JCSR

Journal of
Cognitive Science Research

Cognitive Science Research, **Volume 1, Issue 2, 2025**

University of TEHRAN

Online ISSN:3092-6777

The University of Tehran Press

Journal of Cognitive Science Research

2025, 1(2), 1-14

Home Page: https://jcsr.ut.ac.ir/

Exploring Affective Properties of Emoji's: Identifying the Persian Emoji Lexicon

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ARTICLE INFO

Article type:
Research Article

Article History:
Received: 27 Mar 2025
Revised: 03 Apr 2025
Accepted: 22 Apr 2025
Published: 01 Jul 2025

Keywords:
Emojis, emotions, valence, social media.

ABSTRACT

The present study aimed to validate the Persian Emoji Lexicon (PEL) and examine gender and cultural differences in the perception of the affective properties of selected emoji's. The study consisted of two phases: emoji selection and an online survey. First, we identified the 109 most frequently used emoji's on Twitter. In the second phase, we assessed emotion and valence ratings from a sample of 200 X users (140 females; 27.3 ± 3.5 years). Of the 109 selected emoji's, 90 were perceived as having a positive valence. Gender comparisons revealed that women rated significantly higher emotional intensity across all eight emotion dimensions compared to men. We also compared our findings with a similar database validated among Canadians. The inter-rater reliability for emoji valence ratings between Iranian and Canadian participants showed a fair level of agreement (Kappa coefficient = 0.357), while also highlighting significant cultural differences in emotion perception. This database serves as a valuable resource for sentiment analysis of social media texts containing emoji's, as well as for practical applications where emoji's function as emotional cues to influence behavior (e.g., in marketing and education).

Cite this article: Rezaei, Z., Hatami, J., Karsazi, H., Malekar, K., & Rezapour, T. (2025). Exploring Affective Properties of Emoji's: Identifying the Persian Emoji Lexicon. *Journal of Cognitive Science Research*, *1*(2), 1-14. doi:10.22059/jcsr.2025.392645.1010

Publisher: University of Tehran Press
DOI: https://doi.org/10.22059/jcsr.2025.392645.1010

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Introduction

Communication has been reshaped by the advent of new digitalized social media (e.g., social apps, messaging apps, online forums) in the last few decades (Rodrigues et al., 2018). Face-to-face communication has been supplanted by online chat and texting, which are generated using verbal symbols and graphical interfaces. Verbal symbols (e.g., words, phrases, sentences) are the primary element of textual communications, lacking the traditional features of non-verbal cues and emotional expression that are often emphasized in face-to-face conversations. With the increasing prevalence of online social communication platforms, the way people communicate with each other has evolved (Lin & Luo, 2023). New tools have been developed to enrich reciprocal communication and facilitate the perception of emotional meaning conveyed through text. One such novel means is the graphical interfaces, encompassing emoticons and emojis. Emoticons, the first developed graphical interfaces, are generated with letters, numbers, and punctuation (e.g., ;-D) indicating a prototypical version of facial expressions. In contrast, emojis (e.g., 😀) are more evolved interfaces that serve as visual representations of a more comprehensive set of concepts, including facial expressions, activities, inanimate objects, living beings, and symbols (Bai et al., 2019). Although emoticons are still used in text-based communication, emojis are more preferred and popular among users (Fernández-Gavilanes et al., 2018; Rodrigues et al., 2018). One possible reason could be their similarity to facial expressions and their ability to convey emotions even faster and more accurately than faces (Dalle Nogare et al., 2023).

Given the popularity of emojis and the socioemotional functions they serve in conveying emotion (Godard & Holtzman, 2022; Lin & Luo, 2023), several studies have explored different aspects of these symbols. Some studies investigated the emotional features (e.g., valence, emotion) of emojis perceived by users, while others explored their communicative functions within different online contexts. While the latter line of research investigates the similarities between emojis and emotional cues (e.g., words, facial expressions) (Gantiva et al., 2020), and the communicative contributions they may yield to the content (e.g., clarifying sender's intention, emotion, attitude) (Bai et al., 2019; Choi et al., 2023), the majority of studies in the former group focus on the emotional profile of emojis in different cultures. For example, Kutsuzawa and colleagues evaluated 74 facial emojis in terms of valence and arousal, categorizing them into six clusters that align with human emotional states (Kutsuzawa et al., 2022). Meanwhile, two recent studies generated lexicons for German (Scheffler & Nenchev, 2024) and Spanish (Ferré et al., 2023) speakers (Emoji-SP), encompassing 107 human face emojis and 1,031 emojis from various categories (e.g., faces, sports, food), respectively. These emojis were rated on dimensions including visual complexity, familiarity, frequency of use, clarity, emotional valence, and emotional arousal. Additionally, Rodrigues et al. (2018) created the Lisbon Emoji and Emoticon Database (LEED), which includes 153 emojis primarily focused on facial expressions with fewer symbols and hand gestures. It was evaluated based on dimensions such as aesthetic appeal, familiarity, visual complexity, clarity, valence, arousal, and meaningfulness in a sample of Portuguese speakers (Rodrigues et al., 2018). None of these studies incorporated specific emotions into the emoji profiles. In contrast, the Canadian Multidimensional Lexicon of Emojis (MLE) is more developed than the previous datasets in terms of variations in emoji categories and the rated affective dimensions (i.e., eight basic emotions). While it is the most comprehensive dataset, it does not account for gender differences in the perception of emotions in emojis (Godard & Holtzman, 2022).

Gender differences have been inconsistently shown to affect emotion comprehension for both real and emoji-based facial expressions. Some studies suggest an advantage for females in nonverbal sensitivity, including emotion recognition (Chen et al., 2024; Hampson et al., 2006; McClure, 2000; Thompson & Voyer, 2014), while others argue that there are no gender-related differences (Fischer et al., 2018). Several potential explanations have been proposed to support the female superiority in emotion recognition tasks. One such explanation is the "primary caretaker hypothesis," which highlights women's historically predominant role in caring for and raising infants, making them more attuned to emotional cues (Babchuk et al., 1985). Another is the negativity bias, which is more pronounced in women and increases their sensitivity to negative facial emotions compared to men (Connolly et al., 2019). Moreover, the findings appear to be quite heterogeneous when comparing women and men in recognizing specific emotions (e.g., sadness, anger) (Forni-Santos & Osório, 2015). For example, studies by Abbruzzese et al (Abbruzzese et al., 2019) and Sullivan et al (Sullivan et al., 2017), showed that women are more likely to identify emotions by focusing on the eyes, while men are more attuned to the mouth. This finding highlights that emotion recognition may vary depending on whether the emotions are conveyed primarily through the upper (eyes) or lower (nose and mouth) parts of the face. Other studies suggest that females are more accurate in identifying subtle emotions (e.g., fear, disgust) as they perceive emotions in a gestalt fashion, making quick and automatic judgments (Dalle Nogare et al., 2023). Therefore, gender differences in emotion recognition may be due to various mechanisms that still need to be explored. Given the similarity between the processes of emotions conveyed through real faces and emojis (Liao et al., 2021), some studies have begun examining how gender may influence emotion interpretation in the context of online communication. For example, chen et al (Chen et al., 2024) conducted a cross cultural survey on 523 participants asking them to recognize 24 facial emojis based on six emotions (happy, sad, angry, surprised, fearful, disgusted). They found higher accuracy of classification for happy, fearful, sad, and angry emojis for women than men, but not for surprised or disgusted ones. Again in the study by Nogare et al (Dalle Nogare et al., 2023), women and men were compared in their ability to recognize emotions from facial expressions in human and emoji faces. They found that while females were better at recognizing all emotions in human faces, males outperformed females in identifying emotions conveyed by emojis, except for fear. This may be because males are more inclined to use emojis to express their emotions in online communication (familiarity). Although this evidence supports gender differences in recognizing emotions conveyed by emojis, there is a lack of studies examining how gender may influence the perception of emotion intensity in emojis.

Another factor that may influence emotion recognition in human faces, and subsequently in emojis, is cultural differences. For example, people from Western cultures, which emphasize individualism and overt emotional expression, generally tend to focus on the mouth when identifying emotions. In contrast, people from Eastern cultures, which are more collectivistic in nature, tend to focus on the eyes (Gao & VanderLaan, 2020; Viola, 2024). It is noteworthy that studies on cultural differences in emotion recognition often highlight in-group advantages or out-group biases when recognizing emotions from human faces. However, this may not apply to emojis, as their appearance is not culturally limited to specific facial features or expressions but instead follows standardized designs that are widely recognized across cultures. The most important factor that could explain cultural differences in emoji identification is the extent to which a certain culture uses emojis in their communications (familiarity) as well as the specific meaning they assign to these emojis based on cultural norms and context (Bai et al., 2019). For example, different studies showed that Chinese people are less familiar with emojis and less accurate in emotion recognition as they used emojis in different ways compared to other Western cultures (Chen et al., 2024; Guntuku et al., 2019). Investigating and comparing emoji-based emotion recognition across diverse cultures represents an emerging area of research that warrants further exploration.

Given the massive use of emoji for communication within each cultural context, having a database specifically characterizing the emotional features of emojis as they are perceived by users in that culture is critical. In this study, we present the Persian Emoji Lexicon (PEL), which includes subjective norms of 109 frequently used X (former Twitter) emojis in terms of valence and the emotion, as rated by a sample 200 participants. We used the X platform to conduct our study for three primary reasons. First, this study is part of a larger project aimed at examining the role of emojis in emotional contingency when used in text messages (e.g., tweets). Specifically, it explores how the congruence or incongruence between the affective properties of text and emojis can influence the emotional contingencies of a posted tweet on receivers across two separate study days (described later in the method section). Second, emojis are commonly cues embedded within the written posts shared by X users, making it a highly suitable platform for this research. It is also important to note that while the types of emojis are relatively consistent, their appearance varies notably across social media platforms (e.g., Telegram vs. X). Given that X has currently over 400 million active users worldwide (Statista, 2022), it is more globally representative than other platforms such as Telegram, WhatsApp, and Facebook. Moreover, X users primarily consist of adolescents and young adults, who are the predominant users of emojis in their social communications (Herring & Dainas, 2020; Koch et al., 2022).

