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RECEIVED 21 October 2025
REVISED 05 January 2026
ACCEPTED 18 February 2026
PUBLISHED 04 March 2026

CITATION
Avilés-Castillo F, Buele J, Salazar M and
Palacios-Navarro G (2026) Influence of
continuous navigation modes on the
immersive experience in a
virtual supermarket.
Front. Virtual Real. 7:1729505.
doi: 10.3389/frvir.2026.1729505

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Influence of continuous navigation modes on the immersive experience in a virtual supermarket

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Introduction: Virtual reality has established itself as an effective tool for analyzing user experience and simulating everyday activities. However, there are still many questions remaining, such as how the type of movement in immersive environments influences this experience. The present study evaluated these variables in a virtual supermarket developed for Oculus Quest 2, with the aim of comparing the perceptual and cognitive experience under two navigation modalities: locomotion and joystick.

Methods: Twenty-two young adults (18–32 years old) participated in both groups. Usability (SUS), presence (PQ), everyday memory (PRMQ), and cybersickness (CSQ-VR) questionnaires were administered, all with moderate and high reliability ($\alpha = 0.685–0.912$).

Results: The results showed high levels of usability in both conditions ($SUS \geq 79$), with no statistically significant differences between navigation modes ($p = 0.521$). Natural presence was significantly higher in locomotion mode (6.17 vs. 5.47); however, this result should be interpreted with caution, as it was derived from exploratory subscale-level analyses ($p = 0.038$). Cybersickness symptoms remained low ($p > 0.05$). A very strong positive correlation was also observed between usability and presence in the joystick group ($\rho = 0.902$; $p < 0.001$), indicating that interaction fluidity enhances immersion.

Discussion: Both modes were ergonomic and safe, although with distinct profiles: physical locomotion increased perceptual naturalness, while the joystick reinforced the relationship between ease of use and immersion. These findings provide empirical evidence on how movement modulates the immersive experience and propose an experimental model, with implications for the design of virtual environments applicable to different populations in the future.

KEYWORDS

continuous navigation, cybersickness, presence, usability, user experience, virtual reality

1 Introduction

Virtual reality (VR) has become established in recent years as a technology with diverse applications in fields such as education, healthcare, entertainment, and training (Javaid and Haleem, 2020; Checa et al., 2023). Its definition encompasses computer-generated three-dimensional environments that enable real-time interaction through visual, auditory, and, in some cases, haptic stimuli (Tyagi, 2021), supported by a historical evolution of hardware,

from the initial HMDs that reduced costs and improved accessibility (Wells and Haas, 1992). This ability to generate immersive experiences facilitated the development of controlled scenarios in which human behaviors, cognitive processes, and interaction patterns were studied (Ferguson et al., 2020).

Based on VR's ability to create immersive and controlled environments, a frequent application is simulated scenarios that allow the study of behavior and decision-making in everyday contexts (Holdnack and Brennan, 2021). In this context, virtual supermarkets could be reference scenarios, since they offer a familiar and structured space that facilitates the simulation of purchasing behaviors with high ecological validity. These environments allow the analysis of the user experience (UX) under realistic conditions, providing a useful framework to study how different design factors influence user interaction and perception (Kim et al., 2020; Sagnier et al., 2020). It has also been shown that this experience is modulated by interaction factors, such as hand tracking (which alters the perception of control and interaction load (Varela-Aldás et al., 2023) or environment personalization (which increases preference and engagement) (Pardini et al., 2022). According to recent reviews, interest in evaluating UX in VR has grown steadily in recent years, with special attention to immersion and presence (Avilés-Castillo et al., 2025).

Recent research has highlighted the importance of designing VR shopping experiences that go beyond simply replicating a physical supermarket, incorporating dynamics that leverage the immersive capabilities of these environments (Sun et al., 2024). In this context, (Speicher et al., 2017), introduced the Virtual Reality Shopping Experience (VRSE) model, which aimed to bring the advantages of physical and online stores to the virtual environment, combining the efficiency of e-commerce with the immersion inherent in VR. This model integrated satisfaction measures and task performance as evaluation criteria. Furthermore, VR shopping experiences were used as a nutrition education tool, where guided tours helped interpret product labels and costs, connecting the immersive experience with applied learning goals (Lanningham-Foster et al., 2022).

Other researching works have compared access technologies, ranging from PC and tablet displays to HMDs, and found that greater immersion heightens the sense of presence but also increases the risk of discomfort (Woodall et al., 2025). The literature describes this set of adverse effects under the term cybersickness, which includes dizziness, nausea, and disorientation due to sensory discrepancies between the visual and vestibular systems (Caserman et al., 2021; Biswas et al., 2024). This phenomenon poses a challenge to the widespread adoption of VR, as it degrades the perceived quality and acceptance of the system. The relationship between cybersickness and presence remains under debate: although several studies report negative or compensatory associations, the results are still inconsistent (Weech et al., 2019). In this sense, the most recent international literature has shown that not only the level of immersion associated with the hardware, but also the navigation modality, can influence the perception of presence and the appearance of symptoms (Rihs et al., 2024).

