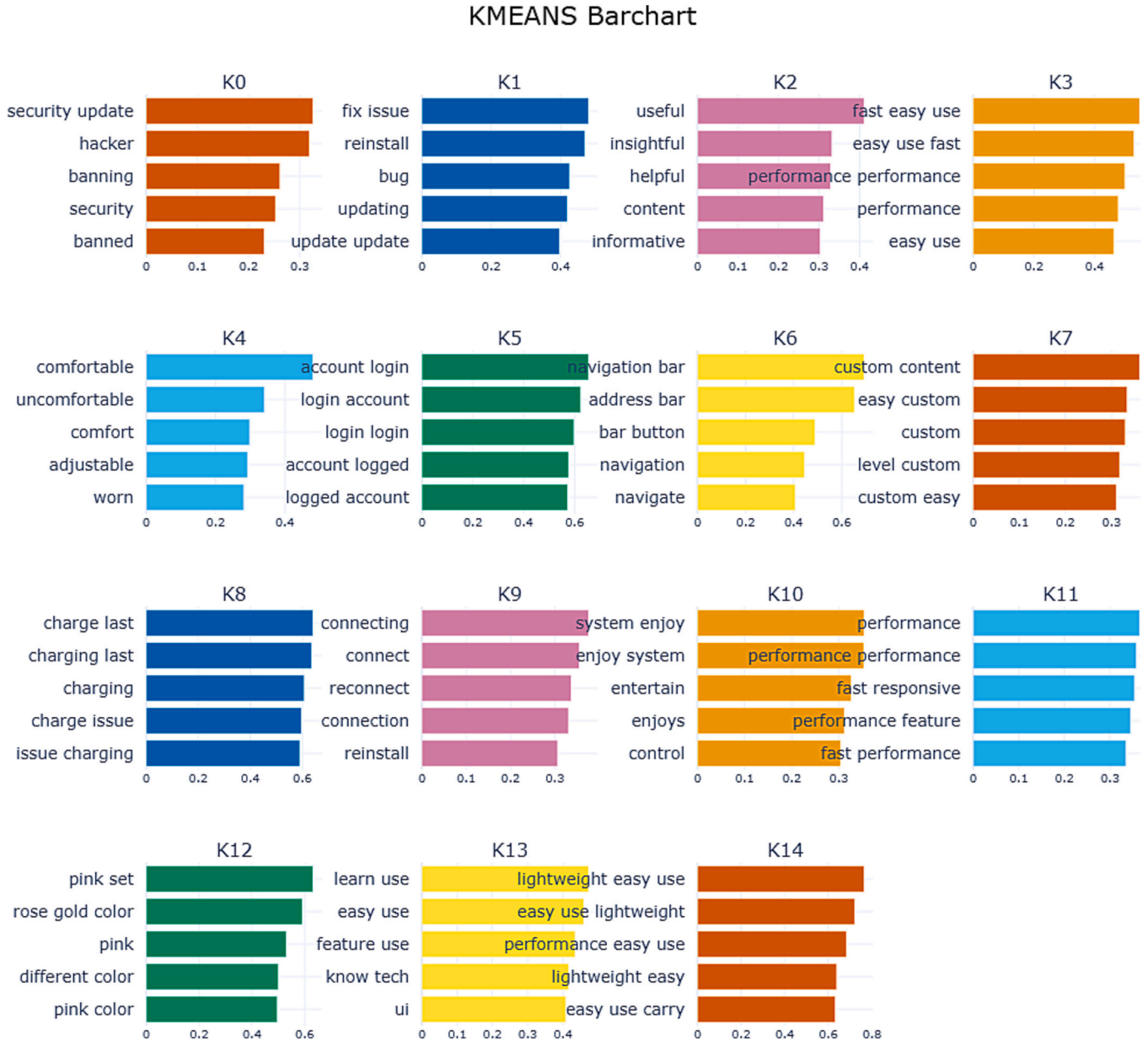


Fig. 4. Keyword distributions of topics derived from k-means clustering-based BERTopic modeling.

more general and universal user needs, rather than domain-specific characteristics.

For each topic model, topic coherence, topic diversity, and topic similarity were examined to evaluate topic quality and identify potential redundancies. First, the results of topic coherence evaluation for the communal topic models are presented in Table 5. In this study, BERTopic was performed by considering unigrams, bigrams, and trigrams, the Cv coherence score was calculated for each case. In both topic models, the lowest Cv coherence score was observed under the trigram condition. However, even in these cases, the scores remained close to the commonly accepted threshold of 0.5. The UMass coherence score was −4.670 for HDBSCAN and − 6.344 for k-means clustering. This means that all of them have achieved an acceptable level of topic coherence.

To check for overlap between topics, we examined related indicators: topic diversity and similarity. First, the topic diversity examination revealed that the topic diversity score for the HDBSCAN-based model was 0.9467, and for the k-means clustering-based model, it was 0.9400, both values being close to 1. This indicates that the topics are composed of diverse words with little overlap.

Next, topic similarity was calculated using Jaccard similarity and cosine similarity. First, the results of the Jaccard similarity are presented in Fig. 5 for the HDBSCAN-based model and in Fig. 6 for the k-means clustering model. While there is no defined evaluation value for assessing Jaccard similarity, a value closer to 0 indicates entirely different sets. For the two topic models, the highest values were 0.1765 for the HDBSCAN model and 0.1111 for the k-means clustering model, confirming that most topics are composed of different sets of keywords. The cosine similarity matrices for the HDBSCAN-based model and the k-means clustering model are presented in Figs. 7 and 8, respectively. Similarly, while there is no universal standard for interpreting cosine similarity scores, many studies consider scores above 0.8 to indicate high similarity. In the k-means clustering model of this study, three topic pairs showed similarity scores exceeding 0.8. However, after reviewing the Jaccard similarity results and the keyword results in Appendix B, we determined that although some keywords were duplicated, the overall topic meanings could be distinguished, so no further merging was performed.

4.2. Identification of communal user needs using thematic analysis

This section presents the results of the thematic analysis conducted on the domain-specific topic models and the communal topic model derived through BERTopic.

As shown in the analysis of domain-specific user needs and intended outcomes in Appendix A, the expressions of user needs exhibited clear differences across technological domains, which appear to stem from variations in the characteristics and types of the respective technologies. For example, web browsers and video games, which serve different purpose of technology use, exhibit distinct user needs. Web browsers prioritize specific practical features that facilitate functional goals, such as ‘Enhanced download feature’ and ‘Print and save as PDF functionality,’ which support downloading and printing capabilities. In contrast, video games, driven by the goal of enjoyment, emphasize performance related specifications, such as ‘High graphic quality,’ ‘High sound quality,’ and ‘High-quality audio and microphone,’ reflecting the need for superior game visuals and audio. Additionally, in terms of emotional

Table 5
Topic coherence evaluation across clustering methods.

	Cv coherence score (unigram)	Cv coherence score (bigram)	Cv coherence score (trigram)	UMass coherence score
HDBSCAN	0.695	0.535	0.476	−4.670
K-means clustering	0.624	0.521	0.471	−6.344

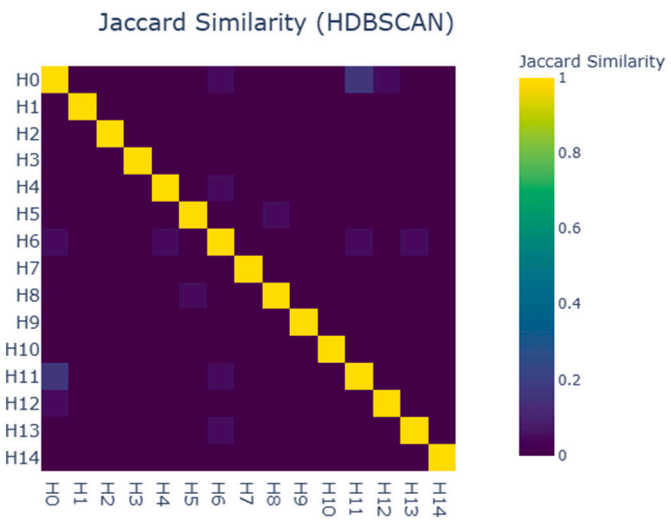


Fig. 5. HDBSCAN-based Jaccard similarity heatmap.

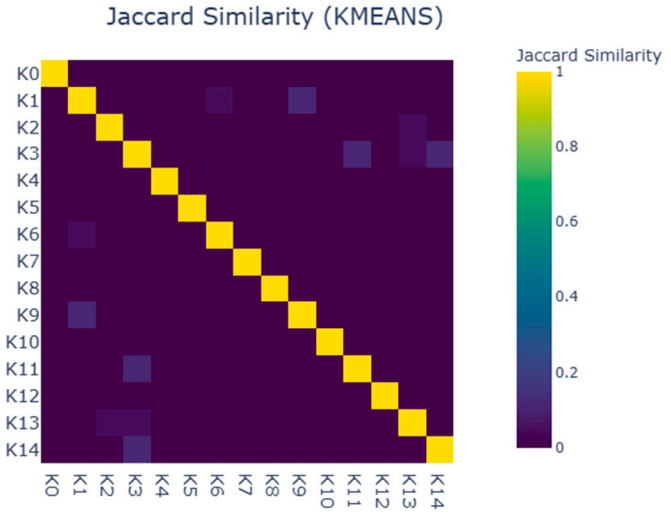


Fig. 6. K-means clustering-based Jaccard similarity heatmap.

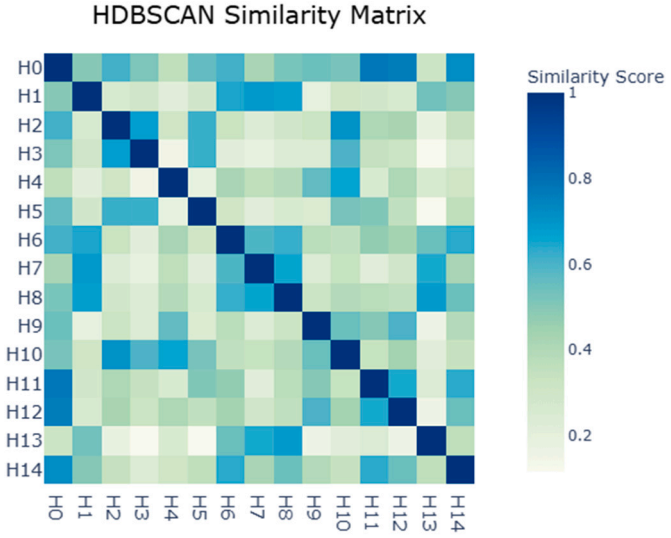


Fig. 7. HDBSCAN-based topic similarity heatmap.

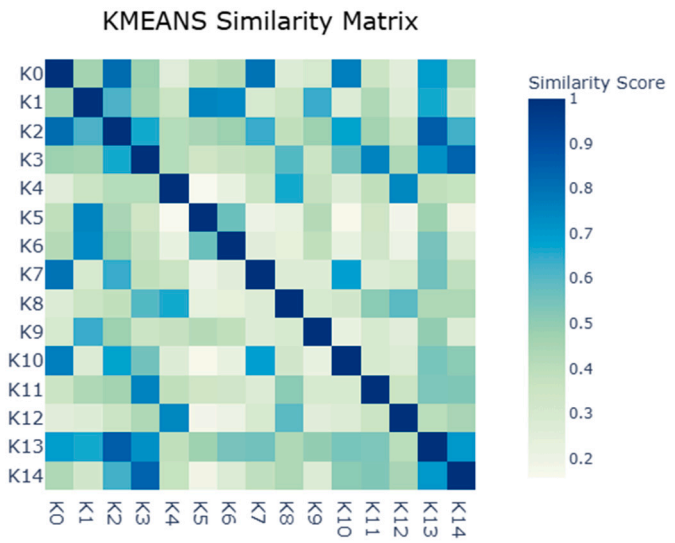


Fig. 8. K-means clustering-based topic similarity heatmap.

satisfaction, web browsers primarily mention features such as the 'Background color selection option,' which allows users to adjust the background color. In contrast, video games exhibit a much more granular expression of emotional satisfaction, encompassing aspects such as game difficulty, elements that stimulate creativity and immersion, appropriate reward systems, and various game modes.

In terms of technology maturity, it is known that as new features are introduced to existing technologies, new user needs emerge accordingly (Querbes & Frenken, 2017; Silberer et al., 2023). In pragmatic technologies, web browsers and generative AI share a similarity in that they are both used for information retrieval. However, they differ in terms of technology maturity. Web browsers primarily express user needs related to avoiding inconvenience during information retrieval, such as 'Advertisement blocking,' as well as needs for key search-related features like tabs and downloads. In contrast, generative AI generates information based on user requests through artificial intelligence. Due to this new functionality, user needs have evolved to include concerns about information accuracy, up-to-date content, and even emotional interaction with the AI. Hedonic technologies are increasingly associated with XR-related technologies as the adoption of XR grows. Specifically, traditional technologies such as video games and social media platforms are now linked to XR games and social XR platforms, respectively. These XR-related technologies exhibit similar user needs under the same intended outcome as their corresponding traditional technologies. At the same time, new XR-specific needs have emerged, such as the requirement for immersion and presence within the XR environment, as well as concerns about XR device comfort and wearability, which were not previously present in non-XR technologies.

However, the results of the communal topic model presented in Appendix B confirm the existence of universal characteristics of user needs that commonly emerge across different technological domains. As mentioned earlier, to ensure the reliability of the results of the combined technological domain dataset and to address algorithmic bias, both k-means clustering and HDBSCAN were applied during the document clustering step of the BERTopic process. The two results obtained from the clustering approaches were analyzed using thematic analysis, where codes for intended outcome and user needs were generated. Based on the intended outcome, topics exhibiting similar trends were grouped, leading to the identification of 11 themes. The final results are summarized in Table 6, along with the communal intended outcome and communal user needs.

The 11 identified themes are as follows. Cluster 1 focuses on enabling users to customize the system according to their preferences and

Table 6
Identified communal user needs and intended outcome.

Cluster No	Communal user needs	Communal intended outcome	Related topics by methodology
Cluster 1	The users need to be able to customize or personalize the system	In order to ensure interactions that reflect individual preferences and situational contexts	K7 H7
Cluster 2	The users need the beautiful appearance and an enjoyable experience	In order to experience visceral and behavioral delight	K10, K12 H6
Cluster 3	The users need the system designed to avoid factors that may lead to physical strain or mental stress	In order to use the system comfortably	K4 H4
Cluster 4	The users need the system to enable a quick, effortless transition to readiness	In order to easily start interaction when needed	K5, K14 H3, H14
Cluster 5	The users need the user-friendly user interface	In order to intuitively understand the information to make efficient decisions without confusion	K6 H5
Cluster 6	The users need to learn how to use the system and its functions easily	In order to efficiently learn how to use the system and save time and effort	K13 H13
Cluster 7	The users need the simple and easy way to control the system	In order to perform smooth functionality and prevent mistake	K3 H8
Cluster 8	The users need quick feedback from system	In order to enhance responsiveness and interact quickly	K11 H11
Cluster 9	The users need the system that is consistent and continuous	In order to get consistent performance over time	K8, K9 H9, H10
Cluster 10	The users need the system that is resilient and stable	In order to withstand external factors and maintain reliable performance	K0, K1 H1, H2, H12
Cluster 11	The users need the specific function and sufficient specifications	In order to achieve specific purpose effectively and accurately	K2 H0

characteristics. Cluster 2 relates to the desire to experience positive emotions while using the system. Cluster 3 is associated with the need to use the system comfortably. Cluster 4 addresses the ease of initiating interaction with the system. Cluster 5 concerns the ability to intuitively understand the information provided by the system. Cluster 6 emphasizes the importance of easily learning how to use the system to save time and effort. Cluster 7 signifies that users should be able to operate the system easily and without errors, and Cluster 8 highlights the need for the system to respond quickly to user interactions. Cluster 9 pertains to the desire to use the system's functions consistently over an extended period. Cluster 10 reflects the need for the system to remain stable and unaffected by external factors. Finally, Cluster 11 indicates that the system must meet specific functional and technical requirements to help users achieve their intended goals.

After completing the coding of intended outcomes and user needs based on each topic model, the codes were synthesized to define and name the communal user needs, which represent the overarching themes. Initially, topics with similar codes were categorized within each technological domain, and these were further integrated across domains to derive higher-level themes. These results were then mapped to the eleven codes presented in Table 6, and, based on their associations with domain-specific user needs, the final set of communal user needs was defined and named. The relevant outcomes are summarized in Table 7.

Table 7
Communal user needs and corresponding domain-specific user needs examples.

