An Experiment-Based Study on Decision Evaluation in Metaverse

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Short Paper

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Abstract

The advancement of metaverse has accelerated individuals' entry into fully digitalized reality. However, academic research on how the metaverse influences individuals' main activities such as making decisions remains limited. Therefore, this study conducts a controlled laboratory experiment (N = 183) in a finance context to investigate the effects of two VR features–immersion and embodiment–on decision evaluation through satisfaction, self-esteem and anxiety across five virtual settings (2D as the control). Preliminary descriptive results indicate that participants reported the lowest decision satisfaction and self-esteem in a highly immersive 3D environment, while anxiety was lowest in the traditional 2D environment. Additionally, the level of embodiment appears to interact with the level of immersion, resulting in varying effects on anxiety. More granular analyses are required for further examination. This study will contribute to IS, HCI, and consumer psychology, providing practical implications to VR designers, developers and practitioners, and improving decision experience.

Keywords: Virtual reality, 3D graph, FinTech, decision-making, data visualization

Introduction

The rapid development of emerging technologies, represented by virtual reality (VR) is transforming how we perceive and understand our surroundings, self and others. It paves a way towards a future in which all human activities such as education, business, health and leisure take place in a fully immersive artificial reality known as the *Metaverse*. Enabled by various displays and interactive devices, individuals can freely navigate in a 3D digital world and interact with a range of information presented in diverse ways. Traditionally, humans have primarily engaged with and processed information in 2D formats outside of real-life settings. However, with the advancement of computer vision and interactive technology, it is anticipated that daily activities—including searching, processing, interpreting information, and making decisions—will increasingly occur in 3D virtual settings. Practical examples of this shift include matters such as making investing decisions (e.g., Matterport, Zillow 3D Home), shopping decisions (e.g., Walmart Realm), tourism decisions (e.g., Virtual Tour of the Forbidden City), and healthcare-related decisions (e.g., Osso VR, Surgical Theater).

Due to the nascent stage of VR applications, current research predominantly relies on experiment-based studies, comparing specific VR systems to real-life settings such as physical or online environments (Pizzi et al., 2019; Xi & Hamari, 2021), often focusing on overall user experience and technology adoption rather than decision-making activities, system characteristics, and variations in information presentation and interaction approaches (Kang et al., 2020; Tcha-Tokey et al., 2016; Xi et al., 2024). Additionally, while many decision-making studies in VR have been conducted in virtual business and consumption settings; likely due to their familiarity and complexity, these evaluations typically emphasize efficiency metrics (time, speed, completion rate) or hedonic aspects of VR systems which provide more enjoyable and game-like experiences (Kang et al., 2020; Nevelsteen, 2018; Pizzi et al., 2019). There is a significant research gap in understanding how VR features influence decision-making performance. For example, how users evaluate the decision-making process and perceive outcomes, either positively or negatively.

This study employs a between-subjects laboratory experiment to examine the effects of two core VR features—immersion and embodiment—on decision-making performance (N=183). Referring to avoidance-approach theory, the study explores decision self-esteem and anxiety from both positive and negative perspectives, with decision satisfaction identified as a key predictor variable. The experiment features four conditions based on levels of immersion (high/low) and embodiment (high/low) in 3D virtual settings, compared to a control condition using a 2D interface. All conditions utilize the same virtual environment and amount of information to facilitate the decision-making.

Background

The Metaverse: Immersion and Embodiment

Since Facebook's rebranding as Meta, 'metaverse' has gained widespread usage in both academia and industry, often interchangeably with VR and reflects the integration of advanced technologies and complex social interactions (Ritterbusch & Teichmann, 2023; Xi & Hamari, 2021). With the development of VR technologies such as high-fidelity, resolution VR Head-mounted displays (HMDs) and the integration of multisensory modalities for different sensory perceptions, the academic definition of VR has evolved from simply focusing on immersive experience provided by computer-generated 3D content, to all positive embodied experiences (Duan et al., 2021). Technologically, VR aims to digitally duplicate the "real reality", which is the physical reality individuals can perceive (Xi & Hamari, 2021). Computer vision and rendering technology enable the creation of realistic 3D environments, allowing for a more immersive experience when presenting 3D content on large screens compared to 2D content (Park & Kim, 2022). HMDs further intensify immersion by covering users' entire field of view, blocking external visual or other sensory stimuli from entering their attention (Xi & Hamari, 2021). Consequently, varying levels of technological immersion lead to difference senses of presence (psychological immersion), and a sense of feeling like "being there" (Bampouni et al., 2023).