Given the widespread use of emojis in online communication, both within and across cultures, it is essential to explore this partially global language further. While some similarities exist, there are also notable differences shaped by both inter- and intra-individual factors. The aim of the current study is to provide a database of 109 emojis evaluated by Iranian participants who were familiar with use of emojis, in terms of emoji's emotion and valence. Similar to previous studies (Godard & Holtzman, 2022; Mohammad & Turney, 2013; Plutchik, 1960), we focused on eight basic emotions including anger, anticipation, disgust, fear, joy, sadness, surprise, and trust to categorize emotions. Moreover, we aimed to examine gender differences in the intensity of emotions perceived by Iranian men and women from each emoji assuming women perceive higher intensity of emotion rather than the men. And lastly, we aimed to compare the Iranian emoji database with a Canadian database (Godard & Holtzman, 2022) to explore both cross-cultural similarities and differences in emoji perception in terms of valence and emotion.

Method

The current study consisted of two phases: emoji selection and an online-based survey. The following sections describe each phase in detail.

Emoji Selection: Phase 1

In the first phase, we selected the most frequently used emojis from two sources. First, similar to previous studies, we checked Emojitracker (http://emojitracker.com/), a website that monitors emojis usage on Twitter in real-time (Aduragba et al., 2022; Kralj Novak et al., 2015; Paggio & Tse, 2022). From this source, we selected the top 100 most frequently used emojis. Since this study is part of a larger project investigating the role of emojis in emotional contingencies on Twitter, we also analyzed two separate datasets, each containing 1,000 impactful tweets collected on different days. Impactful tweets were defined as those with a high engagement rate, measured by the number of likes and retweets. One of these days was chosen as the "main day," during which a tragic event occurred (the collapse of an important building), significantly affecting the emotions of Iranian people. The second day served as a control, with no notable social events taking place. After identifying the most frequently used emojis on these two days, we found 10 additional emojis that were not present in the Emojitracker dataset. Consequently, we compiled a final set of 110 emojis. To culturally adapt the dataset for the Iranian population, we removed the 💩 emoji from the final selection. Figure 1, depicts the list of emoji included in our database.

Figure 1: List of included emoji (n=109), according to EmojiTracker.com Emojis named as: (1) Face with tears of joy, (2) Loudly crying face, (3) Smiling face with heart eyes, (4) Grinning face, (5) Grinning squinting face, (6) Grinning face with sweat, (7) Rolling on the floor laughing, (8) Slightly smiling face, (9)Winking face, (10) Smiling face with smiling eyes, (11) Smiling face with halo, (12) Star struck, (13) Face with raised eyebrow, (14) Smiling face with sunglasses, (15) Astonished face, (16) Face with stream from nose, (17) Pensive face, (18) Pouting face, (19) Face with medical mask, (20) Face blowing a kiss, (21)Winking face with tongue, (22) Face with peeking eye, (23) Face holding back tears, (24) Face with diagonal mouth, (25) Sneezing face, (26) Dotted line face, (27) Melting face, (28) Saluting face, (29) Face with open eyes and hand over mouth, (30) Sad but relived face, (31) Neutral face, (32) Face screaming in fear, (33) Hugging face, (34) Expressionless face (35) Zipped face, (36)Thinking face, (37) Face with hand over mouth, (38) Unamused face, (39) Grimacing face, (40) Flushed face, (41) Confounded face, (42) Angry face, (43) Sleeping face, (44) Persevering face, (45) Downcast face with sweat, (46) Smiling face with hearts, (47) Weary face, (48) Face savoring food (49)Squinting face tongue, (50) Heart on fire (51) Green heart, (52) Sparkling heart (53) Revolving hearts, (54) Purple heart, (55) Growing heart, (56) Pink heart, (57) Black heart, (58) Red heart, (59) Broken heart, (60) Heart with arrow, (61) See no evil monkey, (62) Speak no evil monkey, (63) Sweat droplets, (64) Dizzy, (65) Skull, (66) Smiling face with Horns, (67) Hundred points, (68) Kiss mark, (69) New moon, (70) Cyclone, (71) High voltage, (72) Sun, (73) Fire, (74) Star struck, (75) Sparkles, (76) Party popper, (77) Rose, (78) Four leaf clover, (79) Hibiscus, (80) Round pushpin, (81) Money bag, (82) Crown, (83) Camera, (84) Musical notes, (85) Person tipping hand, (86) Palms up together, (87) Heart hands, (88) Handshake, (89) Flexed biceps (90) Folded hands, (91) Backhand index Pointing up, (92) Victory hand, (93) Pinched fingers, (94) Ok hand, (95) Waving hand, (96) Raised back of hand, (97) Thumbs up, (98) Clapping hands, (99) Raising hands, (100) Oncoming fist, (101) Backhand index pointing down, (102) Backhand index pointing right, (103) Eyes, (104) Double exclamation mark (105) Left arrow, (106) Play button, (107) Minus, (108) Check mark button, (109) Large red circle.

Emoji Validation: Phase 2

Participants

A sample of 200 participants (140 females and 60 males; average age = 27.3, SD = 3.5) was randomly recruited online through leaflets distributed on social media (e.g., Instagram, Telegram, X). Volunteer participants contacted a research member (ZR) via the phone number provided in the leaflet, sending her, their email address and phone number to screen for eligibility before gaining access to the survey link. All participants were X users, familiar with emojis, and frequently used them in their online interactions. The final sample comprised 47 participants (23.5%) with a diploma, 62 (31%) with a bachelor's degree, 76 (38 %) with a master's degree, and 15 (7.5%) with a doctoral degree.

Procedure

This phase was conducted via a survey-like system on the website specifically designed for the current study. Eligible volunteers accessed the survey through a link sent to them via both SMS text messaging and email. After reading and accepting the online consent form, participants were automatically directed to the instruction page, and once they clicked the "Ready" button, the online survey was initiated. At the onset of the survey, participants completed a demographic form asking for information such as age, gender, education, being X users, and frequency of emoji usage. Next, the selected emojis were sequentially and randomly presented at the top of the screen against a white background. Participants were asked to look at the emojis and pay attention to the valence and intensity of the emotions they perceived. For each emoji, participants were initially asked to identify whether the emoji induced a positive or negative emotion (valence) using binary choices (positive indicated with "+" and negative indicated with "-"). Following the valence identification, a screen with a response scale appeared, and participants were asked to rate the intensity of each emotion (anger, anticipation, disgust, fear, joy, sadness, surprise, and trust) perceived by them. The emotional intensity was rated using a 5-point Likert scale ranging from 1 to 5 (1 = very low, 2 = low, 3 = neutral, 4 = high, and 5 = very high. The highest score among the eight dimensions of emotions was considered the dominant emotion induced by the emoji. The participants were required to make a choice and could not skip any part without answering. When they made their choice for each emoji, the next page with the subsequent emoji was shown. There was no time limitation for responses; however, participants were asked to respond to emojis as accurately and quickly as possible and if they did not respond within 60 min, the survey was stopped. The entire survey process took approximately 30–45 minutes for each single participant, depending on their response speed. Figure 2 shows the schematic representation of the experimental procedure. The study procedure adhered to a protocol approved by the ethics committee of the Institute for Cognitive Science Studies (ICSS), with approval number [IR.UT.IRICSS.REC.1402.021]. Participant's contact information was kept confidential and anonymous (identified by a code), and only a member of the research team (ZR) had access to this data. After completing the survey, participants received a discount code to purchase a book from an online store as compensation for their time.

Statistical analysis

The analysis of the data was performed with the software IBM SPSS Statistics 26.0.0.1. Descriptive analysis was used for frequency, percentages, mean scores and standard deviation. To evaluate the association between variables, we used the Chi-square test. It is noteworthy that scores for each emoji on valence and eight dimensions of emotion were generated by averaging the ratings provided by raters.

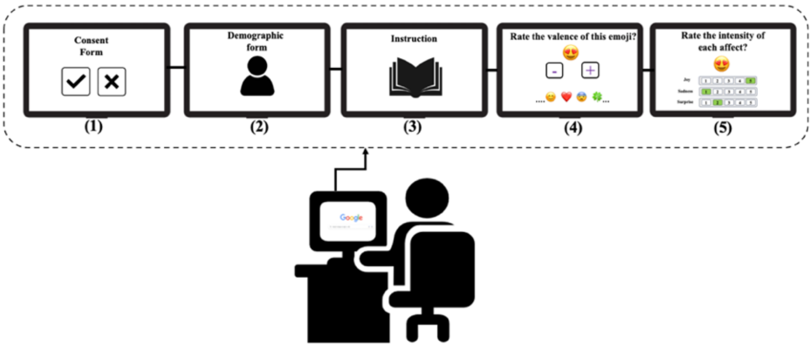

Figure 2: Study design. (1) Informed Consent: participants were provided with an informed consent form; (2) Demographics: After giving consent, participants completed a demographic questionnaire (e.g., age, gender); (3) Instructions: participants then received clear instructions on how to respond to the subsequent emojis; (4) Valence Rating: participants were presented with each of the 109 emojis one at a time. For each emoji, they recognize its valence (positive or negative); (5) Emotional Intensity Rating: each emoji was presented again and participants rated the intensity of eight dimensions of emotions (fear, anger, sadness, anticipation, joy, surprise, disgust, and trust) perceived from emojis.

Results

Affective Properties

A total of 109 emojis were assessed by 200 raters in terms of valence and emotion. Of these, 68 (62.4%) emojis represented smileys and faces, 19 (17.4%) represented people, 9 (8.3%) represented animals, 6 (5.5%) represented symbols, 5 (4.6%) represented objects, and 2 (1.8%) represented activities (Fig 3). This categorization is adopted from https://emojipedia.org/ . Out of 109 emojis, participants rated 90 (82.6%) emojis as inducing positive valence and 19 (17.4%) emojis as inducing negative valence (Fig 4). Overall, the highest percentage of emojis was categorized as indicating joy (n=36, 33%), while the lowest percentage was categorized as indicating disgust (n=2, 1.8%). Trust (n=20, 18.3%), anticipation (n=16, 14.7%), surprise (n=11, 10.1%), sadness (n=10, 9.2%), anger (n=8, 7.3%), and fear (n=6, 5.5%) followed, respectively (Fig 5). Table S1 indicates the descriptive characteristics separated by each emoji.

Figure 3: Honeycomb diagram, emoji classification based on the indicator emotion: (1) Joy: Represented by the color green, this category encompasses 36 emojis. (2) Trust: Represented by the color blue, this category includes 20 emojis. (3) Anticipation: Represented by the color cyan, this category comprises 16 emojis. (4) Surprise: Represented by the color yellow, this category includes 11 emojis. (5) Fear: Represented by the color orange, this category encompasses 6 emojis. (6) Sadness: Represented by the color brown, this category includes 10 emojis. (7) Anger: Represented by the color red, this category comprises 8 emojis. (8) Disgust: Represented by the color purple and includes 2 emojis.

