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## Cover Page Footnote

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# Antecedents of User Experience in the Immersive Metaverse Ecosystem: Insights from Mining User Reviews

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**Abstract:**

Metaverse, a digitally simulated immersive technology, has potential business value in enabling its users to execute their professional and recreational activities. It engages the users and helps them to serve their purposes. Few studies exist discussing metaverse as an immersive technology though there is a dearth of studies that empirically examine the factors associated with the corresponding user experience. We analysed over 400 thousand user reviews on 14 metaverse applications from Google Play Store to identify those factors associated with the corresponding user experience. We uncovered the pertinent factors with the help of a topic modelling technique and explained their associations with the help of Cognitive Load Theory (CLT) and Cognitive Absorption Theory (CAT) crafting a unified framework. Multiple regression models help us to validate the proposed framework. We find that sociability, density, telepresence, temporal dissociation, focused immersion, heightened enjoyment, curiosity, and playfulness positively influence the user experience of the virtual immersive space of the Metaverse. These insights can help policymakers and academicians take apt measures to make the Metaverse space more immersive and engrossing.

**Keywords:** Metaverse, Immersive Technology, Virtual Ecosystem, Cognitive Load Theory, Cognitive Absorption Theory, User Experience, Big Data Analytics.

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# 1 Introduction

Recent technological advancements blur the demarcation of physical and digital environment, leading to a hybrid "phygital" system (von der Au et al., 2023). A phygital system facilitates the interaction of users and digital systems, leading to higher levels of user engagement (John et al., 2022; Xu et al., 2024). Metaverse, a web 3.0 virtual technology (Belk et al., 2022), enhances that ecosystem resulting in a social virtual reality (VR) (Suh, 2024). The socio-technical platform of Metaverse enables users to interact with virtual objects in the immersive three-dimensional (3D) virtual platform with the help of head-mounted displays (Singla et al., 2022; Suh, 2024). In comparison to augmented reality (AR) platforms that can only generate an imaginary space, the VR platform overlays physical reality into the virtual. Thus, an immersive experience can be more effectively leveraged in a VR platform in comparison to an AR platform (Belk, 2024). Immersive virtual platforms may enable users to execute many professional and recreational activities. Users can immerse themselves in various activities, resulting in a lively, intense, and engrossing experience (Mandolfo et al., 2023; Suh, 2024). The current user base of the metaverse exceeds 400 million individuals on a monthly basis, with a global market projection of $1.5 trillion by the year 2030 (BYBIT, 2023). The Metaverse market is expected to reach $800 billion by 2024 (Yoo et al., 2023).

Such immersion and engagement lead to cognitive absorption into the virtual space (Mandolfo et al., 2023). Users can perceive their physical presence in the virtual platform by interacting with live actors in the ecosystem (Park et al., 2023). The live participants in the virtual platform interact with each other via their representative avatars, as if they are interacting in real life. The Metaverse virtual platform enables users to collaborate and co-create, which further bolsters their social presence in the ecosystem (Barrera & Shah, 2023). The immersion thus draws the user's attention and vivifies their experience throughout the user's journey in the virtual session (Chen & Yao, 2022). This subjective experience with the virtual technology has been considered as flow (Agarwal & Karahanna, 2000), stemming from the fulfilment of the pertinent purposes and actions (Thomas et al., 2023). Therefore, the subjective experience is situational, depending on the circumstances and participants in the VR platform. People can encounter new experiences or re-experience an older situation contingent upon the complex interplay of the current users' action sets and the present virtual environment at the time he/she is using (Agarwal & Karahanna, 2000).

The environmental stimulus in the context of the virtual platform encompasses a combination of factors such as the ambiance of the store, technical characteristics, and situational details (Yoo et al., 2023). Prior research on the Metaverse has employed technology cues, such as visual displays, movement tracking, and interactivity, as well as content-based stimuli, such as virtual journeys and gaming (Elodie et al., 2023; Thomas et al., 2023; Xu et al., 2024) to elicit psychological and behavioural reactions. It is believed that the major purpose of virtual experiences is to seek to engage people to interact with and mimic the environment virtually (Kakaria et al., 2023). The ability to combine and record any type of information on the working environment in a spatially meaningful way allows the Metaverse to be a more effective medium for information display (Biocca et al., 2007). Visual representation using animation, photos, and words helps to minimize the complexity of the virtual environment and absorb contextual knowledge (He & Wu, 2023). Seamlessly incorporating information objects like labels, overlays, 3D objects, and other relevant data onto activities and locations enhances navigation. The computer-mediated virtual realm, designed to be user-friendly, improves task performance and decreases cognitive effort (Biocca et al., 2007).

Existing literature has investigated the influence of the digital personae on user's confidence (Elodie et al., 2023; Kar & Varsha, 2023). Zuo and Shen (2024) proposed a model indicating how various utilitarian and hedonic affordances fulfil the users' needs. Few studies have also discussed how the users' presence and their interaction with digital objects and other members facilitated by the Metaverse virtual ecosystem can influence their experience (Ahn et al., 2023; Barta et al., 2023; Hennig-Thurau et al., 2023; Puntoni, 2024). Barnes and Pressey (2014) have empirically ascertained how various cognitive absorption factors influence user experience. However, none of these studies have addressed the virtual platform orientation factors along with the cognitive absorption of the users stemming from their multiple visits to the Metaverse platforms.

Therefore, to address the gap, our study has resorted to the cognitive load theory (CLT) and cognitive absorption theory (CAT) to gain a comprehensive view of the Metaverse platform, a virtual immersive socio-technical ecosystem, and the nuances of the platform influencing user experience. Following the guidelines of the design science principles, the current investigation has undertaken a big-data driven theory building approach, founded on CLT and CAT. As per design science research, the study should be founded on

appropriate theory and methodology, apt to address the research objectives (Peffers et al., 2007). Semblance and interplay among various research components help the current investigation in fulfilling its proposed agenda (Dincelli & Chengalur-Smith, 2020; Iivari, 2007). Data collection and research design should supplement the research procedure and thus the insights resulting from the analysis have to focus on the aim of the investigation. CLT explains how the design and organization of the virtual platform eases the usage and reduces the cognitive load to accomplish a task (Biocca et al., 2007). CAT sheds light on the intrinsic flow factors resulting from the usage of the platforms (Agarwal & Karahanna, 2000). Therefore, CLT is complemented by CAT, as the intrinsic hedonic factors are captured alongside the metaverse interface-related features. This current work has leveraged the user reviews on various mobile metaverse platforms from public app stores to craft a unique big data-driven model in line with Agrawal et al. (2022). Extant studies have highlighted the usefulness of big data modelling in drawing insights on virtual ecosystems (Ivanov, 2023).

To fulfill the proposed objective, we frame two research questions (RQs). The first RQ answers the "what" aspect (i.e., what are important parameters influencing the user experience of the Metaverse immersive platform). The second RQ deals with the "how" aspect (i.e., how those factors are associated with the user experiences). We hereby posit two RQs:

**RQ1: What are the important factors influencing the user experience (UX) of metaverse apps?**

**RQ2: How are these factors associated with the UX of metaverse apps?**

This study has utilized an inductive investigation to unearth the significant parameters and their associations with the UX of the Metaverse immersive ecosystems (Kar et al., 2023; Kar & Dwivedi, 2020). We have proposed a unique overarching framework, "Unified Framework for User Experience of the Immersive Ecosystem of Metaverse" (UFUEIEM) by integrating CAT and CLT theoretical models, following the blueprint of the big data-oriented computationally theory building framework (Berente et al., 2019; Miranda et al., 2022).

The rest of the paper is organised as follows: Section 2 provides a thorough review of the relevant extant literature. Section 3 documents the blueprint of the investigation. Section 4 captures the modus operandi and insights from the exploratory analysis. Section 5 discusses confirmatory analysis. Section 6 highlights the discussion of the results, important methodological and practical contributions, along with the limitations of the study. Conclusions along with a future research agenda are provided in Section 7.

# 2 Literature Review

## 2.1 Theoretical Background

The concept of Cognitive Load Theory (CLT) was introduced in 1988 by Sweller (1988). Cognitive load is the cumulative mental workload placed on an individual's cognitive system during a particular task. The user's cognition is viewed as a form of resource consumption. Later scholars have further developed the theory. The cognitive organization of humans, as defined by the CLT, comprises long-term memory and working memory. Long-term memory can store newly acquired information after it has been initially processed in working memory (He & Wu, 2023). CLT emphasizes the constraints caused by working memory. Based on CLT, individuals have cognitive limitations that restrict their ability to handle many pieces of information simultaneously. When the amount of information to be processed reaches above a certain threshold individuals become overwhelmed (Wang et al., 2014).

Users and interface designers have developed many techniques to guide visual attention in interpersonal interaction, architectural contexts, and standard interfaces with the aim of minimizing cognitive burden (Biocca et al., 2007). In mobile augmented reality (AR) and virtual reality (VR) settings, attention is distributed and dispersed across various elements in both the real and digital surroundings. Tasks in the virtual space may not be the major focus of the user. These tasks deviate significantly from conventional computer operations, such as those performed in normal menu-driven digital interfaces (Biocca et al., 2007), where humans have the freedom to operate within the environment, utilizing tangible tools and items, and engaging with others while handling virtual data without being personified virtually (Biocca et al., 2007).