However, despite these advances, most research has focused on the content and functionality of virtual supermarkets, neglecting a relevant aspect of interaction: the mode of movement within the environment. The way users navigate could not only influence the

sense of presence, but also the level of perceptual comfort and task performance. (Cherep et al., 2023). reported that teleportation, although efficient, can induce spatial disorientation and reduce the cognitive coherence of the environment, which calls into question its suitability for tasks requiring spatial continuity. With this idea in mind, it has been suggested that the degree of control and the type of movement performed influence memory and orientation (Sauzéon et al., 2016).

Despite its relevance to immersive interaction, the effect of movement modality on user experience has not yet been sufficiently explored, particularly regarding how different forms of movement influence presence, perceptual comfort, and task performance in ecologically valid virtual environments. Specifically, this study focuses on two continuous movement modalities (physical locomotion and joystick navigation) and seeks to provide empirical evidence by jointly analyzing subjective measures of user experience and objective performance indicators, such as accuracy and task completion time, in a virtual supermarket.

2 Methodology

2.1 Study design

The study followed an experimental design with random assignment to two virtual reality cognitive training conditions. Participants were allocated to either a locomotion-based navigation condition or a joystick-based navigation condition. Each intervention was delivered in a single individual session lasting approximately 60 min.

The experimental session included a brief practice phase to familiarize participants with the virtual environment, followed by nine experimental trials distributed across three levels of difficulty, with short breaks between blocks. At the end of the session, participants completed the assessment instruments in digital format using Microsoft Forms. The total effective exposure time in the virtual environment was approximately 30 min.

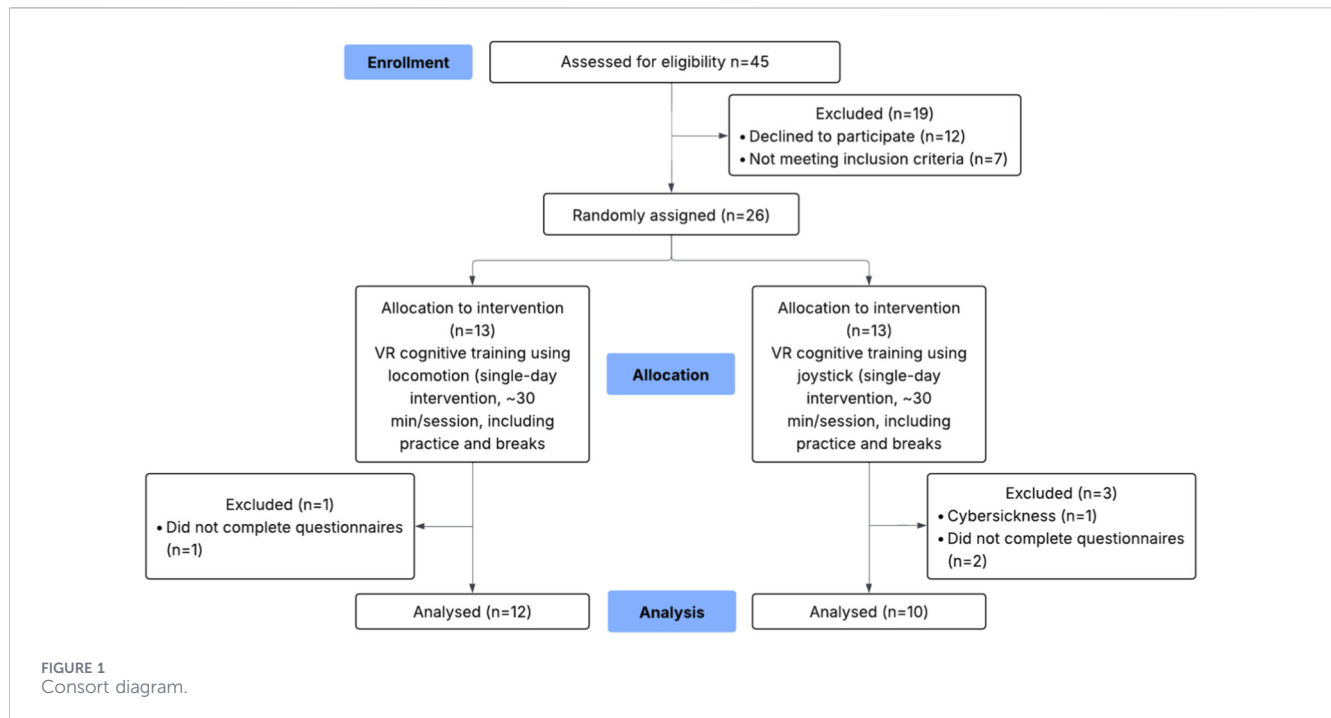
2.2 Participants

2.2.1 Recruitment

Participants were young adults residing in the city of Ambato, Ecuador, recruited through in-person invitations and social media posts. The invitation was open, and participants were informed of the study's general objectives and the conditions for participation. Those interested attended an in-person information session, during which the purpose of the research, potential risks and benefits, and eligibility criteria were explained. Candidates who met the inclusion criteria signed the informed consent form, guaranteeing their voluntary participation.

2.2.2 Inclusion criteria

The inclusion criteria were: (i) young adults aged between 18 and 35 years; (ii) no visual or auditory limitations that would impede interaction with the application; (iii) no history of



neurological or psychiatric illnesses; and (iv) voluntary participation by signing an informed consent form.

2.2.3 Exclusion criteria

Exclusion criteria included: (i) a previous diagnosis of epilepsy, chronic migraine, or balance disorders; (ii) a history of severe nausea or dizziness while using virtual reality environments; (iii) motor difficulties that prevented manipulation of the headset or controllers.