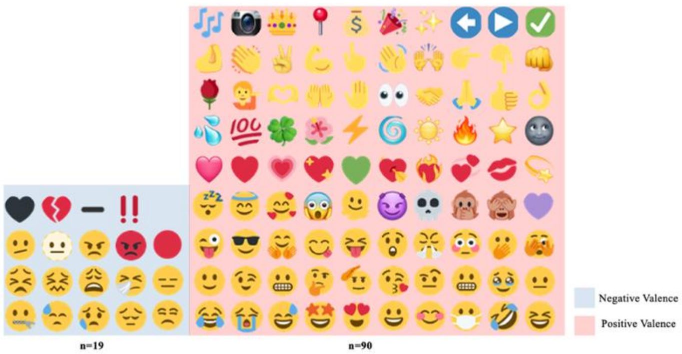

Figure 4: Distribution of emojis based on positive and negative valence

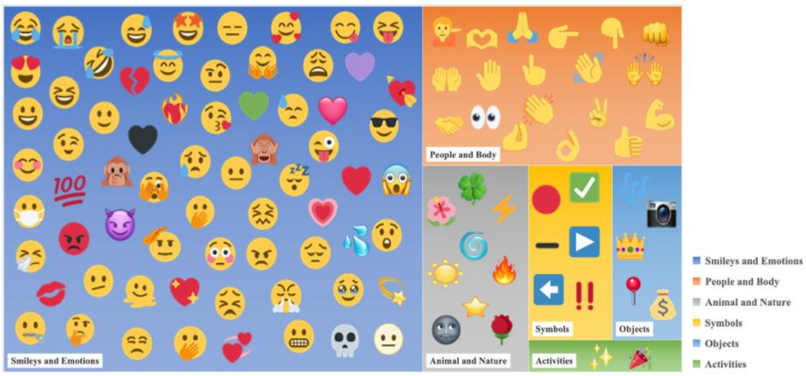

Figure 5: Tree map plot represent hierarchical distribution of emojis based on the semantic categories

According to the mean number of raters on perceived valence in each category of emotional emojis (joy, trust, anticipation, surprise, fear, sadness, anger, disgust), all emojis in the joy and trust categories were totally rated as positive, and all emojis in the disgust category were rated as negative. For other categories, some similarities were found. A Chi-square test indicated that there is a significant difference in terms of perceived valence (positive vs. negative) for the anticipation category [$\chi 2$ (1, N = 16) = 12.25, $p < 0.001$], while no significant differences were found for surprise, fear, sadness, and anger (**Fig** 6). We conducted this analysis because there are some variations in valence perception for emojis categorized under each emotion. For example, for the emotion of fear, which is perceived with both positive and negative valence, participants rated some fear-associated emojis (e.g., face with medical mask) as positive rather than negative. Notably, while these dimensions revealed differences between the mean number of positive and negative ratings, the chi-square test's sensitivity to sample size and expected frequencies can undermine its ability to accurately capture the significance of these differences. When sample sizes are small and expected frequencies are low, the limitations of the chi-square test may lead to inaccurate results, including a heightened risk of Type II errors (Cochran, 1954; McHugh, 2013).

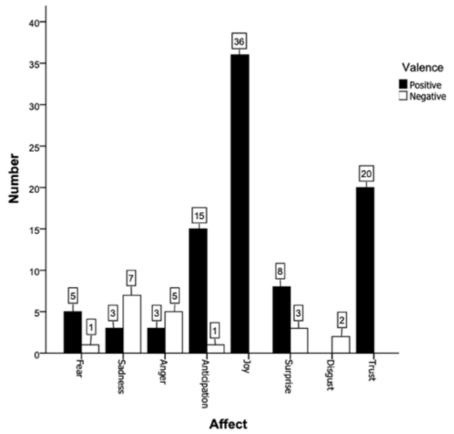

Fig 6. Distribution of types of valences across eight emotions

Gender Comparison
The general results of the comparison between men and women regarding the perceived intensity of emotions, is shown in Table 1, indicating in all types of emotions, women perceived higher intensity then men.

Table 1. Mean and SD statistics of emojis by gender

Emotion	Number	Total (n=200)	Women (n=140)	Men (n=60)	T	*p*	95%CI
		M (SD)	M (SD)	M (SD)			
Fear	6	2.85 (0.39)	2.95 (0.42)	2.19 (0.40)	11.89	< 0.001	0.63 - 0.88
Sadness	10	3.56 (0.82)	3.64 (0.84)	3.30 (0.81)	2.65	< 0.001	0.08 - 0.59
Anger	8	3.39 (1.04)	3.51 (0.96)	3.03 (1.38)	2.82	< 0.001	0.14 - 0.81
Anticipation	16	2.11 (0.43)	2.23 (0.40)	1.71 (0.57)	7.36	< 0.001	0.38 - 0.65
Joy	36	3.17 (0.70)	3.26 (0.71)	2.91 (0.71)	3.19	< 0.001	0.13 - 0.56
Surprise	11	3.44 (0.66)	3.47 (0.62)	3.24 (0.95)	2.03	0.04	0.006 - 0.45
Disgust	2	2.91 (0.74)	3.02 (0.74)	2.56 (0.43)	4.49	< 0.001	0.25 - 0.66
Trust	20	3.14 (0.62)	3.13 (0.67)	2.90 (0.71)	2.18	0.030	0.02 - 0.43

Semantic Categories Comparison
Another interesting finding is related to the semantic categories of emojis. Chi-square tests revealed significant differences between specific semantic categories and the valence induced by emojis. The category of smileys and faces significantly induces positive valence, while the categories of people, animals, objects, and activities consistently induce positive valence. Symbol-related emojis were equally rated as positive and negative, which could be presumed to be more neutral (Table 2). The test results also showed that the category of *smileys and faces* significantly induced joy, while the *people and body* category induced the emotion of trust. For other categories, no significant results were found (Table 3).

Table 2. Differences in the distributions of the valence between semantic categories (Chi-squared test)

Valence	Semantic Categories					
	Smileys and faces (n = 68)	People and Body (n = 19)	Animals (n = 9)	Symbols (n = 6)	Objects (n = 5)	Activities (n = 2)
Positive	52	19	9	3	5	2
Negative	16	0	0	3	0	0
$\chi 2$	19.05	NA	NA	0.000	NA	NA
Df	1	NA	NA	1	NA	NA
P	<0.001	NA	NA	1	NA	NA

Table 3. Differences in the distributions of the emotions between semantic categories (Chi-squared test)

Emotion	Semantic Categories					
	Smileys and faces (n = 68)	People and Body (n = 19)	Animals (n = 9)	Symbols (n = 6)	Objects (n = 5)	Activities (n = 2)
Fear	6	0	0	0	0	0
Sadness	9	0	1	0	0	0
Anger	6	1	0	1	0	0
Anticipation	5	5	2	3	1	0
Joy	24	2	4	0	4	2
Surprise	9	1	0	1	0	0
Disgust	2	0	0	0	0	0
Trust	7	10	2	1	0	0
$\chi 2$	36.47	15.47	2.11	2.000	1.8	NA
Df	7	4	3	3	1	NA
P	<0.001	0.004	0.55	0.57	0.18	NA

Cross Cultural Comparison

Due to the similarities in methodology between our study and the study conducted by Godrad and Holtzman in assessing the emotional content of emojis, we compared their results with ours to identify cultural differences in the affective perception of common emojis (n = 95) between the two cultures (Godard & Holtzman, 2022). Table S2 shows the results. We found that both cultures similarly identified four emojis—Pouting Face, Expressionless Face, Unamused Face, and Angry Face—as negative, whereas Canadians perceived the remaining emojis as positive. Regarding emotion perception, we found that both cultures shared the same dominant emotion perception for 29.47% (28 out of 95) of the emojis, specifically for joy (n = 17), trust (n = 9), and anticipation (n = 2). Notably, Canadians perceived these three emotions as the dominant affect for all the common emojis, while Iranians also perceived other emotions such as anger, surprise, sadness, fear, and disgust. Moreover, to assess the consistency of emoji valence perception between the Canadian and Iranian datasets, Cohen's Kappa was calculated. The resulting Kappa coefficient of 0.357 falls within the range of fair agreement (Landis & Koch, 1977). This suggests that while there is moderate consistency between the two datasets, the agreement remains limited, implying potential cultural differences in how emojis are interpreted in terms of positive and negative valence

Discussion and Conclusion

The present study aimed to provide subjective ratings for 109 emojis in terms of valence and emotional intensity across eight dimensions: anger, anticipation, disgust, fear, joy, sadness, surprise, and trust. Besides gender comparisons in terms of emotional intensity, we also compared our data with a similar emoji dataset developed and validated by Godard et al. to highlight cultural differences in emoji perception between the Iranian and Canadian samples (Godard & Holtzman, 2022).

Overall, of the 109 selected emojis, 90 were perceived as having a positive valence, while 19 were perceived as having a negative valence. This is consistent with various previous studies, which indicated that many emojis convey a positive or neutral emotional valence rather than a negative one (Riordan, 2017; Rodrigues et al., 2018). This issue is because people typically think that emojis are fun in essence and can loosen up their conversations (Fischer & Herbert, 2021). Regarding individual emoji valence, some parts of our findings align with previous research, while some heterogeneities exist in terms of emoji selection and the tools used to evaluate their valence (Kutsuzawa et al., 2022). For example, compared to the study by Jaeger et al., who selected 33 facial emojis and used a Likert scale to assess valence sentiment, we selected 109 emojis from various categories and used a binary question (positive versus negative) to evaluate their valence (Jaeger et al., 2019).

Our results showed that all emojis with the highest scores in joy or trust emotions induced positive valence, while those with the highest scores in disgust were rated as negative valence. These results indicate a high level of agreement for these types of emotions, which is consistent with the study by Godard et al. (2022). Ratings for emojis perceived as expressing anticipation indicated a significant level of positive valence rather than negative. For the remaining emotions, including sadness, fear, anger, and surprise, no significant differences were observed, and they were interpreted as both positive and negative. The fact that all joy-induced emojis were rated as having positive valence may be due to distinct and agreeable elements embedded in emojis, such as hearts, smiling eyes, open smiles, pink cheeks, clapping hands, V signs, celebration poppers, stars, the sun, fire, crowns, money, and music notes. All trust-induced emojis were interpreted as having positive valence. Interestingly, the majority of emojis in this group depicted *body parts*, particularly hands, and included green-colored elements such as hearts, check marks, and leaves, which conveyed positive feelings. These results contrast with a large body of literature highlighting the role of facial features and cues (e.g., open eyes, smiling mouth) in forming first impressions of trust, even at a subliminal level (Bar et al., 2006; Mo et al., 2022; Willis & Todorov, 2006).

