A Study on the Impact of Embodiment in AR Learning on Learners' Technology Acceptance

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Abstract : *This study focuses on the impact of embodiment in AR learning on learners' technology acceptance. Based on the embodied AR application (Experiment group) designed and developed in this study, a controlled experiment was conducted with a common AR application (Control group). The participants were 122 senior high school students from China, with 63 in the experimental group and 59 in the control group. The research findings show that embodiment in AR can significantly improve learners' perceived usefulness of AR technology, but adding embodiment to AR makes learners perceive a lower ease of use. This study will provide empirical support for the design of embodiment in AR.*
Keywords: AR, technology acceptance, AR learning, embodied

1. Introduction

Augmented reality (AR) technology has evolved relying on computer graphics, human-computer interface technology, and sensing technology, and has drawn substantial attention in recent years. The authoritative Horizon Report has listed the educational applications of AR as an educational technology to be adopted in the medium and short term for several consecutive years (Gao & Huang, 2017). AR disrupts the conventional education paradigm, which is circumscribed by temporal and spatial constraints, via its visual effects that blend real and virtual elements and its portability (Ciloglu & Ustun, 2023). Within an AR setting, learners are able to undergo a rich state of flow, emotional experiences, and other immersive encounters (Abdul Hanid et al., 2022; Ciloglu & Ustun, 2023; Weerasinghe et al., 2022). These experiences, in turn, serve as a catalyst for their active engagement in the learning process and the construction of knowledge, thereby promoting the development of their thinking skills and capabilities. Nevertheless, the advantages of implementing AR in the educational domain extend beyond these aspects. AR has the capacity to substitute the abstract experiences denoted by textual symbols with intuitive ones through the utilization of virtual models or embodied interactions (Cai et al., 2019; O'Meara & Szita, 2021), thereby further augmenting learners' educational experiences.

The theory of embodied cognition posits that knowledge concepts can be comprehended and acquired through somatic experiences, and that individuals are capable of engaging in cognitive processes through physical involvement in actions (Borghi & Cimatti, 2010). Moreover, embodied cognition places a strong emphasis on the subject's physical engagement and perceptual awareness, underscoring the body's agency and its significance within the realm of experience (Zahavi, 2003). AR provides learners with experiences that are intertwined with the real world, digitally generated objects, and their own bodies. Learners can interact with the components within the AR environment by means of physical movements in the real space, thus attaining experiences of embodied participation. Technology acceptance has become a theoretical framework model that can significantly predict and reflect individuals' intentions to use information technology. Numerous studies have applied AR in educational settings and measured technological acceptance, revealing that learners' PU and PEU are generally favorable (Iqbal & Sidhu, 2022; Liu et al., 2023). However, does the incorporation of embodiment into AR incontrovertibly bring about benefits for students' technological acceptance? This is the pivotal research question that this study endeavors to explore. Therefore, this study takes the inclusion or exclusion of embodiment as the independent variable, with two groups set up: with embodiment (control group) and without embodiment (experimental group). The dependent variables are technology acceptance (perceived usefulness, perceived ease of use), to examine the effect of embodiment in AR on learners' technology acceptance.

2 . Theoretical framework

The Technology Acceptance Model (TAM), put forward by Davis, is predominantly applied to elucidate individuals' acceptance of information technology while they carry out tasks (Yang & Yoo, 2004). This model introduces two fundamental concepts: perceived usefulness (PU) and perceived ease of use (PEU) (Davis & Davis, 1989). PU is defined as "the extent to which a person believes that using a specific system would enhance their job performance." It is associated with work efficiency, productivity (in terms of time - savings), and the system's relative significance to an individual's work. PEU refers to "the degree to which a person believes that using a particular system is effortless." This concept encompasses both physical and cognitive exertion, along with the ease of learning (Venkatesh & Davis, 2007).

In this study, PU and PEU of technology acceptance are treated as outcome variables to explore the influence of embodiment in AR. As an emerging technology, AR needs to be embraced by users to fully unlock its educational potential (Al - Rahmi et al., 2019). When learners use AR, they typically demonstrate high levels of technology acceptance, this is likely because of AR's strong engaging nature and interactive allure, which have a positive impact on learners' subjective perceptions (Liu et al., 2023; Su et al., 2022). In the direction of this study, the following questions are handled:

1.What is the impact of the embodiment in AR experiences on learners' PU of technological acceptance?