2.2.4 Participant flow

A total of 45 young adults were initially assessed for eligibility. Of these, 26 met the inclusion criteria and agreed to participate in the study. During the experimental procedure, one participant withdrew due to the onset of cybersickness, which had not been identified prior to testing. Additional participants were excluded due to incomplete post-test questionnaires. Consequently, the final analysis was conducted with 22 participants. The complete participant flow and exclusion process are presented in [Figure 1](#).

2.3 Randomization

The study was designed as a single-center, parallel-group, randomized experimental trial. After verifying eligibility criteria, each participant received a unique identification code. An independent research assistant generated a random sequence of numbers using a spreadsheet (1 = locomotion, 2 = joystick), assigning participants to one of the two groups. This procedure ensured concealment of the allocation process and prevented bias in group composition. The evaluators who administered the post-test questionnaires were blinded to the participants' group assignment.

However, complete blinding was not possible due to the evident differences in navigation modes.

2.4 VR application

The intervention was based on an immersive virtual supermarket application, developed in Unity and run on the Oculus Quest 2 headset with wireless controllers. The scenario sought to recreate an everyday shopping environment, similar to a convenience store, to make it feel natural and familiar to participants. This simulated a daily shopping experience in which the user had to remember, locate, and select specific products from three three-dimensional shelves. The product arrangement varied depending on the level of difficulty.

2.4.1 Encoding phase

At the beginning of each trial, the participant selected the difficulty level and received written instructions on a panel within the environment. A list of items to be memorized was then presented once ([Figure 2a](#)). At the easiest level, the list included 10 items distributed across three categories (e.g., bananas, apples, and milk cartons); at the medium level, 15 items across four categories; and at the most difficult level, 20 items across five categories were included. Although the number of categories and the total number of items were fixed for each difficulty level, the specific combination of products varied randomly across participants and trials within these predefined constraints.

Category manipulation sought to progressively increase cognitive load. Increasing the variety of items reduces the possibility of grouping them into semantic chunks ([Miller, 1956](#); [Baddeley and Hitch, 1974](#)). Increasing the number of categories limits this strategy, requiring greater attentional effort, updating,

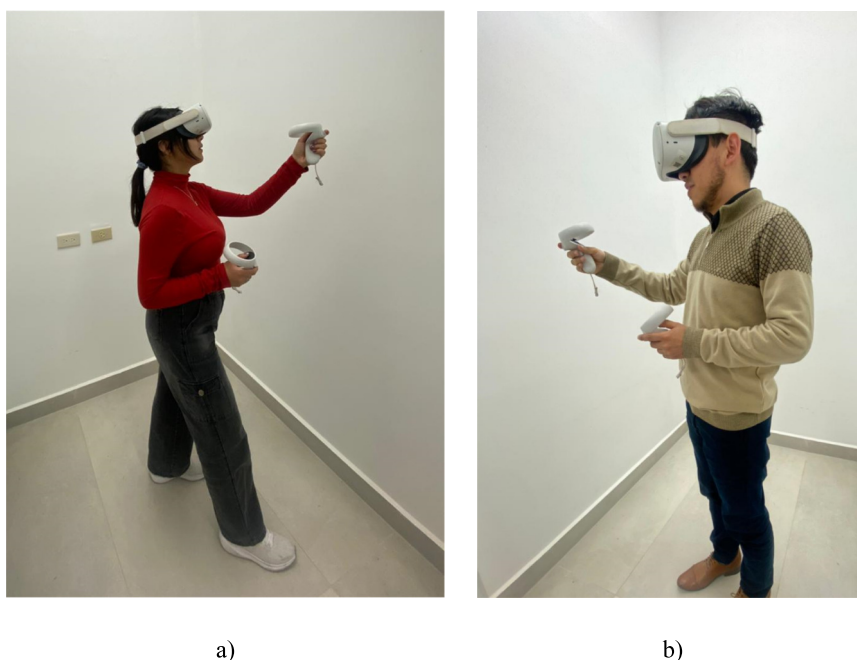


FIGURE 3
Participants in the navigation modalities in the virtual supermarket: (a) physical locomotion (b) joystick navigation.

Memory Questionnaire (PRMQ-S), originally developed by (Smith et al., 2000) and subsequently adapted and validated for Spanish-speaking populations by (González-Ramírez and Mendoza-González, 2011). This 16-item questionnaire assesses the frequency of self-perceived everyday memory lapses, differentiating between prospective memory (remembering to perform actions in the future) (eight items) and retrospective memory (remembering past events or information) (eight items).

The perceived usability of the application was assessed using the Spanish version of the System Usability Scale (SUS), created by (Brooke, 1996) and later translated and validated for Spanish-speaking populations by (Sevilla-Gonzalez et al., 2020). This questionnaire consists of 10 items with a Likert-type response format, and its final score is transformed into a scale of 0–100, where higher values indicate a better perception of usability and ease of interaction.

The perception of immersion was assessed using the Presence Questionnaire (PQ), designed by (Witmer and Singer, 1998). This 32-item instrument measures the degree of perceived realism and the feeling of “presence” in the virtual environment, considering dimensions such as control, focused attention, adaptability, and involvement in the experience. The questionnaire is organized into six subscales: involvement/control (INV/C), naturalness (NATRL), interface quality (IFQUAL), visual resolution (RESOL), auditory (AUD), and haptic (HAPTC) resolution. The AUD and HAPTC subscales were omitted in this study, since the developed application did not include sound stimuli or tactile feedback.