AR setups possess the capability to exhibit substantial quantities of informational cues to tangible items inside the surroundings (Biocca et al., 2007). Individuals participate in the virtual realm by generating games, avatars, landscapes, and other digital entities. When images are included, these ideas are more likely to be remembered compared to only using verbal or written prompts (Banken et al., 2019). Understanding

information and solving problems based on learned knowledge require significant cognitive power (Aysolmaz & Reijers, 2021). The central capacity theory, as applied in information systems research, investigates the allocation of attentional resources by users when accessing web pages (Aysolmaz & Reijers, 2021). It implies how different tasks can compete for limited mental resources during information processing, thereby increasing the cognitive burden of the users (Aysolmaz & Reijers, 2021). Specifically, the introduction of intrinsic cognitive load occurs as a result of the intricate nature of the subject matter being examined. The resulting cognitive overload affects the inherent experience with the virtual interface (Bunjak et al., 2021).

Virtual worlds facilitate place attachment by allowing individuals to engage in sensory perceptions, develop awareness, and engage in meaningful relationships. The relevant senses are primarily auditory, visual, or both (Goel et al., 2011). Virtual worlds offer the ability to interact and become aware through visual and auditory experiences. One notable aspect is the provision of support for many-to-many interactions (Goel et al., 2011). During an ongoing engagement, the environment can indicate to an individual whether someone else is open to engaging in interaction by observing the actions of their avatar. This enhances the sense of being present in a social context (Agarwal & Karahanna, 2000; Goel et al., 2013). Regarding virtual worlds, we perceive other individuals as avatars, as they serve as representations of users. Avatars serve as a means of representing and conveying existence or the existence of an individual (Dwivedi et al., 2022).

Users use the Metaverse for multiple professional and recreational purposes. Virtual assets (NFTs), digital personae (avatars), and other artifacts are present within a virtual environment, and the limits of this space should be created to provide users with a clear understanding of their disposition-fit with their requirements (Goel et al., 2011). This is the basis for sociability, which overlays a virtual platform where a user can feel or reflect themselves, which is known as telepresence (Agarwal & Karahanna, 2000). Location awareness refers to an individual's understanding of their position in space based on the presence of objects and the activities taking place in that space (Agarwal & Karahanna, 2000; Goel et al., 2013). Therefore, the virtual space creates a symbolic representation of the real world by utilizing virtual objects and participants, resulting in a mentally stimulating experience (Bunjak et al., 2021). Metaverse is a VR technology, mediated by a computer. Digital technology empowers liminality in the Metaverse platform. There, any actor or participant can take part in the space freely without any spatial boundary (Belk, 2024). Actors deploy their actants-Avatars or other digital objects, say NFTs, to fulfil their purposes. Too many actants can create congestion, whereas, too few actants can leave the space unfilled and that makes the interaction weak. Weak interaction further weakens the immersive experience on the Metaverse platform. Therefore, we employ cognitive load theory to understand the actant activities and interactions and how that can ease or hinder the immersive experience of the users. Simultaneously, we have also undertaken the cognitive absorption theory of the users' hedonic dimensions that govern their experiences.

Cognitive absorption refers to the subjective experience of individuals when using digital technologies (Agarwal & Karahanna, 2000; Bunjak et al., 2021). It arises from the continued use of the specific digital platform that users are engaged with (Lee et al., 2012). Cognitive absorption refers to a state where individuals are deeply engaged with information technology. This state is influenced by the concepts of flow (Barnes & Pressey, 2014; Goel et al., 2013) which is a state of complete immersion in a task, cognitive engagement, and intrinsic motivation related to one's beliefs about using IT (Bunjak et al., 2021). Expanding upon these principles, temporal dissociation, focused immersion, and heightened enjoyment are identified as distinct aspects of cognitive absorption when engaging with technology (Agarwal & Karahanna, 2000). Temporal dissociation refers to the inability to perceive the passage of time while using technology. Focused immersion describes the state of complete engagement disregarding other potential obligations. Heightened enjoyment refers to the enjoyable qualities experienced when interacting with technology. Table 1 captures the pertinent factors with their definitions adapted from the theoretical frameworks discussed.

**Table 1. Connotations of the Constructs with Respective Theoretical Frameworks**

| Theoretical lenses | Factors | Operational definitions | Sources |
|---|---|---|---|
| Cognitive Load Theory, i.e., CLT (Biocca et al., 2007) | Interactivity | The extent to which the user can modify, control, and customize the virtual objects | (Animesh et al., 2011) |
| | Sociability | The extent to which the virtual ecosystem facilitates the intimation and portrayal of the real time environment | |
| | Density | Perception of a user that the number of virtual objects is large, enhancing social interaction and proximity | |

| | | | |
|---|---|---|---|
| | Stability | Familiarity of the users with the Avatars appearing usually and regularly, enhancing social integration | |
| | Telepresence | Perception of a user being present in the virtual space | |
| | Social presence | Feeling of closeness, cordiality, or warmth due to social interaction leading to more engagement and attachment with the stakeholders of the virtual space | |
| Cognitive absorption factors (Agarwal & Karahanna, 2000) | Temporal dissociation | Inability to feel how time passed by while using the virtual metaverse platform | (Agarwal & Karahanna, 2000) |
| | Focused immersion | Undistracted involvement and engagement in the metaverse interface | |
| | Heightened enjoyment | Delight while using the metaverse system | |
| | Curiosity | Induced interestedness and inquisitiveness in using the metaverse platform | |
| | Playfulness | Multidimensional flow experiences, such as spontaneity, imaginativeness, originality, flexibility, and others while using the metaverse platform | |

## 2.2 Metaverse as an Immersive Virtual Landscape

The defining features of the Metaverse include the enduring nature of identity and items, a communal setting, avatars, synchronization, three-dimensional space, interoperability, and an immersive and socially engaging user experience (Hadi et al., 2024; Richter & Richter, 2023). The Metaverse is a highly developed virtual experience that provides users with a completely immersive environment that combines physical and virtual worlds (Gao et al., 2023; Richter & Richter, 2023). This is achieved through the utilization of advanced technologies like virtual reality (VR), augmented reality (AR), artificial intelligence (AI), haptic feedback, blockchain, non-fungible tokens (NFTs), game engines, and the principles of Web 3.0, among others. These technologies enable a more seamless, realistic, and multi-sensory experience (Richter & Richter, 2023). The combination of these technologies is believed to generate a metaverse that is economically and socially dynamic, enabling users to possess and exchange virtual assets, participate in decentralized communities, and engage in a higher level of complexity in virtual commerce (Gao et al., 2023; Ivanov, 2023; Richter & Richter, 2023; Yoo et al., 2023). The Metaverse finds its application in various fields, including education, business management, tourism, healthcare, transportation, and others (Dwivedi et al., 2023; Gao et al., 2023; Yoo et al., 2023).

Game engines facilitate the development of sophisticated virtual worlds and experiences while the principles of Web 3.0, such as decentralization and interoperability, can establish a more inclusive and easily accessible metaverse for users (Belk et al., 2022; Richter & Richter, 2023). Moreover, the utilization of virtual reality (VR), augmented reality (AR), artificial intelligence (AI), and haptic feedback has the potential to provide a completely immersive encounter that obscures the distinction between the physical and digital realms. This novel approach provides an elevated degree of involvement and interactivity (Dwivedi et al., 2023; Richter & Richter, 2023). On a metaverse platform, individuals can connect simultaneously with different kinds of communication channels (Schöbel & Leimeister, 2023). Interaction occurs when avatars engage with the avatars of others. These avatars establish a social presence, which refers to the feeling of being together in a mediated setting (Schöbel & Leimeister, 2023). An avatar is generated using a 3D scan of a real person, aiming to digitally replicate their physical appearance with high accuracy. This process incorporates immersive technology (Dwivedi et al., 2023). Table 2 captures the prior literature discussing multiple aspects of the immersive space of the Metaverse ecosystem.