Cluster No	Communal user needs	Technology	Domain-specific user needs
Cluster 1	Adaptable	Wireless audio devices	Earbud selection for a proper fit
			Adjustable controls
		Mobile devices	Customizable display setting
		Web browsers	Customization option
			Custom wallpaper
		AI assistants	Customizable wake word
		Generative AI	Universal accessibility
		Social media platforms	Channel customization and management
			Customizable text size
		Video games	Customizable variety in levels
			Customizable creative design and costume creation
			Customization and freedom in gameplay
		XR games	Well-balanced and engaging level design
			Playability for diverse conditions
			Play based on preferences
		XR headsets	Adjustable headstrap for a proper fit
			Accommodation for prescription glasses
		Social XR platforms	Creative modeling and customization
Cluster 2	Enjoyable	Wireless audio devices	Color options
		Mobile devices	Color options
			Elegant design
		Web browsers	Background color selection options
		AI assistants	Color options
		Generative AI	Companionship
		Social media platforms	Easy sharing and engagement with diverse content
			Color options
			Sharing of interesting and useful content
			Engaging and informative information
		Video games	Reasonable difficulty and reward system
			Creative and autonomy game elements
			Challenging and rewarding game contents
			Variety in game modes
			Immersive gameplay
		XR games	High-quality XR games environment
			Immersive gameplay
			Interactive and detailed environments
			Gradual and well-balanced difficulty progression
			Physically engaging gameplay
		XR headsets	Immersive experience
			Immediately attention-grabbing design
		Social XR platforms	Immersive experience
			Engaging content
			Full-body tracking system
Cluster 3	Comfortable	Wireless audio devices	Hands-free convenience
			Wearability
		Mobile devices	Resolution of overheat issues
		Web browsers	Advertisement blocking
		AI assistants	Disable and uninstall stock apps and minimizing intrusions
		Generative AI	Freedom from excessive regulations
			Frustration-free typing
		Social media platforms	The level of less intrusive advertisements
			Ease of profile picture and name change without annoyance
			Scroll issue resolution
			Comfortable interface and option
			Sensitive contents settings
			Caption management option
		Video games	Comfortable grip design
		XR games	Minimal motion sickness
			Sufficient playspace
		XR headsets	Wearability
			Minimal motion sickness
		Social XR platforms	Mental health support and psychological safety
			Safety platform environment
Cluster 4	Easy to access	Wireless audio devices	Portability and compact size
			Ease of initial setup
		Mobile devices	Easy interface setup
			Lightweight design
		Web browsers	Easy login process
		AI assistants	Sound of voice activation
			Easy login process
		Generative AI	Easy login process
		Social media platforms	Easy login process
		Video games	Support for using included activation codes
			Easy installation process
		XR games	Easy installation process
		XR headsets	Ease of initial setup
			Simplification of account requirements
		Social XR platforms	Easy login processes
Cluster 5	Easy to understand	Wireless audio devices	Performance that meets expectations
		Mobile devices	Intuitive interface design
		Web browsers	Intuitive address bar design
		AI assistants	Clear display and sound
		Generative AI	Intuitive interface design
		Social media platforms	Intuitive interface design
		Video games	A well-balanced intuitive and portable handheld system
		XR games	Vibration feedback
		XR headsets	Easy to navigate
		Social XR platforms	User-friendly onboarding
Cluster 6	Easy to learn	Wireless audio devices	Clear instructions
		Mobile devices	Fast learning curve
		Web browsers	Fast learning curve
		AI assistants	Fast learning curve
		Generative AI	Guidance on crafting effective prompts
		Social media platforms	Fast learning curve
		Video games	Intuitive tutorial
		XR games	Fast learning curve
		XR headsets	Fast learning curve
		Social XR platforms	Fast learning curve
Cluster 7	Easy to control	Wireless audio devices	Intuitive earbuds control
			Easy-to-operate earbuds
		Mobile devices	User-friendly touch
		Web browsers	Efficiency and accuracy of link sharing
		AI assistants	Efficient smart home management
			Easy-to-operate AI assistants
			Enhanced voice recognition with appropriate sensitivity
			Optimal display size
			Improved command recognition and efficiency
		Generative AI	Easy-to-operate generative AI

(*continued on next page*)

Table 7 (*continued*)

		Social media platforms	Seamless typing
		Video games	Optimal keypad size
		XR games	Natural interaction
		XR headsets	Easy-to-operate XR headsets
		Social XR platforms	Balance between virtual and real-world interaction
Cluster 8	Responsive	Wireless audio devices	Optimized touch sensitivity
		Mobile devices	Fast loading Fast responsiveness
		Web browsers	Fast loading
		AI assistants	Fast responsiveness
		Generative AI	Improvement in response speed
		Social media platforms	Fast media loading Minimizing of lag Fast comment loading
		Video games	Ensuring responsiveness and minimizing lag
		XR games	Smooth turning
		XR headsets	Faster load time
		Social XR platforms	Minimizing of lag
Cluster 9	Consistent	Wireless audio devices	Long battery life Stable ear tips Connectivity
		Mobile devices	Long battery life
		Web browsers	Efficient battery usage Consistent tab Fast connectivity
		AI assistants	Connectivity Compatibility Efficient battery usage Easy integration and connectivity of smart home device
		Generative AI	Connectivity
		Social media platforms	Efficient battery usage
		Video games	Compatibility in any device Compatibility
		XR games	Wired and wireless connection option Fair refund policies
		XR headsets	Long battery life Fast connectivity Robust casting capabilities
		Social XR platforms	System optimization Compatibility
Cluster 10	Resilient	Wireless audio devices	Durability Sweatproof design Waterproofing
		Mobile devices	Durability against shattering Waterproofing Defect-free device Robustness performance Application stability Durability
		Web browsers	Smooth update Input stability and predictability Secure connection
		AI assistants	Stability of voice recognition Accuracy and reliability of responses
		Generative AI	Updating with the latest information Avoidance bias and unwanted contents Application stability
		Social media platforms	Bug-free condition Enhanced privacy features Opening links in external browsers Improved account security Reliable buttons feature Stability of the space feature
			Contact synchronization Reliable dark mode feature
		Video games	Scratch and light impact protection
		XR games	Stable mod feature with meaningful updates, Bug-free condition Reliable game launching Responsible and player-focused development Privacy and data protection
		XR headsets	Reliable game launching Facial guard designed to reduce sweat
		Social XR platforms	Improved security and safety Stable environment Stability of basic features such as uninstallation Stable and meaningful updates
Cluster 11	Functional	Wireless audio devices	High sound quality Balanced Sound quality
		Mobile devices	High storage and memory performance Latest technology and performance
		Web browsers	Enhanced download feature Automatic data clearing feature Print and save as PDF feature High storage performance
		AI assistants	Improved sound quality Offline voice recognition capability Improved reminders feature Simple execution of routine feature Enhanced reading feature quality Accurate sensing function Enhanced AI comprehension Accurate understanding of accents and clear speech
		Generative AI	Various types of features Accurate and fast answer Conversation history feature Context-aware characteristics Interactive and accurate responses Supporting creative and organizational tasks
		Social media platforms	Accurate photo uploading feature Clear status indication High storage performance
		Video games	High graphic quality High sound quality Clarity and completeness of included content Split-screen feature
		XR games	Optimal memory and performance High-quality audio and microphone High storage performance High graphic quality Save and load feature
		XR headsets	High graphic quality High storage performance
		Social XR platforms	Diverse content

Based on Table 7, the content of each cluster is described as follows. In addition, a case-based analysis was conducted to examine how the eleven identified communal user needs are concretely manifested at the domain-specific level. For this purpose, two technological domains were selected, web browsers and XR-related technologies, which not only overlap with the scope of the ITU-T recommendations but also differ in

terms of technology maturity and the purpose of technology use. Each case focuses on how user needs are expressed within the context of the respective technology.

Cluster 1 was named 'Adaptable' as it reflects the characteristics that allow users to customize the system according to their individual preferences and characteristics. The 'Adaptable' aspect is broadly categorized into personalization and customization. Personalization involves the system delivering individualized content by automatically recommending relevant information, retaining previous conversation contexts, and optimizing interactions based on the user's characteristics, interests, preferences, and communication style (Bol et al., 2018; Oinas-Kukkonen et al., 2022). Customization refers to the process in which users manually adjust the system to fit their preferences, such as modifying game content or customizing an avatar, allowing them to tailor the system to their needs (Kim et al., 2017; Luo et al., 2023; Oinas-Kukkonen et al., 2022). This need is currently recognized as a key aspect of UI/UX design and enhancing user experience (Khamaj & Ali, 2024). In the 'adaptable' aspect, user needs in the case of web browsers were expressed primarily through customization of option settings, as illustrated by the need for "customization options." In contrast, XR-related technologies revealed a broader range of user needs across multiple contexts. Examples include "playability for diverse conditions," which reflects environmental adaptability; "accommodation for prescription glasses," which addresses considerations related to users' physical conditions; and needs related to content customization, such as "creative modeling and customization" and "customization and freedom in gameplay."

Cluster 2 was named 'Enjoyable' as it pertains to the desire for aesthetic satisfaction and enjoyment in technology use. It involves amplifying positive emotions while minimizing negative ones, ultimately enhancing overall user satisfaction (Khalid, 2006). On the hardware side, user needs related to device appearance, color, and design were mentioned. Similarly, in software, users expressed needs related not only to interface color and design but also to the experience of interacting with the system and other users. Additionally, needs related to immersion, a sense of challenge, and enjoyment identified from software usage were identified. This confirms that the 'Enjoyable' aspect is not limited to visual aesthetics but also encompasses broader experiential aspects (Hekkert, 2006). In terms of the 'enjoyable' aspect, user needs in the context of web browsers were primarily reflected in the design of the user interface, such as the availability of "background color selection options." In contrast, XR-related technologies revealed needs associated with immersive and satisfying experiences, including "immersive gameplay" and "immersive experience," as well as satisfaction with content, as illustrated by the need for "engaging content."

Cluster 3 was named 'Comfortable' as it relates to using technology without discomfort. Two main types of user needs were identified: physical comfort, which includes minimizing eye strain, headaches, and muscle pain, and emotional comfort, which involves reducing annoyances such as excessive ads, inappropriate content, or disruptive users, preventing feelings of frustration, irritation, or discomfort. Previous studies have also assessed specific user attitudes toward interfaces based on the degree to which they cause physical discomfort (e.g., strain, pain) and mental strain (e.g., frustration, distraction, cognitive overload) (Hornbæk, 2006). While the expressions of needs may vary, the intended outcome, the desire to use technology comfortably without physical or mental discomfort, remains the same. Therefore, these aspects can be merged into a single factor. In the 'comfortable' aspect, user needs in the context of web browsers were associated with emotional comfort, as evidenced by the desire for "advertisement blocking." In contrast, XR-related technologies primarily revealed needs related to physical comfort, such as the need for "minimal motion sickness."

Cluster 4 was named 'Easy to access' as it relates to the ability to easily initiate interaction whenever the user desires. Several previous studies have identified user needs related to ease of installation and setup, as well as portability, emphasizing the importance of seamless access to technology for effortless interaction (Alnawayseh et al., 2023; Chan et al., 2008; Pan et al., 2024; Park et al., 2014). Specifically, for hardware, user needs were identified regarding lightweight and portable devices, while for software, needs related to easy installation, login, and initial setup were observed. Although the expressions differ depending on whether the technology is hardware or software, they share the common characteristic of enabling easy access to the technology. In relation to the 'easy to access' aspect, both technological domains revealed a communal user need for an "easy login process." Additionally, in the case of XR-related technologies, further needs were identified, including "easy installation process" and "ease of initial setup,"

Cluster 5 was named 'Easy to understand' as it primarily pertains to the need for an interface that enables intuitive comprehension and seamless navigation. It emphasizes the ability to grasp the technology effortlessly before engaging in learning or usage. The 'Easy to understand' aspect has been extensively studied, particularly in the context of web browsers. Research has shown a negative relationship between visual complexity and user satisfaction, highlighting the importance of simple and intuitive navigation (Guo et al., 2021). As a result, studies emphasize the need for clear layouts, minimal menu options, and an appropriate level of hierarchy to ensure easy comprehension for users (Lowndes & Connelly, 2023; Marquis, 2002). However, oversimplification can reduce the perceived usefulness of the system (Lun et al., 2024). Therefore, it is essential to find an appropriate trade-off between simplicity and complexity to maintain both usability and functionality. In relation to the 'easy to understand' aspect, both domains commonly revealed user needs associated with navigational clarity, such as "intuitive address bar design" and "easy to navigate." Additionally, in the context of XR-related technologies, further needs were identified in the area of interactive support for understanding, exemplified by features like "vibration feedback."

Cluster 6 was named 'Easy to learn' as it reflects the need to easily acquire the knowledge and skills necessary for interacting with technology. This study identified user needs related not only to the inherent ease of learning the technology itself but also to the clarity and difficulty level of tutorials and manuals when such resources are provided. Various previous studies have also assessed the 'Easy to learn' aspect using similar definitions, considering factors such as the clarity of the interface, the degree of data organization, and the time and effort required for learning (Kim et al., 2015; Lin & Hsieh, 2016). In the 'easy to learn' aspect, a communal user need was identified across both domains, namely, the desire for a "fast learning curve," reflecting the importance of systems that are easy to learn and require minimal effort to become proficient.

Cluster 7 was named 'Easy to control' as it pertains to interacting with technology with minimal effort and without errors. The primary user needs to emphasize ease of control and error-free operation. Regarding interaction, users prefer that touch and voice recognition are neither overly sensitive nor unresponsive, ensuring smooth operation. Additionally, user needs related to ease of editing were identified in generative AI prompts and video editing features within social media platforms (SNS). Overall, these needs reflect a desire to achieve the intended outcome through simple and effortless controls. In the 'easy to control' aspect, user needs related to operational effectiveness and efficiency were commonly identified across both domains, for example, "efficiency and accuracy of link sharing" and "easy-to-operate XR headsets." Additionally, in XR-related technologies, users expressed needs for more natural interaction, as illustrated by phrases such as "natural interaction" and "balance between virtual and real-world interaction."

Cluster 8 was named 'Responsive' as it represents the need for the system to react swiftly to user inputs, facilitating seamless and efficient interaction between humans and the system. Various technologies highlight the importance of delivering information or feedback at the right moment to ensure efficient interaction (Ahmetoglu et al., 2024; Jain et al., 2023; Sarikaya, 2017). In terms of the 'responsive' aspect,

common needs such as “fast loading” and “faster load time” highlight the importance of smooth interaction enabled by rapid system responses. In XR-related technologies, additional needs were identified, such as “smoothing turning,” which highlights the importance of smooth synchronization between users' physical movements and in-environment virtual actions.

Cluster 9 was named ‘Consistent’ as it relates to the ability to interact with technology consistently over extended periods. With the increasing use of mobile networks and computing, most technologies emphasize the need for uninterrupted connectivity with the internet, bluetooth, and other devices. Additionally, on the hardware side, long battery life is highlighted as an essential factor for maintaining consistent usage (Alnawayseh et al., 2023; Conti et al., 2017; Silva et al., 2024). In terms of the ‘consistent’ aspect, users of web browsers expressed needs such as “fast connectivity” and “consistent tab”, indicating a desire for stable connections and sustained tab usage. In XR-related technologies, in addition to the emphasis on “fast connectivity”, there were also user needs related to system compatibility, as reflected in mentions of “compatibility”.

Cluster 10 was named ‘Resilient’ as it represents the need to prevent external risks and quickly recover to the original state without causing additional issues. In terms of product sustainability, the importance of reliability-based design and improvement is increasingly emphasized (Feng et al., 2018; He et al., 2020). From the “Resilient” aspect, software such as chatbots emphasizes the importance of security and trust (Al-Shafei, 2024). In the case of VR devices, durability was the most frequently mentioned concern (Bhowmik, 2024). Similar to the aforementioned previous studies, software-related technologies primarily exhibited user needs related to security, while hardware-related technologies mainly emphasized durability. In the ‘resilient’ aspect, user needs commonly revolved around system updates, as reflected in expressions such as “smooth update”, “stable mod feature with meaningful updates”, and “stable and meaningful updates”. In addition, within XR-related technologies, needs were also observed regarding hardware durability and security, such as “facial guard designed to reduce sweat”, which aims to prevent device damage due to perspiration, and “privacy and data protection”, reflecting concerns about safeguarding personal information.

Finally, Cluster 11 was named ‘Functional’ as it represents the user's need to perform tasks effectively and accurately using technology. Since user experience stems from both the core functionality of technology and user perception (Szabó & Hercegfi, 2023), the ‘Functional’ aspect has been regarded as an essential factor in various previous studies. In particular, functionality diversity, performance, and speed are frequently mentioned (Quiñones et al., 2024; Renaud et al., 2019). Similarly, this study also identifies user needs related to performance, encompassing both universal attributes like graphics and sound quality and domain-specific functionalities. In terms of the ‘Functional’ aspect, both domains commonly revealed user needs related to storage capacity, such as “high storage performance.” In the case of web browsers, additional needs were identified, including features related to downloading and printing, such as “enhanced download feature” and “print and save as PDF feature.” In XR-related technologies, users expressed needs associated with content utilization, including “save and load feature,” “high graphic quality,” and “diverse content,” reflecting a desire for both quality and variety.

To verify the reliability and validity of the final set of eleven intended outcomes and user needs, Krippendorff's α was calculated. A random sample of 1000 reviews from the merged dataset was independently coded by three researchers based on the eleven communal user needs. The resulting α value of 0.805 exceeds the commonly accepted threshold of 0.8, indicating a high level of inter-rater reliability.

4.3. Toward a universal model based on communal user needs

This section analyzes the characteristics of the eleven identified communal user needs and examines the potential for constructing a universal model focused on user-centered design. Specifically, the manifestation patterns of communal user needs across technological domains were analyzed based on the number of reviews per topic presented in the “Count” column of Appendix A and the classification results summarized in Table 7. The results of this analysis are presented in Fig. 9. Overall, while the number of times varies due to differences in the core values that users prioritize during their interactions with each technological domain, all 11 communal user needs are consistently present across all technologies.

Next, the relationship between user needs and human-computer interaction (HCI) was analyzed. User needs are essential not only in the context of HCI but also from the perspective of user-centered design, as they must be actively reflected in the design of technology and continuously evaluated for their fulfillment. As such, their significance has been increasingly emphasized (Chao, 2009; Jain et al., 2023). Therefore, in relation to the 11 identified communal user needs, it is essential to explore various environments to enhance the feasibility and ease of interaction. Moreover, understanding predictable user responses to interaction design is crucial for optimizing the overall user experience (Chao, 2009). Accordingly, this study aims to explain the relevant communal user needs in connection with the HCI process illustrated in Fig. 10 and analyze user responses by examining the number of times these needs appeared. First, the ‘Adaptable’ aspect relates to both the ability to control the system as desired and receiving recommendations through the system, encompassing various aspects of display customization throughout the interaction process. Additionally, the ‘Enjoyable’ aspect pertains to experiencing pleasure while using technology, and the ‘Comfortable’ aspect refers to feeling at ease, free from discomfort or inconvenience. Both of these aspects fall under the emotional dimensions of user needs. The ‘Easy to access’ aspect refers to the need to quickly and easily reach a state where interaction with the technology is possible, even before the HCI process begins. The ‘Easy to understand’ aspect and the ‘Easy to learn’ aspect relate to the process of receiving feedback from the computer and processing information, allowing users to intuitively grasp the system and quickly learn how to use it. The ‘Easy to control’ aspect refers to the ability to seamlessly operate the system through the interface after processing information, minimizing errors, and ensuring ease of use. The ‘Consistent’ aspect, the ‘Resilient’ aspect, and the ‘Functional’ aspect are related to the process in which the computer translates user actions into feedback. The ‘Functional’ aspect pertains to the overall process of utilizing a technology's features and performance to achieve a goal. Meanwhile, the ‘Consistent’ aspect refers to the need for this process to function smoothly over extended periods, and the ‘Resilient’ aspect reflects the need for the system to operate reliably and stably, even in the presence of external disruptions. Finally, the ‘Responsive’ aspect refers to the need for rapid feedback following user input.

5. Discussion

This study collected and analyzed user review data from various technological domains to derive 11 communal user needs. Based on these results, the possibility of building a universal QoE model based on user needs was explored.

In this section, the theoretical implications of the research results are compared with the existing psychology theory and existing QoE evaluation model, and practical implications for user-centered design are presented. Finally, the limitations of this study and future research directions are proposed.