The onset of symptoms associated with cybersickness was assessed using the Cybersickness Questionnaire for Virtual Reality (CSQ-VR), recently developed by (Kourtesis et al., 2023). This questionnaire consists of six items distributed across three subscales (nausea, vestibular, and oculomotor) and allows for the identification of the presence and intensity of adverse symptoms,

such as blurred vision, dizziness, or discomfort while using VR headsets. In the absence of a formally published Spanish validation at the time of the study, the PQ and CSQ-VR questionnaires were administered using a translated and adapted version, with efforts made to ensure semantic equivalence with the original version.

2.6 Ethics

This preliminary study was approved by the Ethics Committee of the Universidad Tecnológica Indoamérica under code UTI-IIDI-043-2023 (17 March 2023), in compliance with the guidelines of the Declaration of Helsinki. Before the start of the experiment, participants were informed about the objectives, procedures, benefits, and potential risks, and the confidentiality and anonymity of the data collected were guaranteed. Participation was entirely voluntary, and participants could withdraw at any time without any consequences. In accordance with the approved ethical protocol, the data were analyzed and reported exclusively in aggregated form.

2.7 Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics (version 26). Descriptive statistics (means, standard deviations, and ranges) were calculated for all variables. Comparisons between the locomotion and joystick groups were performed using independent samples t-tests for normally distributed variables and Mann-Whitney U tests when normality assumptions were not met. Effect sizes were calculated using Cohen’s *d* for parametric tests and *r* for nonparametric tests. Primary outcomes included total scores on the PRMQ, SUS, PQ, and CSQ-VR. To control for multiple comparisons among these primary outcomes, *p*-values were adjusted using the Holm-Bonferroni procedure. Analyses that included subscales and correlational

TABLE 1 Demographic characteristics of the group.

Variables	All (N = 22)	Locomotion (n = 12)	Joystick (n = 10)	p-value
Gender, n (%)				0.392 ^a
Male	11 (50.0)	7 (58.3)	4 (40.0)	
Female	11 (50.0)	5 (41.7)	6 (60.0)	
Age, mean, SD (range)	22.95, 4.21 (18–32)	22.33, 3.34 (18–28)	23.70, 5.16 (18–32)	0.462
VR/video game experience, n (%)				0.624 ^b
Yes	17 (77.3)	10 (83.3)	7 (70.0)	
No	5 (22.7)	2 (16.7)	3 (30.0)	

^aChi-square test.

^bFisher's exact test.

TABLE 2 Internal consistency of the assessment instruments and their respective subscales.

Scale/Subscale	Cronbach's alpha coefficient
TOTAL PRMQ	0.912
PROSPECTIVE PRMQ	0.831
RETROSPECTIVE PRMQ	0.825
SUS	0.808
TOTAL PQ	0.828
INV/C PQ	0.771
NATRL PQ	0.661
IFQUAL PQ	0.681
RESOL PQ	0.459
TOTAL CSQ	0.685
NAUSEA CSQ	0.366
VESTIBULAR CSQ	0.191
OCULOMOTOR CSQ	0.843

Regarding cybersickness, the overall CSQ, showed acceptable internal consistency ($\alpha = .685$). The reliability of the subscales was variable, with low values observed for the nausea and vestibular dimensions, which should be interpreted with caution due to the small number of items and the exploratory nature of their use in this study.

tests were considered exploratory. Separate correlational analyses were performed for each navigation condition using Spearman's rank correlation coefficients. Holm-Bonferroni corrections were applied to account for multiple correlations within each group. Statistical significance was assessed using an adjusted α threshold where appropriate. Given the sample size, the results should be interpreted with caution and are intended to provide exploratory information, not confirmatory evidence.

3 Results

3.1 Demographic data

The study included 22 participants, distributed across two experimental conditions of navigation in the virtual environment:

locomotion (n = 12) and joystick (n = 10). The average age was similar in both groups, falling within the first half of their twenties ($p = 0.462$). Regarding gender distribution, a general balance between men and women was observed, although with slightly different proportions in each group ($p = 0.392$). Furthermore, most participants reported previous experience using VR or video games, with no significant differences between groups ($p = 0.624$) (Table 1).

3.2 Psychometric measures by group

Before proceeding to the quantitative analysis of the main variables, the internal consistency of the instruments used was assessed using Cronbach's alpha coefficient (α) (Table 2). It should be noted that internal consistency is reported as an indicator of reliability and does not in itself establish the construct validity of the instruments. The PRMQ demonstrated excellent internal consistency ($\alpha = 0.912$), with both prospective and retrospective subscales showing good reliability. The SUS also showed good internal consistency ($\alpha = 0.808$). Regarding presence, the overall PQ score indicated good reliability ($\alpha = 0.828$), while its subscales showed moderate internal consistency. The lower alpha values observed in some subscales (NATRL, IFQUAL, RESOL) are likely due to the small number of items per subscale (2–3 items), a known limitation when estimating internal consistency.