**Table 2. Relevant Studies Along with the Theoretical Lenses and Methodologies Applied**

| Studies | Focus | Theoretical frameworks applied | Applied methodologies |
|---|---|---|---|
| (Kim et al., 2023) | Factors influencing user-avatar relationship and intention to use avatar | Construal level theory, Source attractiveness model | Experiment |
| (Barta et al., 2023) | Effect of telepresence in live-stream shopping in Instagram (Low | Technology acceptance model (TAM) | Quasi-field experiment |

| | | | |
|---|---|---|---|
| | telepresence) vs Metaverse (High telepresence) | | |
| (Hennig-Thurau et al., 2023) | Proposed a framework for social interactions in the Metaverse | Crafted a new and unique model, based on multiple theories | Experiment |
| (Thomas et al., 2023) | Framework for gamification in metaverse era: Factors influencing nudge experience, alternate reality experience, hedonic experience, flow experience | Crafted a new and unique model, based on multiple theories | Thematic analysis |
| (Elodie et al., 2023) | How the design and the non-verbal behaviour induce immersive experience among the users | -- | Experiment |
| (Xu et al., 2024) | What influences the continuance intention of online learning in metaverse platform | -- | Binary logit model |
| (Singla et al., 2022) | Nuances of metaverse ecosystems | Design considerations, affordances, socio-technical elements | Qualitative analysis; Bibliometric literature review |
| (Suh, 2024) | What cognitive and emotional factors influence continuous intention, behavioural engagement, and social self-efficacy | Cognitive appraisal theory | Hypothetico-deductive |
| (von der Au et al., 2023) | How the Metaverse virtual platform, objects, and their plausibility can facilitate utilitarian benefits and congruence | -- | Experiment |
| (Mancuso et al., 2024) | How various macro variables and micro factors influence business model innovation for 2 metaverse platforms: Roblox and Meta | -- | Multiple case studies |
| (Zuo & Shen, 2024) | Metaverse features and how they facilitate user engagement | Needs-affordances-features framework | Thematic analysis |
| (Mandolfo et al., 2023) | How emotion affection influences interaction frequency and browsing time | Stimulus-Organism-Response framework | Experiment |
| (Jiang et al., 2023) | What influences the Metaverse brand experience and consumer happiness | Broaden-and-build theory | Hypothetico-deductive |
| (Kim & Bae, 2023) | Effect of actual and persona self-congruence on luxury brand attachment and purchase intention | Attachment theory | Hypothetico-deductive |
| (Park et al., 2023) | Effect of flow factors on fashion product and purchase intention | Theory of consumption values | Hypothetico-deductive |
| (Chen & Yao, 2022) | Telepresence and transportation facilitate the strategic use of immersive media and narrative message in virtual marketing in the Metaverse | Transportation theory | Experiment |

Multiple recent editorials and scholarly discussions have highlighted the importance of the role of consumer views in analysing the Metaverse immersive platforms (Belk, 2024; Dwivedi et al., 2023; Puntoni, 2024). However, these studies did not employ any empirical investigation to draw useful insights. Chang et al. (2023) demonstrated that smartphone-based apps facilitated the Metaverse platforms' deployment and public Play Store reviews depict the users' reflections on those platforms. Very few studies mined users' standpoints to evaluate the nuances of the Metaverse virtual space (Chakraborty et al., 2023; Dolata & Schwabe, 2023). Therefore, there is a lack of a comprehensive encompassing view covering the artifacts of the Metaverse virtual platform as well as users' hedonic feelings of using the same. Therefore, to fulfil this gap in the literature, we craft a theory-driven unified conceptual model exploiting the user reviews on Metaverse apps from the public app stores capturing the Human-Metaverse interface (Dwivedi et al., 2022). We rely on CLT to cull the factors pertinent to the Metaverse virtual platforms and CAT to understand the users' intrinsic emotions stemming from the usages of those platforms.

# 3 Research Design

This study has addressed the proposed research objectives with the help of publicly available user reviews on various Metaverse platforms pursuing a design science research paradigm to understand the nuances impacting the user experiences (Abbasi et al., 2019). We have undertaken a Natural Language Processing (NLP)-driven text analytics algorithm to extract insights from those user reviews following the guidelines of a computationally intensive theory building framework (Miranda et al., 2022). Text mining enables us to extract the factors for user experience from the corpus. The relationships between the factors and the user experience have been explained in the light of CLT and CAT. Such an inductive research-based technique is a suitable mechanism for implementing exploratory and confirmatory research to carve out data-driven insights (Kar & Dwivedi, 2020). Kar (2021) and Kar and Kushwaha (2021) analysed user-generated content to examine user experiences. Figure 1 shows the consolidated diagram of the research design carried out in due course of the study.

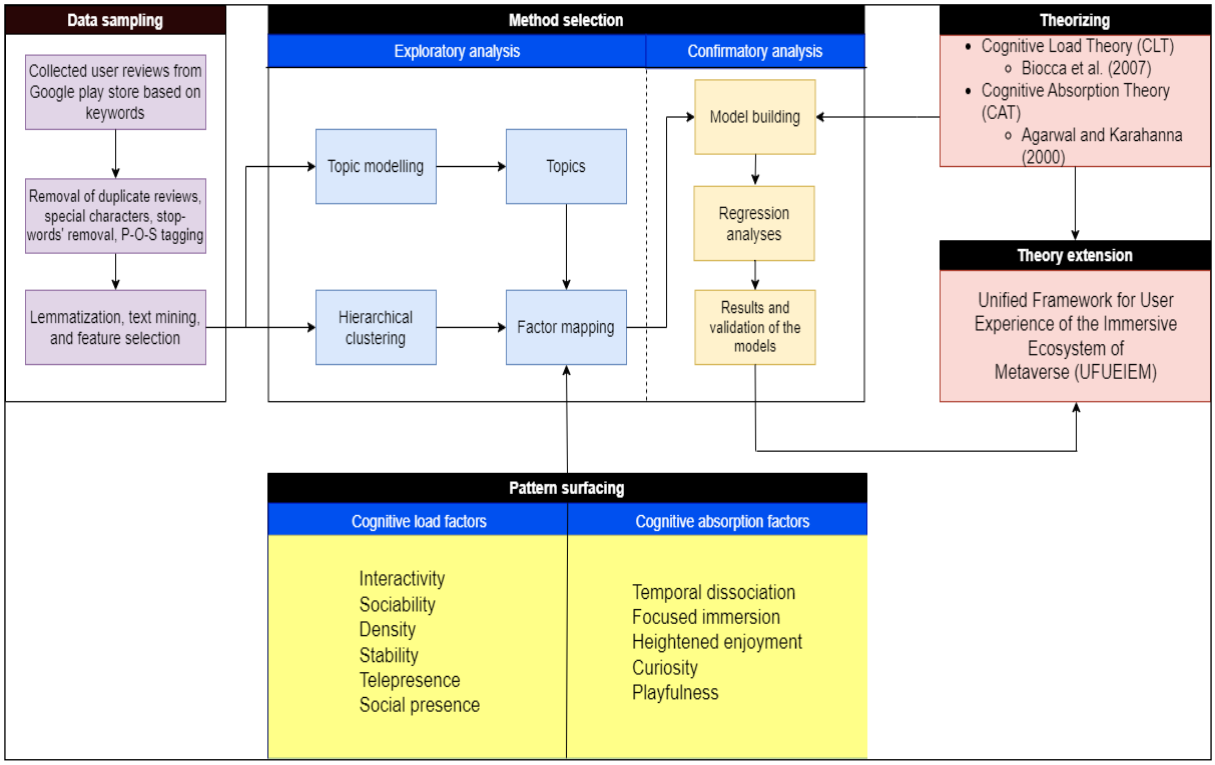


**Figure 1. Consolidated Research Design Following the Computation Theory Construction Framework (Source: Basu et al. (2024) and Miranda et al. (2022))**

The research design has two main phases: exploratory and confirmatory study. In the exploratory study phase, we perform content analysis and text summarization. In the content analysis phase, we carry out data cleaning and processing, followed by clustering. A clustering technique is useful to group the theoretical lexicons to acquire a pre-theoretical understanding of the factors. Text summarization is essentially comprised of a topic modelling technique, which elicits the significant latent themes prevalent in the textual corpus. We map the themes with the relevant factors based on experts' ratings. Insights from a clustering technique help to solidify the outputs of topic modelling. Thereafter, with the help of mapped factors, we predict the user experience employing multiple regression models.

## 3.1 Data Collection

We have scraped public reviews on various Metaverse applications from the Google Play Store. We preferred the Google Play Store over Apple App Store because Android users are much more numerous than iPhone users. As of now, around 3 billion active Android users are there whereas the iPhone is used by around 1 billion people (Backlinko Team, 2024). This allows us to accommodate more diverse viewpoints. Reviews are one of the potential sources, capturing the public takes on the nuances and artifacts of the Metaverse ecosystem (see Figure 2 in Appendix A). We have utilized "Google_Play_Scraper", a Python

package, to scrape the reviews from the respective 14 mobile applications (Kim et al., 2023; Mandolfo et al., 2023; Schöbel & Leimeister, 2023; Zuo & Shen, 2024). For this study, we have considered social life-based Metaverse virtual apps along with few commerce and gaming-based Metaverse apps. We have scraped a total of 409,755 reviews on those apps starting from February 2017 to September 2023. The app-wise number of reviews is shown in Table 3.

**Table 3. App-wise Collected Reviews**

| Types of Metaverse apps | Name of the apps | No. of reviews |
|---|---|---|
| Apps for socialization | Lovemetaverse | 971 |
| | Itsme | 8387 |
| | GoArt | 17 |
| | Nevermet | 297 |
| | Avakin | 200200 |
| | Woozworld | 15545 |
| | Metaworld | 950 |
| | Avaland | 546 |
| | HighRise | 35328 |
| | Zepeto | 121600 |
| Apps for commerce and gaming | Metamask | 25327 |
| | TapFantasy | 146 |
| | Decentraland | 10 |
| | Spatial | 431 |

### 3.2 Data Sanitization

After extracting user reviews, we applied NLP-based processing to sanitize the reviews and carve out the theoretical lexicons (Kar & Dwivedi, 2020). After removing duplicate reviews and reviews with no textual content, we were left with 409,750 reviews. We have cleaned the special characters, numbers, regular expressions, and stop words. Then we tokenised the corpus into words, applied a named entity recognition (NER) technique, and parts-of-speech based filtering. Thereafter, we have lemmatized the tokens and used bigram and trigram-based language models in Gensim to finalize the theoretical lexicons considered in further analyses.