When interacting with virtual systems, individuals perceive both the system's immersive qualities, and also develop self-awareness in the sense of 'having' and 'using' a body (Bampouni et al., 2023; Blanke & Metzinger, 2009). Embodiment, defined as "the ensemble of sensations that arise in conjunction with being inside, having and controlling a body" (Kilteni et al. 2012), is mostly manipulated in present study by a 'sense of agency' — the subjective sense of action, control and motor selection integral to self-motion. Self-motion in virtual and real environments can be achieved through self-propulsion or passive movement (Bampouni et al., 2023; Campos & Bülthoff, 2012). In the designed high embodiment conditions, the users are allowed to conduct physical movement and bodily interact with the virtual environment, gaining a strong sense of self-motion. With low embodiment conditions, users can only control objects and interact with the system via controller key-binds, with movement being restrained with participants anchored in one spot.

Decision-Making Performance

The evaluation of decision-making performance is a multifaceted process, often encompassing both subjective assessments of the process and its outcomes. The evaluation of a decision-making process is often reflected in decision satisfaction, indicating how consumers perceive their experience throughout the decision-making process. This satisfaction is often analyzed through the lens of expectation confirmation theory which compares consumers' initial expectations with actual experiences (Hossain & Quaddus, 2012; Lu et al., 2022). Consumers are more satisfied when their experience meets or exceeds expectations (Hudson et al., 2019; Jones, 1996). Heitmann et al. (2007) showed that decision satisfaction not only affects final consumption, but also influences post-consumer behavior. Specifically, when consumers feel the decision-making process is smooth and well-informed, it increases both purchase likelihood and their willingness to recommend.

The evaluation of decision outcomes involves how individuals assess the results of their decisions and cope with the consequences, which is often complex and may have both positive and negative aspects. According to approach-avoidance theory, decision-making is driven by the desire for positive outcomes (approach) and the need to avoid negative consequences (avoidance). Decision self-esteem is associated with approach motivation, and involves the positive assessment of one's decision-making abilities and self-affirmation (Chen et al., 2015; Steele et al., 1993). For instance, in investment decisions, when individuals successfully predict the direction of the market and gain, their decision self-esteem is boosted, which may lead them to be more confident in future investments (Forbes & Kara, 2010; Statman et al., 2006). Conversely, cognitive anxiety as an expression of avoidance motivation reflects anxiety and concern about the potential failure or poor performance of their decisions, and for instance, high anxiety predicts conservative financial decisions (Gambetti & Giusberti, 2012). The balance between both aspects may influence consumer's decision making (Teo & Yeong, 2003).

Research Gap

While VR and the metaverse evolve towards rich multisensory experiences, current VR applications and research predominantly focus on visual experiences in immersive 3D environments, where visual information presentation and interaction have been key influencers of individuals' decision-making. Drawing on Tufte's (2001) principles of information visualization, VR's unique features, particularly its ability to present information, may impact the decision-making process. These features can provide more comprehensive and interactive visual information, potentially enhancing decision satisfaction through increased perceived information completeness (Bi et al., 2024). However, they may also lead to information overload or interaction complexities, possibly having a negative effect on satisfaction and cognitive processing (Gronowski et al., 2024). This complex interplay underscores the need to understand how VR features influence decision-making performance such as satisfaction of the process, and anxiety and self-esteem towards outcome. Therefore, this study provides a more comprehensive view by integrating the decision process and decision outcome assessment (both positive and negative aspects) into the metaverse. By designing and conducting a between-subjects experiment (see *Method* Section), this study aims to address the two research questions: When making decisions based on the presented visual information, how do consumers' evaluations of decision-making performance (satisfaction, anxiety, and self-esteem) in the metaverse (3D) differ from those in traditional 2D setting? (***RQ1***), and how do different levels of metaverse features including immersion and embodiment influence these evaluations? (***RQ2***)