5.1. Theoretical implications

This study deepens the theoretical understanding of user needs and QoE by identifying communal user needs across diverse technological domains, based on the relationship between intended outcomes and user

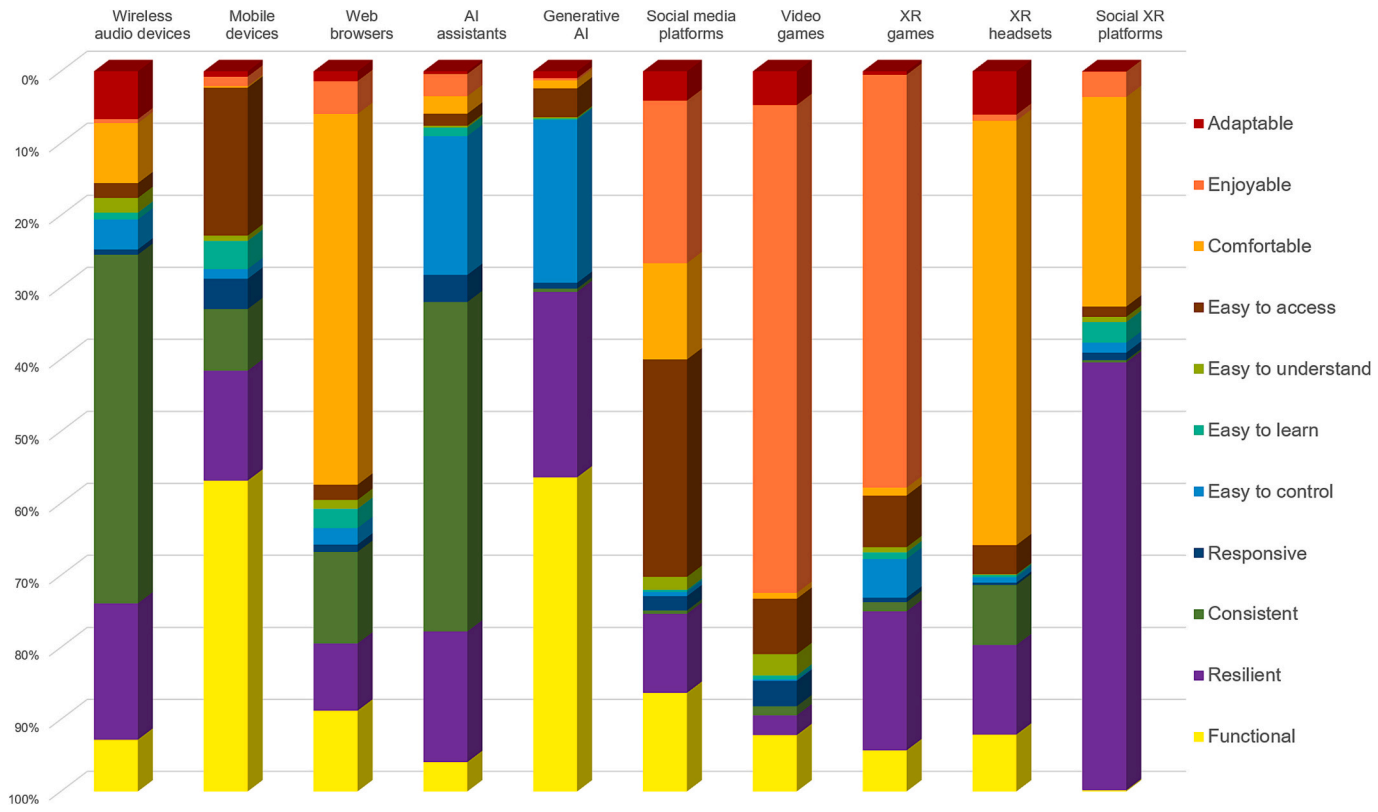


Fig. 9. Number of times communal user needs were mentioned across different technologies.

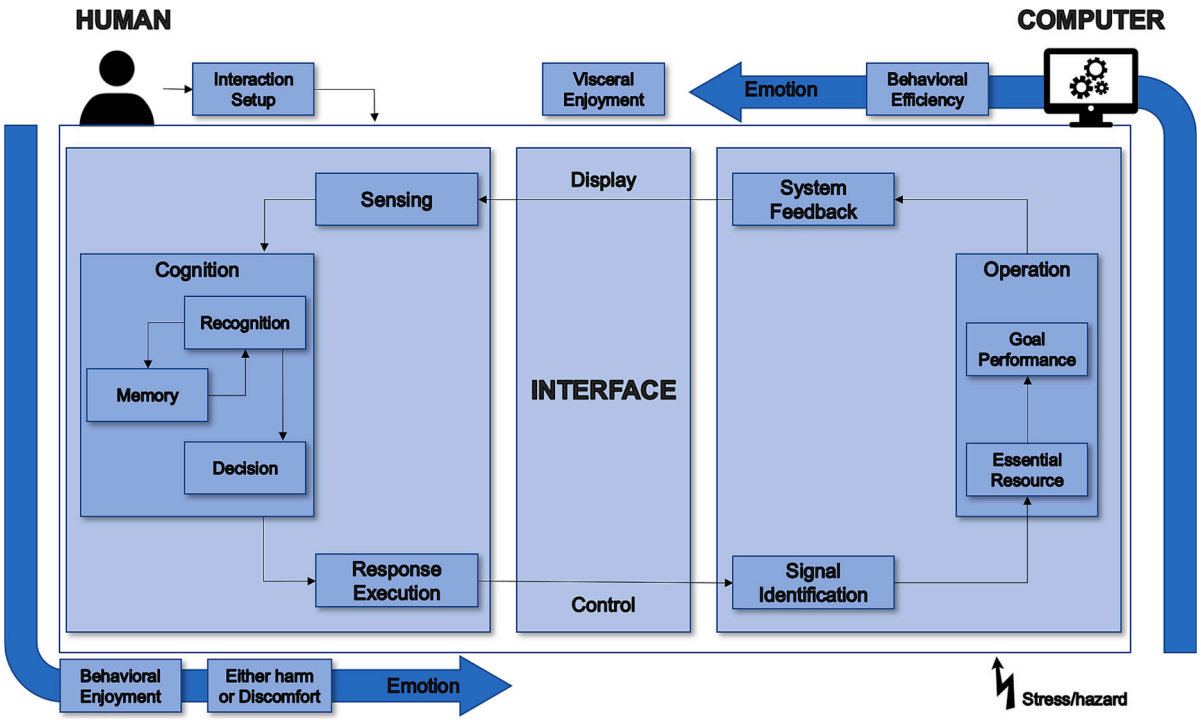


Fig. 10. Human-computer interaction (HCI) processes.

needs, and confirming the feasibility of developing a universal QoE model. Although the current definitions of QoE highlight the importance of user needs, their inherent difficulty in measurement has led to a predominant reliance on Quality of Service (QoS) indicators, which are relatively easier to quantify. Furthermore, most existing studies adopt a top-down approach that incorporates only a limited set of domain-specific factors, resulting in technology-specific models that lack generalizability across different contexts.

In this context, the first theoretical implication of this study is that the 11 communal user needs identified can serve as reliable evaluation

factors that can explain user behavior and satisfaction through their connection with motivation theory. User needs are not simply functional requirements but are considered psychological constructs that influence user experience (Hassenzahl & Tractinsky, 2006). From this perspective, various motivation theories provide an important theoretical foundation for understanding and evaluating user needs. Specifically, Maslow's Hierarchy of Needs Theory (Maslow, 1943) and Herzberg's Two-Factor Theory (Herzberg, 1959) have been widely used as frameworks for structuring and prioritizing user needs in previous research in the UX and HCI fields (Geng & Guo, 2022; Partala & Kallinen, 2012; Peters et al., 2018). The results of this study also show structural and conceptual similarities to these two motivational theories.

Specifically, Aarron Walter proposed a hierarchy of user needs based on Maslow's hierarchy of needs, which consists of four levels: functional, reliable, usable, and pleasurable (Walter, 2011). The 11 common user needs derived in this study show a pattern similar to Walter's four-tier structure. The 'Adaptable' aspect, the 'Enjoyable' aspect, and the 'Comfortable' aspect correspond to the pleasurable level, which emphasizes the user's positive and enjoyable experience. The 'Easy to access' aspect, the 'Easy to understand' aspect, the 'Easy to learn' aspect, the 'Easy to control' aspect, and the 'Responsive' aspect are connected to the usable level, which ensures the system's ease of use and intuitiveness. The 'Consistent' aspect and the 'Resilient' aspect are related to the reliable layer, which requires system stability and reliability. Finally, the 'Functional' aspect directly aligns with the functional layer, ensuring users can complete tasks without issues. These results suggest that the 11 communal user needs identified can be further abstracted into four layers or categorized according to other criteria.

The Two-Factor Theory distinguishes between motivators, which lead to satisfaction, and hygiene factors, which cause dissatisfaction, positing that these two sets of factors operate independently. Concerning this, a number of studies have both theoretically and empirically explored the connection between the two-factor theory and user experience (Calvillo-Gámez et al., 2015; Cockton, 2006; Hassenzahl et al., 2010; Raita & Oulasvirta, 2014; Tuch & Hornbæk, 2015). For example, Hassenzahl et al. (2010) discussed the relationship between pragmatic and hedonic quality from the perspective of needs fulfillment, drawing on the two-factor theory (Hassenzahl et al., 2010). This dichotomous framework has since been adopted in various UX studies. Furthermore, Tuch and Hornbæk (2015) empirically validated the relevance and applicability of the motivator–hygiene factor distinction within the UX context (Tuch & Hornbæk, 2015). The findings of this study suggest theoretical relevance to the two-factor theory. User needs can be categorized into two groups: (1) three emotion-oriented needs, such as the "adaptable" aspect, the "enjoyable" aspect, and the "comfortable" aspect; and (2) eight system-oriented needs related to the usable layer, the reliable layer, and the functional layer. In light of the above, the findings of this study indicate the potential for constructing a user needs evaluation framework grounded in motivational theory. Furthermore, incorporating the Kano model, a product planning theory related to the two-factor theory, into the evaluation process may enable a more nuanced assessment of user needs (Kano, 1984). The Kano model is a theoretical framework that explains the relationship between the fulfillment of a technology's performance and the consumer's subjective satisfaction or dissatisfaction. It categorizes the correlation between product or service performance and user satisfaction into five distinct quality attributes. This model serves as an effective tool for prioritizing improvements in products and services, and it also emphasizes that these quality attributes may evolve. Since the communal user needs identified in this study were defined by linking them with domain-specific user needs across diverse technological domains, they enable the evaluation of technological performance in conjunction with relevant user needs. This structure allows for a more precise understanding of the relationship between technological functionality and user expectations, thereby supporting more accurate and actionable evaluation outcomes.

The second theoretical implication is that this study demonstrated the possibility of building a universal QoE model based on common user needs. Existing QoE models tend to focus on a single domain, often related to multimedia or network aspects (Skorin-Kapov & Varela, 2012; Koniuch et al., 2024; Akhtar et al., 2019; Wu et al., 2009; Reichl et al., 2015). These trends show that existing QoE models have limited scalability and applicability. As shown in Fig. 9, the relative frequency of common user needs varies across technology domains, but the fact that they are mentioned in all domains suggests that they can function as universal elements of QoE configuration applicable to various domains, moving away from a tendency to focus on specific domains.

Furthermore, the factors considered in existing domain-specific QoE models are conceptually linked to the communal user needs identified in this study, and their relative importance also shows similar patterns. For example, Shahid Anwar et al. (2020) defined the QoE perceptual dimensions of a 360-degree video environment, which correspond to 'high graphic quality', 'immersive experience', and 'minimal motion sickness' in XR headsets. At this time, the 'Comfortable' aspect was often associated with motion sickness, while the 'Consistent' aspect and the 'functional' aspect were related to the performance of the video environment. Suznjevic et al. (2019) identified immersion, responsiveness, fluidity, and challenge as dimensions of QoE in the MMORPG game environment, which correspond to the 'creative and autonomous game elements', 'ensuring responsiveness and minimizing latency', and 'challenging and rewarding gameplay' of this study, respectively. From the perspective of communal user needs, these previous studies emphasized enjoyment and responsiveness, and these two items also showed high mention frequency in this study. Furthermore, it indicates that while the expressions differ depending on the technical domain, they can converge into common factors at a higher level. For example, elements such as presence, responsiveness, and enjoyment conceptually align with the 'Comfortable' aspect, the 'Responsive' aspect, and the 'Enjoyable' aspect in this study. Therefore, while a communal user needs-based model may have increased structural complexity compared to traditional bottom-up QoE models, it can encompass a wider range of user needs that are not limited to a specific domain. This suggests that by building a universal model, we can efficiently evaluate and manage models without needing to establish a new one each time a new technology is released.

This suggests that the core components of existing QoE models can be meaningfully linked to the underlying user needs revealed in this research. Furthermore, this is consistent with previous studies suggesting that the progression of user needs is not strictly hierarchical from lower to higher levels but can shift depending on various technological characteristics (Maslow, 1954; Thielke et al., 2012). This suggests that a concrete, universal QoE model can be developed by linking communal user needs with technology specifications and adjusting their relative importance based on the varying number of times the user needs are mentioned.

5.2. Practical implications

The findings of this study provide several practical implications not only for technology developers involved in QoE evaluation and user-centered design processes, but also for academic researchers studying user experience and technology acceptance.

The first practical implication is that, during the design and evaluation of products and services, it is possible to move beyond a sole focus on functional elements and instead ensure the timely assessment and incorporation of core user needs. Although the importance of user needs has been continuously emphasized in fields such as user experience and QoE, evaluation and development processes still predominantly focus on functional aspects. For example, in app's development requirements reports authored by developers, detailed descriptions are typically provided regarding how an application achieves its functional objectives, whereas features intended to satisfy users' psychological needs and

enhance the overall user experience are rarely mentioned (Geng & Guo, 2022). In addition, as previously mentioned, the ITU-T recommendations that define QoE also show a strong emphasis on functional aspects. For example, in the case of VR services, the recommended QoE factors highlight several function-oriented elements: spatial audio and spatial depth related to content; storage and transport, bitrate, resolution, and frame rate in terms of media and codecs; delay and bandwidth for network performance; and comfort level of the HMD as a hardware-related factor. Similarly, in the case of web browsing, the ITU-T recommendations classify QoE factors in detail based on functional aspects. These include response time and capacity related to the server; the number, type, and size of content; transaction time and capacity associated with the network; and client-side factors such as resource loading procedures and processing power. However, these classifications do not indicate which functions are directly related to specific user needs. However, based on the perspective that user experiences and the needs that emerge from them may differ in expression but are fundamentally similar across technological domains (Hassenzahl, 2008), this study identified eleven communal user needs. These findings not only provide a practical foundation for incorporating user needs into the design and evaluation of products and services but also suggest that linking these needs to system functionalities can be achieved more easily, as the communal user needs were defined through their association with domain-specific user needs.

The second practical implication is that the approach proposed in this study can offer meaningful support for the research and improvement of emerging technologies, where measuring user needs is often challenging or limited by a lack of available information. In the case of newly released or relatively immature technologies, the small number of actual users results in limited feedback, making it difficult to quantify or structure user needs effectively. For example, in the case of generative AI, which is classified as a relatively new technology, research on users is relatively low, so the focus is still on QoS, which is easier to measure and understand in relation to QoE improvement (Du et al., 2024; Huang et al., 2023; Liu et al., 2023). The 11 communal user needs identified in this study were derived through the analysis of technologies that include emerging domains such as AI-based systems and XR, which have rapidly expanded following the Fourth Industrial Revolution. As such, the proposed framework can function as a user-centered approach applicable even in data-scarce areas of emerging technologies. Therefore, it holds significant practical utility and scalability, as it can be applied to various real-world activities such as research on technology acceptance, early prediction of user needs, and the development of product and service strategies.

5.3. Limitations and further research

Despite the significance of this study, several limitations remain. First, the process of deriving user needs was based on a limited selection of technologies. Therefore, to further verify the generalizability of communal user needs, future research will involve expanding the dataset to include technologies not covered in this study and applying the same methodology to compare the results. Secondly, this study did not establish the relationship between communal user needs and QoE. To determine whether the identified communal user needs influence QoE and serve as valid QoE evaluation factors, future research should develop survey instruments and conduct statistical analyses to verify this relationship. Third, it is essential to clarify the relationship between communal user needs and technology specifications. Since technology specifications are the key elements that ultimately need to be adjusted for evaluation and improvement, future research should focus on defining this relationship more precisely. Furthermore, future research will focus on quantifying the relative importance of communal user needs and technology specifications, considering their dynamic nature. While these user needs remain constant, their relative importance may fluctuate. By systematically conducting the aforementioned follow-up studies, the ultimate goal is to develop a universal QoE model that enables evaluation and improvement in alignment with users' genuine expectations.

6. Conclusion

By considering various technological characteristics and types, this study identified communal user needs and examined the feasibility of constructing a universal QoE model. The findings are as follows: While expressions and content may differ at the individual technology level, communal aspects exist at a more abstract level, leading to the identification of 11 communal user needs. These needs were observed across all technologies, with differences only in how many times they appeared for each technological domain. These findings suggest that the limitations of traditional QoE evaluation and improvement methods, which apply domain-specific assessment criteria, can be overcome. Instead, a user needs-based universal QoE evaluation and improvement approach can be established. Furthermore, it appears feasible to construct a universal QoE model by linking fixed communal user needs with domain-specific specifications and adjusting their relative importance. Therefore, future research will focus on establishing a concrete, universal QoE model by investigating the relationship between communal user needs and domain-specific aspects, deriving their relative importance, and refining the adjustment process.

CRediT authorship contribution statement

Beom-Su Kim: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization. **In-Seok Heo:** Writing – review & editing, Formal analysis, Data curation, Conceptualization. **Krishna Sahithi Karur:** Writing – review & editing, Formal analysis, Data curation, Conceptualization. **Sang-Ho Kim:** Writing – review & editing, Supervision, Resources, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government (MSIT*) (No. 2021R1A2C2095410). * MSIT: Ministry of Science and ICT.

Appendix A. The result of domain-specific topic model

Table A.1
Domain-specific topic model of wireless audio devices.

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Long battery life	The users need wireless audio devices with a long battery life (in order to get consistent performance over time)	battery cancellation, cancellation battery, charge case, charging case, cancellation, charging, case charge, cancellation work, charge, battery last	5837
Durability	The users need wireless audio devices with durable and reliable performance (in order to withstand external factors and maintain reliable performance)	sounding reasonably, durable, reliable, advertised, performance, paid low, reasonably, ordering, comfortable lose, ticket	1407
Earbud selection for a proper fit	The users need wireless audio devices with a customizable earbud option (in order to adjust it to suit their physical conditions)	fit small fit, fit fit fit, small fit, fit small, smallest size fit, use fit small, fit fit, fit comfortable fit, fit fine, small fit small	828
Hands-free convenience	The users need wireless audio devices with hands-free convenience (in order to use comfortably in various situation and ensure seamless work)	comfortable use, touch use, distracting, useful, distraction, hears, interruption, fine use, distortion, jogging	807
Sweatproof design	The users need wireless audio devices with a sweatproof design (in order to prevent malfunctions and slippage caused by sweat)	sweatproof, sweat resistant, sweat proof, use sweat, stay sweat, sweat sweat, think sweat, sweat, sweating, lifetime comfortable	799
High sound quality	The users need wireless audio devices with high-sound quality (in order to achieve uninterrupted performance and optimal listening experiences)	sounding owned, sounding, budget friendly, using comfortable, compare, budget, slight issue, complaint touch, reasonably, lanyard	569
Intuitive earbuds control	The users need wireless audio devices with intuitive control for noise cancellation and pairing (in order to make device operation easier)	easy use cancellation, fit portable, cancellation, use cancellation, battery last, fit bill, battery easy use, comfortable, size battery, wired	448
Balanced sound quality	The users need wireless audio devices that have a well-balanced range of bass and treble frequencies (in order to listen to various types of songs)	sounding, decibel, tinny treble, sounded, treble tinny, tone, clear frequency, surround, comfortable, treble	375
Wearability	The users need wireless audio devices with good wearability (in order to enhance their overall comfort during usage)	comfortable easy use, easy use comfortable, comfortable comfortable use, comfortable use, easy find comfortable, comfortable comfortable easy, use comfortable easy, decently comfortable, comfortable easy, use comfortable	287
Waterproofing	The users need wireless audio devices with sufficient waterproofing (in order to prevent failure from water penetration)	waterproofing, touch sensitive use, submerged, showering, touch sensitive, resistant dropped, touch, sweat, touch sensor, stop touch	282
Performance that meets expectations	The users need wireless audio devices that perform as expected (in order to interact intuitively)	expected advertised work, advertised work, advertised work described, advertised work advertised, work advertised work, expected work advertised, work advertised, working flawlessly, worked working, work intended	268
Stable ear tips	The users need wireless audio devices that fit securely and stay in place (in order to avoid the hassle of having the user adjust it to fit their ears)	TIP stay, stay size, stay tip, losing fit, tip, stay small, keep stayed, stay bad, matter tip, size help	267
Connectivity	The users need wireless audio devices with an easy and continuous connection (in order to use it for a long time without interrupting)	easy connect easy, easy easy connect, connect easy use, connect easy, easy easy use, easy use easy, easy use, easy use use, work easy use, easy connect	258
Portability and compact size	The users need wireless audio devices with portable and compact size (in order to conveniently carry and store the earbuds)	case smaller, easier case, case smooth, smaller case, comparing, battery touch, comparison, case case, size case, secure fit	143
Ease of initial setup	The users need wireless audio devices that are easy to set up and use (in order to start interaction immediately with minimal effort)	easy setup use, setup easy use, easy setup easy, easy use setup, easy setup, setup use easy, setup easy, use easy setup, set easy setup, easy setup comfortable	128
Clear instructions	The users need clear instructions (in order to efficiently learn how to use the system and save time and effort)	sounding, distortion, surround, sounding dislike, need improved, improved, instruction hard, plain bad, instruction hard understand, smoothly	125
Easy-to-operate earbuds	The users need wireless audio devices that are easy to operate (in order to enhance convenience)	easy easy use, easy use use, easy use easy, easy use, use easy use, satisfied easy use, described easy use, easy use convenient, work easy use, using easy use	98
Optimized touch sensitivity	The users need wireless audio devices with optimized sensitive touch controls (in order to interact quickly and seamlessly)	touch control annoying, canceling sensitive touch, hold touch control, use touch control, touch control sensitive, control touch, touch control, sensitive touch control, touch adjust, touch instead button	97
Color options	The users need wireless audio devices with a variety of color options (in order to feel aesthetic satisfaction)	Rose gold color, rose gold pink, color rose gold, gold pink color, gold pink, rose gold, case rose gold, rose gold expected, color rose, gold color	72
Adjustable controls	The users need wireless audio devices with adjustable controls and customizable sound settings (in order to achieve their preferred audio experience)	Button adjust work, adjusting worked, button worked, complaint raise lower, worked reset, button adjust, charge button, button work, anymore working, difficult adjust	47

Table A.2
Domain-specific topic model of mobile devices.