## 4 Exploratory Study

In the previous section, we have described the process of collecting and processing the data. We extracted theoretical lexicons from the processed textual corpus. In this section, we will analyse the textual content with the help of a clustering technique and undertake a Latent Dirichlet Allocation (LDA)-based topic modelling technique to make sense of the theoretical lexicons subjected to undergo factor mapping for confirmatory analysis.

### 4.1 Content Analysis

A textual corpus can be summarized in many ways. Existing literature has applied principal component analysis for summarization (Yadav et al., 2023). Topic modelling can be apt too for such purposes (Kar & Dwivedi, 2020; Miranda et al., 2022). A clustering technique (Figure 3 in Appendix B) can help to verify and enrich the understanding on the topics reported by topic modelling (Eryilmaz et al., 2022).

After the subsequent tokenization and lemmatization, we have applied a clustering technique. A clustering technique groups the lexicons based on similarity. We have gone for K-means and hierarchical clustering in tandem. K-means based clustering helps us to deduce the optimal number of grouping (see Figure 4 in Appendix C) and we have used that in hierarchical clustering (see Figure 3 in Appendix B). The lexicons are grouped in level-by-level until all the lexicons get subsumed in one single cluster. This similarity-based grouping helps to gather pre-theoretical insights.

Theoretical lexicons then underwent topic modelling. This groups the lexicons based on probability distribution and correlation of the occurrences of the same (Blei et al., 2003). It outputs the latent themes or topics from the corpus as required. To decide on the optimal number of topics, we have iterated the number of topics from 1 to 50 and chose 35 as the optimal topic number as it carries the highest coherence score.

Clustering and topic modelling techniques together provide us with a unified way to summarize the texts and identify the relevant theoretical lexicons. The pre-theoretical grouping, stemming from the similarity

based clustering helps us to ascertain the theoretical latent themes resulting from the topic modelling mechanism. However, the topic clusters should undergo a rigorous mapping procedure with the constructs, adapted from the conceptual studies in Table 1. We looked for the extent of semantic overlapping of the topic keywords with the items of the pertinent constructs (Basu et al., 2024; Larsen et al., 2023). We display the most important keywords for every factor in Figure 5 with word clouds. To verify our mappings of the latent themes with the bedrock conceptual factors adapted from Agarwal and Karahanna (2000) and Animesh et al. (2011), we have employed two domain experts. We have randomly collected 454 reviews from the dataset. The experts separately and independently coded the topics based on the selected reviews (Basu et al., 2024; Kumar et al., 2023). Based on their classification, we have calculated Cohen's Kappa coefficients, representative of the degree of agreement of the raters (Cohen, 1960). For all the constructs, we have found the values of Cohen's Kappa coefficients as more than 0.8, which shows the high interrater concordance. Table 4 captures the Cohen's Kappa coefficients for the constructs. This type of technique ensures the face and content validity, as the theoretical substances of the constructs have been aptly portrayed.

**Table 4. Factor-wise Cohen's Kappa Scores**

| Factors | Cohen's Kappa |
|---|---|
| Interactivity | 0.8414 |
| Sociability | 0.8367 |
| Density | 0.8412 |
| Stability | 0.8366 |
| Telepresence | 0.8401 |
| Social presence | 0.8922 |
| Temporal dissociation | 0.8017 |
| Focused immersion | 0.8244 |
| Heightened enjoyment | 0.8376 |
| Curiosity | 0.8187 |
| Playfulness | 0.8178 |

## 4.2 Exploratory Findings

Figure 3 (see Appendix B) describes the output of the hierarchical clustering technique. Hierarchically arranged lexicons have been clustered based on their similarities. For example, the words "create_avatar", "explore", and "fun" have been connected with a link (see Figure 3 in Appendix B). However, the simple clustering techniques do not address the hidden latent meaning and deduce the prevalence probability of the topics per documents (reviews). Therefore, we exploit the LDA based topic modelling approach for confirmatory analysis.

Figure 5 shows the factors along with respective keywords, reported by LDA-based topic modelling algorithm. Figure 3 and 5 enable us to recognize the germane factors. For example, the topic with the words "socialize", "love", "live", "meet_new_people" denote the factor "Social presence" in Figure 5. In a similar manner, all the factors have been identified and depicted. This leads us to propose the conceptual model following the design science paradigm addressing the user experience of the immersive ecosystem of the Metaverse (Abbasi et al., 2019; Peffers et al., 2007).

The hypothetical model, UFUEIEM, has been proposed by integrating CLT and CAT. CLT highlights the design of the virtual platform to make the interface user-friendly, thereby helping to reduce the cognitive burden (Biocca et al., 2007). CAT delineates the users' intrinsic emotions, stemming from using the immersive virtual space (Agarwal & Karahanna, 2000). The factors adapted from these frameworks influence the user experiences. We have carved out the factors using the theoretical lexicons, extracted from the textual corpus with the help of NLP-driven technique. Figure 6 shows the curated conceptual model.

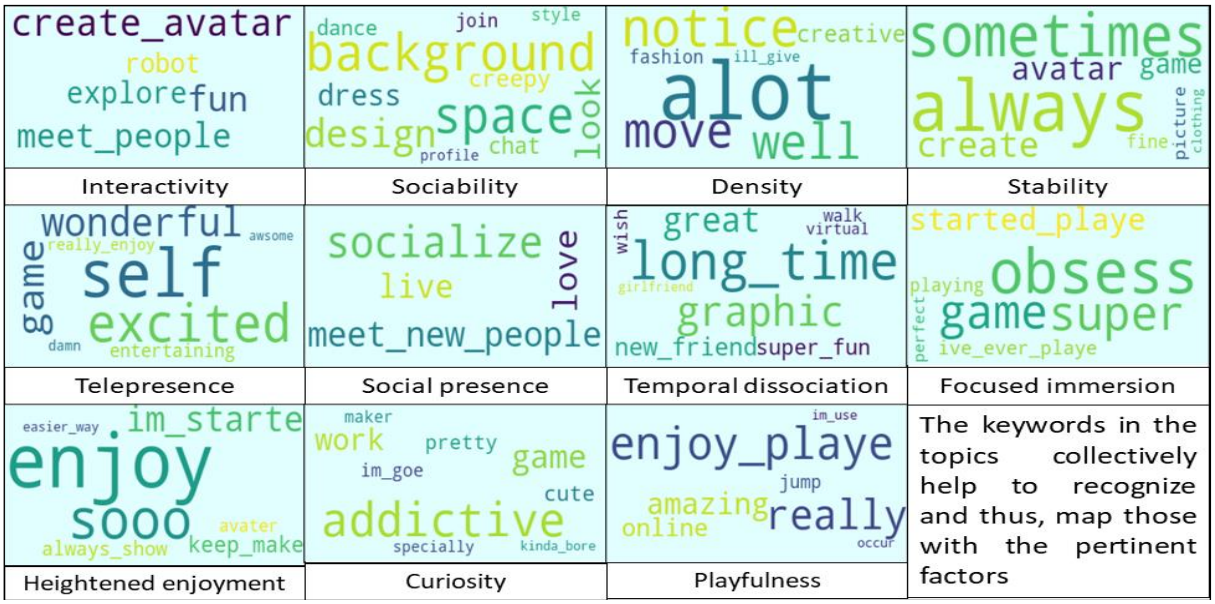


**Figure 5. Word clouds of the Factors Along with Representative Keywords**

### 4.2.1 Interactivity

The technological attributes of an immersive virtual environment can either promote or impede users' interactions with virtual items, impacting their virtual experiences. Participants engage with a virtual world by controlling the actions of their avatars (Schöbel & Leimeister, 2023). In the Metaverse, participants have the ability to alter their surroundings and control different virtual things by interacting with their avatar (Hennig-Thurau et al., 2023). Avatars serve as the means by which users immerse themselves in the virtual world, personify their presence, and establish a genuine connection with the virtual environment (Schöbel & Leimeister, 2023). The level of participant immersion in the virtual world is directly proportional to the frequency of their interactions with the virtual environment and items through their avatar. The brain's ability to adapt to the virtual environment is enhanced by interactivity, allowing the avatar to be perceived as an extension of the participant's self (Animesh et al., 2011). It reduces cognitive overload and facilitates the usage of the virtual environment (Aysolmaz & Reijers, 2021). So, we can posit the following hypothesis:

**H1: Interactivity is positively associated with user experience.**

### 4.2.2 Sociability

Sociability refers to the degree to which the computer-mediated communication environment enables the creation of social space through the provision of social affordances (Animesh et al., 2011). This attribute primarily emphasizes interactions between participants. The sociability aspect of a particular virtual place, say the Metaverse, fosters social interaction and cultivates a strong sense of camaraderie among the individuals involved, both in terms of physical proximity and shared experiences (Belk, 2024). Virtual environments with heightened sociability can foster greater social connections and evoke emotions of affection, belongingness, and warmth (Animesh et al., 2011). Avatar-mediated interactions facilitate socialization in the Metaverse (Suh, 2024). This allows them to construct and portray a desired identity to others. This sense of presence urges the users to spend more time with the virtual platform and generates a pleasant experience (Kraus et al., 2023). So, we can frame the following hypothesis:

**H2: Sociability is positively associated with user experience.**

### 4.2.3 Density

Density refers to the count of individuals operating in each unit of the virtual space. Density can have both positive and negative sides for virtual platform users. Too many avatars and users can create congestion in the space leading to complications for trading and transactions, whereas, too few avatars result in a dispersed state, less interaction, and less socialization (Animesh et al., 2011). Therefore, optimal density has to be maintained to facilitate the virtual space usage with the Metaverse without exception. Optimal

density can make the system less chaotic, less hectic, less complex, seamless, and user-friendly for trading (Banken et al., 2019). So, we can formulate the following hypothesis:

**H3: Optimal density is positively associated with the user experience.**

### 4.2.4 Stability

Stability refers to the persistence of the digital personas and users in the space. It indicates the minimum possible going out and coming in of the users and their assets in the ecosystem. In this way, stability breeds familiarity (Kim et al., 2023). It helps the users get acquainted with the space and its stakeholders and the users become comfortable in using the virtual platform (Kim et al., 2023). Thus, stability brings out social ties among the users, attachment to the ecosystem, and facilitates virtual trading. Therefore, we can pose the following hypothesis:

**H4: Stability is positively associated with the user experience.**

### 4.2.5 Telepresence

Telepresence refers to the perception of the users being present in the ecosystem (Barta et al., 2023). Users' selves are reflected through the digital personas or avatars in the virtual platform. In the immersive virtual space, telepresence bolsters the users' self-reflection, and, thereby, the avatar becomes the extended-self of the user (Park et al., 2023). Thus, the more the telepresence, the less there will be the demarcation between the physical and virtual disposition, which ties the users into the virtual system and channels the usage (Kakaria et al., 2023). Therefore, we can state the following hypothesis:

**H5: Telepresence is positively associated with the user experience.**

### 4.2.6 Social Presence

Social presence is defined as the users' feelings generated while interacting with the other users in the virtual platform (Kim et al., 2023). The digital innovation enables the virtual space conducive for interaction via avatars and helps the users associate with others on the ecosystem, exchanging warmth, heartiness, and cordiality (Schöbel & Leimeister, 2023). Such reciprocation helps in an apt portrayal of real life as the virtual platform and the user become engrossed and absorbed in the virtual platform and feel connected more with the same (Kakaria et al., 2023). Therefore, we can posit the following hypothesis:

**H6: Social presence is positively associated with the user experience.**

### 4.2.7 Temporal Dissociation

Temporal dissociation denotes the user losing track of time in due course of using the virtual platform (Visinescu et al., 2015). The computer-mediated virtual space engages the user in its ecosystem and thereby he/she gets detached from other mundane activities. Such absorptive engagement entangles the user with the virtual platform and immerses him/her in the same. Therefore, we can pose the following hypothesis:

**H7: Temporal dissociation is positively associated with the user experience.**

### 4.2.8 Focused Immersion

Focused immersion asserts the user gets absorbed and engrossed in a system with focused attention (Saadé & Bahli, 2005). The cyber-enabled virtual medium engages the user without letting him/her get distracted in their surroundings and facilitates him/her taking part in respective activities happening in the ecosystem. Such engagement enhances the usage of the ecosystem, a reflection of a positive experience. Therefore, we can state the following hypothesis:

**H8: Focused immersion is positively associated with the user experience.**

### 4.2.9 Heightened Enjoyment

The virtual ecosystem of the Metaverse leverages its digital capability to make its activities enjoyable to the users (Barnes & Pressey, 2014). The users can have fun and amusement while enjoying the social transaction, interaction, and acclimatization of those engaged in them in the system. Users can exploit the

opportunities of the Metaverse ecosystem for their personal, professional, and entertainment purposes (Barnes & Pressey, 2014). Therefore, we can postulate the following hypothesis:

**H9: Heightened enjoyment is positively associated with the user experience.**

### 4.2.10 Curiosity

Curiosity is triggered when the user interacts with the digitally curated virtual environment and encounters with the artifacts (Mimoun et al., 2014). The digital assets, objects, and other stuff in the virtual immersive system attract the users, urge them to use those repeatedly, and explore them further. It engenders sensory and cognitive excitement about the ecosystem. Such excitement lessens the cognitive burden and facilitates virtual interaction, leading to a favourable perception (Agarwal & Karahanna, 2000). Therefore, we can frame the following hypothesis:

**H10: Curiosity is positively associated with the user experience.**

### 4.2.11 Playfulness

Playfulness is a multi-dimensional concept having its foundation deeply rooted in psychology (Agarwal & Karahanna, 2000). The digital medium enables the users to curate their artifacts and customize the same in accordance with their own imagination. The users can spontaneously showcase their creativity in crafting their own digital assets (Dwivedi et al., 2022). Also, the users can leverage various flexible and cutting edge technological features to not only produce those but also sell, buy, and price the same (Dwivedi et al., 2022). Thus, the digital features facilitate the users promoting and laying out their creations leading to a state of contentment. Therefore, we can posit the following hypothesis:

**H11: Playfulness is positively associated with the user experience.**

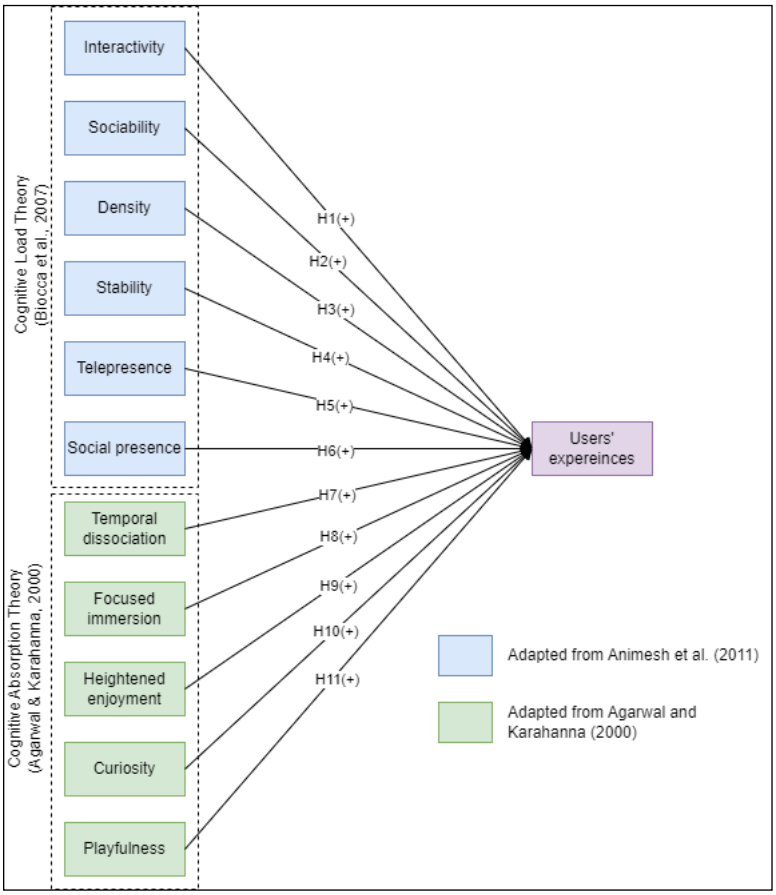


**Figure 6. Proposed Conceptual Model, UFUEIEM to Assess the User Experience of Metaverse Immersive Ecosystem**

# 5 Confirmatory Study

In the previous section, we have described the mapping of the factors that arose from the topic modelling technique. We have operationalized these explanatory variables with prevalence likelihood, reported by LDA-based topic modelling. Prevalence likelihood is the contribution that every document (review) puts forth in forming every topic. We have preferred an LDA-based bottom-up topic modelling approach in lieu of other text summarization techniques, like the Linguistic Inquiry and Word Count (LIWC). LIWC is a top-down topic modelling approach that deduces the prevalence scores based on the similarity between the words present in the corpus with a pre-defined dictionary comprised of a fixed set of lexicons (LIWC, 2022), whereas LDA-based topic modelling groups the corpus words dynamically. Prior to utilizing the prevalence likelihoods in empirical validation, we have preferred to normalize those with the help of box-cox transformation, which may boost the model's performance (Baesens et al., 2021; Peng et al., 2011). We have operationalized the user experiences using star ratings against the reviews in the Play Store. We have estimated the model with a Poisson count regression model to predict the number of stars, typically lying between 1-5. We have assigned "0" rating to the reviews without any star rating. Also, we have applied multiple ordinal models, ordered Logit and Probit, to estimate the ordinal star rating system. The greater the number of stars, the better the experience is. We have employed the licensed Stata software to run the regression models. Table 5 captures the regression coefficients and standard errors and Table 6 exhibits the corresponding fitness metrics. We have chosen 5% as a significant value. Table 7 (see Appendix D) highlights the cut values or benchmark scores for the ordinal regression models.