Regarding the anticipation-perceived emojis, which were also rated as having positive valence, the most prominent elements were *directional symbols*, represented by hands or other symbols. The two disgust-rated emojis, characterized by narrowed eyes, raised lips, and a nose crinkle, were associated with negative valence. Although no significant differences were found between positive and negative ratings for anger, fear, sadness, and surprise, some prominent features were identified among these groups. For the anger-induced emojis, features such as clenched fists, furrowed brows, tense jaws and lips, flared nostrils, and the color red were prominent, likely contributing to the more negative valence ratings assigned to this group. For the sadness-perceived emojis, the negative valence rating was higher than the positive, possibly due to prominent affective elements such as lowered corners of the mouth, descended eyebrows, dropped eyelids, crying faces, black hearts, broken hearts, and hearts with arrows. For the fear-induced emojis, it was interesting that more participants assigned positive rather than negative valence. This may be due to prominent facial expressions, such as open eyes and mouths, which can induce a comic perception of the emojis. Surprise perceived emojis were mostly rated as positive, characterized by prominent features such as raised eyebrows, wide-open eyes, and O-shaped or straight-line mouths. Another point deserving mention is that, regarding semantic categories, we found that for all categories, excluding symbols, the average number of positive valence attributions was higher than the negative ones. The group of smileys and faces significantly induced joy, while people and body emojis induced trust emotions. This corresponding relationship between semantic categories and perceived emotions is likely culturally bound and varies across different social contexts due to their diversity in communication styles (e.g., language) (Neel et al., 2023).

Another important result concerns gender differences in perceiving the intensity of emoji emotions. We found that women significantly perceived higher intensity in all eight dimensions of emotions compared to men. This result aligns with previous studies indicating higher sensitivity of females to affective stimuli (Ferré et al., 2023), likely due to developmental mechanisms (e.g., primary caretaker hypothesis) or emotional biases that make women more emotionally sensitive than men.

Last but not least, the interesting findings indicated cultural differences between Iranian and Canadian participants in perceiving the affective features of common emojis. The inter-rater reliability for emoji valence ratings between Iranian and Canadian participants indicated a fair level of agreement between the two cultural groups, suggesting that while there is some overlap in emoji interpretation, cultural differences are still present. The differences in emoji interpretation between Iranians and Canadians highlight significant cultural variations in emotional expression. For instance, the pensive face emoji, which may be perceived as a neutral or thoughtful expression in Canadian culture, was viewed more negatively by Iranian participants, possibly reflecting cultural tendencies to associate introspection with worry or sadness. Similarly, the sneezing face emoji, generally seen as a natural response to illness in Canada, was considered negative in Iran, where it may induce feelings of discomfort. Additionally, emojis such as the persevering face and the weary face were interpreted differently across cultures. In Canadian culture, these emojis might symbolize resilience and determination, potentially perceived positively as signs of persistence. In contrast, Iranian participants may associate these expressions with exhaustion or emotional fatigue, leading to a more negative interpretation. The broken heart emoji, widely associated with sadness and emotional distress, was similarly seen as negative in both cultures. However, its meaning can vary in depth. While it likely symbolizes pain and grief universally, in Canada, it may also signal a more normalized emotional process of healing, whereas in Iran, it could evoke a more profound sense of loss and sorrow. These examples show how cultural contexts shape the interpretation of emotions conveyed through emojis particularly in on-line communications which lack of traditional non-verbal cues. Differences in emotional expression, social norms, and even language nuances play a crucial role in how individuals perceive and respond to these digital symbols. Understanding such cultural nuances is essential for researchers and practitioners in cross-cultural communication and digital psychology.

Regardless of the novelties of our study in terms of using emojis from various categories, comparing men and women in emotional perception, as well as analyzing cultural differences, we must address some of our limitations. First, we used a binary rating for valence perception instead of a continuous scale. Although we acknowledge the advantages of a more precise evaluation using a Likert scale for valence interpretation, we intentionally used binary classification to simplify the analysis and focus on the clear emotional polarity of the emojis, which is more preferred in Iranian culture. Another reason for this choice is that the present study was part of a larger project in which we needed to categorize the sentiment of texts as either positive or negative; therefore, we applied the same approach to emojis to align with the text sentiment analysis. Our second limitation was that our study asked participants to rate the affective profile of emojis in isolation, whereas the results might have been different if the emojis were presented in context (Ferré et al., 2023). Third, we did not collect or examine additional demographic characteristics such as level of education or specific personality traits (e.g., extraversion, autism, depression, anxiety), which could moderate the interpretation of affective features (Kennison et al., 2024; Mohan et al., 2021). Finally, we selected the limited number of the most frequently used emojis on the X platform, while the number of available emojis are now reached over 3500 (Unicode version 15.1: https://unicode.org/emoji/charts/full-emoji-list.html) and their appearance varies across different platforms (Fernández-Gavilanes et al., 2018). Future studies should include a more comprehensive and updated set of emojis to expand this novel tool of communication and explore how individual and cultural factors influence emoji interpretation.

In the present study, we have provided the Persian Emoji Lexicon (PEL), which includes the affective profiles of 109 face and non-face emojis frequently used on X (former Twitter) in terms of valence and emotion dimensions. We collected subjective ratings from 200 participants through an on-line survey and examined gender and cultural differences in the perception of their affective features. This database could serve as a valuable resource for other studies analyzing the sentiment of content posted on social media, as well as for applied studies using emojis to evoke specific emotions that may influence certain behaviors in marketing, training, or other professional contexts.

Declarations

Author Contributions

TR: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft. ZR: Data curation, Formal analysis, Software, Methodology, Writing – original draft. JH: Conceptualization, Methodology, Funding acquisition. HK: Formal analysis. KM: Data curation. All authors participated in the revising of the manuscript.

Data Availability Statement

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

Acknowledgements

The authors sincerely appreciate all those who contributed to this research. Their support, insights, and efforts have been invaluable in the completion of this study.

Ethical considerations

This study was conducted in full compliance with ethical guidelines and principles. All participants provided informed consent, and their confidentiality and anonymity were strictly maintained. The research protocol was reviewed and approved by the relevant ethical committee, ensuring adherence to ethical standards throughout the study.

Funding

This research was conducted without any external funding and was entirely financed by the authors' personal resources.

Conflict of interest

The authors declare that the research 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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The University of Tehran Press

Journal of Cognitive Science Research

2025, 1(2), 15-29

Home Page: https://jcsr.ut.ac.ir/

Psychophysiological Responses to Mindful Equanimity Induction in Virtual Reality: An Exploratory Study

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ARTICLE INFO

Article type:
Research Article

Article History:
Received: 03 May 2025
Revised: 19 May 2025
Accepted: 10 Jun 2025
Published: 01 Jul 2025

Keywords:
Equanimity, HRV, Mindfulness, Psychophysiological Responses, Virtual Reality

ABSTRACT

Equanimity, as a critical feature of well-being can be strengthened and Virtual reality (VR) can be employed to cultivate this capacity. No previous study has directly investigated the impact of different equanimity practices within VR and compared people's preferences for different practices. This study was conducted to explore whether practicing equanimity within three VR scenarios can increase mind-body calmness. Three VR scenarios (<10 min) were developed. A within-subject study (n=75) was designed to assess impact of these practices in improving calmness indices. Participants were exposed to VR practice sessions combining sound of a teacher and three animation environments including Mountain, Ocean, and Sky facing with changes during a year or day. Participants' experience of each session was assessed using heart rate variability (HRV), respiratory rate, and self-reported ratings. Subjective state anxiety was also assessed at baseline and after the end of three VR sessions. Physiological indices were improved in Ocean practice compared to baseline and two other practices. Results showed that physiological indices during practices were correlated with self-reports of mindfulness, self-knowledge, and interoceptive awareness ($p<.05$). A significant reduction was observed in self-reported assessment of state anxiety. Generally, VR practices of equanimity were shown to induce mind-body calmness.

Cite this article: Abbasi Sooreshjani, M., Ghorbani, N., & Vartanian, M. (2025). Psychophysiological Responses to Mindful Equanimity Induction in Virtual Reality: An Exploratory Study. *Journal of Cognitive Science Research*, *1*(2), 15-29. doi:10.22059/jcsr.2025.394621.1011

Publisher: University of Tehran Press
DOI: https://doi.org/10.22059/jcsr.2025.394621.1011

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Introduction

The mindfulness construct has received increasing attention in recent years. According to this notion, it would be better to cultivate inner consciousness through acceptance and compassion instead of outsourcing to create desired external conditions of well-being and happiness (S. L. Shapiro, Jazaieri, & de Sousa, 2009). Happiness in the absence of pleasure is also referred to as "equanimity" (Bokenkamp, 2005; Harvey, 2012). Mindful equanimity is defined as mind’s ability to face changes and challenges of life while maintaining calmness, simultaneously having exact knowledge of one's own and others̉ needs as well as environmental necessities (Goldstein & Kornfield, 2001).

Concept of equanimity has been recently adopted from Eastern traditions to have a new holistic look at suffering and well-being (Wallace & Shapiro, 2006). From the Buddhists̉ perspective, cultivating equanimity capacity is necessary to reduce suffering and to attain long-lasting happiness. This quality of mind influences emotional and physiological responses to a stressor (Stellar, Manzo, Kraus, & Keltner, 2012). For example, it has been shown to have benefits like decreasing mental and physiological agitation (e.g., (Ayduk & Kross, 2008, 2010). While this quality is investigated in meditation centers, it is rarely integrated into psychological research. Thus, innovative and easily achievable teaching tools are required with a focus on cultivating equanimity. Some practices have been introduced in the literature for developing equanimity capacity that can be quickly delivered in an immersive virtual reality (VR). Herein, the following definition of equanimity is used: approaching pleasant, unpleasant and neutral sensory/cognitive experiences with no preference (Desbordes et al., 2015).

Meditation in general and mindfulness-related practices in particular (including equanimity) have been shown to be effective techniques for treating a wide range of difficulties (Parsons, Crane, Parsons, Fjorback, & Kuyken, 2017). However, they can be challenging for beginners. Beginner meditators have been suggested to use system applications helping them to focus effectively on meditation assignments and eliminate other audio and visual distractors, especially in busy environments. Current technologies like VR environment can be a useful tool in teaching mindfulness-related practices and overcoming these barriers. VR technology also offers a deep sense of presence in comparison with other media and provides a safe place for practicing mindfulness and cultivating reflective self-awareness (Sliwinski, Katsikitis, & Jones, 2017).