2.What is the impact of the embodiment in AR experiences on learners' PEU of technological acceptance?

The following research hypotheses are proposed:

Hypothesis 1: The embodiment in AR has a positive effect on learners' PU of the technology.

Hypothesis 2: The embodiment in AR has a positive effect on learners' PEU of the technology.

3. Methodology

3.1. AR applications

The AR applications in this research are chiefly designed for high - school students to learn the abstract biological concept of "cell structure". The content is drawn from the textbook utilized by first - year high - school students in China (Biology, Compulsory Volume 1, People's Education Press). To guarantee the effectiveness of the AR application in real - world teaching, three Chinese high - school biology teachers were enlisted to offer guidance throughout the design and development of the AR application. Once the development of the AR application was finalized, an evaluation was conducted. All three teachers opined that the AR application in this study is appropriate for students to use during the biology class of the first grade in senior high school. This study features two AR applications. One is embodied, and the other is non-embodied.

The embodied AR application in this study incorporates an embodiment with haptic feedback. Haptic feedback represents an interactive experience that furnishes learners with a realistic sensory perception, mainly incorporating vibrations or force - based feedback. In this study, the haptic feedback experience is intended to offer learners force - based feedback. Learners can touch specific areas of the AR marker, which will trigger the enlargement of corresponding virtual organelles, as depicted in Figure 1.

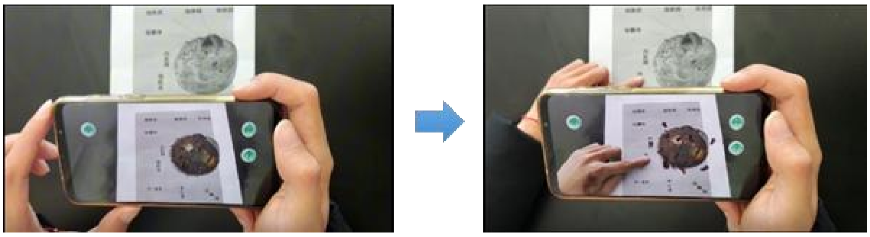

Figure 1 The process of haptic feedback experience

3.2. Participants

To guarantee the relevance of the knowledge within the AR applications for the participants, 122 first - year students from regular high schools in China were recruited (60 males and 62 females, with an average age of 15.8 years). Participation was on a voluntary basis. The participants were randomly allocated into two groups: Control group with 59 participants and Experient group with 63 participants. Each group had an approximately equal gender distribution. Every participant was provided access to the experimental equipment—smartphones and AR markers—for the conduct of learning activities.

3.3. Measures

3.3.1. Survey for PU of Technology Acceptance

The measurement of PU was adapted from Moore and Benbasat's (1991) scale regarding the advantages of technology use. The objective was to gather participants' feedback on the utility of AR applications in the learning process. This scale consists of five nine - point Likert - scale items. It exhibits a Cronbach's alpha of 0.831, signifying good reliability. Through factor analysis, it yields a KMO value of 0.776. The results of Bartlett's Test are $\chi^2 = 233.126$ ($p < 0.001$), demonstrating its validity. These figures suggest that the scale effectively measures PU in AR - based learning, with good reliability and construct validity.

3.3.2.Survey for PEU of Technology Acceptance

The PEU measurement was adapted from Venkatesh and Davis's (2000) perceived ease of use scale. It was used to gather participants' feedback on the ease of using AR applications for learning. The scale, featuring five nine - point Likert - scale items, has a Cronbach's alpha of 0.765 for reliability. Factor analysis shows a KMO value of 0.746 and Bartlett's Test results of $\chi^2 = 145.51$ ($p < 0.001$) for validity, indicating that the scale demonstrates good reliability and construct validity for measuring PEU in AR - based learning.

3.4. Procedures

The initial step entailed pre - experiment preparation. This involved acquainting participants with AR concepts and elucidating the experimental guidelines, a process that spanned 10 minutes. The introduction of AR concepts was intended to counteract any adverse impacts on the learning process stemming from participants' lack of familiarity with AR concepts or the AR learning environment during their inaugural AR learning encounter. This was achieved through teacher - led instruction, enabling participants to gain an understanding of AR technology and the AR learning environment. The explanation of experimental guidelines was designed to govern participants' actions during the experiment. It detailed the procedures, format, and duration of the AR learning experiment, while also highlighting the prohibition of activities unrelated to AR learning.