The inferential results are summarized in Table 3. Regarding everyday memory, both in its prospective and retrospective dimensions, scores were in the middle range, suggesting that participants perceived moderate difficulties in recalling everyday events during the task. Usability scores were high in both groups (≥ 79 points), and overall levels of presence and cybersickness were comparable between navigation conditions ($p = 0.521$).

To control for multiple comparisons among the primary outcomes, p-values were adjusted using the Holm-Bonferroni procedure (adjusted $\alpha = 0.0125$). Under this corrected threshold, none of the primary comparisons reached statistical significance (SUS: $p = 0.521$; PRMQ: $p = 0.290$; PQ: $p = 0.312$; CSQ: $p = 0.108$), indicating that the navigation mode did not produce statistically significant differences in the main outcome measures.

Regarding the sense of presence, both groups reported high levels across the different dimensions. In particular, the natural

TABLE 3 Comparison between groups in usability, memory, presence and cybersickness.

Scale/Subscale	Locomotion: M (SD)	Joystick: M (SD)	t/U (Z)	p	d/r
TOTAL PRMQ	2.43 (0.64)	2.68 (0.38)	t (20) = -1.09	0.290	-0.47
PROSPECTIVE PRMQ	2.42 (0.65)	2.55 (0.38)	t (20) = -0.57	0.573	-0.25
RETROSPECTIVE PRMQ	2.45 (0.63)	2.81 (0.43)	t (20) = -1.55	0.136	-0.67
SUS	82.9 (6.2)	79.5 (15.3)	t (11.45) = 0.66	0.521	0.31
TOTAL PQ	5.16 (0.63)	4.91 (0.41)	t (20) = 1.04	0.312	0.45
INV/C PQ	5.28 (0.69)	5.11 (0.58)	t (20) = 0.64	0.528	0.28
NATRL PQ	6.17 (0.77)	5.47 (0.69)	t (20) = 2.22	0.038*	0.96
IFQUAL PQ	4.03 (1.43)	3.83 (1.03)	t (20) = 0.36	0.724	0.15
RESOL PQ	6.58 (0.67)	6.05 (0.76)	U = 36.00 (Z = -1.73)	0.085	r = 0.37
TOTAL CSQ	1.44 (0.38)	1.80 (0.55)	U = 36.00 (Z = -1.61)	0.108	r = 0.34
NAUSEA CSQ	1.46 (0.50)	1.80 (0.42)	U = 35.00 (Z = -1.75)	0.080	r = 0.37
VESTIBULAR CSQ	1.42 (0.36)	1.65 (0.63)	U = 48.00 (Z = -0.84)	0.401	r = 0.18
OCULOMOTOR CSQ	1.46 (0.54)	1.95 (1.26)	U = 49.00 (Z = -0.79)	0.430	r = 0.17

*p < 0.05; M = mean; SD, standard deviation; t = Student’s t-test; U (Z) = Mann-Whitney U test, and the standardized Z value is reported; p = level of statistical significance; d = effect size (Cohen’s d); r = effect size in nonparametric tests.

presence subscale showed higher values in the locomotion group; however, this result should be interpreted with caution, as subscale-level analyses were exploratory. The other subscales (involvement, visual resolution, and interface quality) did not show statistically significant differences between conditions. Regarding cybersickness, scores were low in both groups, with means close to the “moderate” level, indicating that symptoms were acceptable. Although the joystick group had higher mean scores for nausea and slightly higher scores for the subscales, these differences did not reach statistical significance (p > 0.05).

3.3 Correlational analysis

In the correlational analysis (Table 4), distinct patterns were observed according to the type of movement. Correlations were considered exploratory, and p-values were adjusted within each navigation condition using the Holm-Bonferroni procedure (effective $\alpha \approx 0.0083$, based on six correlations per group). No significant associations emerged in the locomotion group, suggesting that memory perception, usability, presence, and cybersickness were relatively independent dimensions in this condition.

In contrast, distinct associations were observed in the joystick group. A very strong positive correlation was found between perceived usability and sense of presence (SUS-PQ; $\rho = 0.902$, $p < 0.001$), indicating that higher perceived system usability was associated with a greater sense of presence when interaction was mediated by a joystick. No other correlations reached statistical significance within this group.

3.4 Performance results

Aggregated performance metrics were used to characterize task performance across all difficulty levels, in accordance with ethical restrictions regarding individual-level data. The analyses presented in this section are descriptive in nature and aimed to explore general

TABLE 4 Correlations between memory, usability, presence and cybersickness according to each group.

Variables	Locomotion (ρ , p)	Joystick (ρ , p)
PRMQ - CSQ	-0.439 (p = 0.153)	-0.144 (p = 0.691)
PRMQ - SUS	0.098 (p = 0.763)	-0.613 (p = 0.059)
PRMQ - PQ	-0.387 (p = 0.214)	-0.651 (p = 0.041)
CSQ - SUS	-0.280 (p = 0.378)	0.255 (p = 0.478)
CSQ - PQ	0.158 (p = 0.624)	0.502 (p = 0.140)
SUS - PQ	-0.181 (p = 0.573)	0.902* (p < 0.001)

*p < 0.0083.

performance trends. The analysis of errors committed in the task is summarized in Figure 4. It is observed that, in both groups, the frequency of errors tends to increase as the level of difficulty increases, although with high individual variability reflected in the outliers. At the easy level, the locomotion and joystick groups presented a low number of errors, while at the difficult level both groups showed a greater dispersion of incorrect responses.