VR has great benefits for treatment because it can create a sense of presence of mind/body, as a fundamental quality of mindfulness. This quality can rarely be achieved by imagination (Riva et al., 2015). In fact, VR essentially provides a place where a person can live and experience. In this regard, Baños et al., (2015) compared sense of presence between virtual and imaginary spaces. Participants were randomly allocated to one of two conditions, virtual versus imaginary environment, and subjective perception of presence was investigated at three times. They indicated that participants in "imaginary" environments expressed a decreased sense of presence, while those in virtual spaces reported the opposite. Freeman et al., (2004) investigated influence of VR on sense of presence in context of relaxation teaching. They showed that VR-based relaxation training induced greater sense of presence than narrative-based relaxation training. That is, VR seems to enable the users to "stay there" over time. In fact, VR can provide an experiential form of imagery that can be effective in inducing emotional responses at the same level as reality (Vincelli, Molinari, & Riva, 2001). This technology can be applied for experiencing different identities and other unexperienced aspects of self (Baños et al., 1999).

Recently, researchers have increasingly applied VR environments in the field of mindfulness and they have designed VR-based therapies for treating psychological disorders (e.g., (Seol et al., 2017)). For example, Meditation Chamber as a combination of VR and biofeedback (Shaw, Gromala, & Seay, 2007) provides relaxation and mindfulness training to participants. The

RelaWorld (Kosunen et al., 2016) was designed for meditation training using different scenarios to engage players in practice. Neurofeedback was combined with VR to visualize body scan and focused attention practices and their physiological effects.

Although, some physiological indices have also been studied for showing physical changes during practice of mindfulness, to the best of our knowledge, no study has used heart rate variability (HRV) to quantify physical indicators of equanimity during mindfulness practice. Particularly, HF (power in high frequency range), an index of parasympathetic activity has also been considered as an indicator of equanimity (Desbordes et al., 2015).

Herein, brief and accessible forms of equanimity training were introduced and studied in VR technology to make training available for novice users. Three VR-based equanimity practices (Ocean, Mountain, and Sky) were introduced where trainee was taught to keep calmness while confronting unpredictable situations and environments and these three practices were compared regarding their efficacy in reducing (psychological and physiological) stress and inducing sense of presence. Popular psychophysiological markers of this capacity were also measured including heart rate (HR), respiratory rate (RR), and HRV (Desbordes et al., 2015). These three practices are introduced in the following.

A mountain is among the images often applied to show equanimity. It remains still, centered, and quiet through changing climate and time. In this practice, a person is instructed to vividly imagine a mountain that he knows and likes with its stability and grounded presence. After some moments of shaping and holding that image in his mind, he can imagine bringing it inside himself and becoming a mountain, sitting in a calm and still position like a mountain, and observing all the changes in weather and seasons, etc. Just like a mountain withstanding changes and challenges, all of us experience different thoughts, feelings, and life adversities. This practice helps a person to deeply feel calmness and stillness in the middle of internal and external constant changes (Pollak et al., 2014). According to Kabat-Zinn, by feeling oneself as a mountain, one can be linked up with strength and stability of mountain within the ever-changing thoughts, images ,and emotional storms (Kabat-Zinn, 1994). Furthermore, another equanimity-strengthening meditation that can be taught for unstable moods and times is based on metaphor of stillness beneath waves of the lake or ocean (Pollak, Pedulla, & Siegel, 2014). This practice uses metaphor of centeredness beneath wild waves of the sea or ocean to cultivate equanimity. This practice was designed for managing distressful times like illness, grief, or loss. A person is instructed to visualize a boat with an anchor in a deep harbor while he is present in a sunny day with blue sky and tranquil sea. After a while, dark clouds come and cover the sky, and winds and rain start to make huge waves in the sea. Then, he imagines that he can drop into the sea allowing his attention to be focused on the boat’s anchor and resting there in a tranquil and still point in the middle of storm. Another related metaphor is visualizing the mind as a sky. In this practice, a person is instructed to imagine a vast sky. Sky might be occupied with different contents including sun, rain, and snow every day and with moon and stars every night allowing everything comes and goes, accepting change and not resisting against it. The sky is always present no matter what content is here (Pollak et al., 2014). These practices can be used for meditation beginners and are more effective when accompanied with concentration practices (e.g., awareness of breath) (Pollak et al., 2014).

Although, these three meditations seem to vary in different ways, they have the same basic logic that is building the capacity of being open to changing aspects of life with balance. General aim of this study was exploring whether practicing equanimity within these three VR scenarios can improve emotional and physiological calmness of participants compared to baseline. Therefore, two hypotheses and one question were set forth: (a) VR-based equanimity practices can be induce psychological and physiological calmness, (b) higher levels of mindfulness-related capacities are associated with higher levels of physiological calmness during equanimity practices, and (c) Which practice is the most preferable one based on users' self-ratings of presence?

Method

Participants

A within-subject design of study was used where 76 participants (including 47 females) aged between 20 - 49 (M=25.6) years old were recruited through advertisements at the University of Tehran. Eligible participants had no fear of height (acrophobia) and sea. They were exposed to three meditation practices for cultivating equanimity.

Materials

Instrument and Scenarios of VR

All three scenarios (Sky, Ocean, and Mountain) were based on metaphors of equanimity and adopted from imagery-based equanimity practices (Kabat-Zinn, 1994; Pollak et al., 2014). VR environment was created using Unity 3D world building software and was displayed using an Oculus Rift DK2 head-mounted display (HMD) device, with head tracking allowing them to see 3D computer-generated environments (where they find themselves in an animated computer-generated Ocean shore, within a Mountain area, and sitting on sandy reefs and watching the Sky) while listening to an instructor's recorded voice using headphones. Participants were asked to sit while practicing, and instructions were only provided through audio guidance. Visuals and audios were combined and presented as a multisensory experience using Unity3D software. In virtual world, participants were sitting toward the main scenery (e.g., Mountain), and they could turn their heads to see changing environment around central landscape (Figs 1-3). No interaction was designed in virtual environment.

Measures

For evaluating participants' background information, some items were included in a questionnaire: age, gender, job, education as well as, hours of using TV, playing video games, VR previous experiences, background knowledge about movie or animation, history of meditation and frequency of meditation practice during last month, and fear of height (acrophobia) and sea.

VR Experience Questionnaire

Six items were extracted from existing tools assessing sense of presence in virtual environments (e.g., (Baños et al., 2000)). A subset of items was chosen to keep experiment duration reasonable. This scale was only based on participants' personal assessments of their experience in VR. After completing meditation session, participants completed an 8-point Likert questionnaire (0-7) where their experience was evaluated in terms of the following dimensions: (a) spatial presence, (b) involvement, (c) mental immersion, (d) satisfaction, (e) perceived relaxing experience, (f) attention and attraction (Appendix I). Participants completed the questionnaire following immersion in a virtual version of each of three practices.

Integrative Self-Knowledge Scale

ISK (α=0.84, M=41.65, SD=9.66) includes 12 items recording individuals̓ efforts to develop past, present, and desired future self-experience into a meaningful whole (Ghorbani, Watson, & Hargis, 2008). For example, "If necessary, I can reflect on myself and clearly understand feelings and attitudes underlying my past behaviors." Responses were scored on a 5-point Likert scale ranging from 1 (largely untrue) to 5 (largely true). This scale has been shown to have good psychometric properties (Ghorbani et al., 2008).

Multidimensional Assessment of Interoceptive Awareness (MAIA)

MAIA is a tool used for evaluating eight dimensions of interoceptive awareness. This scale contains 32 items rated on the 6-point Likert scale, ranging from zero (never) to 5 (always) and higher scores show more interoceptive awareness. Its validity and reliability were confirmed in an English version (Mehling et al., 2012). Five specific dimensions of MAIA were included in analyses: not distracting (ND, tendency to not distracting and ignoring unpleasant senses), not worrying (NW, tendency to not worrying or not experiencing emotional distress facing pain or unpleasant senses), attention regulation (AR, ability to control and keep focusing on senses), listening to body (LB, dynamically paying attention to body to get insights), and trusting (TR, experiencing a safe and reliable body). These dimensions were selected because they had the most powerful psychometric properties in the Persian version of MAIA (Abbasi et al., 2018).

Mindful Attention and Awareness Scale (MAAS)

MAAS is a 15-item scale and has been widely employed in assessment of mindfulness. Responses are scored on a 6-point Likert scale ranging from 1 (almost always) to 6 (almost never). This scale has been shown to have acceptable psychometric properties (Brown & Ryan, 2003).

Spielberger State-Trait Anxiety Inventory (STAI)

This standardized scale was developed by Spielberger (1970) and is one of the most frequently used measures of anxiety. It has been shown to have good psychometric properties. STAI consists of 40 items measuring state (20 items) and trait (20 items) anxiety. Here, state anxiety subscale was used.

Psychophysiological Measures

Psychophysiological response data (HRV and RR) were recorded during each VR practice using dual-modality encoding system of biofeedback unit and BioGraph Infiniti ver.4.5 software (Procomp; Thought Technology Ltd., Quebec, Canada).