**Table 5. Regression Results to Estimate the User Experience**

| Explanatory factors | Poisson model (Standard errors) | Ordered Logit model (Standard errors) | Ordered Probit model (Standard errors) | Remarks |
|---|---|---|---|---|
| Interactivity | 0.0001 (0.00003) (Significant) | 0.0004 (0.0001) (Significant) | 0.00003 (0.00007) (Non-significant) | Rejected by Probit, Accepted by Poisson, and Logit |
| Sociability | 0.0005 (0.00001) (Significant) | 0.0022 (0.00005) (Significant) | 0.0012 (0.00003) (Significant) | Accepted |
| Density | 0.0005 (0.00003) (Significant) | 0.0018 (0.0001) (Significant) | 0.0011 (0.00006) (Significant) | Accepted |
| Stability | -0.0004 (0.00007) (Significant) | -0.0022 (0.0002) (Significant) | -0.0014 (0.0001) (Significant) | Contradicted |
| Telepresence | 0.0043 (0.0001) (Significant) | 0.0191 (0.0004) (Significant) | 0.0110 (0.0002) (Significant) | Accepted |
| Social presence | 5.44e-07 (0.00006) (Non-significant) | 0.00001 (0.0002) (Non-significant) | -0.0002 (0.0001) (Non-significant) | Rejected |
| Temporal dissociation | 0.0014 (0.00002) (Significant) | 0.005 (0.00008) (Significant) | 0.0032 (0.00005) (Significant) | Accepted |
| Focused immersion | 0.0008 (0.00005) (Significant) | 0.0035 (0.00017) (Significant) | 0.0019 (0.00010) (Significant) | Accepted |
| Heightened enjoyment | 0.0086 (0.00009) (Significant) | 0.0445 (0.0004) (Significant) | 0.0263 (0.0002) (Significant) | Accepted |
| Curiosity | 0.00046 (0.00004) (Significant) | 0.0016 (0.00015) (Significant) | 0.0008 (0.0001) (Significant) | Accepted |
| Playfulness | 0.0012 (0.00002) (Significant) | 0.0053 (0.00009) (Significant) | 0.0031 (0.00005) (Significant) | Accepted |

**Table 6. Fitness Parameters for Regression Models**

| Parameters | Poisson model | Ordered Logit model | Ordered Probit model |
|---|---|---|---|
| Pseudo R-squared | 0.0205 | 0.0549 | 0.0531 |
| Likelihood ratio Chi-squared (q = 11) | 32545.24 (Significant) | 51733.66 (Significant) | 50093.22 (Significant) |
| AIC | 1557466 (df = 12) | 891175.4 (df = 16) | 892815.8 (df = 16) |
| BIC | 1557597 (df = 12) | 891350.2 (df = 16) | 892990.6 (df = 16) |

Table 5 shows the regression estimates for the factors associated with the user experience of the Metaverse immersive ecosystem. Interactivity and social presence are rejected by at least one regression model. Stability is reported as negatively associated with the user experience by all the regression models, as

opposed to theorization. The rest of the other parameters influence the user experience positively as theorized.

# 6 Discussion

Table 6 captures the fitness parameters for the regression models. A Poisson model tends to suffer from over-dispersion issues that challenge the fundamental premise of the model, $variance = mean$. So, it is imperative to find out whether the fitted Poisson model is getting affected by the over-dispersion effect. For that, we have undertaken two hypotheses testing, Deviance and Pearson goodness-of-fit. For the degree of freedom, 409738, the statistics came out to be 266953.8 and 219003.9, respectively. These make both the tests as non-significant. Therefore, we can conclude that the employed Poisson model is not affected by an over-dispersion issue.

Furthermore, to verify our result for the Poisson model, we have applied one more count regression model- Negative Binomial regression model. Unlike Poisson, this does not make any assumption of equi-dispersion. It reported exactly the same estimates as the Poisson model. Also, the overdispersion parameters for Negative Binomial model came out to be non-significant, which provides further support in favour of the fitted Poisson model. Unlike R-squared, Pseudo R-squared does not denote the amount of variance explained by the model. It is defined as $1 - \frac{L_1}{L_0}$, where $L_1$ represents the log-likelihood of the fitted model with all the independent factors, whereas, $L_0$ represents the log-likelihood of the restricted model with no independent factors except for an intercept. Furthermore, the higher the value of Pseudo R-squared, the better the model is. AIC and BIC stand for Akaike and Bayesian Information Criterion, respectively. The lesser the values of both information criteria, the better the model is. All the fitness metrics, Pseudo R-squared, AIC, and BIC show that the Logit model performed better than the other two regression models. The likelihood ratio Chi-squared test represents the overall fitness of the model applied.

In this study, we have resorted to the NLP-driven text analytics technique to explore the factors associated with the user experience of the Metaverse immersive ecosystem. After scraping user reviews from multiple apps in the Google Play Store, we applied LDA-based topic modelling to carve out the important themes and mapped them with factors, adapted from CLT and CAT. Thereby, we proposed our unique conceptual model, UFUEIEM, to understand the factors' associated with the user experiences. Multiple regression models help us to confirm our findings. We explain the findings with the help of the extant literature and media reports.

From Table 5, we can observe the CLT factors, sociability and telepresence, which are positively associated with the user experience as theorized by Barta et al. (2023). Sociability denotes the computer-mediated social space that fosters interactions among the actants (Barrera & Shah, 2023). Metaverse digital technology enables the virtual reality by mimicking the physical reality aptly and the users can feel their presence without any demarcation. Density positively impacts the virtual experiences (see Table 5). This agrees with Animesh et al. (2011). The optimal number of Avatars active in the virtual space avoids congestion and thus enhances the user experience. Also, too loose density makes the Metaverse space sparse, leading to much less interaction (Animesh et al, 2011). In Table 5, we find that all the CAT factors, temporal dissociation, focused immersion, heightened enjoyment, curiosity, and playfulness, influence the user experience in line with Balakrishnan and Dwivedi (2021). The digital technology can depict the virtual space in an engaging and creative manner so that the users can be engrossed in the system completely. However, the hypotheses associated with interactivity and social presence have been rejected in Table 5. Social presence gets fostered with the interactions of the actants and, therefore, generates a pleasant experience in the users (Barrera & Shah, 2023). Also, stability is negatively influencing the user experience, contrary to the proposition. These findings go against the earlier findings and discussions by the existing studies (Hennig-Thurau et al., 2023; Park et al., 2023). The stability of the actants brings out familiarity, whereas, too much stability may result in a lack of diversity and stereotypes. We further shed light on the insights acquired from the empirical investigation in the subsequent sections.

## 6.1 Theoretical Contributions

The study has several noteworthy academic contributions. First, we have combined two pertinent theoretical frameworks, CLT and CAT to unearth the nuances of the virtual immersive ecosystem of the Metaverse. CLT empowers us to explain the factors related to the digital space and their effective design and deployment to overlay the Metaverse platform in order to ease the Metaverse usage, vivify the platform, and

thus, lessen the cognitive burden (Biocca et al., 2007). On the other hand, CAT has provided us with the flow factors stemming from subsequent usage of the Metaverse platform (Agarwal & Karahanna, 2000). The proposed integrative framework, UFUEIEM, captures a unified view of the immersive ecosystem, which engages the users and shapes their experiences. We incorporated Metaverse or VR-specific idiosyncratic constituents in both the lenses and, thereby, provided new and unique dimensions to those. Thereby, we enrich and extend both of the lenses. Our conceptual model complements the digital platform factors by juxtaposing the constructs oriented to users' intrinsic perceptions, and, thus, contributes to the theoretical underpinnings of the immersive ecosystem of the Metaverse virtual platform. Furthermore, following the design science research outline and combining the theoretical lenses with the analytics techniques help us to carve out the overarching conceptual model capturing the antecedents of the user experience of the Metaverse immersive ecosystems and empirically validate the same (Dincelli & Chengalur-Smith, 2020; Peffers et al., 2007).

Secondly, we have undertaken a text analytics technique to mine and analyse substantial user reviews to craft the proposed model. Online reviews or electronic word of mouth (eWoM) capture genuine feedback on virtual platforms (Deng et al., 2021). Therefore, our proposed hypotheses are more socially grounded, and closer to the actual phenomena. Subsequently, we validated the curated conceptual model with the help of multiple regression models that confirm our findings. This proves the authenticity and reliability of the insights drawn from the model. Existing studies have analysed users' standpoints without empirical validation (Dolata & Schwabe, 2023). Confirmatory analysis assured us about the significant factors associated with the user experience in the Metaverse virtual ecosystem.

Thirdly, our study examined the factors of the Metaverse system and how they are influencing user experiences. The interaction with the Metaverse platform excites the users to explore the interface. These repeated encounters form opinions and perceptions, which we have analysed in this study. These factors can help organizations to enhance their interfaces and channel resources accordingly (Mancuso et al., 2024). In this way, our investigation contributes to the literature on human-metaverse interface (Dwivedi et al., 2022).