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
High storage and memory performance	The users need mobile devices with sufficient RAM and a powerful processor (in order to handle resource-intensive tasks efficiently)	gb ram, ram, processor, battery camera, performance, memory, camera, camera fast, lightweight, gb	16,103
Easy interface setup	The users need mobile devices that are easy to set up and use (in order to start interaction immediately with minimal effort)	easy setup, easy use easy, work easy use, easy use, use easy, set easy use, use easy use, need easy use, easy set use, setup	6840

(*continued on next page*)

Table A.2 (*continued*)

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Durability against shattering	The users need durable and impact-resistant mobile devices (in order to prevent damage such as cracks or breaks)	cracked, broken, dropped case, issue work fine, working fine, accidentally dropped, work fine, complaint, shattered, crack	4302
Long battery life	The users need mobile devices with a long battery life (in order to get consistent performance over time)	battery lasting, battery last easy, fast battery last, lasting battery, battery last, work battery last, battery last work, battery battery last, battery last longer, friendly battery	3265
Fast learning curve	The users need mobile devices that are easy to learn (in order to efficiently learn how to use the system and save time and effort)	easy use feature, feature easy use, feature user friendly, learn use feature, use feature easy, feature easy, easy use, feature use, use feature, use feature need	1495
Fast loading	The users need mobile devices with a faster loading feature (in order to avoid prolonged wait times and interact quickly)	internet slow, load slow, slow internet, slow processor, processor slow, slow load, slow slow, use slow, connection slow, slow use	1326
Waterproofing	The users need mobile devices with sufficient waterproofing (in order to prevent failure from water penetration)	waterproof feature, waterproof camera, feature waterproof, camera waterproof, waterproof easy, battery waterproof, easy use waterproof, waterproof battery, picture waterproof, waterproof waterproof	1036
Lightweight design	The users need a lightweight and easy-to-carry mobile devices (in order to enhance portability and convenience)	lightweight easy use, easy use lightweight, lightweight easy, easy carry lightweight, lightweight easy carry, lightweight weight easy, lightweight need, fast lightweight easy, size lightweight easy, machine lightweight	1002
User-friendly touch	The users need mobile devices with a user-friendly touchscreen (in order to operate easily and efficiently)	touch user friendly, easy use touch, touch feature easy, touch easy use, touch convenient, display touch, performance touch, use touch feature, useful touch, touch using	513
Color options	The users need mobile devices with a variety of color options (in order to feel aesthetic satisfaction)	rose gold color, color rose gold, gold color beautiful, color rose, color color beautiful, color beautiful color, rose gold, gold color, color gold, rose gold gold	445
Defect-free device	The users need defect-free mobile devices (in order to avoid functionality issue)	defective camera, camera work, working camera, defective, defect, return expired, repair, issue worked, black return, issue	397
Latest technology and performance	The users need mobile devices that incorporate the latest technology (in order to perform their task effectively)	edged, easy use feature, graphic easy use, useful feature, easy use graphic, touch, feature easy, feature useful, case feature, palm touch	367
Customizable display setting	The users need mobile devices with customizable features (in order to adjust the reading and content viewing features to suit the characteristics)	easy use reading, using reading, work reading, use reading, reading work, reading size, reading easier, reading, useful reading, reader slow	282
Fast responsiveness	The users need mobile devices with a responsive display and seamless performance (in order to interact quickly and seamlessly)	responsive, ease display, storage use, performance included, megapixel, ui, beautiful display, use display, gorgeous display, drawer	280
Intuitive interface design	The users need mobile devices that are easy to navigate through an intuitive interface design (in order to understand intuitively and efficiently)	work easy navigate, easy easy navigate, easy use navigate, navigate easy use, easy navigate, easy navigate easy, friendly easy navigate, easy navigate work, easy navigate sound, easy navigate fast	279
Resolution of overheat issues	The users need mobile devices that maintain a stable temperature during charging and usage (in order to use the device comfortably)	battery overheat, charging overheats, overheating, overheats charging, issue overheats, overheats, overheat, fine overheat, overheat fast, overheats use	79
Elegant design	The users need mobile devices with an elegant design (in order to feel aesthetic satisfaction)	elegant style, elegant feature, elegant, elegant easy, feature elegant, aesthetic, beautifully feature, beautiful tech, customizable, performance elegant	61
Robustness performance	The users need mobile devices that perform without freezing and crashing (in order to get reliable operation)	issue freezing, freeze restart, keep freezing shutting, freezing shutting, battery freeze, freezing, issue rebooting, freeze freeze, freeze froze, freezing work	49
Application stability	The users need mobile devices with stable performance (in order to prevent crashes and ensure uninterrupted usage)	reliable issue, concern issue, issue concern, complaint issue, complaint update, complaint battery, fast reliable issue, concern, battery complaint, looked complaint	22
Durability	The users need durable mobile devices (in order to withstand external factors and maintain reliable performance)	durable battery last, durable battery, friendly battery, comfortable battery, durability battery, battery last, battery last cheap, battery lightweight, friendly fast battery, battery purpose	20

Table A.3
Domain-specific topic model of web browsers.

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Advertisement blocking	The users need web browsers with fewer intrusive advertisements (in order to use the application comfortably)	adblock, ad block, block ad, ad blocking, blocking ad, annoying ad, use ad, popups, ad ad, ad	16,920
Smooth update	The users need web browsers without unnecessary updates (in order to avoid disruptions and issues)	unable update, issue update, update keep crashing, update issue, fix update, updating update, update updating, update update, update working, updating	2882
Enhanced download feature	The users need web browsers with enhanced downloading features (in order to efficiently download content)	downloading stop, stop downloading, downloads downloading, fix downloading, file downloading, downloading downloading, file downloads, issue downloading, downloads show, downloads downloads	2130
Efficient battery usage	The users need web browsers that minimize battery drain (in order to get consistent performance over time)	battery drain, battery draining, draining battery, drain battery, battery use, battery fast, consuming battery, battery using, used battery, battery used	1905
Background color selection options	The users need web browsers interface with a selection of background color options (in order to feel aesthetic satisfaction)	background white, white background, change theme, bar background, background color, use theme, black background, background black, theme work, black theme	1498

(*continued on next page*)

Table A.3 (*continued*)

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Consistent tab	The users need web browsers with consistent tab (In order to avoid tabs reloading and the screen being cut off in landscape mode)	landscape fix, stuck landscape, keep reloading, rotate landscape, update landscape, reloads, fix bug, reload, fix issue, landscape	1194
Fast connectivity	The users need web browsers with a fast connection (in order to enable smooth usage and low-latency performance)	slow issue, slow connection, slow using, blocked site, slow slow, downloading, slower slow, work slow, slow, connection	1079
Fast learning curve	The users need web browsers that are easy to learn (in order to efficiently learn how to use the system and save time and effort)	use learn, internet, helpful tool, innovate, useful, relevance, improvement, improve, technology, information	878
Automatic data clearing feature	The users need web browsers with automatic data clearing upon app exit (in order to simplify the process of managing tabs and history)	clearing history, clear history, history button, close button, history closing, history cleared, history closed, set clear, history clear, use close	776
Efficiency and accuracy of link sharing	The users need web browsers with efficient and accurate link sharing (in order to share links easily and avoid errors during the sharing process)	tap link, share menu, share button, share link share, share link, link share, link fix, link opening, opening link, share feature	752
Print and save as PDF feature	The users need web browsers with a reliable and easily saving feature (in order to streamline the process of preserving web content)	printing save, save missing, allow save, save available, removed save, save feature, change save, save removed, saved update, missing saved	723
Easy login process	The users need web browsers with an easy login process (in order to start interaction immediately with minimal effort)	account login, login account, login, use account, account hacked, account help, hacked account, unable login, logged account, log account	692
Intuitive address bar design	The users need web browsers intuitive address bar that are easy to navigate (in order to understand intuitively and efficiently)	address bar easier, address bar button, button address bar, address bar, address bar bar, address bar feature, address bar navigation, ui address bar, address bar used, address bar hiding	408
Fast loading	The users need web browsers with a faster loading feature (in order to avoid prolonged wait times and interact quickly)	load slow slow, loading slow, slow loading slow, load slow, load fast slow, slow loading, slow load slow, slow take load, slow load, slow site	337
Customization option	The users need web browsers with a customizable homepage setting (in order to maintain control over their preferred start page)	feature missing, button gone, broken fix, set site, customize, default, customize, address bar, replaced button, site set	276
Custom wallpaper	The users need web browsers with a customizable wallpaper feature (in order to allow them to set their own backgrounds)	wallpaper feature, use wallpaper, custom wallpaper, wallpaper change, wallpaper allow, change wallpaper, background wallpaper, wallpaper wallpaper, wallpaper bar, wallpaper	173
Input stability and predictability	The users need web browsers with stable and predictable input functionality (in order to ensure that typing, editing or navigating within input fields without interruptions)	typing bar, bar typing, type address bar, address bar, issue typing, type bar close, typing typing, tap address bar, address bar tap, type bar	160
High storage performance	The users need web browsers with an option to manage storage usage effectively, including saving data (in order to prevent the app from consuming excessive internal space and slowing down their devices)	gb storage use, gb storage take, gb storage, amount storage, gb storage space, gb user data, gb data, amount downloads, storage use, gb background data	53
Secure connection	The users need web browsers with a seamless and secure connection feature (in order to protect their personal information)	secure connection failed, connection secure error, connection failed, secure error, connection failed error, saying connection secure, connection secure, secure connection, certificate error, kept saying connection	25

Table A.4
Domain-specific topic model of AI assistants.

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Connectivity	The users need AI assistants with continuous connection (in order to avoid disruptions caused by connectivity issues and recent updates)	ui, sound, reset, navigate, connect, connecting, setting, feature, internet, issue	16,366
Stability of voice recognition	The users need AI assistants with stable voice recognition (in order to enable seamless interaction and avoid interruptions)	voice working, voice command, responding voice, retrained voice, recognize voice, retrain voice, retraining voice, voice work, feature unavailable, working voice	6221
Efficient smart home management	The users need AI assistants integrated with a smart home hub, offering intuitive controls and voice command capabilities (in order to efficiently manage connected device)	easy setup use, work easy setup, use easy setup, easy use sound, sound easy setup, sound easy use, easy setup, easy use, easy setup sound, setup use	6207
Fast responsiveness	The users need fast and responsive AI assistants (in order to interact quickly and seamlessly)	slow take load, slow unresponsive, load slow, slow load, working slow, lagging, crashing slow, slow slow, fix slow, slow feature	1438
Color options	The users need a speaker available in a variety of color options (in order to feel aesthetic satisfaction)	easy use color, color easy use, easy use small, easy use price, convenient small, easy setup use, easy use, small use, color easy, use easy	1174
Disable and uninstall stock apps and minimizing intrusions	The users need an option to fully disable certain feature (in order to prevent them from automatically reactivating and causing unnecessary interruptions)	annoying disable, uninstall annoying, need disable, uninstall disable, annoying uninstall, disable uninstall, disable, deactivate, use disable, wish uninstall	923
Accuracy and reliability of responses	The users need AI assistants that provide accurate and reliable responses (in order to get helpful and consistent assistance for tasks)	answer voice, voice asked, use helpful, helping useful, polite, helpful useful, useful helpful, useful helped, helping, helpful	697
Compatibility	The users need AI assistants with a compatibility (in order to avoid compatibility issues and ensure smooth installation)	connect working, keep losing connection, losing connection, update connect, issue connecting, unable connect, trouble connecting, reconnect, reconnecting, connected unable	649
Easy-to-operate AI assistants	The users need AI assistants that are easy to control (in order to facilitate quick adoption and intuitive operation)	convenient easy use, easy use convenient, useful easy use, easy use useful, use easy use, helpful easy use, easy use, easy use easy, easy use easier, work easy use	473
Fast learning curve	The users need AI assistants that are easy to learn (in order to efficiently learn how to use the system and save time and effort)	easy use helpful, learn use, feature use, easy use find, easy use, use helpful, easy use found, technology help, useful, tool use	453

(*continued on next page*)

Table A.4 (*continued*)

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Improved sound quality	The users need AI assistants with an improved sound feature (in order to enhance their listening experience)	sound improved, improved sound, sound improved sound, sound improvement, improvement sound, improved sound feature, newer sound, superior sound, clearer sound, sound feature	383
Efficient battery usage	The users need an app update that minimize battery drain (in order to get consistent performance over time)	update draining battery, background drain battery, battery drain, update drain battery, drain battery background, draining battery, drain battery, draining battery force	373
Sound of voice activation	The users need AI assistants with sound feedback to confirm voice activation (in order to start interaction immediately)	beeping sound, sound respond, sound update, respond sound, sound working, update sound, confirmation sound, sound gone, sound fix, beeping	365
Enhanced voice recognition with appropriate sensitivity	The user needs AI assistants that accurately recognize their voice while maintaining an appropriate level of sensitivity (in order to enable smooth and error-free interaction)	voice easy use, voice work useful, easy use voice, voice feature, use voice, recognizes voice easy, voice command easy, voice capability, voice technology, voice use work	354
Offline voice recognition capability	The users need AI assistants with offline voice command capabilities (in order to perform essential tasks without relying on an internet connection)	offline voice work, offline voice, offline speech, enabled offline, offline feature, use offline, offline offline, issue working offline, voice online, using offline	331
Improved reminders feature	The users need AI assistants with an intuitive reminder feature (in order to effectively manage schedules)	reminding, keep setting, notify, reminded, scheduled, set useless, bug, fix issue used, useless, set keep	287
Easy login process	The users need AI assistants with an easy login process (in order to start interaction immediately with minimal effort)	login account, fix login, email account, login login, login, account email, take login, login use, account account, unable sign	274
Optimal display size	The users need AI assistants with an appropriately sized display (in order to enhance ease of use)	display ease use, useful display, small display, display ease, easy use display, size display, large display, display easy use, larger display, display size	257
Simple execution of routine feature	The users need AI assistants with a simple and efficient routine execution feature (in order to streamline tasks and improve task management effectiveness.)	easy use complicated, programming functionality, functionality confusing, handle simple task, programming, understand user friendly, complicated understand work, multiple run, feature avaliable, necessary feature	154
Customizable wake word	The users need the ability to customize their AI assistant's name (in order to do a more personalized interaction)	change name word, name change, use change name, change name need, name change name, change name, need change name, change name name, allow change name, change name change	147
Enhanced reading feature quality	The users need AI assistants with a good reading feature (in order to smoothly obtain information through the reading feature)	reading feature, reading stop, reading repeat, reading fix, frustrating using voice, update reading, reader, reading work, use reading, stop reading	120
Accurate sensing function	The users need AI assistants with an accurate sensing function (in order to gain useful health insight)	sensing sleeping, feature useful sound, monitoring, sensing feature, work sensing, sensing sound, functionality sensing, feature useful, sensing, user friendly feature	111
Clear display and sound	The users need AI assistants with a clear display and high-quality sound (in order to intuitively understand)	clear sound display, sound display clear, clear display sound, display clear sound, show clear sound, sound enjoy display, sound display, clear sound, clear sound use, use clear sound	95
Enhanced AI comprehension	The users need AI assistants that consistently understand and respond accurately to queries (in order to get meaningful and accurate assistance for achieving the user's purpose)	intelligent need, improvement artificial, advanced technology understand, intellectual, intelligent, artificial, improvement frustrated, technology simple, understands use, machine	92
Accurate understanding of accents and clear speech	The users need AI assistants that understand diverse accents and clear speech (in order to ensure effective communication)	speech typing, sound speak clear, deaf, understands saying using, unresponsive understand, frustrating word, wish voice choose, talkative, irritating frustrating, understand word	75
Improved command recognition and efficiency	The users need AI assistants that accurately process and execute commands (in order to perform the task accurately without errors)	command ease use, command programmed, command effectively, command plug, command simple, command sense, command standard, use command, command accurately, understand command used	62
Easy integration and connectivity of smart home device	The users need AI assistants with easily integration and connectivity of smart home device (in order to easily connect without confusion)	connected use, heater, control work easy, control using feature, setup alert, easy control work, function control, know control, control disappointing, change compatible	51

Table A.5
Domain-specific topic model of generative AI.