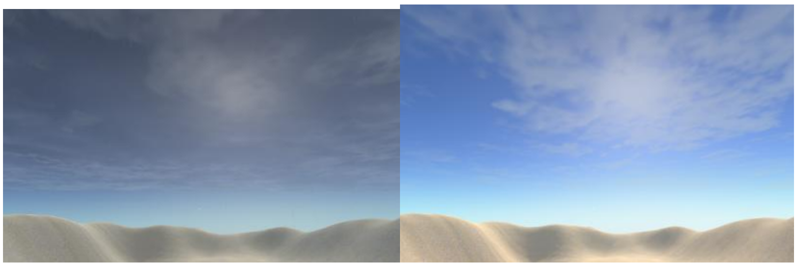

Figure 1. Sky meditation snapshots

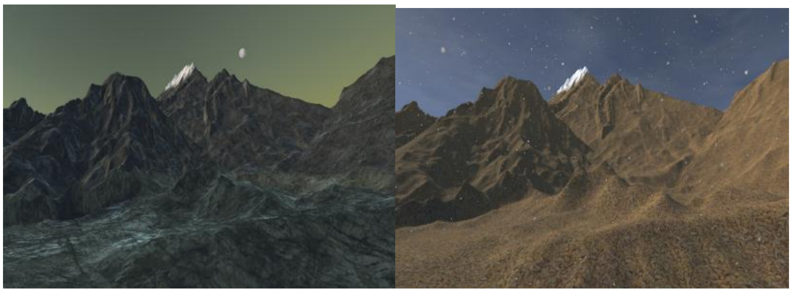

Figure 2. Mountain meditation snapshots

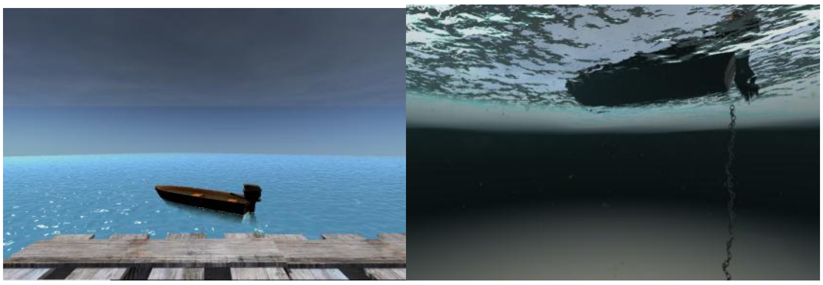

Figure 3. Ocean meditation snapshots

Procedure

Participants entered the lab and were provided with written information about purpose and methodology of the study and then, they filled out consent form. System features were explained to them and they got familiar with it using a demo. Also, they completed basic information form and studied questionnaires. Baseline physiological assessments including HRV and RR were recorded for each participant during completion of these questionnaires. Completing the questionnaires lasted about 15-20 minutes. For assessing changes in state anxiety, STAI test was used both before and after the experiment. Each meditation practice lasted about10 minutes. Three VR environments were randomly presented. After this experiment, electrodes were removed, and participants were appreciated for their collaboration.

Data Analysis

All statistical analyses were conducted using SPSS ver. 22 software (SPSS Inc., Chicago, IL). Paired-Samples t-test and Repeated-Measures ANOVA were employed to address differences in interval target variables, and Friedman test was used to test differences between ratings of each practice (two-tailed statistical analysis, $p<.05$). Also, Pearson correlation coefficient was employed for investigating the association between physiological indices and scores of mindfulness-related self-reports.

Results

Changes in Physiological Indices

HRV and RR recordings were visually evaluated for any artifacts. All files were shown to have usable data. Then, changes in HR, HRV-related data, and RR were averaged across baseline, Ocean, Sky, and Mountain practices. Table 1 shows means and standard deviations of physiological indices for baseline and during every three practices.

To test for specific impact of each practice in inducing physiological and psychological calmness, a series of within-subject contrasts were conducted. Contrasts were analyzed through F tests to determine significant changes in HF-HRV, RR, HR, and LF/HF HRV ratio from baseline through each practice. A significant difference was found between four conditions (baseline and three equanimity practices) in all of the above indices: HF-HRV ($F (3,219) =7.71$, $p<.0001$), HR ($F (3,222)= 82.45$, $p<0.0001$), LF / HF HRV ratio ($F (3, 219) = 3.07$, $p=.02$), and RR ($F (3,222) =7.34$, $p<.0001$). Post-hoc tests were run to confirm differences between the variables.

HR Changes

Results of post-hoc tests using Bonferroni correction revealed that HR, corresponding to better relaxation was reduced from baseline by an average of 6.42 (beats per minute, bpm) through

Ocean (p<.0001), by 5.83 (bpm) during Sky and by 5.50 (bpm) during mountain practice (p<.0001).

HRV

HF-HRV

This index of parasympathetic activity was improved relative to baseline, during exposure to equanimity practices. It was respectively higher than baseline for Ocean (mean difference=219.39, p<.0001), Mountain (mean difference=103.85, p=.009), and Sky (mean difference= 89.82, p<.01) practices.

LF/HF HRV Ratio

A greater mean drop was observed in LF-HRV (sympathetic) relative to HF-HRV (parasympathetic activity) in Ocean (mean difference=.31, p<.05) and Sky (mean difference=.30, p=.07) practices compared to baseline LF/HF-HRV ratio. However, this ratio showed no difference for Mountain practice compared to baseline ratio (p=.50) .Ocean and Sky practices were respectively shown to influence sympathovagal balance as indicated by LF/HF HRV ratio (von Rosenberg et al., 2017).

Changes in RR during Practices

Practicing equanimity caused a significant decrease in RR (breath per minute or br/min), as an index of parasympathetic activity, compared to baseline rates. The maximum effect was respectively observed after exposure to Ocean (br/min mean difference=1.72, p<.0001), Sky (br/min mean difference=.84, p<.01), and Mountain (br/min mean difference=.60, p<.03) practices.

Self-Report Measures

Mean and standard deviation of self-reported measures are shown in Table 1. Bivariate correlations were carried out between mindfulness-related capacities and changes in physiological reactivity scores from baseline through mindfulness practices to see how changes in physiological indices induced by practices are related to mindfulness-related capacities (signified by MAAS, ISK, and MAIA). For testing the hypothesis stating that higher levels of mindfulness-related capacities are positively associated with the increased parasympathetic indices and negatively with sympathetic as well as RR changes during each practice, a series of bivariate correlations were executed. Studying the association between MAAS and physiological changes during each practice showed that MAAS was positively correlated with HF-HRV changes during Ocean practice [r (75) = .32, p<.01]. Also, integrative self-knowledge capacity was positively correlated with changes in HF index during Ocean practice [r (75) = .23, p<.05] and ISK was negatively correlated with LF-HRV (sympathetic activity) relative to HF-HRV (parasympathetic activity) during Mountain practice [r (75) = -.25, p<.05]. Regarding assessing the effect of embodied presence and involvement in VR environment, five specific dimensions of MAIA were also included in analyses: ND, NW, AR, LB, and TR. Higher scores on ND were correlated with changes in LF/HF HRV ratio scores in Ocean [r (75) = -.23, p<.05] and Sky practices [r (75) = -.25, p<.05]. Higher levels of ND were correlated with lower change scores of RR [r (75) = -.23, p<.05] in Sky practice. Higher level of LB was related to higher HF in Ocean practice [r (75) = .22, p<.05], indicating that participants who are able to monitor and regulate their psychological and physical experiences are more likely to benefit from self-regulatory and equanimity trainings.

Table 1. Means, standard deviations, and ranges of physiological and self-report measures

	ISK	MAAS	ND	NW	AR	LB	TR	BASELINE HR	BASELINE HF	BASELINE RR	BASELINE LF/HF	OCEAN HR	OCEAN-HF	OCEAN RR	OCEAN LF/HF	SKY HR	SKY HF	SKY RR	SKY LF/HF	MOUNTAIN HR	MOUNTAIN HF	MOUNTAIN RR	MOUNTAIN LF/HF
MEAN	44.67	63.31	2.4	2.16	2.59	2.38	2.71	91.28	301.1	14.90	1.90	84.74	378.8	13.73	1.56	85.26	252.61	14.06	1.57	85.60	264.61	14.29	2.03
SD	8.16	9.32	.84	.92	.89	.95	1.17	12.04	422.4	1.64	1.49	10.84	610.05	2.29	1.42	11.45	291.95	2.60	1.21	10.59	333.62	2.32	2.11
RANGE	25-60	32-82	.67-4	.33-4.67	0-4.57	0-4	0-5	65.11-122.67	4.43-3283.2	10.88-18.11	.37-7.64	64.15-119.47	13.17-3404.80	7.96-17.90	.07-9.19	61.53-122.2	2.84-1638.91	6.95-19.46	.11-5.18	63.30-121.6	3.22-1979.3	8.51-17.57	.12-13.24

ISK= Integrative Self-Knowledge Scale; MAAS= Mindfulness Attention and Awareness Scale; MAIA= Multidimensional Assessment of Interoceptive Awareness; ND= Not Distracting; NW= Not Worrying; AR= Attention Regulation; LB= Listening to Body; TR= Trusting

Subjective Experience

The data extracted from 6 items were considered as ordinal, and Mann-Whitney U tests were employed to find differences in scores between the three practices. Fig. 4 shows distribution of ratings across the questionnaire items for each practice and Table 2 illustrates corresponding mean ranks and medians. One at a time, each outcome measure was considered as dependent variable. The comparisons using Mann-Whitney U tests showed significant differences between practices:

Spatial Presence

A significant difference was found in the level of the induced sense of presence between three practices (*Chi square= 10.77, p=.005*). Post-hoc comparisons showed higher levels of sense of presence in Ocean compared to Sky practice (z= -2.53, p=.01), and Mountain compared to Sky practice (z= -2.53, p=.01). But the level of sense of presence induced by Ocean and Mountain practices was not statistically different (z= -.18, p=.85).

Involvement

Three practices were also different in level of involvement experienced by the users when exposed to the practices (*Chi square=6.27, p=.043*) so that, more involvement belonged to Mountain practice than Sky practice (z=-2.29, p=.02). No significant difference was found in this variable between Mountain and Ocean practices (z= -1.53, p=.12). Furthermore, Ocean was not notably different from Sky practice regarding level of experienced involvement (z= -.81, p=.41)

Mental Immersion

The users rated the practices differently regarding level of induced mental immersion (*Chi square=18.86, p= .0001*). The differences were in favor of Ocean practice compared to Sky (z= -4.38, p=.0001) and Mountain practices (z= -1.70, p=0.08). Also, more immersion belonged to Mountain practice than Sky practice (z= -2.96, p=.003).

Satisfaction

Users' level of satisfaction with the practices was not similar (*Chi square=16.66, p=.0001*). They had more satisfying experience with Ocean (z=-3.15, p=.002) and Mountain (z= -2.40, p=.01) practices compared to Sky practice. However, Ocean and Mountain practices were not different regarding satisfaction ratings (z=-1.04, p=.29)

Perceived Relaxing Experience

Meditation in the three environments induced different levels of relaxation (*Chi square=11.01, p=.004)*. Participants perceived the Ocean (z=-1.98, p=.047) and Mountain (-3.17, p=.001) practices more comforting than Sky one. Also, no differences (z=-.95, p=.34) were found between Ocean and Mountain practices regarding level of induced relaxation.