These results suggest that the type of movement did not influence performance when task complexity varied. However, at the medium level, while the locomotion group maintained a trend of increasing error frequency, the joystick group showed a decrease compared to the easy level, followed by an increase at the difficult level. This behavior suggests nonlinear performance in the joystick, which could be associated with an initial adaptation effect to the task or a product of individual variability.

The task resolution time as a function of the task difficulty level is presented in Figure 5. It is observed that, as task complexity increases, both groups require more time to complete the task, with a greater dispersion in the difficult condition. At the easy level, the locomotion

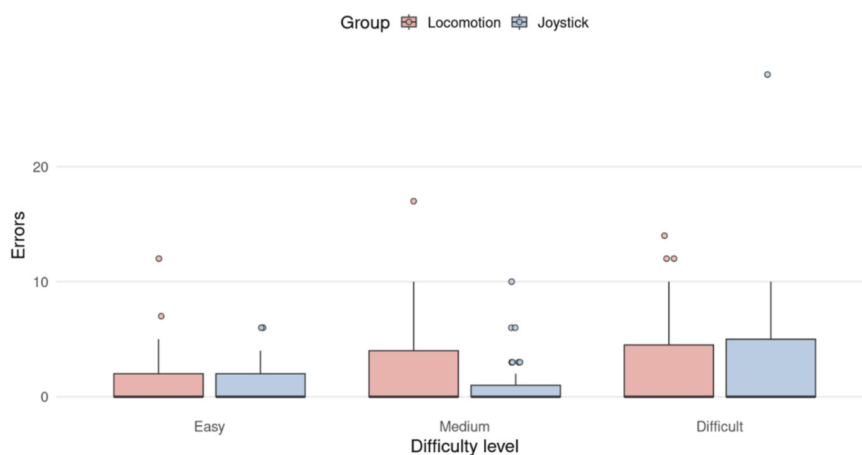


FIGURE 4 Average number of errors categorized by difficulty level and group.

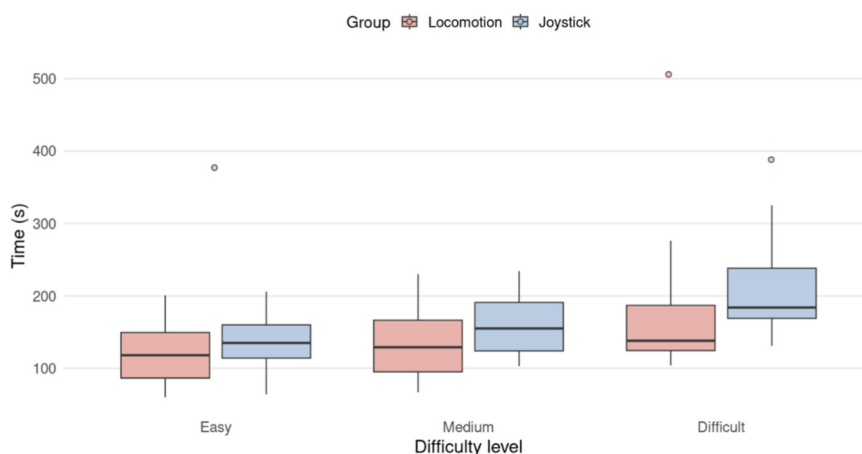


FIGURE 5 Average time categorized by level of difficulty and group.

and joystick groups showed relatively similar times, although at the medium and difficult levels, a trend toward longer times is observed in the joystick group. As expected, the pattern indicates that increasing difficulty directly impacts task duration in both groups.

These findings suggest that, although the locomotion group required real physical effort to navigate the environment, this did not translate into a longer execution time. In contrast, the joystick group, despite remaining physically static, tended to take longer in more complex scenarios, possibly due to the need to transform navigation into manual commands.

4 Discussion

4.1 Usability and perceived presence

The results show that both navigation modalities offered satisfactory user experiences, with high usability ($SUS \geq 79$) and

high overall presence, with no differences in most subscales (De Back et al., 2025). This finding suggests that, beyond the navigation technique used, interaction in a carefully designed immersive environment, in this case, the simulation of a virtual shopping task, can be fluid, intuitive, and comfortable for users. The fact that both conditions achieved high values of usability and presence confirms the importance of a coherent and stable design in which the naturalness of movements and the consistency of the system's responses become determining factors for a positive experience (Lim et al., 2026).

However, a higher value of natural presence was observed in the physical locomotion condition compared to the joystick. This difference can be attributed to the sensory congruence that arises when real body movement aligns with visual feedback, reducing the discrepancy between the vestibular and visual systems and reinforcing the feeling of “being there.” This result is consistent with previous studies indicating that physical movement within a virtual environment increases immersion by providing a more

natural and coherent experience (Rihs et al., 2024). In this sense, locomotion provides a perceptual realism that is difficult to match using indirect modalities.

While previous literature has extensively compared continuous (walking) and discontinuous (teleportation) navigation methods, demonstrating that spatial continuity favors cognitive coherence and strengthens the sense of presence (Langbehn et al., 2018; Cherep et al., 2023), our study provides a novel contrast: the comparison between two continuous techniques, physical locomotion and joystick. This approach is less common in the literature, where studies analyzing drastic differences between walking and teleportation predominate (Buttussi and Chittaro, 2021; Rantala et al., 2021; Hořejší et al., 2025; Hussain et al., 2025). The evidence presented here shows that, even maintaining spatial continuity, the navigation modes generated differentiated profiles: while locomotion maximizes perceptual naturalness, the joystick offers stable and efficient control that contributes to maintaining immersion thanks to its usability.