Method

Design

To address the proposed research questions, this study employed a 2 (immersion: low vs. high) × 2 (embodiment: low vs. high) factorial between-subjects design laboratory experiment, with 2D condition as the control. Immersion level was operationalized using two different VR display devices: PC screen and VR HMD. Embodiment level was manipulated via two different interaction approaches within the 3D environment. In the high-embodiment conditions participants could 'physically' move and bodily interact with the environment, while in the low-embodiment conditions participants were self-anchored and restricted to a fixed location to interact with the objects and environment with the assistance of additional interactive devices such as controllers, keyboard and mouse.

The decision-making scenario was set in a financial investment context where participants were able to navigate in one of the 3D environments or a 2D interface, and interact with a graph displaying four assets with price and time information. They were asked to make a series of decisions within a 10-minute experiment window. This study focused on evaluating the decision based on the performance in the first allocation task (see *Material* section). A link to the demo videos for all conditions is provided: https://cutt.ly/aemFAShx

Participants

From July to November 2022, an experiment was conducted at a university in north Europe with 216 non-colorblind student volunteers, with 33 participating in pilot tests to refine the experiment design. The final sample of 183 students comprised 50.3% male (aged 18 to 48), 48.1% female (aged 19 to 45) and 1.6% non-binary or undeclared participants. 97 were studying for a master's degree, 70 for bachelor's, 15 for PhDs, and 1 other. Notably, 80.9% had little or no prior VR experience. Participants came from over 40 countries, with more than 60% earning less than 1,000 euros monthly (pre-tax).

Materials

Physical settings and device: The experiment was conducted in the university's LUDUS research lab providing a 6m×8m XR dedicated area for the two HMD-based conditions (Oculus Quest 2 and controllers). The three PC-based conditions including 2D control were conducted in a standard research cubicle in the same lab. Information presentation and interaction used a monitor (24.5 inch), mouse and keyboard.

Virtual settings: The virtual space was a minimalist 3D-rendered bright room created in Unity (a 3D development platform) for all four experimental conditions. At the center of the room was a 3D line graph displaying price information for four colored financial assets across 29 periods (Figure 1 shows the interface of one experimental condition). The control condition employed a conventional 2D graph application, which displayed the same room as a static background image. To enhance the realism of the investment decision process and mitigate bias associated with only using one graph, personalized graphs for each participant were generated based on the same standardized formula. Regardless of the condition, participants could also see pop-up information about each data point for more detailed and tailored examination.

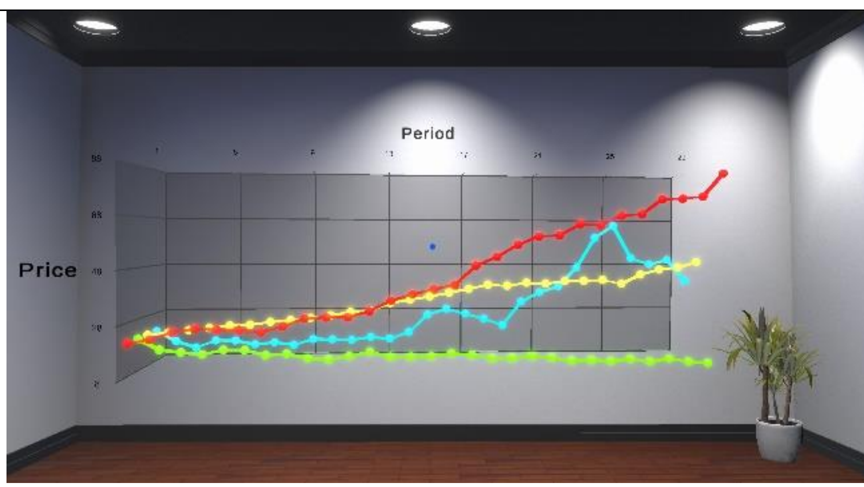

Figure 1. The interface of the 3D line graph containing price and time information