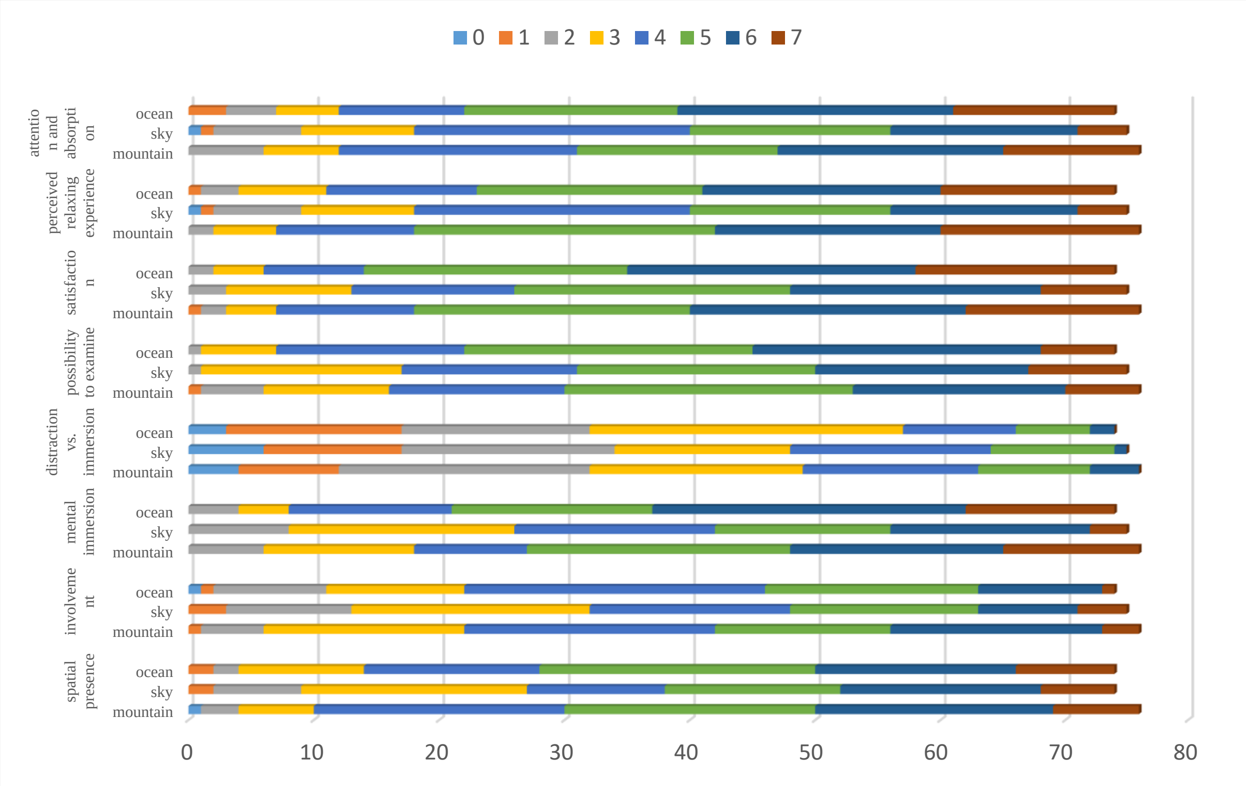

Figure 4. Distribution of self-ratings for practices

Attention and Absorption

Different levels of excitement were produced in the environments (*Chi square= 19.98, p=.0001)*. Ocean (z= -3.04, p=-002) and Mountain practices (z= -2.62, p=.009) were more helpful in drawing attention and inducing attraction compared to Sky practice, but they were not rated differently in this variable (z= -.99, p=.31).

Table 2. Mean ranks and medians corresponding to each item of self-ratings for VR practices

Self-rating Items of experience with VR practices	Mean ranks			Medians		
	Ocean	Sky	Mountain	Ocean	Sky	Mountain
1. To what extent did you experience a sense of being there inside the environment you saw (spatial presence)?	2.14	1.72	2.14	5	4	5
2. How much did your experiences in the virtual environment seem consistent with your real-world experiences (involvement)?	1.97	1.83	2.20	4	4	4
3. How involved were you in the virtual environment experience (mental immersion)?	2.30	1.66	2.04	5.50	4	5
4. To what extent did the virtual experience seem satisfying to you (satisfaction)?	2.25	1.69	2.06	6	5	5
5. How relaxing was the experience (perceived relaxing experience)?	2.09	1.74	2.18	5	5	5
6. How exciting was the experience (attention and absorption)?	2.24	1.64	2.12	5	4	5

Change in Perceived State Anxiety after Practices

General changes in state anxiety levels were also studied before and after presenting three practices using Paired-Samples t-test. The results showed a significant reduction (t (74) =7.40, p<.0001) in self-reported assessment of state anxiety reflected in STAI.

Discussion and Conclusion

Herein, brief and accessible forms of equanimity training were introduced and studied in VR technology to make training available for novice users. The first set of analyses showed impact of practices in inducing physiological and psychological calmness. In the second set of analyses, changes in psychophysiological indices were shown to be related to the users' mindfulness-related capacities, assessed by MAAS, ISK, and MAIA scales. Investigating comparative satisfaction with three practices, represented in users' ratings of their sense of presence finally showed superiority of Ocean practice over Mountain and Sky practices in general .

Taking a look at the nature of each practice can be helpful to explain comparison results. All the three practices help a person to develop the attitude of welcoming pleasant experiences without clinging, and welcoming unpleasant experiences without turning away as well as nurturing the capacity to step into distress with openness and spaciousness. Ocean and Mountain practices focus on acceptance and equanimity in the middle of physical, psychological, or emotional hardships. Therefore, during these practices, a person can find himself closely dealing with difficulties. However, in Sky practice, the person's mind and its turbulence occur far from himself and there is a distance between the person and changes occurring in the sky. Therefore, this practice allows suffering to rise from a distant place and then, let it pass. In other words, Sky practice allows for a separation between person and experienced instability of physical and mental states. Although, this distancing shows to be effective in reducing attachment to contents of the mind (instructing that thoughts come and go like clouds floating through sky) but it may not train a person for engaging with unpleasant experiences without turning away and keeping his equanimity amidst changing emotional and external circumstances. Also, in Sky practice, one may be trained to approach discomfort with openness as the sky is wide and spacious to include a range of pleasant and unpleasant experiences. Gazing up at sky helps him to face the problems with a sense of spaciousness and greater perspective (Coleman, 2010) .

Ocean practice, as a practice for intimately engaging with difficult emotions and painful situations can enhance a person's capacity to tolerate, embrace, and accept difficult experiences in their true form, promoting stability in the middle of changing (internal and external) circumstances. In ocean metaphor, chaos and difficulties of life are likened to waves and storms in the ocean. We have no control over these waves and life stressors. But, we can go underneath of these surface challenges and to the depth where water is calmer and rest in there. While, we sit beneath the waves, we can clearly see and feel challenges and emotional turmoil with courage. Also, a practicing person has a wide-angle lens enabling him to see challenges with greater objectivity, equanimity, and from a centered, deep inner place (S. Shapiro, Siegel, & Neff, 2018) .

In Mountain practice, a person can embody a central and solid stillness and groundedness in face of constant changes in his own life over time. By becoming a mountain, one can connect with its strong, solid, and stable nature and embrace them. As an example of instructions in Mountain practice, we have: "I am sitting cross-legged on the floor so that, my body looks and feels mostly mountain-like, inside and out…simultaneously, embodying universal qualities of "mountain-ness" transcending particular shape and form". Mountain practice seems to make practicing person more engaged with challenges compared to Sky practice that is less engaging regarding face-to-face dealing with challenges. This fact can also be applied to Ocean practice as observed in Kabat-Zinn's instruction (Kabat-Zinn, 2009) for Lake or Ocean practice: "…allow yourself to become one with the lake while lying down on your back ."

Our findings demonstrated that equanimity practice using VR was associated with attenuated involvement of sympathetic nervous system, indicated by LF/HF HRV ratio and HR indices (Berntson, Quigley, & Lozano, 2007). These practices were also associated with stronger engagement of parasympathetic responding, shown in HF-HRV reactivity and RR. Parasympathetic system is responsible for downregulation of bodily tension during stressful events. HF, an index of parasympathetic activity is also considered as a marker of equanimity (Desbordes et al., 2015). Practicing equanimity was shown to enhance stronger involvement of parasympathetic system, reflected in the users' self-ratings of state anxiety.

These findings were supported by convergent validity of self-report measures and psychophysiological indices. It was also hypothesized that the individuals' awareness of physical and psychological experiences in the present moment would be related to enhanced parasympathetic response and reductions in level of sympathetic activity during equanimity practice. Findings showed that users with higher capacity of interoceptive awareness, mindfulness, and integrative self-knowledge more efficiently downregulate autonomic activity using equanimity practices, meaning that individuals who are connected with their immediate internal experiences would more likely show balanced autonomic activity during the practices .

Participant's integrative self-knowledge was shown to be related to a lower sympathetic activity during Mountain practice. Also, MAAS measuring attentional aspect of mindfulness with an emphasis on openness to experiences was related to more physiological calmness during Ocean practice. The relationship between ISK and physiological changes during Mountain practice can be discussed by considering the content of practice. Mountain practice had an abstract and metaphor-laden content (e.g., standing grounded, still, and centered in face of joy, sorrow, and life challenges like a mountain facing changes like storms, wind, darkness, heat, and rain) and attuning with it may need more meta-cognitive insight than the other two practices. On the other hand, MAAS scores were associated with physiological calmness during Ocean practice. As, Ocean practice emphasized openness to experiences and introduced a simple and objective content, which may need higher levels of open and receptive attention and awareness rather than higher-order levels of cognition and reflection .

Interoceptive awareness considered as a potential mechanism for current mindfulness interventions involves being aware of (intense) physical sensations and keeping stillness during this experience (Mehling et al., 2009). For example, LB dimension of MAIA involves the capacity to regulate attention to physical sensations. This capacity was related to high levels of parasympathetic activity in Ocean practice. Detecting signals from physical sensations provides a person with essential feedbacks and non-judgmental awareness from moment to moment and encourages maintaining self-regulation during equanimity practice. According to results, interoceptive awareness was associated with lower levels of physiological stress. The association between interoceptive awareness dimensions and physiological calmness during equanimity training supports the claim that interoceptive awareness can help a person to greatly benefit from practicing equanimity. Overall, ISK and mindfulness capacity together with detecting physical signals and regulating mind and body based on these cues may increase impact of equanimity practices in VR .

Feedbacks after completion of VR practices showed that, participants experienced the same levels of "satisfaction," "relaxation," "attention" (attraction), and "spatial presence" during Ocean and Mountain practices. Level of “mental immersion” was higher in Ocean practice than Mountain practice. However, Mountain practice was the most “involving” practice among three practices. The weakest self-rated experience with VR practices was related to Sky practice. As discussed above, the nature of each practice can explain the results. Finally, based on STAI scores, anxiety level of participants was positively influenced by presenting three practices and was attenuated after finishing three practices .