In particular, the positive correlation between usability and presence in the joystick group ($\rho = 0.902$; $p < 0.001$) highlights that, when navigation relies on a handheld device, technological fluency is crucial for maintaining immersion. This pattern aligns with the principle of technological transparency (Voinescu et al., 2023), which posits that a well-designed interactive system tends to become “invisible” to the user, allowing attention to focus on the experience rather than the interface. In this sense, although the joystick does not offer the same sensorimotor naturalness as physical locomotion, its performance was sufficient to preserve high levels of task satisfaction. The technical support of the platform used, the Oculus Quest 2 headset, and the implementation of a controlled experimental environment likely contributed to minimizing the technical and perceptual burden, reinforcing the validity of the results.

The consistency of these findings with studies reporting high levels of usability across different user profiles, from young university students (Pérez-Ferrara et al., 2025) to older adults undergoing cognitive stimulation programs (Faisal et al., 2025), suggests that a robust design supported by stable hardware can ensure positive experiences across different populations. Thus, our results contribute to the current debate on locomotion in immersive environments, demonstrating that the choice of movement method not only influences the perception of presence, but also how usability and satisfaction interact to promote immersion.

4.2 Impact on cognitive performance

Performance analysis showed no significant differences in the accuracy response between locomotion and joystick, suggesting that, under the present experimental conditions, accuracy did not differ between navigation modes. However, a trend toward longer execution times was identified in the joystick group, especially at the highest difficulty levels. This difference can be interpreted as a reflection of the added cognitive load: by requiring the constant translation of motor intention into a manual command, the joystick introduces an additional visual-motor demand that slows down the action (Lustig et al., 2023). In contrast, physical locomotion minimizes this technological intermediation, freeing up attentional resources and promoting more fluid responses, in line with what has been observed in studies

linking walking with improvements in creativity and general cognitive processing (Opezzo and Schwartz, 2014).

These findings can be understood by analyzing the literature on active navigation. It has been shown that when users directly control their movement within the environment, spatial and episodic memory is enhanced, as it involves a greater degree of motor and proprioceptive coding (Chrastil and Warren, 2012; Sauzéon et al., 2016). Thus, VR locomotion not only provides perceptual naturalness but could also favor the construction of more coherent cognitive maps, which explains its efficiency compared to using a joystick.

The fact that both groups achieved similar levels on accuracy response suggests that overall performance was influenced by other modulating factors. For example, all participants completed the experiment standing, a condition that has been linked to better executive functioning and working memory compared to sitting (Mehta et al., 2016). This factor could have attenuated performance differences between modalities, maintaining a comparable execution threshold. Furthermore, it has been pointed out that the sense of presence does not always translate into measurable performance improvements, as it depends on the type of task and the allocation of attentional resources (Palombi et al., 2023).

4.3 Perceptual comfort and cybersickness

The assessment of perceptual comfort using the CSQ-VR test showed low levels of discomfort in both groups, with scores within the “moderate” range. This result confirms that the experimental environment and exposure conditions were adequate to prevent the onset of relevant symptoms of nausea, disorientation, or visual fatigue. In line with the literature, factors such as the headset’s refresh rate, reduced latency, and visual coherence of the environment are considered critical variables for mitigating virtual reality-induced adverse effects (VRISE) (Kourtesis et al., 2019a; Stauffert et al., 2020). In this study, the use of the Oculus Quest 2 headset, with a 90 Hz refresh rate and low latency, likely contributed to maintaining an optimal level of perceptual comfort.

Regarding exposure duration, (Souchet et al., 2023), recommend limiting continuous VR sessions to between 20 and 30 min, incorporating regular breaks, while (Kourtesis et al., 2019b) demonstrated that, when the software meets ergonomic quality criteria, the maximum recommended duration of immersive sessions ranges between 55 and 70 min. In our study, the total exposure was intentionally less than 30 min and breaks were applied between each exercise, which, together with the technical quality of the hardware and the virtual environment, contributed to minimizing the incidence of cybersickness and preserving the perceptual comfort of the participants.

Unlike research linking physical locomotion with an increase in vestibular symptoms, the results obtained here did not show a direct relationship between the type of movement and the intensity of discomfort. This suggests that the relationship between locomotion and cybersickness depends not only on physical movement, but also on the balance between visual stimulation and postural control (Litleskare, 2021; Kumar et al., 2024). In our virtual supermarket application, movement was limited to controlled trajectories and a constant movement rate, conditions that reduce the sensory

conflicts that often generate dissonance between visual and vestibular information.

The absence of significant differences between groups may also be related to protective factors against perceptual distress. In this sense, Kourtesis et al. reported that in young adults, experience with video games and mobile devices acts as an element of technological habituation that mitigates cybersickness (Kourtesis et al., 2024). Given that our sample consisted of young adults, it is plausible that this same mechanism favored the stability of perceptions in both navigation (Hufnal et al., 2019). One aspect to consider is that even older adults show increasing technological familiarity, as they reach this stage with decades of experience using smartphones, computers, and digital devices (Seifert and Schlomann, 2021). This demographic shift suggests that, in the future, these mechanisms will not be limited to young people but could protect broader age groups.