Last but not least, our research helps us to demonstrate the application of a computationally intensive theory building framework in inductive theory building by identifying theoretical lexicons of the Metaverse immersive platform using NLP methods. Lexicons have been grouped based on various grouping techniques, similarity-based (clustering) and correlation-based (topic modelling). Following the footprints of the computational theory building model (Berente et al., 2019; Miranda et al., 2022), our model can be extended further to other immersive virtual platforms addressing a broader phenomenon.

## 6.2 Methodological Contributions

The applied mixed-method-based approach preformed two types of analyses, namely exploratory and confirmatory. In the exploratory analysis phase, with the help of the sophisticated and cutting-edge NLP-based topic modelling technique, we are able to understand the parameters that impact the user experience of the Metaverse virtual ecosystem. The state-of-the-art NLP-oriented text analytics approach enabled us to summarize a huge amount of text and draw insights from that text corpora. Also, we did not solely rely on a single method (i.e., topic modelling), to extract the important themes from the societal texts that are qualitative in nature. We confirmed them with the help of a hierarchical clustering technique, which provides an output similar to topic modelling. In the confirmatory analysis phase, using a quantitative approach, we empirically validated our factors and their possible associations with the outcome (i.e., user experience), with three regression models. We did not depend solely on a single regression model. This experimentation allowed us to safely deduce the significant antecedents of the user experience. Also, multiple regression models have helped us corroborate our proposed model's validity and credibility. Mining the factors, from the eWoM, accounts for the practicality and dependability of the model and the proposed hypotheses as well as their significance. Similarly, this combined mixed-method-based inductive methodology can be extended in formulating organizational policies for other virtual reality platforms as well.

## 6.3 Practical Contributions

This study has many significant practical contributions. By investigating the factors of a computer-mediated system, this work unearthed useful relationships. Focusing on those aspects, the Metaverse platform-owners can improve the quality of the virtual space. Also, from the users' hedonic intention factors, the owners can understand how the user experience is getting affected and how to use the digital system to satisfy the users more and thereby increase their consumer base (Belk, 2024; Hadi et al., 2024). Table 5

shows that sociability is positively associated with the user experience. In due course of the usage, the users get the opportunity to socialize themselves with the other users empowered by the digital technology. Users can project themselves with the help of a curated digital persona (i.e., Avatar). Immersive interactive marketplace is skyrocketing due to rise in social VR platforms, gaming market, and digital assets (i.e., NFTs). However, from Table 5, it is evident that stability is negatively associated with user experience contrary to the theorization. Also, the hypotheses pertinent to social presence and interactivity are not significant (see Table 5). It seems the real time interactions, facial expressions of Avatars, physical touch, and soaring cost, are the possible impediments to facilitating social exchange (EUTD, 2023). Also, too many ways to create new identities using different costumes, attributes, and belongings make them difficult to be recognized in the virtual space (Butler, 2022). Digital technology is still in a nascent stage. It requires more maturity to stimulate the immersive experience. App developers can observe these aspects and develop customized interfaces depending on the purpose of the apps, keeping a close eye on the interacting IT artifacts following design principles so that the interface becomes more robust, user-friendly, interactive, vivifying, and useful (Peffers et al., 2007). Also, the online virtual platform has to be cost-effective and easy-to-use. Continuous monitoring of the user experiences can help the developers gain relevant insights and modify the design accordingly.

### 6.4 Limitations and Future Research Agendas

Like several other studies, this study has a few limitations. Our investigation mainly utilized user reviews on multiple Metaverse applications. Our study would have been more comprehensive if we would have considered a few more Metaverse spaces. By not including them, we might have missed certain more important aspects. We have considered only the apps from Google Play Store. Other app store reviews could have been accounted for. We could not examine the interrelationships between the factors. We believe the fitness parameters, such as pseudo R-squared/R-squared would have been improved if we had done so. Social media content or grey literature could have complemented our study. We have integrated CLT and CAT to explain the relationships between various factors pertinent to the Metaverse immersive system and corresponding user experiences. Future work can extend our proposed framework with other theoretical lenses. User experiences of similar virtual ecosystems can be examined using a similar kind of inductive methodology.

## 7 Conclusion

This study has explored the relevant factors related to the user experience of the virtual immersive ecosystem of the Metaverse. We have mined the factors from the user reviews from the public app store and explained their associations with the user experience with the help of relevant frameworks, CLT and CAT used to propose the UFUEIEM. An LDA-based topic modelling algorithm helped us to unearth the factors of the UFUEIEM. Thereafter, multiple regression models helped us to confirm the relationships. We have found that sociability, density, telepresence, temporal dissociation, focused immersion, heightened enjoyment, curiosity, and playfulness positively influence user experience. We have elaborated on our findings with the help of existing studies and various reports. Our findings can help the system developers and researchers to make design level decisions to make the Metaverse systems more engaging and useful to the users.

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# Appendix A

Sample reviews have been culled from one of the Metaverse applications, Avakin. The reviews capture the user experience of the Metaverse space perpetuated by the digital applications. Figure 2 shows a few of the representative reviews utilized in the current study for the data-driven analysis.