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Various types of features	The users need generative AI with various types of features (In order to achieve various types of their purpose)	functionality, useless, automatically, uninstall, use feature, setting, annoying, use use, button, manually	4294
Updating with the latest information	The users need generative AI with up-to-date and intelligent features (in order to access accurate and trust information)	update information, updated information, update data, learning, useful, feature, intelligent, improvement, upload, technology	4086
Easy-to-operate generative AI	The users need generative AI with ease of use and practical utility (in order to get easily well-structured content and information)	useful easy use, easy use useful, helpful easy use, easy use helpful, easy use, use easy use, useful use, useful easy, easy use easy, easy use help	3841
Accurate and fast answer	The users need generative AI with accurate and fast answers (in order to achieve their purpose effectively)	software, answer using, answer use, learning, teach, improve, use answer, useful, answer helpful, answer information	2434
Easy login process	The users need generative AI with reliable login process and error management (in order to start interaction immediately with minimal effort)	error occurred, error occured, error error occurred, error occurred later, error login, error occured later, error error, saying error occurred, error, unable	682

(*continued on next page*)

Table A.5 (*continued*)

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Conversation history feature	The users need generative AI with a reliable history feature (in order to efficiently manage and retrieve text from their chat history for enhanced productivity.)	history button, history feature, history loading, history load, button history, update history, history offline, history stored, missing history, show history	278
Context-aware characteristics	The users need generative AI that provide context-aware conversational experience (in order to engage in natural and effectively interaction for various purpose)	user friendly easy, user friendly, natural engaging, engaging user, tool, tool task, understands context, easy navigate, contextually, generating creative	269
Universal accessibility	The users need generative AI that are universally accessible (in order to use it regardless of location or device)	supported country supported, supported supported available, supported supported, supported available, available supported, supported country, supported error, country supported, supported, supported working	162
Avoidance bias and unwanted contents	The users need generative AI with unbiased and inclusive responses (in order to get accurate and neutral information)	white bias, biased white, bias white, bias, politically motivated, find biased, biased asked, biased, biased woke, politically	156
Improvement in response speed	The users need generative AI with improved response speed (in order to enhance responsiveness and interact quickly)	need improvement, need improvement improvement, need improvement need, slow need improvement, need improve slow, slow need improve, need improve, slow improvement, need improve need, improvement need	138
Application stability	The users need generative AI with stable performance (in order to prevent crashes and ensure uninterrupted usage)	keep crashing, crashing, crashing use, use crashing, working crashing, crashing saying, crashing several, crashing keep, crashed, reinstall	129
Freedom from excessive regulations	The users need generative AI that are less restricted by rigid guidelines (in order to allow for more open and free-flowing interactions without the inconvenience of excessive regulations)	biased software, personally, compare, convenient, bad, sense humor, polite, software, kidding, humor	109
Interactive and accurate responses	The users need generative AI with interactive features and accurate responses (in order to effectively handle queries and complete programming tasks)	answer interactive, accurate answer interactive, intelligent capable, human intelligent, interactive feature, used responds, programming need, enjoy using, answer query user, artificial advanced	89
Frustration-free typing	The users need generative AI with frustration-free typing (in order to edit and input text comfortably)	backspace, using backspace, edit fix, erase typing, bug edit, frustrating edit, bug erase, edit typed, issue edit, fix bug	80
Connectivity	The users need generative AI with a continuous connection (in order to use it for a long time without interrupting)	connection bad, connection error, internet connection fine, issue connection, unable connect, network error, connection working, poor network connection, poor connection, attempting connect connect	79
Companionship	The users need generative AI that can be a conversational partner just like a friend (in order to feel emotional connection and companionship)	trust useful, bestfriend, trusted, trust, useful easy use, mutual, betrayed, useful easy, need share, share	52
Supporting creative and organizational tasks	The users need generative AI that support both creativity and organizational capabilities (in order to achieve their purpose seamlessly)	helpful creative, creative helpful, helpful creative need, creative tool, generating content creative, creative need, thought tool, generating thought, organize thought, creative thinking	42
Guidance on crafting effective prompts	The users need guidance on crafting effective prompts (in order to easily learn how to help generative AI better understand nuanced queries)	generating human understand, linguistic, linguistic finesse, understand respond, information generating, providing information engaging, provide insightful, coherent contextually relevant, coherent contextually, valuable tool task	34
Intuitive interface design	The users need generative AI with a simple and intuitive user interface (in order to easily understand information from the interface)	easy ui using, easy ui, friendly user friendly, improve user friendly, using user friendly, ui using, ui, user friendly user, user user friendly, user friendly	27

Table A.6
Domain-specific topic model of social media platforms.

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Easy login process	The users need social media platforms with an easy login process (in order to start interaction immediately with minimal effort)	unable login, login, error occurred, log expired, login account, reinstall, unable, logged account, error, fix issue	11,614
Easy sharing and engagement with diverse content	The users need social media platforms that facilitate easy sharing of content (in order to connect with others and enhance their social interaction)	sharing, share, use, benefit, easy use, user friendly, content, using, communicating, useful	6711
Accurate photo uploading feature	The users need social media platforms with an improved photo uploading feature (in order to get a seamless posting experience)	upload photo, upload picture, picture status, photo status, multiple photo post, photo post, post photo, multiple photo, post picture, photo sd	4560
The level of less intrusive advertisements	The users need social media platforms with less intrusive advertisements (in order to use the application comfortably)	ad annoying ad, ad annoying, ad ad post, ad post ad, post ad ad, annoying ad, advertisement ad, content ad, stop ad, ad stop	2833
Color options	The users need social media platforms interface with a variety of color options (in order to feel aesthetic satisfaction)	update green color, color update, update color, theme green, color change, color theme, change color, update green, change green, theme update	1694
Channel customization and management	The users need social media platforms with an option to customize or disable the channel feature (in order to prioritize and easily access status updates without interference from unwanted or unnecessary elements)	status update channel, status channel, channel status, channel update, channel annoying, status annoying, update channel feature, update channel, status bar, annoying channel	1427
Bug-free condition	The users need social media platforms with a bug-free condition (in order to maintain reliable performance without bugs)	fix bug, last update, fix issue, tap skip, lagging, double tap skip, issue fast, lag, update sound, bug	1239
Ease of profile picture and name change without annoyance	The users need a seamless profile update feature (in order to change their profile without encountering bugs or errors)	profile picture change, change profile picture, changing profile picture, profile picture fix, update profile picture, change profile,	990

(*continued on next page*)

Table A.6 (*continued*)

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
		changing profile, profile update, upload profile picture, profile picture	
Intuitive interface design	The users need social media platforms with intuitive interface design (in order to understand intuitively and efficiently)	fix navigation bar, navigation bar bad, navigation bar moved, navigation bar stupid, navigation bar, moved navigation bar, need navigation bar, moving navigation bar, front navigation bar, navigation bar update	690
Enhanced privacy features	The users need social media platforms with a lock feature (in order to maintain their desired level of privacy)	using lock, lock different, lock using, use lock, change lock, lock working, lock updated, lock setting, lock showing, lock code	638
Clear status indication	The users need a calling feature that clearly distinguishes between online and offline statuses (in order to avoid confusion and ensure accurate status information)	offline showing online, issue offline, offline showing, offline update, online offline update, update offline, update offline show, showing offline, offline connected	591
Opening links in external browsers	The users need social media platforms with an option to open links in an external browser (in order to have greater control over their browser and avoid unnecessary restrictions)	link opening, opening link, link external, link external link, external link, link externally, set link external, link internal, link opened, link fix	541
Fast media loading	The users need social media platforms with a faster loading feature (in order to avoid prolonged wait times and interact quickly)	picture loading, keep loading, stop loading, load fix, photo loading, longer load, slow load, picture load, loading loading, load slow	511
Improved account security	The users need social media platforms with a robust and efficient account recovery system (in order to regain access to hacked accounts and protect their personal information)	account hacked help, account hacked recover, help account hacked, account hacked hacker, hacked account, account hacked, security account hacked, account hacked account, account account hacked, account hacked used	502
Reliable buttons feature	The users need reliable button feature (in order to control the interface stably without issues)	button fixed, fix button, button work annoying, button fix, button work fix, button stop working, update fix button, last update button, button issue, button bug	470
Scroll issue resolution	The users need a smooth and predictable scrolling experience (in order to scroll comfortably and prevent unexpected feed refreshes)	thread scroll, scroll thread, scroll annoying, issue scroll, scroll annoying fix, scroll fix, scroll bug, annoying fix scroll, fix scroll	435
Comfortable interface and option	The users need a stable and refined interface that resolves UI bugs (in order to enhance user comfort and provide a frustration-free experience)	update annoying, annoying update, annoying updated, useless update, update irritating, ui, unnecessary update, tired updating, stop updating, use update	430
Stability of the space feature	The users need a stable and fully functional Space feature (in order to participate seamlessly without dealing with sound issues, exit failures, or persistent UI glitches)	space working, space bug, space fix bug, fix space, space uninstall reinstall, space fix, leave space, keep saying space, space showing, ui space	424
Sensitive contents settings	The users need social media platforms with a reliable sensitive content setting (in order to manage sensitive media to reduce discomfort)	show sensitive content, sensitive content post, sensitive content, content setting, content hidden, contain sensitive content, post sensitive, allow sensitive, show sensitive, blocked sensitive	245
Seamless typing	The users need social media platforms that allow for easy text input and editing (in order to ensure smooth and uninterrupted typing without cursor issues or text duplication)	typing issue, comment typing, typing comment, edit typing, typing edit, comment typing comment, word typing, typing, type typing, type comment	225
Contact synchronization	The users need social media platforms with reliable contact synchronization and display settings (in order to ensure that contact names are correctly shown and settings like last seen work properly)	contact update, update contact, updated contact, contact updating, contact fix issue, contact number showing, update update contact, refresh contact, contact refresh, contact disappeared	215
Caption management option	The users need social media platforms with options to disable or manage captions effectively (in order to avoid inconvenience and ensure unobstructed content viewing)	caption annoying, annoying post caption, annoying caption, issue caption, caption fix, caption button, caption update, closed caption, caption feature, update caption	206
Reliable dark mode feature	The users need social media platforms interface with dark mode (in order to feel comfortable for the eyes)	white background black, background white text, text black, black background, background black white, white background, theme black, background black, white background white, white white background	191
Efficient battery usage	The users need social media platforms that minimize battery drain (in order to get consistent performance over time)	battery draining, battery drain, cause battery drain, draining battery, battery background, drain battery, consume battery, battery use, stop disable, battery battery	179
Minimizing of lag	The users need social media platforms without any kind of lag (in order to interact quickly)	lagging scroll, lag scroll, keep lagging scroll, fix lagging, lag profile, slow lag, lagging, stutter lag, smooth lag, keep lagging	169
Sharing of interesting and useful content	The users need social media platforms that facilitate easy sharing of interesting and useful content (in order to connect with others and enhance their social interaction)	share easy use, communicate sharing, functionality becoming, satisfaction progress, provides personal, reach share, find interesting useful, useful friendly, reason connect, connect promote	146
Customizable text size	The users need a customizable and consistent text size feature (in order to enhance readability and prevent automatic size changes)	text size, change size, size change, size annoying, display change size, change small, size typing, size setting, size edit, size increased	140
Engaging and informative information	The users need social media platforms with engaging and informative information (in order to gain valuable insights and maintain their interest)	informative interesting, interesting informative, interesting information, informative informative, informative, simple informative, informative information, information informative, interesting content, use informative	134
Fast learning curve	The users need social media platforms that are easy to learn (in order to efficiently learn how to use the system and save time and effort)	useful, helpful keep, learn useful, useful easy, connecting useful, learning useful, sharing keeping, easy communicate keep, helpful helped, helpful	114
High storage performance	The users need social media platforms with an option to manage storage usage effectively, including saving data (in order to prevent the app from consuming excessive internal space and slowing down their devices)	storage take space, storage gb, gb storage, gb storage space, unnecessary storage, storage space, storage large, storage size, change storage, storage storage	114
Fast comment loading	The users need social media platforms without comment loading and lagging issues (in order to avoid prolonged wait times and interact quickly)	comment loading, comment lagging need, comment lagging, comment feature, load reply comment, loading load comment, point comment lagging, data comment section, comment post comment, showing comment	86

Table A.7
Domain-specific topic model of video game.

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Reasonable difficulty and reward system	The users need video games with a balance between challenging gameplay and accessible design (in order to reduce frustration and ensure an engaging)	beginning, repetitive, mode, frustrating, challenging, difficulty, reason, run, challenge, last	23,534
Creative and autonomy game elements	The users need creative and autonomy contents (in order to enjoy the game with immersion)	creative, enjoying, enjoys, display, quality, different, case, except, force, detailed	3507
Support for using included activation codes	The users need video games with clear processes for redeeming or activating included (in order to start interaction immediately with minimal effort)	code included, downloading, issue, account, activate, code work, entered code, unable, install, receive	3166
Ensuring responsiveness and minimizing lag	The users need video games without any kind of lag (in order to interact quickly)	lag, wirelessly, useful, input lag, performance, wired, hardware, setup, troubleshooting, use	1475
A well-balanced intuitive and portable handheld system	The users need video games with a handheld system that balances intuitiveness and portability (in order to understand the information provided on the interface intuitively under appropriate portability)	handheld system, handheld, hardware, touchscreen, system design, gb sd, portable system, gb, sound, newer	1237
High graphic quality	The users need remakes of video games with improved graphics (in order to achieve the purpose of enjoying the game)	replaying, remake, enjoying, ported, system graphic, quality, lag, hooked, memory, surround	1222
Scratch and light impact protection	The users need a device with a protector case (in order to prevent damage such as cracks or breaks)	protector case, case protector, protector easy, protector fit, case cover, protector protector, protector scratch, protector work, case fit, hard case	1148
Customizable variety in levels	The users need video games that enable creative level design and seamless sharing of user-generated content (in order to encourage imaginative playing and customization)	level design, level challenging, level different, level easy, level level, classic level, different level, easy level, level, level complete	1087
Challenging and rewarding game contents	The users need video games that play challenging content (in order to enjoy the game with immersion)	challenging, higher level, difficulty, rewarding, level, dying, punishing, raid, reward, difficult	646
High sound quality	The users need video games with high-quality sound (in order to achieve the purpose of enjoying the game)	level difficulty, sound choose, vocal, sound, choose sound, sounding, style mix, level, mode, difficulty	616
Customizable creative design and costume creation	The users need video games with a creative costume design and outfit customization features (in order to foster customizable experience)	fashion fashion, fashion, costume use, costume, putting outfit, outfit, creative design, designing, dress, design	476
Variety in game modes	The users need video games with well-implemented modes (in order to have a sufficiently enjoyable experience through a variety of modes)	online mode, online enjoys, challenge mode, online repetitive, online mode short, mode online, frustrating mode, mode, mode mode, online functionality	446
Clarity and completeness of included content	The users need complete and inclusive game in terms of language, expansion (in order to achieve the purpose of enjoying the game)	disappointing, content decided, disappointed condition, content system, disappointed ended, included, includes, complete content, including, taken rise iron	429
Compatibility in any device	The users need video games with compatibility across newer operating systems and seamless installation processes (in order to avoid compatibility issues and ensure smooth installation)	newer operating, install compatible, newer operating system, compatibility issue, compatibility mode work, compatibility mode run, compatibility mode, system install, operating system, installs fine	401
Split-screen feature	The users need video games with split-screen feature (in order to enable shared-screen for cooperative and multiplayer modes)	mode, lack split, reason split, level, graphic improved, covenant, confusing level, similar reach, except, shield	396
Customization and freedom in gameplay	The users need video games with customization features that allow players to tailor their preference (in order to foster customizable experience)	lack customization, dialogue, enjoying, fright, disappointed lack, wish easy system, disappointed, training mode, system online, memory	394
Optimal memory and performance	The users need video games with good specification (in order to ensure smooth performance and achieve the purpose of enjoying the game)	newer brings memory, gb ram graphic, gb run, memory gb, remastering, gb ram, memory gb ram, ram, run quality, hard gb	384
Comfortable grip design	The users need a device with an ergonomic and comfortable grip design (in order to reduce hand discomfort and accommodate various hand sizes)	grip different, quality grip, grip quality, different grip, comfortable grip, wider grip, grip grip, easier grip, analog grip, cover grip	341
Intuitive tutorial	The users need video games with an intuitive tutorial (in order to efficiently learn how to use the system and save time and effort)	learn tutorial, take tutorial, skip tutorial, tutorial instruction, stupid tutorial, tutorial use, tutorial point, tutorial hard, tutorial complete, complicated tutorial	228
High-quality audio and microphone	The users need XR games with high-quality sound (in order to enhance the storytelling and achieve the purpose of enjoying the game)	sound quality, quality sound, clear sound, sound need, surround sound sound, surround sound, comfortable sound, work sound quality, sound sound, sound plugging	218
Immersive gameplay	The users need video games that balance engaging gameplay, intuitive mechanics, and clear progression guidance (in order to ensure an enjoyable and frustration-free experience for both new and experienced players.)	easier control different, enjoying clue, choose spell, easy spend random, challenging obsessed, spell, duel interesting, value familiar, easier control, design base	152
Compatibility	The users need video games that ensure compatibility (in order to avoid compatibility issues and ensure smooth installation.)	faulty control, handheld mode, colored button, learning eye, modulator hook, using blurry, quality eye, use eye, led base, online repair	122
Optimal keypad size	The users need a keypad with appropriate space (in order to enhance typing accuracy)	key button, key stroke, enter key, type key, typing, use key, command key, set key, key use, key space	83
Easy installation process	The users need video games with clear installation process (in order to start interaction immediately with minimal effort)	minor complaint hardware, needed setup, sturdy system, setup easy, fit base, assemble need, rail, base base, falcon bm, adjustability	44

Table A.8
Domain-specific topic model of XR games.