The subsequent step was AR learning, during which the two groups of participants were tasked with using different AR applications. This phase lasted for 20 minutes. Participants in the Control group undertook AR experiences through observation. In contrast, participants in the Experiment group engaged in AR experiences featuring haptic - feedback - enabled embodied interactions.

The final step involved post - experiment questionnaire measurement. The questionnaire incorporated the technology acceptance (PU & PEU) scale. Participants were given 10 minutes to complete the questionnaire.

3.5. Data analysis

The data were analyzed by utilizing SPSS 26.0. The outcomes of the measured variables in this research all adhered to the normal distribution pattern, and they had successfully passed the test for the homogeneity of variances. Consequently, an independent samples t-test was carried out (with the Cohen's d effect size being computed through the use of G*Power) in order to examine and analyze the disparities in the measurement results between the two experimental groups.

4.Result

This study aimed to measure differences in technology acceptance among learners after using AR applications of embodiment. To achieve this, a independent samples t-tests were employed to explore differences in prior knowledge scores, cognitive load and technology acceptance between the two groups. The test results are presented in Table 1.

Table 1. T-test Results for the technology acceptance based on the embodiment in AR learning.

Variable		Control group(N=59)		Experiment group(N=63)		t	Cohen's d
		Mean	SD	Mean	SD		
Technology	PU	27.93	7.521	34.96	6.428	-5.532**	-1.006
Acceptance	PEU	33.34	6.064	26.89	7.01	5.445**	0.981

**p<0.001

Independent samples t - test results for technology acceptance revealed that the level of embodiment in AR experiences had a substantial influence on the PU and PEU of technology acceptance, as presented in Table 3.

Regarding PU, the Control group, with a mean (M) of 27.93 and a standard deviation (SD) of 7.521, had significantly lower scores than the Experiment group, which had an M of 34.96 and an SD of 6.428. The t - value was - 5.532, with a p - value less than 0.001, and the effect size (d) was -

1.006, indicating a high - level effect. This suggests that when using AR applications, AR with embodiment led to a higher level of PU compared to AR without embodiment.

As for PEU, the Control group, having an M of 33.34 and an SD of 6.064, scored significantly higher than the Experiment group, which had an M of 26.89 and an SD of 7.01. The t - value was 5.445, with a p - value less than 0.001, and the effect size (d) was 0.981, also showing a high - level effect. This implies that when using AR applications, AR without embodiment led to a higher level of PEU compared to AR with embodiment.

The research contributions lie in revealing, via independent samples t-tests, that embodiment in AR enhances perceived usefulness (PU) but reduces perceived ease of use (PEU), highlighting a critical trade-off between functional immersion and usability. This offers practical insights for AR design, urging developers to balance embodied features to optimize both PU and PEU. The findings also lay groundwork for future research by identifying the need to simplify embodied interactions and explore user preferences across demographics, advancing more effective and user-friendly AR educational applications.

5. Discussion

The findings from the independent samples t - test in this study present intriguing insights into the impact of embodiment in AR experiences on technology acceptance, specifically in terms of PU and PEU.

Regarding PU, the significant difference between the Control group (non - embodied AR) and the Experiment group (embodied AR) is notable. The higher PU scores in the Experiment group suggest that the embodied AR experience makes users perceive the application as more useful. This could be because the haptic feedback and embodied interactions in the AR application provided a more immersive and engaging learning environment. Users may have felt that these embodied features enhanced their understanding and learning outcomes, thereby increasing the perceived value of the application. In educational contexts, this implies that incorporating embodied elements in AR can potentially boost students' belief in the utility of the technology for learning.

Conversely, for PEU, the Control group (non - embodied AR) had higher scores. This indicates that users found the non - embodied AR application easier to use. It might be that the additional haptic and embodied interaction elements in the experimental AR application added complexity, making it seem less intuitive. This finding is important as it highlights a potential trade - off between the added functionality of embodied AR (leading to higher PU) and its impact on ease of use.

Overall, these results have implications for the design of AR applications. Developers need to carefully balance the inclusion of embodied features to optimize both PU and PEU. Future research could explore ways to simplify embodied interactions to maintain high PEU while still capitalizing on the benefits for PU. Additionally, investigating user preferences across different demographics could further inform the design of more user - friendly and effective AR learning applications.

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