Decision-making task: In this study, only the main decision-making task related to asset portfolio decision was examined. Figure 2 describes the task interface where the participants were asked to allocate 100% of the available budget to five assets (four assets in the graph plus a bank deposit). All assets are independent of each other. Participants were asked to make an investment decision for the next period, namely *Period*

30, based on their best judgment through examining the performance of the four assets across all 29 periods provided (considering both possible growth and risk; the bank deposit was risk-free with 1% fixed return). This portfolio decision task closely mirrors the common decision processes in daily life, involving complex and real-world decisions of information gathering, processing, evaluating choices (e.g., evaluating future returns and risks), and making decisions.

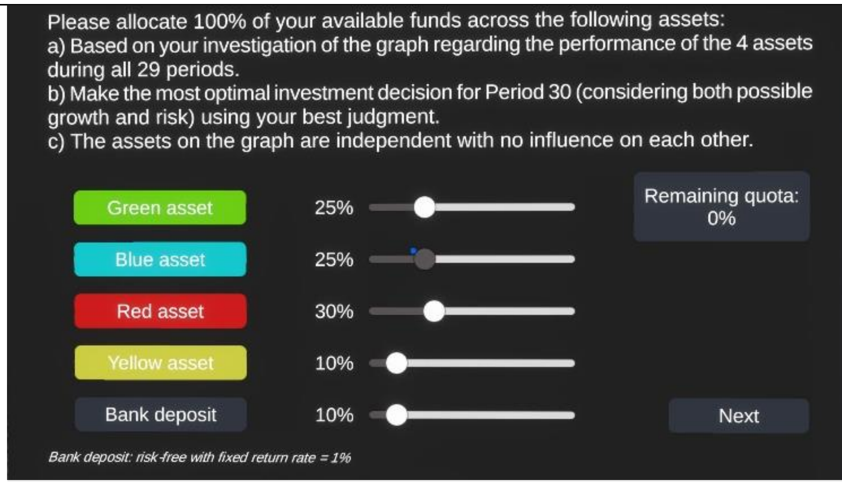

Figure 2. Interface of the asset allocation task

Measures: This study evaluated decision-making performance using three variables measured in the post-survey after completing the experiment. Decision satisfaction was measured through three items adapted from Heitmann et al. (2007), focusing on evaluating the decision-making process. Cognitive anxiety specific to the virtual reality environment was measured using a framework based on a study by Hong et al. (2019), Decision self-esteem was measured using the adapted four-item scale originally developed by Mann et al. (1997), related to positive aspects of decision evaluation outcomes. All assessments were conducted using a 7-point scale, ranging from 1 (strongly disagree) to 7 (strongly agree) –more details are presented in Table 1. All of the Cronbach's α of the variables were above 0.50, and CR values higher than 0.70. Therefore, internal reliability was ensured. The AVE values were 0.511, 0.660, and 0.637, respectively, indicating adequate convergent validity.

Variables	Items	Sources
Evaluation on process		
Satisfaction	DES 1: I found the process of making the decision frustrating. (Reversed)	Heitmann et al. (2007)
	DES2: I found the process of making the decision interesting.	
	DES3: I was satisfied with my experience of making the decision.	
Evaluation on outcome		
(Cognitive) Anxiety (avoidance perspective)	COA1: I worried about making a wrong decision while I completing it.	Hong et al. (2019)
	COA2: I was worried about my performance if I made a decision wrong.	
	COA3: Even though the decision task was familiar to me, I got too nervous to do correctly.	
Self-esteem (approach perspective)	DSE 1: I felt confident about my ability to make the decision.	Mann et al. (1997)
	DSE2: I felt inferior to others in making the decision. (Reversed)	
	DSE3: I think I was a good decision maker.	
	DSE4: I felt so discouraged when making the decision. (Reversed)	

Table 1. The measurement items

Procedure

Participants were recruited through campus advertisements and completed an online survey about basic information before scheduling their experiments (step 1). Upon arrival at the laboratory, they filled out a pre-experiment survey (step 2) and were pseudo-randomly assigned to one of four experimental conditions and a control group. First, they were required to complete tailored tutorial tasks under two experimental researchers' guidance so as to ensure a full understanding of all procedures and devices (step 3). All participants signed a consent form for voluntary participation and data collection.