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
High-quality XR games environment	The users need XR games with a sophisticated and beautiful environment (in order to experience an innovative and unique gameplay)	set bar, bar, hoping, innovative, revolutionary, standard, set standard, disappoint, tech, engaging	12,604
Stable mod feature with meaningful updates,	The users need updates that prioritize stability (in order to avoid disruptions and issues)	stop updating, stop update, update stop, update annoying, updating, last update, update update, patch, work update, update fix	5227
Immersive gameplay	The users need XR games with an immersive and well-structured game story (in order to feel a deep flow and fulfillment)	infinitely replayable, replayable, replayablity, finished multiple, tedious, think finish, finishing, optional, think finished, finish	3744
Easy installation process	The users need XR games with easy-to-install custom content (in order to start interaction whenever they want with minimal effort)	official custom, install custom, use custom, downloading custom, custom, easy custom, custom content, need custom, custom enjoy, different custom	2168
Natural interaction	The users need XR games intuitive control system (in order to interact with the game system without unnecessary interruptions)	handed control, control handed, handed handed, grip, handed, aiming, learn use, control, handling, easy use	1623
High storage performance	The users need XR games with an option to manage storage usage effectively, including saving data (in order to prevent the app from consuming excessive internal space and slowing down their devices)	performance issue, hardware run, ram run, low graphic setting, gb ram run, run smoothly, optimized run, lag run, performance, ram gb	802
High graphic quality	The users need XR games with high-quality and engaging graphics paired with innovative dialogue (in order to enhance the storytelling and overall gameplay)	graphic engaging, engaging graphic, solid graphic, graphic level, graphic solid, graphic dialogue, graphic performance, performance graphic, beautiful graphic graphic, innovative graphic	760
Interactive and detailed environments	The users need XR games with highly detailed and interactive environments (in order to feel immersion and create a tangible sense of presence)	immerses, immerse, presence, engaging, detailed interactable, interactive, detailed interactive, interactable, level attention, attention graphic	622
Fast learning curve	The users need XR games with an intuitive learning curve (in order to efficiently learn how to use the system and save time and effort)	easy learn hard, easy learn, learn hard, simple learn, easy difficulty, easier difficulty, hardest difficulty, higher difficulty, hard difficulty, learning	281
Wired and wireless connection option	The users need XR games with a connection for link cables or wireless options (in order to use the game reliably and without interruptions)	link connection, link software, latency link, low latency link, link load, link managed, using link, link worked, need connection, using link link	251
Bug-free condition	The users need XR games completely free of even minor bugs (in order to maintain reliable performance without bugs)	bug bad, bug mainly, noticeable bug, bug caused, bug unplayable, except bug, bug causing, bug need, bug fix, need bug	246
Minimal motion sickness	The users need XR games without any kind of sickness (in order to play the game comfortably)	sickness smooth, use sickness, continuous sickness, sickness enjoy, sensitive sickness, induce sickness, sickness run, sickness sickness, sickness continuous, sickness minimal	240
Gradual and well-balanced difficulty progression	The users need XR games that play challenging content (in order to enjoy the game with immersion)	difficulty selection, different difficulty, hard difficulty, higher difficulty, harder difficulty, difficulty level, default difficulty, difficulty hard, increasing difficulty, level difficulty	230
Vibration feedback	The users need XR games controller with precise input recognition and feedback (in order to maintain seamless interaction)	vibration, touch, button, enable, menu button, wand, update menu, stop working, binding, working setting	214
Smooth turning	The users need to get immediate and smooth responses to controls (in order to interact quickly and play the game accurately)	smooth turning, need smooth turning, added smooth turning, smooth turning edit, control turning, turning, need smooth, control smooth, issue smooth, edit smooth	194
Reliable game launching	The users need XR games with a reliable launch system to start the game (in order to start the game without needing frequent restarts)	launch fix, issue fixed, resolved issue, need restart, issue load, fix issue, installed error, restart, rebooting, issue fix	166
Save and load feature	The users need XR games which save the gaming data in a simple and lossless manner (in order to restart the game continuously)	loaded save, loading save, load save, loading dying, issue restart, save eventually, stop loading, corrupted, unplayable load, issue launch	162
Physically engaging gameplay	The users need XR games that integrate physical activity, making exercise a fun and engaging part of gameplay (in order to combine gaming with exercise for a fun and engaging)	theme, physicality, simple style, spiritual, style, fencing, swinging, becomes easy, power, becomes	133
Fair refund policies	The users need XR games with a flexible and fair refund policy that adapts to individual situations (in order to address unexpected problems)	bug low, sold devil, last appeal, account waited, low memory, responded, refused, disappeared, ended, unsuccessfully	132
Responsible and player-focused development	The users need developers to take responsibility for fixing issues, prioritize long-term playability, and respect player engagement (in order to maintain trust and interest consistently about the game)	develop, blame, fault, audacity, neglected, abandon, abandoned, seemingly, neglect, recreation	122
Sufficient playspace	The users need a large space for playing XR games (in order to play the game smoothly and safely without discomfort)	playspace, small space, larger space, smaller space, reasonable space, limited space, foot space, space limited, cramped, large space	94
Privacy and data protection	The users need safe and reliable personal information management (in order to protect their data)	content owned, privacy, allow content, official launch, lawsuit, company stop, complaining update, marketplace, annoying content, intellectual property	74
Well-balanced and engaging level design	The users need XR games with well-balanced and engaging level design (in order to convey information seamlessly and get diverse experiences across different stages)	level detailed, level level level, level level, level control, level show, art level, level content, take level level, level last level, level simple	73
Playability for diverse conditions	The users need XR games that accommodate diverse user conditions and characteristics (in order to get positive feelings such as achievement and satisfaction through their game play)	enjoying, sadly, disagree, bad, improve, sadly upset, higher level, level, bad bad, annoying	42
Play based on preferences	The users need XR games with the ability to play the game in a way that aligns with their preferences (in order to get a customized game play)	favor pick, favor, proud need, normal need, need, pick, unfortunately, care think, ability, care	33

Table A.9
Domain-specific topic model of XR headsets.

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Wearability	The users need good wearability (in order to enhance their overall comfort during usage)	enjoy using, system enjoy, performance, responsive, seamless, budget, hardware, advancement, design, improved	15,046
Reliable game launching	The users need XR headsets with a reliable launch system to start the game (in order to start the game without needing frequent restarts)	factory reset, hard reset, reset, restart, troubleshooting, factory, returning, issue issue, ended returning, boot	3128
High graphic quality	The users need XR headsets with improved graphical performance (in order to have a more immersive experience in XR environments)	graphic performance, lighter graphic, graphic improvement, performance graphic, graphic improved, improved graphic, graphic smoother, graphic smooth, graphic heavy, graphic run smooth	1387
Adjustable headstrap for a proper fit	The users need XR headsets with adjustable and universally comfortable designs, such as customizable head straps (in order to accommodate different head shapes)	easy use comfortable, use comfortable, comfortable easy use, default comfortable, find comfortable, need comfortable, comfort comfortable, issue comfortable, uncomfortable comfortable, comfortable	1320
Long battery life	The users need XR headsets with a long battery life (in order to get consistent performance over time)	battery longer, battery quickly, battery last longer, longer battery, battery battery last, battery fast, battery last, battery longer battery, fast battery, battery easy	1248
Ease of initial setup	The users need XR headsets that are easy to set up and use (in order to start interaction immediately with minimal effort)	easy setup use, setup easy use, easy use setup, easy setup easy, use easy setup, easy setup, setup easy, setup fairly easy, easy easy use, easy use easy	701
High storage performance	The users need XR headsets with sufficient storage capacities (in order to store a large library of application without running out of space)	storage gb, gb storage, gb gb storage, gb storage capacity, memory gb, storage option, storage, storage space, gb use, gb memory	675
Fast connectivity	The users need XR headsets with fast wireless connectivity (in order to enable smooth usage and low-latency performance)	wi fi, connect wirelessly, use wirelessly, wirelessly, using wirelessly, connected wirelessly, wirelessly work, work wirelessly, connectivity, connection use	674
Simplification of account requirements	The users need flexible account requirements, avoiding mandatory integration with specific social media accounts (in order to get autonomy and preserve access to their data)	use account, use account use, account use, need account use, requires account, requiring account, account need, account requirement, require account, account required	356
Minimal motion sickness	The users need XR headsets which do not cause any kind of sickness (in order to use the device comfortably)	sickness using, sickness easily, sickness issue, sickness use, sickness take, sickness dizzy, sickness sick, sickness work, sickness system, careful sickness	343
Robust casting capabilities	The users need XR headsets with robust casting capabilities (in order to enhance accessibility across different platforms)	casting, connect cast, casting feature, option cast, using casting, cast record, capability cast, cast, using dish, dish	254
Accommodation for prescription glasses	The users need XR headsets with adaptable designs that fit prescription glasses (in order to adjust it to suit their physical conditions)	prescription adapter, prescription using, prescription, prescription easy, sighted, eye setting, use fit, uncomfortable fit, fit technology, using fit	252
Easy-to-operate XR headsets	The users need XR headsets that are easy to control (in order to enhance convenience)	control user friendly, easy use control, control user, control easy, easy control, user friendly system, control use, use control, supervision, manage control	200
Immersive experience	The users need XR headsets that offer a transformative experience (in order to enhance their enjoyment and sense of exploration)	take dimension, changing, dimension, enjoy different, take different, transported different, transformed, stepping, different bring, change	175
Facial guard designed to reduce sweat	The users need XR headsets with facial guards designed to reduce sweat (in order to enhance hygiene and prevent failure from sweat)	faceguard, sweat option, sweating, facial mask, sweat prone, sweat, weight mask, mask, hold odor sweat, working sweat	118
Faster load time	The users need to get immediate and smooth responses to controls (in order to interact quickly)	smooth performance, comfortable faster, performance stunning, responsiveness, comfortable control, easy use comfortable, changing technology, sync, use comfortable, faster load	84
Fast learning curve	The users need XR headsets that are easy to learn (in order to efficiently learn how to use the system and save time and effort)	putting, learned use, learned, hold, hard, hardly, gotten hard, set, waiting use, rest	80
Immediately attention-grabbing design	The users need XR headsets that instantly grab their attention (in order to fully enjoy the content on the device)	fast, fast easy, span, describe, set fast, attention, easy, short, spent, save	46
Easy to navigate	The users need XR headsets that are easy to navigate (in order to understand intuitively and efficiently)	easy navigate easy, easy navigate, easy navigate use, easy use navigate, navigate easy, use easy navigate, setup easy navigate, hard navigate, navigate, navigate use	25

Table A.10
Domain-specific topic model of social XR platforms.

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
Improved security and safety	The users need social XR platforms with improved security features and community management (in order to safely enjoy it)	stop user, content, security, friendly, security update, improve, safe, join, ruining, learn	28,105
Mental health support and psychological safety	The users need social XR platforms with a psychologically supportive and relaxing environment (in order to improve mental well-being and reduce anxiety)	mental, psychological, relax, depressed, cured, risk, mind, join, suffer, lose	12,644
Fast learning curve	The users need social XR platforms that are easy to learn (in order to efficiently learn how to use the system and save time and effort)	learn easy, fast difficulty easy, progress level need, fast difficulty, level need, necessary progress level, depends, difficulty easy easy, difficulty easy, easy easy learn	1368
Safety platform environment	The users need social XR platforms environment with safer community (in order to reduce exposure to disruptive behaviors)	unsafe, unsafe need, insecure need, yelling swearing, shouting, act, reason graphic, sibling, scream, yelling	1263
Immersive experience	The users need diverse and interactive features (in order to easily understand and enjoy dynamic social interactions)	interesting interactive, interactive interesting, interactive interesting interesting, least interesting, interesting least, interesting	868

(*continued on next page*)

Table A.10 (*continued*)

Domain-specific user needs naming	Domain-specific user needs (Domain-specific intended outcome)	Keywords (by BERTopic)	Count
		interesting interesting, choose interesting, interesting visit, random interesting, interesting interesting	
Engaging content	The users need social XR platforms with engaging content (in order to stay and enjoy the experience)	came stayed, stayed, came ended, thought leaving, random disappointed, disappointed stop, stay, came disappointed, cause stay, respect stop	727
Easy login processes	The users need social XR platforms with seamless login processes (in order to access their accounts without encountering repeated errors or unnecessary verification step)	login work, account login, login, use login, work login, failed, account account, reset, issue fixed, log account	680
Balance between virtual and real-world interaction	The users need social XR platforms with features that encourage real world interaction (in order to balance virtual experiences with a sense of connection to the physical world)	touch whit, touch, touch touch, touching touch, need touch, touch touching, touched touch, touch disgusting, touch friendly, disgusting touch	662
Minimizing of lag	The users need social XR platforms without any kind of lag (in order to interact quickly)	dislike lag, lag including, lag need, lag frustrating, lag, lag lag, lag using, fix lag, lag enjoy, handle lag	498
User-friendly onboarding	The users need social XR platforms with user-friendly onboarding (in order to adapt quickly in the early stages)	account, join, decided account, join brought, hosted, spend, later involved, spend found, lose need, borrow	346
Stable environment	The users need social XR platforms with stable updates (in order to continue using the platform without disruptions)	stay use update, unplayable update, removed unplayable, update lose, gone update, reinstalling, join gone, update stable, disappointed update	116
Stability of basic features such as uninstallation	The users need social XR platforms with a seamless uninstall feature (in order to easily remove it when desired)	uninstall button, uninstall button helpful, uninstall button work, pressed uninstall button, uninstall button looked, feature uninstall button, touch uninstall button, pressed uninstall, easy uninstall	110
System optimization	The users need social XR platforms with a highly optimized system (in order to use the system smoothly without issues)	system optimized, optimized, optimize, optimize optimize, optimized optimized, optimized system, setting optimized, optimize, optimized need, work optimized	86
Full-body tracking system	The users need social XR platforms with full-body tracking (in order to enhance engagement and make interaction more enjoyable)	strapped, setting, setup, experiencing, attention imagine, use, change attention, normal, symptom, confirm	85
Diverse content	The users need social XR platforms with diverse content (in order to achieve the purpose of interacting with others and exploring the content)	multiverse, content, user content, content hanging, trust interesting interesting, functioning, exists, interesting, trust interesting, busy	77
Compatibility	The users need social XR platforms with broader platform compatibility (in order to access and enjoy the game on a wider range of devices)	supported, wish compatible, available easy, supported cause, wish available, compatible, user flat, available user, cause issue, platform	64
Stable and meaningful updates	The users need updates that prioritize stability (in order to avoid disruptions and issues)	experiencing lag, frame stutter, low frame issue, update performance issue, unplayable, improve frame, frame dropping, adding unplayable, install unplayable, freeze frame	47
Creative modeling and customization	The users need social XR platforms that lower the barrier to entry by providing user-friendly tools and intuitive settings (in order to ensure intuitive understanding when creating and enjoying custom content)	modeler, creative modeling, modeling, custom creative, need upload, uploading, upload, custom, uploading take, upload edit	25

Appendix B. The result of communal topic model

Table B.1
Communal topic model by HDBSCAN.

Topic Number	Keywords (by BERTopic)	Count
H0	performance performance, performance, processor, ram, gb ram, lightweight, lightweight easy, fast reliable, responsive, efficient	21,525
H1	prevent, hacker, banning, security, care, implemented, cause, rid, stop, negative	16,762
H2	reinstall, need update, updating, update update, update work, unable, update updated, reinstalling, last update, restart	12,415
H3	account login, account hacked, login account, login login, login, logged account, log account, recover account, hacked, account log	10,648
H4	comfortable, fitting, uncomfortable, different sized, cover, comfort, different tip, discomfort, shape, cushion	8070
H5	address bar, navigation bar, menu, navigation, navigate, disable, default, ui, button, bar	6475
H6	enjoying enjoying, enjoying, enjoys, hardware, performance, feature, comfortable, technology, graphic, curious	5188
H7	enjoy custom, custom easy, level custom, custom content, custom, custom level, official custom, need custom, custom available, use custom	3073
H8	control, remote, use remote, shift, adjustable, different, easier, use, adjust, button	2810
H9	charge last, charging last, charge charging, charging, charge charge, charging charge, charging charging, charged charging, charge charge charging, last charging	2570
H10	connect disconnect, disconnect reconnect, reconnect, disconnecting, use disconnect, disconnect use, disconnect, connecting, use connect, connect	1813
H11	fast responsive, responsive, performance, storage, storage sd, expandable storage, ram, charge quickly, memory, fast easy use	1778
H12	reliable easy use, easy use reliable, durable, lightweight reliable, sd easy use, lightweight durable, fast reliable, proof feature, reliable fast reliable, reliable easy	383
H13	different level easy, learn process, enjoyment need, level easy, learning different use, learning minor, coming learning, feature enjoys, enjoys, different level	211
H14	easy setup use, setup easy use, easy use setup, easy setup easy, use easy setup, work easy setup, easy setup, use setup easy, setup easy, easy use easy	202

Table B.2
Communal topic model by K-means clustering.

Topic Number	Keywords (by BERTopic)	Count
K0	security update, hacker, banning, security, banned, safe, cause, care, negative, disabled	58,869
K1	fix issue, reinstall, bug, updating, update update, uninstall, unable, last update, downloaded, crashing	31,772
K2	useful, insightful, helpful, content, informative, helping, creative, capability, use, intelligent	29,100
K3	fast easy use, easy use fast, performance performance, performance, easy use, easy use easy, use easy use, fast reliable, use easy, use fast	19,851
K4	comfortable, uncomfortable, comfort, adjustable, worn, fitting, adjusting, adjust, comfortably, cushion	16,494
K5	account login, login account, login login, account logged, logged account, login, log account, logging account, use account, issue account	8947
K6	navigation bar, address bar, bar button, navigation, navigate, menu, bar bar, bar, bug, theme	7844
K7	custom content, easy custom, custom, level custom, custom easy, use custom, custom level, need custom, custom use, custom need	4979
K8	charge last, charging last, charging, charge issue, issue charging, last charging, charge charging, charging use, charging charging, charge keep	4759
K9	connecting, connect, reconnect, connection, reinstall, setting, reset, enable, unable, sync	3957
K10	system enjoy, enjoy system, entertain, enjoys, control, keep active, moving enjoy, enjoying, interactive, hard spend	3778
K11	performance, performance performance, fast responsive, performance feature, fast performance, fast charging, feature performance, responsive, memory, storage	2997
K12	pink set, rose gold color, pink, different color, pink color, rose gold, color, black, green, last set	2839
K13	learn use, easy use, feature use, know tech, ui, functionality, useful, use feature, easy navigate, tutorial	1893
K14	lightweight easy use, easy use lightweight, performance easy use, lightweight easy, easy use carry, use lightweight easy, fast easy use, carry easy use, easy use fast, easy use need	1571

Data availability

Data will be made available on request.

References

Abdelrazek, A., Eid, Y., Gawish, E., Medhat, W., & Hassan, A. (2023). Topic modeling algorithms and applications: A survey. *Information Systems, 112*, Article 102131. https://doi.org/10.1016/j.is.2022.102131

Adams, A., & Cox, A. (2008). Questionnaires, in-depth interviews and focus groups. In P. Cairns, & A. L. Cox (Eds.), *Research methods for human computer interaction* (pp. 17–34). Cambridge, UK: Cambridge University Press.

Ahmetoglu, Y., Brumby, D., & Cox, A. (2024). Bridging the gap between time management research and task management app design: A study on the integration of planning fallacy mitigation strategies. In *Proceedings of the 3rd annual meeting of the symposium on human-computer interaction for work* (pp. 1–14). https://doi.org/10.1145/3663384.3663404. June.

Akhtar, Z., Siddique, K., Rattani, A., Lutfi, S. L., & Falk, T. H. (2019). Why is multimedia quality of experience assessment a challenging problem? *IEEE Access, 7*, 117897–117915. https://doi.org/10.1109/ACCESS.2019.2936470

Ali, N., & Hong, J. E. (2019). Value-oriented requirements: Eliciting domain requirements from social network services to evolve software product lines. *Applied Sciences, 9*(19), 3944. https://doi.org/10.3390/app9193944

Alnawayseh, S. E., Khan, T. A., Farooq, U., Zulfiqar, S., Khan, S., & Al-Kassem, A. H. (2023). Research challenges and future facet of cellular computing. In *2023 international conference on business analytics for technology and security (ICBATS)* (pp. 1–8). IEEE. https://doi.org/10.1109/ICBATS57792.2023.10111407. March.

Al-Shafei, M. (2024). Navigating human-chatbot interactions: An investigation into factors influencing user satisfaction and engagement. *International Journal of Human-Computer Interaction*, 1–18. https://doi.org/10.1080/10447318.2023.2301252

Apsey, C., Di Florio, A., & Stawarz, K. (2024). Developing a mood and menstrual tracking app for people with premenstrual dysphoric disorder: User-centered design study. *JMIR Formative Research, 8*(1), Article e59333. https://doi.org/10.2196/59333

Arthur, W. B. (2009). *The nature of technology: What it is and how it evolves*. New York: Free Press.