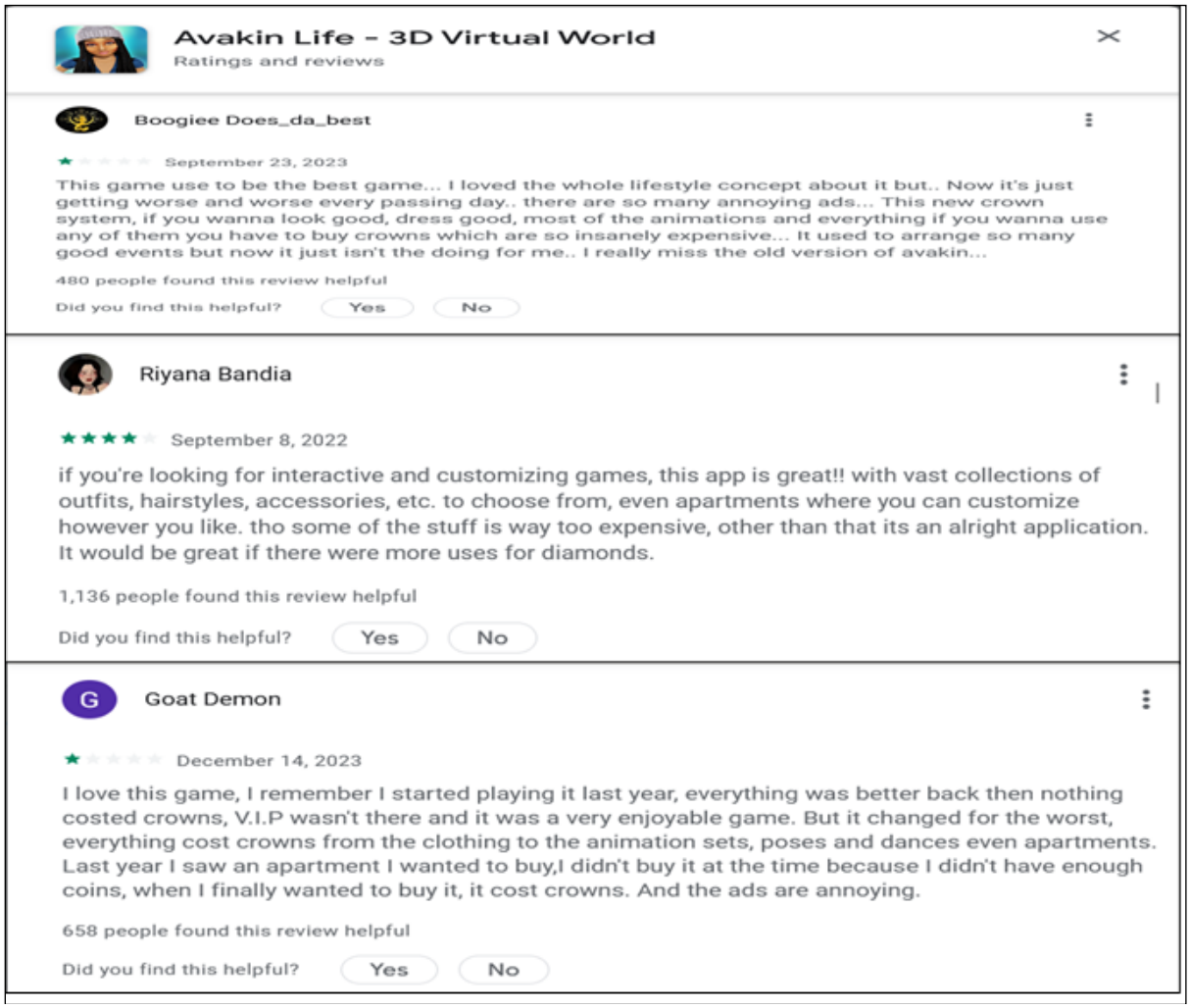


**Figure 2. Sample Reviews Capturing the User Experiences of Metaverse Application, Avakin**

# Appendix B

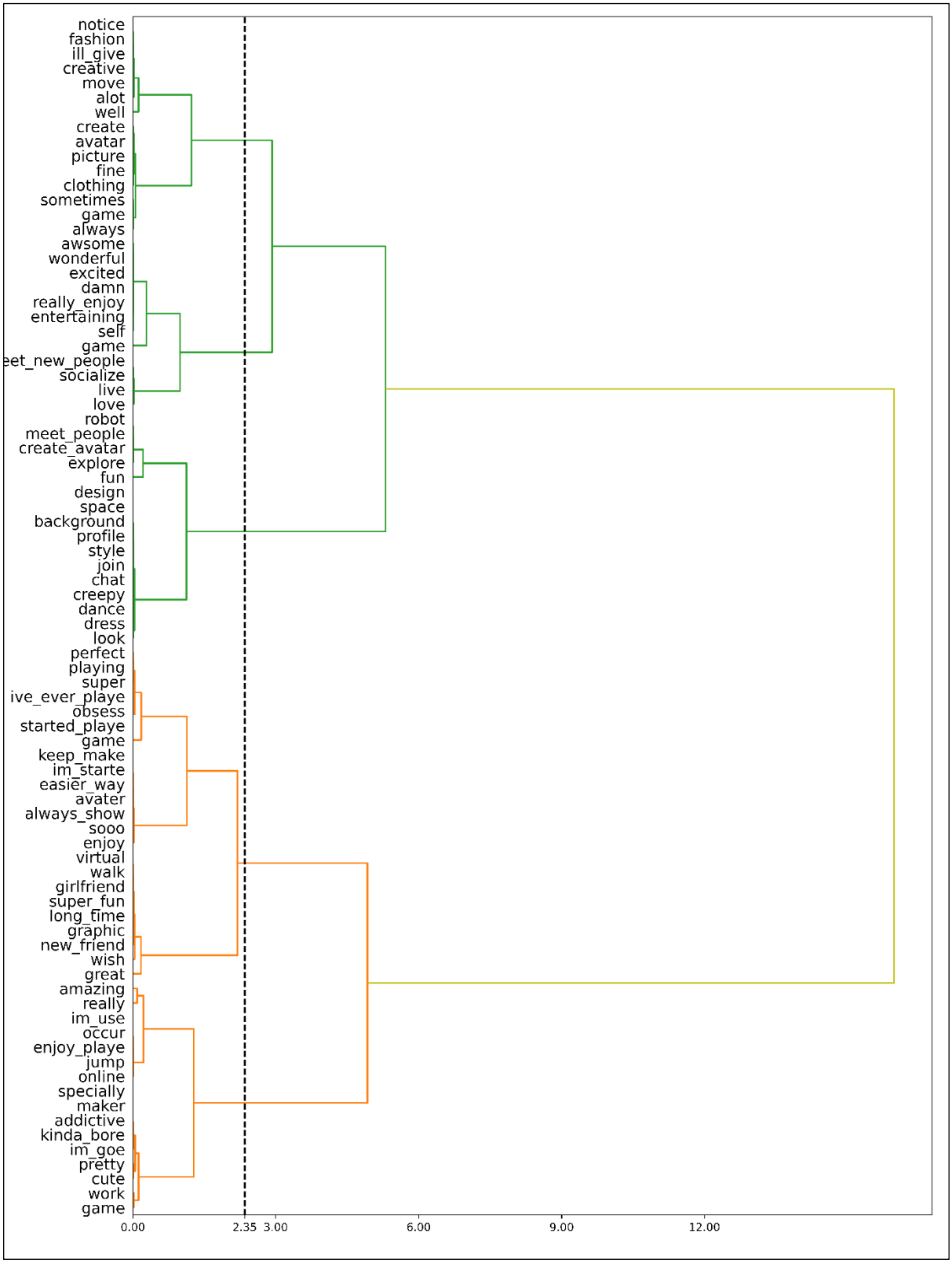


**Figure 3. Hierarchical Clustering to Group Theoretical Lexicons**

# Appendix C

We decided on the optimal number of clusters using a K-means based Elbow method. Figure 4 captures the elbow diagram. Elbow point is the point beyond which the error stops decreasing and becomes almost constant and that denotes the optimal number of clusters. Here, the optimal number of clusters is 5. We then pass this output to hierarchical clustering. We draw the vertical line at x = 2.35, which intersects the linkages at 5 points showing the 5 clusters.

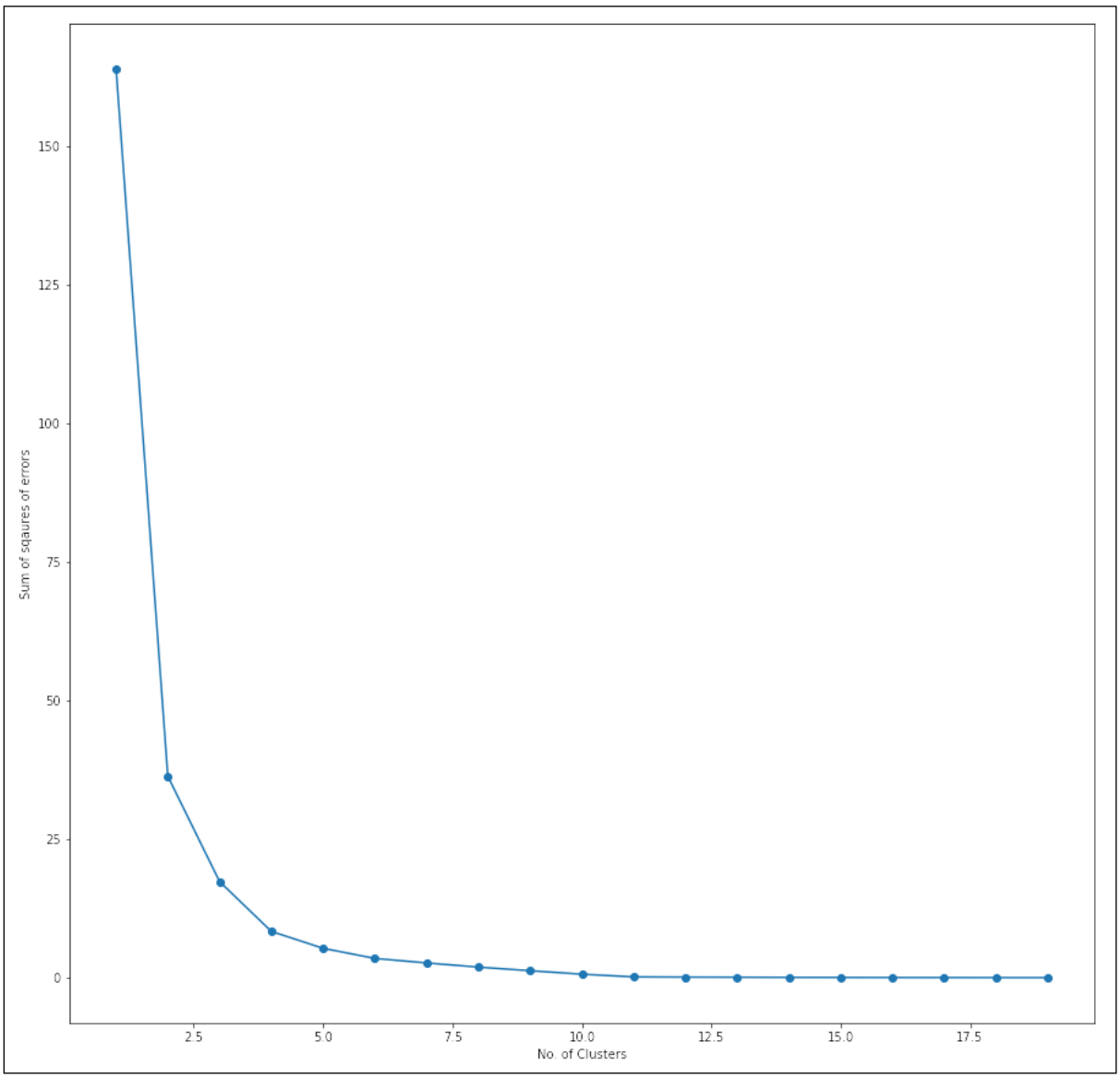


**Figure 4. K-means Based Elbow Diagram**

# Appendix D

Benchmarking points of cut values are the threshold scores of the categories in the ordinal regressions. Table 7 captures the cut values, monotonically non-decreasing in nature.

**Table 7. Cut Values for the Ordinal Regression Models**

| Cut values | Ordered Logit model (Standard error) | Ordered Probit model (Standard error) |
|---|---|---|
| Cut 1 | -19.68173 (1.182) | -8.997 (0.285) |
| Cut 2 | -7.216 (0.030) | -4.188 (0.017) |
| Cut 3 | -6.907 (0.030) | -4.015 (0.0170) |
| Cut 4 | -6.466 (0.0302) | -3.763 (0.0169) |
| Cut 5 | -5.903 (0.029) | -3.428 (0.0168) |

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