Navigation and task: Participants then proceed to the main experiment (maximum 10 minutes) (step 4). The experiment consisted of 2 parts – interacting with a 3D or 2D graph (5 minutes) and making a series of decisions including the main decision-making task investigated in this present study (5 minutes). During the first 5 minutes, each participant was able to freely interact with the graph from the first-person perspective by (physically or virtually) moving their own body or directly manipulating via controllers or keyboard & mouse while the 'body' was anchored. Below are the descriptions of each condition.

C1. (3D) PC-based + self-anchored: Participants used a keyboard and mouse to interact with the 3D graph and navigate the virtual environment displayed on the PC screen. They could perform actions such as zooming in, zooming out, pointing, selecting specific-colored assets and rotating, while their virtual body movement was restricted.

C2. (3D) PC-based + self-motion: The display, interactive device and virtual settings are the same as in C1. While in C2, participants used a keyboard and mouse to control their own 'virtual body' and freely navigate in the 3D environment.

C3. (3D) HMD-based + self-anchored: Participants used Oculus Quest 2 to experience the virtual environment and interact with the 3D graph. They used controllers to perform the same actions as in C1.

C4. (3D) HMD-based + self-motion: The display, interactive devices and virtual settings are the same as in C3. While in C4, participants used hand controllers to control their own 'virtual body' and freely navigate in the 3D environment.

C5. (2D) PC-based (control): Participants used a keyboard and mouse to interact with the 2D graph in a conventional way excluding rotating.

Post-survey and compensation: After 10-minute experiment, participants filled out a post-survey (containing the measures analyzed in this present study) (step 5) and received a digital coupon for local grocery stores as compensation (5-20 euros) depending on their task performance (step 6). The Capital Asset Pricing Model (CAPM) calculated the expected return which was later converted to the compensation. This study followed the 2019 guidelines of the Finnish National Board on Research Integrity (TENK).

Pilot tests: A pilot test was conducted among 33 participants for testing and improving the user interaction experiences with the self-developed VR systems, experiment procedure, and all of the psychometric measures.

Preliminary Results

Table 2 presents descriptive information related to decision satisfaction, self-esteem and anxiety across all five conditions. Overall, participants reported relatively high decision satisfaction and self-esteem (mean scores exceeding 5 on a 7-point scale) and lower anxiety (mean scores below 4). Three main preliminary results are presented and discussed below. While descriptive statistics can provide an overview of the trends and differences, statistical tests are needed to determine if these differences are statistically significant.

Preliminary result 1: The lowest levels of decision satisfaction and self-esteem were reported in the highly immersive 3D environment. Specifically, the mean decision satisfaction scores in conditions C1, C2, and C5 were above 5 (5.176, 5.162, and 5.050, respectively), whereas in the high-immersion conditions C3 and C4, the means were lower at 4.874 and 4.971. A similar pattern was observed for self-esteem, with mean scores of 4.804 and 4.929 in the high-immersion conditions.

Preliminary result 2: Anxiety was rated lowest in the 2D environment. Specifically, the mean anxiety scores in conditions C1-C4 were above 3.7, whereas lowest score was 3.692 in traditional 2D.

Preliminary result 3: Regarding the 3D settings, the level of embodiment appears to interact with the immersion level, resulting in varying effects on anxiety. Specifically, in the lower embodiment conditions, higher immersion was associated with higher anxiety (C3: 3.919 vs. C1: 3.713). However, in the higher embodiment conditions, higher immersion was associated with lower anxiety (C4: 3.771 vs. C2: 3.857).