Austin, E., Makwana, S., Trabelsi, A., Largeron, C., & Zaïane, O. R. (2024). Uncovering flat and hierarchical topics by community discovery on word co-occurrence network. *Data Science and Engineering, 9*(1), 41–61. https://doi.org/10.1007/s41019-023-00239-2

Bao, Y., & Datta, A. (2014). Simultaneously discovering and quantifying risk types from textual risk disclosures. *Management Science, 60*(6), 1371–1391. https://doi.org/10.1287/mnsc.2014.1930

Bao, Y., Lei, W., Zhang, W., & Zhan, Y. (2016). QoE collaborative evaluation method based on fuzzy clustering heuristic algorithm. *SpringerPlus, 5*, 1–29. https://doi.org/10.1186/s40064-016-2459-z

Baraković, S., & Skorin-Kapov, L. (2015). Multidimensional modelling of quality of experience for mobile web browsing. *Computers in Human Behavior, 50*, 314–332. https://doi.org/10.1016/j.chb.2015.03.071

Bhowmik, A. K. (2024). Virtual and augmented reality: Human sensory-perceptual requirements and trends for immersive spatial computing experiences. *Journal of the Society for Information Display, 32*(8), 605–646. https://doi.org/10.1002/jsid.2001

Bickart, B., & Schindler, R. M. (2001). Internet forums as influential sources of consumer information. *Journal of Interactive Marketing, 15*(3), 31–40. https://doi.org/10.1002/dir.1014

Blasco-Arcas, L., Lee, H. H. M., Kastanakis, M. N., Alcañiz, M., & Reyes-Menendez, A. (2022). The role of consumer data in marketing: A research agenda. *Journal of Business Research, 146*, 436–452. https://doi.org/10.1016/j.jbusres.2022.03.054

Bol, N., Dienlin, T., Kruikemeier, S., Sax, M., Boerman, S. C., Strycharz, J., & De Vreese, C. H. (2018). Understanding the effects of personalization as a privacy calculus: Analyzing self-disclosure across health, news, and commerce contexts. *Journal of Computer-Mediated Communication, 23*(6), 370–388. https://doi.org/10.1093/jcmc/zmy020

Børøsund, E., Mirkovic, J., Clark, M. M., Ehlers, S. L., Andrykowski, M. A., Bergland, A., … Nes, L. S. (2018). A stress management app intervention for cancer survivors: Design, development, and usability testing. *JMIR Formative Research, 2*(2), Article e9954. https://doi.org/10.2196/formative.9954

Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Thousand Oaks, CA: Sage.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brinkel, J., Dako-Gyeke, P., Krämer, A., May, J., & Fobil, J. N. (2017). An investigation of users' attitudes, requirements and willingness to use mobile phone-based interactive voice response systems for seeking healthcare in Ghana: A qualitative study. *Public Health, 144*, 125–133. https://doi.org/10.1016/j.puhe.2016.11.017

Bu, L., Chen, C. H., Zhang, G., Liu, B., Dong, G., & Yuan, X. (2020). A hybrid intelligence approach for sustainable service innovation of smart and connected product: A case study. *Advanced Engineering Informatics, 46*, Article 101163. https://doi.org/10.1016/j.aei.2020.101163

Calvillo-Gámez, E. H., Cairns, P., & Cox, A. L. (2015). Assessing the core elements of the gaming experience. In *Game user experience evaluation* (pp. 37–62). Springer. https://doi.org/10.1007/978-3-319-15985-0_3.

Chan, M., Estève, D., Escriba, C., & Campo, E. (2008). A review of smart homes—Present state and future challenges. *Computer Methods and Programs in Biomedicine, 91*(1), 55–81. https://doi.org/10.1016/j.cmpb.2008.02.001

Chang, D., Gu, Z., Li, F., & Jiang, R. (2019). A user-centric smart product-service system development approach: A case study on medication management for the elderly. *Advanced Engineering Informatics, 42*, Article 100979. https://doi.org/10.1016/j.aei.2019.100979

Chao, G. (2009). Human-computer interaction: Process and principles of human-computer interface design. In *2009 international conference on computer and automation engineering* (pp. 230–233). IEEE. https://doi.org/10.1109/ICCAE.2009.23.

Cheddak, A., Ait Baha, T., Es-Saady, Y., El Hajji, M., & Baslam, M. (2024). BERTopic for enhanced idea management and topic generation in brainstorming sessions. *Information (Basel), 15*(6), Article 365. https://doi.org/10.3390/info15060365

Chen, P., & El Zarki, M. (2011). Perceptual view inconsistency: An objective evaluation framework for online game quality of experience (QoE). In *2011 10th annual workshop on network and systems support for games* (pp. 1–6). IEEE. https://doi.org/10.1109/NetGames.2011.6080978.

Chen, T., Zhang, C., Yang, J., & Cong, G. (2022). Grounded theory-based user needs mining and its impact on APP downloads: Exampled with WeChat APP. *Frontiers in Psychology, 13*, Article 875310. https://doi.org/10.3389/fpsyg.2022.875310

Chen, Y., & Xie, J. (2008). Online consumer review: Word-of-mouth as a new element of marketing communication mix. *Management Science, 54*(3), 477–491. https://doi.org/10.1287/mnsc.1070.0810

Chevalier, J. A., & Mayzlin, D. (2006). The effect of word of mouth on sales: Online book reviews. *Journal of Marketing Research, 43*(3), 345–354. https://doi.org/10.1509/jmkr.43.3.345

Chiariotti, F. (2021). A survey on 360-degree video: Coding, quality of experience and streaming. *Computer Communications, 177*, 133–155. https://doi.org/10.1016/j.comcom.2021.06.029

Choi, H. (2024). Technology-push, demand-pull and spillover from the major market demand: The case of the United States wind power market. *Technology in Society, 79*, Article 102684. https://doi.org/10.1016/j.techsoc.2024.102684

Cockton, G. (2006, October). Designing worth is worth designing. In *Proceedings of the 4th Nordic conference on human-computer interaction: Changing roles* (pp. 165–174). ACM. https://doi.org/10.1145/1182475.1182493.

Cong, Y., Yu, S., Chu, J., Su, Z., Huang, Y., & Li, F. (2023). A small sample data-driven method: User needs elicitation from online reviews in new product iteration. *Advanced Engineering Informatics, 56*, Article 101953. https://doi.org/10.1016/j.aei.2023.101953

Conti, M., Passarella, A., & Das, S. K. (2017). The Internet of People (IoP): A new wave in pervasive mobile computing. *Pervasive and Mobile Computing, 41*, 1–27. https://doi.org/10.1016/j.pmcj.2017.07.009

Dawar, S., Ghosh, S., & Nawle, S. S. (2017, May). Designing mobile applications with empathizing user experience. In *Proceedings of the 2017 CHI conference extended abstracts on human factors in computing systems* (pp. 1108–1116). ACM. https://doi.org/10.1145/3027063.3053347.

De Moor, K., Joseph, W., Ketykó, I., Tanghe, E., Deryckere, T., Martens, L., & De Marez, L. (2010). Linking users' subjective QoE evaluation to signal strength in an IEEE 802.11 b/g wireless LAN environment. *EURASIP Journal on Wireless Communications and Networking, 2010*(1), Article 541568. https://doi.org/10.1155/2010/541568

Delgosha, M. S., Hajiheydari, N., & Talafidaryani, M. (2022). Discovering IoT implications in business and management: A computational thematic analysis. *Technovation, 118*, Article 102236. https://doi.org/10.1016/j.technovation.2021.102236

Desmet, P., & Fokkinga, S. (2020). Beyond Maslow's pyramid: Introducing a typology of thirteen fundamental needs for human-centered design. *Multimodal Technologies and Interaction, 4*(3), 38. https://doi.org/10.3390/mti4030038

Du, H., Li, Z., Niyato, D., Kang, J., Xiong, Z., Huang, H., & Mao, S. (2024). Diffusion-based reinforcement learning for edge-enabled AI-generated content services. *IEEE Transactions on Mobile Computing, 23*(9), 8902–8918. https://doi.org/10.1109/TMC.2024.3356178

Feng, Y., Hong, Z., Tian, G., Li, Z., Tan, J., & Hu, H. (2018). Environmentally friendly MCDM of reliability-based product optimisation combining DEMATEL-based ANP, interval uncertainty and Vlse Kriterijumska Optimizacija Kompromisno Resenje (VIKOR). *Information Sciences, 442*, 128–144. https://doi.org/10.1016/j.ins.2018.02.038

Fizza, K., Banerjee, A., Mitra, K., Jayaraman, P. P., Ranjan, R., Patel, P., & Georgakopoulos, D. (2021). QoE in IoT: A vision, survey and future directions. *Discover Internet of Things, 1*, 1–14. https://doi.org/10.1007/s43926-021-00006-7

Gamage, D., Ghasiya, P., Bonagiri, V., Whiting, M. E., & Sasahara, K. (2022). Are deepfakes concerning? Analyzing conversations of deepfakes on Reddit and exploring societal implications. In *Proceedings of the 2022 CHI conference on human factors in computing systems* (pp. 1–19). https://doi.org/10.1145/3491102.3517446

Geng, J., & Guo, Y. L. (2022). App types, user psychological and instrumental needs, and user experience in the sharing economy: An empirical research. *Entertainment Computing, 41*, Article 100467. https://doi.org/10.1016/j.entcom.2021.100467

de Groot, M., Aliannejadi, M., & Haas, M. R. (2022). *Experiments on generalizability of BERTopic on multi-domain short text*. arXiv preprint. https://doi.org/10.48550/arXiv.2212.08459. arXiv:2212.08459.

Grootendorst, M. (2022). *BERTopic: Neural topic modeling with a class-based TF-IDF procedure*. arXiv preprint. https://doi.org/10.48550/arXiv.2203.05794. arXiv:2203.05794.

Guo, Y., Guo, S., Jin, Z., Kaul, S., Gotz, D., & Cao, N. (2021). Survey on visual analysis of event sequence data. *IEEE Transactions on Visualization and Computer Graphics, 28*(12), 5091–5112. https://doi.org/10.1109/TVCG.2021.3100413

Han, Y., & Moghaddam, M. (2021). Eliciting attribute-level user needs from online reviews with deep language models and information extraction. *Journal of Mechanical Design, 143*(6), Article 061403. https://doi.org/10.1115/1.4048819

Hao, J., Gao, X., Liu, Y., & Han, Z. (2023). Acquisition method of user requirements for complex products based on data mining. *Sustainability, 15*(9), 7566. https://doi.org/10.3390/su15097566

Hassenzahl, M. (2008). User experience (UX): Towards an experiential perspective on product quality. In *Proceedings of the 20th conference on l'Interaction homme-machine* (pp. 11–15). ACM. https://doi.org/10.1145/1512714.1512717. September.

Hassenzahl, M., Diefenbach, S., & Goritz, A. (2010). Needs, affect, and interactive products: Facets of user experience. *Interacting with Computers, 22*(5), 353–362. https://doi.org/10.1016/j.intcom.2010.04.002

Hassenzahl, M., & Tractinsky, N. (2006). User experience - A research agenda. *Behaviour & Information Technology, 25*(2), 91–97. https://doi.org/10.1080/01449290500330331

He, B., Li, F., Cao, X., & Li, T. (2020). Product sustainable design: A review from the environmental, economic, and social aspects. *Journal of Computing and Information Science in Engineering, 20*(4), Article 040801. https://doi.org/10.1115/1.4045408

Hekkert, P. (2006). Design aesthetics: Principles of pleasure in design. *Psychology Science, 48*(2), 157.

Heo, I. S., Putri, A. K., Kim, B. S., Kwon, M. S., & Kim, S. H. (2024). Analysis of quality standards for industrial collaborative robots based on user-centered design framework. *Human Factors and Ergonomics in Manufacturing & Service Industries, 34*(2), 100–117. https://doi.org/10.1002/hfm.21014

Herzberg, F. (1959). *The motivation to work*. John Wiley & Sons. https://doi.org/10.7202/1022040ar

Hiniduma, K., Byna, S., & Bez, J. L. (2025). Data readiness for AI: A 360-degree survey. *ACM Computing Surveys, 57*(9), 1–39. https://doi.org/10.1145/3722214

Hornbæk, K. (2006). Current practice in measuring usability: Challenges to usability studies and research. *International Journal of Human-Computer Studies, 64*(2), 79–102. https://doi.org/10.1016/j.ijhcs.2005.06.002

Huang, Q., Stawarz, K., Zhao, L., Yang, S., Xie, W., Song, F., & Liu, H. (2025). Applying cross-modal plasticity principles in auditory training applications. *International Journal of Human-Computer Studies, 180*, Article 103570. https://doi.org/10.1016/j.ijhcs.2025.103570

Huang, Y., Xu, M., Zhang, X., Niyato, D., Xiong, Z., Wang, S., & Huang, T. (2023). AI-generated network design: A diffusion model-based learning approach. *IEEE Network, 38*(3), 202–209. https://doi.org/10.1109/MNET.2023.3321538

Interaction Design Foundation - IxDF. (2016, June 5). What are user needs?. Interaction Design Foundation - IxDF. https://www.interaction-design.org/literature/topics/user-needs/.

Interaction Design Foundation - IxDF. (2016, June 5). What is user centered design (UCD)?. Interaction Design Foundation - IxDF. Retrieved from https://www.interaction-design.org/literature/topics/user-centered-design/.

International Organization for Standardization. (2013). *Systems and software engineering — Systems and software quality requirements and evaluation (SQuaRE) — Common industry format (CIF) for usability: User needs report, ISO/IEC 25064:2013*.

International Organization for Standardization. (2016). *Systems and software engineering — Systems and software quality requirements and evaluation (SQuaRE) — Common industry format (CIF) for usability — Evaluation report, ISO/IEC 25066:2016*.

International Organization for Standardization. (2019). *Systems and software engineering — Systems and software quality requirements and evaluation (SQuaRE) — Common industry format (CIF) for usability: User requirements specification, ISO/IEC 25065:2019*.

International Organization for Standardization. (2023). *Systems and software engineering – Systems and software quality requirements and evaluation (SQuaRE) – Product quality model, ISO/IEC 25010:2023*.

International Telecommunication Union. (2014). ITU-T G.1031: QoE factors in web-browsing (recommendation ITU-T G.1031). https://handle.itu.int/11.1002/1000/12123.

International Telecommunication Union. (2022). ITU-T G.1035: Framework of parametric quality assessment for virtual reality services (recommendation ITU-T G.1035). https://www.itu.int/rec/T-REC-G.1035-202203-I/en.

Jain, P., Gupta, V. K., Tiwari, H., Shukla, A., Pandey, P., & Gupta, A. (2023). Human-computer interaction: a systematic review. In *2023 international conference on Advanced Computing & Communication Technologies (ICACCTech)* (pp. 31–36). IEEE. https://doi.org/10.1109/ICACCTech61146.2023.00015. December.

Kalibatienė, D., Miliauskaitė, J., Slotkienė, A., & Gudas, S. (2023). On the development of the web service quality modelling space. *Expert Systems with Applications, 211*, Article 118584. https://doi.org/10.1016/j.eswa.2022.118584

Kano, N. (1984). Attractive quality and must-be quality. *Journal of the Japanese Society for Quality Control, 31*(4), 147–156. https://doi.org/10.20684/quality.14.2_147

Khalid, H. M. (2006). Embracing diversity in user needs for affective design. *Applied Ergonomics, 37*(4), 409–418. https://doi.org/10.1016/j.apergo.2006.04.005

Khalili, A., & Auer, S. (2013). User interfaces for semantic authoring of textual content: A systematic literature review. *Journal of Web Semantics, 22*, 1–18. https://doi.org/10.1016/j.websem.2013.08.004

Khamaj, A., & Ali, A. M. (2024). Adapting user experience with reinforcement learning: Personalizing interfaces based on user behavior analysis in real-time. *Alexandria Engineering Journal, 95*, 164–173. https://doi.org/10.1016/j.aej.2024.03.045

Kim, H. K., Han, S. H., Park, J., & Park, W. (2015). How user experience changes over time: A case study of social media platformss. *Human Factors and Ergonomics in Manufacturing & Service Industries, 25*(6), 659–673. https://doi.org/10.1002/hfm.20583

Kim, J., Park, S., & Kim, H. M. (2022). Analysis of dynamic changes in customer sentiment on product features after the outbreak of COVID-19 based on online reviews. *Journal of Mechanical Design, 144*(2), Article 024501. https://doi.org/10.1115/1.4052789

Kim, K. J., Shin, D. H., & Yoon, H. (2017). Information tailoring and framing in wearable health communication. *Information Processing & Management, 53*(2), 351–358. https://doi.org/10.1016/j.ipm.2016.11.005

Koniuch, K., Baraković, S., Husić, J. B., Subramanian, S., De Moor, K., Janowski, L., & Wierzchoń, M. (2024). Top-down and bottom-up approaches to video quality of experience studies: Overview and proposal of a new model. *Frontiers in Computer Science, 6*, Article 1305670. https://doi.org/10.3389/fcomp.2024.1305670

Kougioumtzidis, G., Poulkov, V., Zaharis, Z. D., & Lazaridis, P. I. (2022). A survey on multimedia services QoE assessment and machine learning-based prediction. *IEEE Access, 10*, 19507–19538. https://doi.org/10.1109/ACCESS.2022.3149592

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology* (3rd ed.). Sage Publications. https://doi.org/10.4135/9781071878781

Laghari, A. A., He, H., Khan, A., Kumar, N., & Kharel, R. (2018). Quality of experience framework for cloud computing (QoC). *IEEE Access, 6*, 64876–64890. https://doi.org/10.1109/ACCESS.2018.2865967

Le Callet, P., Möller, S., Perkis, A., Brunnström, K., Beker, S., De Moor, K., … Zgank, A. (2013). *Qualinet white paper on definitions of quality of experience*. Qualinet (www.qualinet.eu) https://hal.science/hal-04638470v1.

Lee, T. Y. (2007). Needs-based analysis of online customer reviews. In *Proceedings of the ninth international conference on electronic commerce* (pp. 311–318). https://doi.org/10.1145/1282100.1282159

Lee, W., Jung, K., Park, J., Kim, S., Yoon, S., Kim, M., & You, H. (2009). Development of a quantitative and comprehensive usability evaluation system based on user needs. In , *Vol. 53. Proceedings of the human factors and ergonomics society annual meeting* (pp. 1512–1516). SAGE Publications. No. 19. October.

Li, J., Wang, S., Rudinac, S., & Osseyran, A. (2024). High-performance computing in healthcare: An automatic literature analysis perspective. *Journal of Big Data, 11*(1), 61. https://doi.org/10.1186/s40537-024-00929-2

Lima, M. R., Horrocks, S., Daniels, S., Lamptey, M., Harrison, M., & Vaidyanathan, R. (2023). The role of conversational AI in ageing and dementia care at home: A participatory study. In *2023 32nd IEEE international conference on robot and human interactive communication (RO-MAN)* (pp. 571–578). IEEE. https://doi.org/10.1109/RO-MAN57019.2023.10309459.