While reviews such as the one conducted by (Weech et al., 2019) reported a negative correlation between presence and cybersickness, they also point out that many studies are underpowered and their validity on modern systems may be limited. The weak correlation observed in our experiment suggests that both constructs, although related, may evolve relatively independently. Bearing this idea in mind, Ang and Quarles (Ang and Quarles, 2023) showed that advances in hardware and design (such as higher refresh rates, lower latency, and more visually stable environments) have reduced the incidence of cybersickness in immersive experiences, allowing for a more balanced coexistence between immersion and comfort. Complementarily, (Thorp et al., 2022), showed that presence and cybersickness are modulated with exposure time, without necessarily following a linear relationship.

This finding is relevant to the research community, as it supports the feasibility of using highly immersive environments without compromising user comfort, provided that adequate controls are maintained over exposure duration, movement speed, and image stability.

4.4 Limitations and future research

This study presents some limitations and considerations that should be taken into account when interpreting the results. First, the small sample size ($n = 22$) limits the generalizability of the results. Furthermore, the research intentionally focused on young adults, a group with high technological familiarity and good adaptation to digital environments, which is relevant for exploring how prior experience influences interaction with immersive environments. However, this profile could have attenuated the onset of cybersickness and enhanced the positive perception of usability. Future research could expand the sample and examine other groups, such as older adults or people with less technological experience, to verify whether the observed patterns hold true in populations with greater cognitive or motor vulnerability.

Another consideration concerns the relatively short duration of exposure. Although this interval falls within the recommendations in the literature, which suggest not exceeding 30 min to minimize the risk of cybersickness (Souchet et al., 2023), it may also have limited the observation of phenomena associated with prolonged exposure, such as cumulative cognitive fatigue or the gradual intensification of perceptual discomfort. While available evidence

on longitudinal studies with longer VR sessions is still scarce, such designs would be valuable for exploring how time and task difficulty impact the user experience.

Although inferential analyses were performed, corrections for multiple comparisons were applied only to the primary outcomes. Subscale and correlational analyses were considered exploratory and should therefore be interpreted with caution, especially given the limited sample size. Furthermore, while an overall PQ score was calculated to facilitate general interpretation, this score should be interpreted with caution, as the omission of the auditory and haptic subscales for each modality could have influenced the composite measure. Future research could benefit from the use of immersive environments that allow for the full implementation of all sensory modalities, enabling a more comprehensive and comparable assessment of presence.

Another limitation to consider is that experimental design did not include objective physiological measures, such as heart rate, skin conductance, or eye movements. Although their inclusion could enrich the understanding of the relationship between cognitive load, immersion, and perceptual discomfort, we chose not to employ them to avoid potentially invasive equipment that could interfere with participants' comfort. (Halbig and Latoschik, 2021). pointed out that while many parameters can be recorded discreetly, the most accurate sensors are often cumbersome and poorly compatible with prolonged immersive experiences.

Finally, the study did not include a non-displacement control condition or a comparison with other assisted navigation modes, such as teleportation, which had previously been ruled out due to its discontinuous nature. However, future research could incorporate alternative controls, such as guided automatic navigation or passive observation of the surroundings, in order to more precisely isolate the specific effect of the navigation mode.

5 Conclusion

This study demonstrated that immersive virtual shopping can offer high usability and be comfortable for the user, regardless of the navigation mode employed. However, the comparison between two continuous modes revealed distinct experiential profiles: physical locomotion significantly increased the sense of natural presence, while the joystick enhanced the relationship between usability and immersion. These findings expand on the previous debate, which focused primarily on contrasting continuous versus discontinuous techniques such as teleportation, and show that even within the same travel category, relevant differences can emerge for immersive experience. The low incidence of cybersickness reinforces the idea that, under appropriate technical configurations and controlled exposure times, it is possible to maintain a balance between realism, comfort, and cognitive performance. In this sense, the proposed experimental model is presented as a tool capable of combining subjective and objective measures in a setting with high ecological validity.

In practical terms, the results suggest that the choice of navigation mode should be tailored to the objectives of the environment and the user profile: locomotion is most appropriate when seeking to enhance perceptual naturalness and spatial orientation, while the joystick offers advantages in scenarios requiring control, precision, and reproducibility. Furthermore,

although this work focused on young adults, recent evidence suggests that new cohorts of older adults reach this stage with greater technological familiarity, opening the possibility of extending these results to broader and potentially more vulnerable populations. Thus, the present study provides empirical evidence on how movement factors influence immersive experience, offering conceptual and practical foundations for the design of future applications in virtual reality.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Committee of the Universidad Tecnológica Indoamérica under code UTI-IIDI-043-2023 (17 March 2023), in compliance with the guidelines of the Declaration of Helsinki. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

FA-C: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing. JB: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing. MS: Investigation, Methodology, Resources, Validation, Writing – original draft. GP-N: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software,

Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing.

Funding

The author(s) declared that financial support was received for this work and/or its publication. The APC was funded by Universidad Tecnológica Indoamérica, under the project “Desarrollo y análisis de un entorno virtual con integración de estímulos multisensoriales”, Grant Number: IIDI-046-2026.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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