Condition	Immersion	Embodiment	n	Satisfaction		Anxiety		Self-esteem	
				M	SD	M	SD	M	SD
C1	Low	Low	36	5.176	0.838	3.713	1.307	5.181	0.996
C2	Low	High	35	5.162	0.853	3.857	1.261	5.207	1.096
C3	High	Low	37	4.874	0,963	3.919	1.375	4.804	1.265
C4	High	High	35	4.971	0.830	3.771	1.45	4.929	1.016
C5	-	-	40	5.050	0.734	3.692	1.464	5.094	1.056

Table 2. The descriptive results

Two analyses will be conducted to further examine the differences in consumers' decision evaluations between all 3D settings and the traditional 2D environment, and the main effects of immersion and embodiment and their interaction. *Analysis 1* will compare 2D control (C5) with the pooled data from four 3D conditions (C1-C4) through T-test, aiming to compare the differences in decision satisfaction, anxiety, and self-esteem. There is a need to show and discuss the difference between presenting visual information and interacting in the conventional 2D interface vs. the 3D environment, regardless of employed device. The second research objective proposed in this study aims to explore and investigate the effects of two core VR features –immersion and embodiment– on decision evaluation. Therefore, *Analysis 2* will employ a selection of parametric tests such as ANOVA (Analysis of Variance), which will depend on the results of assumption tests for normality, homogeneity of variances, and independence. If these assumptions are met, ANOVA will be used to evaluate the main effects and interactions of immersion and embodiment on decision satisfaction, anxiety, and self-esteem across four 3D virtual conditions. If the assumptions are violated, non-parametric tests will be considered. Post-hoc comparisons will be conducted as needed using methods such as Tukey's HSD or Bonferroni corrections to identify specific group differences. Additionally, SPSS PROCESS macro plugin will be used to examine the potential mediation effect of decision satisfaction.

Conclusion and Contribution

A large-scale laboratory experiment was conducted in the finance context, combined with a daily-life decision-making task. Asset allocation was selected to simulate how individuals allocate resource based on their interpretation of potential risks and future returns from given historical information. In addition to exploring the differences between traditional 2D and 3D approaches to visual information presentation, this study especially aims to examine how embodiment and immersion impact consumers' evaluations of their decision-making performance across three key aspects: decision satisfaction, self-esteem, and anxiety. Based on the preliminary descriptive analysis, it can be inferred that consumers experience lower anxiety when making decisions using traditional 2D methods. However, regardless of the interaction approach and the resulting different levels of embodiment, emerging VR technology may negatively impact decision satisfaction and self-esteem.

This research enhances our comprehension of decision process and outcome evaluation in VR, contributing to the existing research in IS, HCI, and VR studies. The findings offer insights into consumer engagement and experience enhancement when interacting with immersive technologies, providing practical guidance for VR developers with an emphasis on user decision experiences. Our study enriches the understanding of consumer psychology and decision evaluation within HCI, and provides a deeper understanding of the factors influencing decision behavior.

Limitations

Despite its careful design and rigorous implementation, several limitations warrant discussion for future research. To ensure internal validity and minimize biases from a diverse sample, this study focused on university students as single sample. While we believe the generalizability of the findings is supported, given emerging technologies like VR primarily target younger users, it remains important to investigate whether the applicability to specific groups such as the elderly and individuals with disabilities. Regarding the research content and data analysis, potential control variables were not investigated in this study. Randomization theoretically addresses confounding factors such as prior knowledge and technology familiarity, and despite efforts to ensure VR system usability and task simplification, these confounding variables were not explicitly accounted for. Future research can still incorporate these external variables into the research model to examine their effects. To enhance external validity, a relatively simple yet carefully designed decision-making task was developed. The asset allocation task was chosen as it is common decision-making activity for many people and reflects typical decision-making processes and goals. This task requires decision-makers to rationally and reasonably allocate existing resources to maximize future returns while minimizing risk. While it would be still interesting to see whether users would perform and evaluate decisions in a similar way when facing more complex decision-making tasks.

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