Lin, C. J., & Hsieh, T. L. (2016). Exploring the design criteria of website interfaces for gender. *International Journal of Industrial Ergonomics, 53*, 306–311. https://doi.org/10.1016/j.ergon.2016.02.002

Lindblom, J., & Alenljung, B. (2020). The ANEMONE: Theoretical foundations for UX evaluation of action and intention recognition in human-robot interaction. *Sensors, 20*(15), Article 4284. https://doi.org/10.3390/s20154284

Liu, L., & Ma, B. (2024). User need prediction based on a small amount of user-generated content—A case study of the Xiaomi SU7. *World Electric Vehicle Journal, 15*(12), Article 584. https://doi.org/10.3390/wevj15120584

Liu, L., & Ma, B. (2025). CA-VAR-Markov model of user needs prediction based on user generated content. *Scientific Reports, 15*(1), 7716. https://doi.org/10.1038/s41598-025-92173-8

Liu, Y., Du, H., Niyato, D., Kang, J., Cui, S., Shen, X., & Zhang, P. (2023). Optimizing mobile-edge AI-generated everything (AIGX) services by prompt engineering: Fundamental, framework, and case study. *IEEE Network, 38*(5), 220–228. https://doi.org/10.1109/MNET.2023.3335255

Liu, Z., Li, H., Chen, A., Zhang, R., & Lee, Y. C. (2024). Understanding public perceptions of AI conversational agents: A cross-cultural analysis. In *Proceedings of the CHI conference on human factors in computing systems* (pp. 1–17). https://doi.org/10.1145/3613904.3642840

Lowndes, A. M., & Connelly, D. M. (2023). User experiences of older adults navigating an online database of community-based physical activity programs. *DIGITAL HEALTH, 9*, Article 20552076231167004. https://doi.org/10.1177/20552076231167004

Lun, L., Zetian, D., Hoe, T. W., Juan, X., Jiaxin, D., & Fulai, W. (2024). Factors influencing user intentions on interactive websites: Insights from the technology acceptance model. *IEEE Access, 12*, 122735–122756. https://doi.org/10.1109/ACCESS.2024.3437418

Luo, Y., Yang, L., Ye, Q., & Liao, Q. (2023). Effects of customization and personalization affordances on perceived value and continuance intention of smartwatch use. *Technological Forecasting and Social Change, 194*, Article 122752. https://doi.org/10.1016/j.techfore.2023.122752

Marquis, G. P. (2002). Application of traditional system design techniques to web site design. *Information and Software Technology, 44*(9), 507–512. https://doi.org/10.1016/S0950-5849(02)00050-2

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review, 50*, 370–396. https://doi.org/10.1037/h0054346

Maslow, A. H. (1954). *Motivation and personality*. New York, NY: Harper & Row Publishers.

McInnes, L., Healy, J., & Melville, J. (2018). *UMAP: Uniform manifold approximation and projection for dimension reduction*. arXiv. https://doi.org/10.48550/arXiv.1802.03426. preprint arXiv:1802.03426.

Mimno, D., Wallach, H. M., Talley, E., Leenders, M., & McCallum, A. (2011). Optimizing semantic coherence in topic models. In *Proceedings of the conference on empirical methods in natural language processing (EMNLP '11), 262–272*. Association for Computational Linguistics. https://dl.acm.org/doi/10.5555/2145432.2145462.

Nagamachi, M. (2002). Kansei engineering as a powerful consumer-oriented technology for product development. *Applied Ergonomics, 33*(3), 289–294. https://doi.org/10.1016/S0003-6870(02)00019-4

Nam, H., Kim, K. H., & Schulzrinne, H. (2016, April). QoE matters more than QoS: Why people stop watching cat videos. In *IEEE INFOCOM 2016 - the 35th annual IEEE international conference on computer communications* (pp. 1–9). IEEE. https://doi.org/10.1109/INFOCOM.2016.7524426.

Nasrabadi, M. A., Beauregard, Y., & Ekhlassi, A. (2024). The implication of user-generated content in new product development process: A systematic literature review and future research agenda. *Technological Forecasting and Social Change, 206*, Article 123551. https://doi.org/10.1016/j.techfore.2024.123551

Nguyen, H. N., Lasa, G., Iriarte, I., Atxa, A., Unamuno, G., & Galfarsoro, G. (2022). Human-centered design for advanced services: A multidimensional design methodology. *Advanced Engineering Informatics, 53*, Article 101720. https://doi.org/10.1016/j.aei.2022.101720

Nielsen Norman Group. (2019). User need statements. https://www.nngroup.com/articles/user-need-statements/ Accessed May, 2025.

Norman, D., & Spencer, E. (2019, January 3). Community-based, human-centered design. jnd.org https://jnd.org/community-based-human-centered-design/ Accessed May, 2025.

Norman, D. A. (2005). Human-centered design considered harmful. *Interactions, 12*(4), 14–19. https://doi.org/10.1145/1070960.1070976

Oh, Y. K., Yi, J., & Kim, J. (2023). What enhances or worsens the user-generated metaverse experience? An application of BERTopic to Roblox user eWOM. *Internet Research*. https://doi.org/10.1108/INTR-03-2022-0178

Oinas-Kukkonen, H., Pohjolainen, S., & Agyei, E. (2022). Mitigating issues with/of/for true personalization. *Frontiers in Artificial Intelligence, 5*, Article 844817. https://doi.org/10.3389/frai.2022.844817

Pan, H., Ding, P., Wang, F., Li, T., Zhao, L., Nan, W., Fu, Y., & Gong, A. (2024). Comprehensive evaluation methods for translating BCI into practical applications: Usability, user satisfaction and usage of online BCI systems. *Frontiers in Human Neuroscience, 18*, Article 1429130. https://doi.org/10.3389/fnhum.2024.1429130

Papadia, G., Pacella, M., Perrone, M., & Giliberti, V. (2023). A comparison of different topic modeling methods through a real case study of Italian customer care. *Algorithms, 16*(2), 94. https://doi.org/10.3390/a16020094

Park, E., Baek, S., Ohm, J., & Chang, H. J. (2014). Determinants of player acceptance of mobile social network games: An application of extended technology acceptance model. *Telematics and Informatics, 31*(1), 3–15. https://doi.org/10.1016/j.tele.2013.07.001

Partala, T., & Kallinen, A. (2012). Understanding the most satisfying and unsatisfying user experiences: Emotions, psychological needs, and context. *Interacting with Computers, 24*(1), 25–34. https://doi.org/10.1016/j.intcom.2011.10.001

Pei, H., Xu, M., Liu, X., Gong, H., Li, G., & Bai, Z. (2025). A user demand acquisition method for cloud services based on user sentiment analysis and long- and short-term preferences. *Advanced Engineering Informatics, 65*, Article 103122. https://doi.org/10.1016/j.aei.2025.103122

Peters, D., Calvo, R. A., & Ryan, R. M. (2018). Designing for motivation, engagement and wellbeing in digital experience. *Frontiers in Psychology, 9*, Article 300159. https://doi.org/10.3389/fpsyg.2018.00797

Pimpinella, A., Repossi, M., & Redondi, A. E. (2022). Unsatisfied today, satisfied tomorrow: A simulation framework for performance evaluation of crowdsourcing-based network monitoring. *Computer Communications, 182*, 184–197. https://doi.org/10.1016/j.comcom.2021.11.004

Pornpongtechavanich, P., & Daengsi, T. (2019). Video telephony-quality of experience: A simple QoE model to assess video calls using subjective approach. *Multimedia Tools and Applications, 78*, 31987–32006. https://doi.org/10.1007/s11042-019-07928-z

Querbes, A., & Frenken, K. (2017). Evolving user needs and late-mover advantage. *Strategic Organization, 15*(1), 67–90. https://doi.org/10.1177/1476127016648498

Quiñones, D., Ojeda, C., Herrera, R. F., & Rojas, L. F. (2024). UXH-GEDAPP: A set of user experience heuristics for evaluating generative design applications. *Information and Software Technology, 168*, Article 107408. https://doi.org/10.1016/j.infsof.2024.107408

Raita, E., & Oulasvirta, A. (2014, October). Mixed feelings? The relationship between perceived usability and user experience in the wild. In *Proceedings of the 8th Nordic conference on human-computer interaction: Fun, fast, foundational* (pp. 1–10). ACM. https://doi.org/10.1145/2639189.2639207.

Rathore, A. K., Ilavarasan, P. V., & Dwivedi, Y. K. (2016). Social media content and product co-creation: An emerging paradigm. *Journal of Enterprise Information Management, 29*(1), 7–18. https://doi.org/10.1108/JEIM-06-2015-0047

Ravichandar, R., Arthur, J. D., & Bohner, S. A. (2007). Capabilities engineering: Constructing change-tolerant systems. In *, Vol. HICSS'07. 2007 40th Annual Hawaii international conference on system sciences* (p. 278b). IEEE. https://doi.org/10.1109/HICSS.2007.121.

Reichl, P., Egger, S., Möller, S., Kilkki, K., Fiedler, M., Hoßfeld, T., … Asrese, A. (2015). Towards a comprehensive framework for QoE and user behavior modelling. In *2015 seventh international workshop on quality of multimedia experience (QoMEX)* (pp. 1–6). IEEE. https://doi.org/10.1109/QoMEX.2015.7148138. May.

Renaud, J., Houssin, R., Gardoni, M., & Armaghan, N. (2019). Product manual elaboration in product design phases: Behavioral and functional analysis based on user experience. *International Journal of Industrial Ergonomics, 71*, 75–83. https://doi.org/10.1016/j.ergon.2019.02.003

Röder, M., Both, A., & Hinneburg, A. (2015). Exploring the space of topic coherence measures. In *Proceedings of the 8th ACM international conference on web search and data mining (WSDM '15)* (pp. 399–408). ACM. https://doi.org/10.1145/2684822.2685324.

Sarikaya, R. (2017). The technology behind personal digital assistants: An overview of the system architecture and key components. *IEEE Signal Processing Magazine, 34*(1), 67–81. https://doi.org/10.1109/MSP.2016.2617341

Saunders, M. N., Seepersad, C. C., & Hölttä-Otto, K. (2011). The characteristics of innovative, mechanical products. *Journal of Mechanical Design, 133*(2), Article 021009. https://doi.org/10.1115/1.4003409

Schmiedel, T., Müller, O., & Vom Brocke, J. (2019). Topic modeling as a strategy of inquiry in organizational research: A tutorial with an application example on organizational culture. *Organizational Research Methods, 22*(4), 941–968. https://doi.org/10.1177/1094428118773858

Seo, H., Joo, H., Tak, B., & Suh, Y. K. (2025, March). HARIN: A novel metric for hierarchical topic model assessment. In *Proceedings of the 40th ACM/SIGAPP symposium on applied computing* (pp. 1907–1916). ACM. https://doi.org/10.1145/3672608.3707837.

Seufert, A., Schröder, S., & Seufert, M. (2021). Delivering user experience over networks: Towards a quality of experience centered design cycle for improved design of networked applications. *SN Computer Science, 2*, 1–18. https://doi.org/10.1007/s42979-021-00851-x

Shahid Anwar, M., Wang, J., Ahmad, S., Ullah, A., Khan, W., & Fei, Z. (2020). Evaluating the factors affecting QoE of 360-degree videos and cybersickness levels predictions in virtual reality. *Electronics, 9*(9), 1530. https://doi.org/10.3390/electronics9091530

Shin, D. H. (2017). Conceptualizing and measuring quality of experience of the internet of things: Exploring how quality is perceived by users. *Information & Management, 54*(8), 998–1011. https://doi.org/10.1016/j.im.2017.02.006

Silberer, J., Astfalk, S., Planing, P., & Müller, P. (2023). User needs over time: The market and technology maturity model (MTMM). *Journal of Innovation and Entrepreneurship, 12*(1), 39. https://doi.org/10.1186/s13731-023-00302-2

Silva, C. C., Galster, M., & Gilson, F. (2021). Topic modeling in software engineering research. *Empirical Software Engineering, 26*(6), Article 120. https://doi.org/10.1007/s10664-021-10026-0

Silva, F. S. D., Lima, M. P., Corujo, D., Neto, A. J., & Esposito, F. (2024). A comprehensive step-wise survey of multiple attribute decision-making mobility approaches. *IEEE Access*. https://doi.org/10.1109/ACCESS.2024.3436074

Sim, Y., Chung, T. S., & Park, I. (2025). Analyzing cross-platform gaming experiences using topic modeling. *Entertainment Computing, 54*, Article 100946. https://doi.org/10.1016/j.entcom.2025.100946

Skorin-Kapov, L., & Varela, M. (2012, May). A multi-dimensional view of QoE: The ARCU model. In *2012 proceedings of the 35th international convention MIPRO* (pp. 662–666). IEEE.

Spinuzzi, C. (2005). The methodology of participatory design. *Technical Communication, 52*(2), 163–174.

Sreejith, R., & Sinimole, K. R. (2024). User-centric evaluation of EHR software through NLP-driven investigation: Implications for product development and user experience. *Journal of Open Innovation: Technology, Market, and Complexity, 10*(1), Article 100206. https://doi.org/10.1016/j.joitmc.2023.100206

Suznjevic, M., Skorin-Kapov, L., Cerekovic, A., & Matijasevic, M. (2019). How to measure and model QoE for networked games? A case study of world of warcraft. *Multimedia Systems, 25*, 395–420. https://doi.org/10.1007/s00530-019-00615-x

Szabó, B., & Hercegfi, K. (2023). User-centered approaches in software development processes: Qualitative research into the practice of Hungarian companies. *Journal of Software: Evolution and Process, 35*(2), Article e2501. https://doi.org/10.1002/smr.2501

Tan, Z., & D'Souza, J. (2025). Bridging the evaluation gap: Leveraging large language models for topic model evaluation. arXiv. 10.48550/arXiv.2502.07352. preprint arXiv:2502.07352.

Tang, Z., Pan, X., & Gu, Z. (2024). Analyzing public demands on China's online government inquiry platform: A BERTopic-based topic modeling study. *PLoS One, 19*(2), Article e0296855. https://doi.org/10.1371/journal.pone.0296855

Taylor, T. E. (2024). Users and technology: A closer look at how technology engagement affects users. *Computers in Human Behavior Reports, 15*, Article 100473. https://doi.org/10.1016/j.chbr.2024.100473

Ten Klooster, I., Wentzel, J., Sieverink, F., Linssen, G., Wesselink, R., & van Gemert-Pijnen, L. (2022). Personas for better targeted eHealth technologies: User-centered design approach. *JMIR Human Factors, 9*(1), Article e24172. https://doi.org/10.2196/24172

Thielke, S., Harniss, M., Thompson, H., Patel, S., Demiris, G., & Johnson, K. (2012). Maslow's hierarchy of human needs and the adoption of health-related technologies for older adults. *Ageing International, 37*, 470–488. https://doi.org/10.1007/s12126-011-9121-4

Timoshenko, A., & Hauser, J. R. (2019). Identifying customer needs from user-generated content. *Marketing Science, 38*, 1–20. https://doi.org/10.1287/mksc.2018.1123

Tuch, A. N., & Hornbæk, K. (2015). Does Herzberg's notion of hygienes and motivators apply to user experience? *ACM Transactions on Computer-Human Interaction, 22*(4), 1–24. https://doi.org/10.1145/2724710

Ulrich, K. T., & Eppinger, S. D. (2015). *Product design and development* (6th ed.). McGraw Hill.

Vayansky, I., & Kumar, S. A. (2020). A review of topic modeling methods. *Information Systems, 94*, Article 101582. https://doi.org/10.1016/j.is.2020.101582

Veling, L., & Villing, R. (2024). Assistive robotics needs for older care: Using authentic citations to bridge the gap between understanding older persons' needs and defining solutions. *International Journal of Social Robotics, 16*(4), 775–790. https://doi.org/10.1007/s12369-024-01118-0

Walker, G. H., Stanton, N. A., Jenkins, D. P., & Salmon, P. M. (2009). From telephones to iPhones: Applying systems thinking to networked, interoperable products. *Applied Ergonomics, 40*(2), 206–215.

Walter, A. (2011). *Designing for emotion* (Vol. 9). A Book Apart.

Wang, T., Wang, W., Feng, J., Fan, X., Guo, J., & Lei, J. (2024). A novel user-generated content-driven and Kano model focused framework to explore the impact mechanism of continuance intention to use mobile APPs. *Computers in Human Behavior, 157*, Article 108252. https://doi.org/10.1016/j.chb.2024.108252

Wang, X., Liu, A., & Kara, S. (2022a). Machine learning for engineering design toward smart customization: A systematic review. *Journal of Manufacturing Systems, 65*, 391–405. https://doi.org/10.1016/j.jmsy.2022.10.001

Wang, Z., Zheng, P., Li, X., & Chen, C. H. (2022b). Implications of data-driven product design: From information age towards intelligence age. *Advanced Engineering Informatics, 54*, Article 101793. https://doi.org/10.1016/j.aei.2022.101793

Wiklund-Engblom, A., Hassenzahl, M., Bengs, A., & Sperring, S. (2009). What needs tell us about user experience. In *IFIP conference on human-computer interaction* (pp. 666–669). Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-642-03658-3_71. August.

Witteman, H. O., Dansokho, S. C., Colquhoun, H., Coulter, A., Dugas, M., Fagerlin, A., & Witteman, W. (2015). User-centered design and the development of patient decision aids: Protocol for a systematic review. *Systematic Reviews, 4*, 1–8. https://doi.org/10.1186/2046-4053-4-11

Wu, W., Arefin, A., Rivas, R., Nahrstedt, K., Sheppard, R., & Yang, Z. (2009). Quality of experience in distributed interactive multimedia environments: Toward a theoretical framework. In *Proceedings of the 17th ACM international conference on multimedia* (pp. 481–490). https://doi.org/10.1145/1631272.1631338. October.

Wu, X., Nguyen, T., & Luu, A. T. (2024). A survey on neural topic models: Methods, applications, and challenges. *Artificial Intelligence Review, 57*(2), 18. https://doi.org/10.1007/s10462-023-10661-7

Xu, W. (2014). Enhanced ergonomics approaches for product design: A user experience ecosystem perspective and case studies. *Ergonomics, 57*(1), 34–51. https://doi.org/10.1080/00140139.2013.861023

Xu, Z., & Zhang, A. (2019). Network traffic type-based quality of experience (QoE) assessment for universal services. *Applied Sciences, 9*(19), 4107. https://doi.org/10.3390/app9194107

Xuan, Y., Zhang, L., Bao, H., & Hu, J. (2024). How to obtain product green design requirements based on sentiment analysis and topic analysis: Using washing machine online reviews as an example. *Journal of Environmental Management, 365*, Article 121454. https://doi.org/10.1016/j.jenvman.2024.121454

Yang, J., Jang, H., & Yu, K. (2023). Analyzing geographic questions using embedding-based topic modeling. *ISPRS International Journal of Geo-Information, 12*(2), 52. https://doi.org/10.3390/ijgi12020052

Yang, M., Wang, S., Calheiros, R. N., & Yang, F. (2018). Survey on QoE assessment approach for network service. *IEEE Access, 6*, 48374–48390. https://doi.org/10.1109/ACCESS.2018.2867253

Yau, C. K., Porter, A., Newman, N., & Suominen, A. (2014). Clustering scientific documents with topic modeling. *Scientometrics, 100*(3), 767–786. https://doi.org/10.1007/s11192-014-1321-8

Yi, X., Liu, Z., Li, H., & Jiang, B. (2024). Immersive experiences in museums for elderly with cognitive disorders: A user-centered design approach. *Scientific Reports, 14*(1), 1971. https://doi.org/10.1038/s41598-024-51929-4

Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent manufacturing in the context of industry 4.0: A review. *Engineering, 3*(5), 616–630. https://doi.org/10.1016/J.ENG.2017.05.015

Zhou, X., Bu, J., Zhou, S., Yu, Z., Zhao, J., & Yan, X. (2023). Improving topic disentanglement via contrastive learning. *Information Processing & Management, 60*(2), Article 103164. https://doi.org/10.1016/j.ipm.2022.103164