This study also calls for further research to investigate and design new VR-based approaches for cultivating equanimity. Our results confirmed that training equanimity through VR could be useful in balancing psychological and physiological experiences. Besides, it was found that, in VR-based equanimity practice, awareness of psychological and somatic events is associated with better physiological indices of equanimity. Hence, it can be suggested that integrating the instructions related to mindfulness and interoceptive awareness can enhance equanimity training outcomes .

Results of the current study should be considered along with its limitations. First, the current study only included university students and the results cannot be generalized to other populations. For strengthening the results, it would be recommended to consider between-condition designs. In our study, each meditation practice lasted about 10 minutes, this time may not be enough to generate a good immersion in VR; thus in future research, it is suggested to extend the duration of each immersion and that each one does not exceed 30 minutes. It is suggested to make the immersions in different sessions in order to avoid negative effects regarding using VR (cybersickness). VR-versions of equanimity practices can also be compared with teacher-instructed equanimity practices in future studies. This can help us to understand whether this system can complement existing mindfulness trainings or not.

Declarations

Author Contributions

All authors contributed actively to the conception, design, and execution of the research.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Acknowledgements

We are deeply grateful to Professor Javad Hatami, Department of Psychology, University of Tehran, for generously providing access to the Virtual Reality laboratory, and for his valuable guidance in the design, implementation, and writing of this study. His support and insights significantly enriched the quality of this work.

Ethical considerations

All procedures performed in studies involving human participants were in accordance with the ethical standards of University of Tehran research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Ethic approval has been obtained before conducting the research.

Funding

The authors received no financial support for the research, authorship, and publication of this article.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this research.

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Appendix I: Users' self-evaluation of their experience with VR-based meditation practices

1. To what extent did you experience a sense of presence inside the environment you saw (spatial presence)?

0	1	2	3	4	5	6	7
Not at all							Very Much

2. How much did your experiences in the virtual environment seem to be consistent with your real-world experiences (involvement)?

0	1	2	3	4	5	6	7
Not Consistent							Very Consistent

3. To what extent were you involved in the virtual environment experience (mental immersion)?

0	1	2	3	4	5	6	7
Not Involved							Completely Engrossed

4. To what extent did the virtual experience seem satisfying to you (satisfaction)?

0	1	2	3	4	5	6	7
Not exciting							Very much exciting

5. How relaxing was the experience (perceived relaxing experience)?

0	1	2	3	4	5	6	7
Not relaxing							Very much relaxing

6. How exciting was the experience (attention and attraction)?

0	1	2	3	4	5	6	7
Not exciting							Very much exciting

The University of Tehran Press

Journal of Cognitive Science Research

2025, 1(2), 30-43

Home Page: https://jcsr.ut.ac.ir/

From Rest to Cognitive Engagement: EEG Markers of Tetris Performance

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ARTICLE INFO

Article type:
Research Article

Article History:
Received: 07 May 2025
Revised: 27 May 2025
Accepted: 20 Jun 2025
Published: 01 Jul 2025

Keywords:
Brain networks, Cognitive control, EEG, neuroplasticity, theta oscillations, Tetris.

ABSTRACT

Video games like Tetris engage distinct cognitive processes, yet the neural mechanisms underlying gameplay remain incompletely understood. This study investigates how Tetris modulates brain activity patterns compared to resting state, focusing on oscillatory dynamics and their behavioral relevance. We recorded 32-channel EEG in 32 participants during rest and Tetris gameplay. Spectral analysis identified power differences in key frequency bands (theta: 4-6Hz; alpha2: 10-.11.5Hz; beta3: 28-29Hz). Cluster-based permutation tests ($p<0.03$, FDR-corrected) localized significant changes, while Spearman correlations and regression analyses examined performance relationships. Three main findings emerged: (1) Gameplay increased frontal theta (cognitive control) and occipital beta3 (visual processing) while decreasing parietal alpha2 (attention reallocation); (2) Regional band power correlations showed a shift in co-modulation patterns from stronger frontoparietal theta covariance (rest) to enhanced parieto-occipital synchrony (gameplay), reflecting task-specific regional engagement; (3) Frontal theta modulation predicted performance ($R^2=0.322$, $p=0.004$), with stronger theta increases correlating with better scores ($r=+0.57$, $p<0.01$). Tetris induces rapid changes, with frontal theta emerging as a key marker of cognitive adaptability. These findings demonstrate the utility of Tetris for studying neuroplasticity and suggest its potential as a paradigm for cognitive training interventions. Future research should explore longitudinal changes in these neural patterns with extended practice.

Cite this article: Akbari, SH., & Hajizadegan, M. (2025). From Rest to Cognitive Engagement: EEG Markers of Tetris Performance. *Journal of Cognitive Science Research*, *1*(2), 30-43. doi:10.22059/jcsr.2025.394704.1012

Publisher: University of Tehran Press
DOI: https://doi.org/10.22059/jcsr.2025.394704.1012

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Introduction

Video games have become a ubiquitous part of modern culture, engaging individuals across all age groups with diverse game genres that uniquely influence cognitive functions and behavior. Research has demonstrated that different types of video games yield distinct cognitive benefits, such as puzzle games like Tetris enhancing visuospatial skills, logical reasoning, and problem-solving abilities, while action games improve information processing speed, selective attention, and hand-eye coordination (Green & Bavelier, 2003, 2012; Lau-Zhu et al., 2017). These findings underscore the potential of gaming not merely as entertainment but as a tool for cognitive enhancement.

Understanding the neural mechanisms underlying these cognitive effects is pivotal, especially as video games increasingly serve as platforms for cognitive rehabilitation, education, and therapeutic interventions (Rodrigo-Yanguas et al., 2022). Insights into how gaming modulates brain activity enable the development of targeted, personalized protocols to ameliorate cognitive deficits associated with disorders such as attention deficit hyperactivity disorder (ADHD), schizophrenia, and age-related cognitive decline (Caselles-Pina et al., 2023; Clemenson et al., 2020; De Luca et al., 2024).

Tetris (1984), in particular, has garnered significant neuroscientific interest due to its deceptively simple design combined with complex cognitive demands. It recruits multiple cognitive domains: visuospatial processing requiring rapid mental rotation and pattern matching engages posterior parietal and prefrontal cortices (Gentile & Lieto, 2022; Lau-Zhu et al., 2017); working memory sustains information about upcoming tetrominoes for strategic placement (Lau-Zhu et al., 2017). time-pressured decision-making fosters cognitive flexibility under dynamic conditions ; and motor learning supports sensorimotor coordination required to timely execute actions (Lau-Zhu et al., 2017). Collectively, Tetris functions as a dynamic "cognitive laboratory" for investigating interactions between perception, decision-making, and motor control.

Electroencephalography (EEG), with its millisecond temporal resolution and sensitivity to oscillatory brain activity, is an invaluable method for decoding the rapid neural dynamics underlying complex cognitive tasks like gaming (Ewing et al., 2016). This study leverages EEG to examine frequency power modulations during Tetris gameplay across multiple scalp regions, aiming to elucidate neural correlates of initial gameplay effects and their relationship to performance. Specifically, our research addresses these key questions: a) Which frequency bands and scalp regions show significant absolute power changes during the initial minutes of Tetris gameplay? B) How are these neural activity patterns associated with individual differences in gameplay performance?

The insights gained contribute to a nuanced understanding of game-induced neural plasticity and open avenues for innovative EEG-informed biofeedback approaches. Such findings may eventually inform adaptive systems that leverage real-time neural signals to modulate cognitive and motor performance, including closed-loop paradigms for training and rehabilitation.

Method

Participants

The study sample included university students aged between 18-30 years. The inclusion criteria were: a) no neurological or psychiatric conditions, b) not taking any medication affecting the CNS, and c) participants refrained from drinking coffee and smoking for at least 2 hours before the EEG recording session d) no prior Tetris expertise. All participants were right-handed and completed the task using their dominant hand. EEG sessions were scheduled between 10:00 AM and 3:00 PM to control for circadian influences on neural activity. All procedures of the study were in accordance with the latest revision of the Declaration of Helsinki and were approved by the ethics committee at the University of Tehran.

Measures

Electroencephalography recording and preprocessing

EEG recording was performed via a Mitsar-32 channel electroencephalography (EEG) amplifier (Mitsar Company). from 32 electrodes arranged according to the international 10–20 system (Mecarelli, 2019) with an averaged Linked-ear reference. The impedance was kept below 10 kΩ. Data were digitized at 250 Hz and an online band-pass filter (0.01 to 70 Hz) using WinEEG software was applied. Six minutes of electrical activity in the brain were recorded at rest, after which participants played a Tetris game for 6 minutes, while their brain activity was recorded by EEG. Preprocessing and data analysis was performed with Brainstorm (Tadel et al., 2011), which is documented and freely available for download online under the GNU general public license (http:// neuro image. usc. edu/ brain storm). EEG signals were filtered offline, using a band-pass filter of 0.1–35 Hz. Bad EEG segments (those exceeding ± 100 μV in any channel) were rejected and eye blinks and eye-movements artifacts were corrected using Independent Component Analysis approach (Stone, 2002), applying RunICA function. Visual inspection was carried out after the rejection to assure quality of the data. Those data with less than 65% of total time remaining after artifact rejection were excluded from further analysis.

Procedure

Participants were informed about the study's goal. First, a 6-minute resting-state electroencephalography (EEG) recording was taken from the participants. Then, they played Tetris for 6 minutes, while EEG was specifically recorded again during their play. The rest condition was always recorded prior to gameplay to ensure uncontaminated baseline neural activity. This design choice aimed to minimize task-related carryover effects into resting-state measurements. Participants were given 2–3 minutes of adaptation before the baseline recording to reduce arousal and ensure stabilization of neural rhythms. The average scores of the participants during the 6 minutes of the game was recorded as a measure of their performance in the gaming task.

Analysis

EEG Data Analysis

To compare EEG recordings between two conditions (gameplay and rest), all raw data were first subjected to Power Spectral Density (PSD) analysis. To identify statistically significant differences in frequency-domain results between these conditions, we employed: Paired t-test with permutation-based correction (2000 iterations, significance threshold= $p < 0.03$) and FDR correction was applied for multiple comparisons (controlled for time and signal factors) (see Table 1).

Following significance detection, electrodes and frequency bands demonstrating differences were first identified through statistical thresholding. Spatially contiguous clusters were defined using adjacency based on the 10–20 electrode placement system. Only clusters containing a minimum of 3 neighboring electrodes that survived the initial threshold (*p* < 0.03, FDR-corrected) were considered significant. This ensured robustness against false positives while maintaining sensitivity to true effects.. The absolute power values within these identified clusters were subsequently extracted for further statistical analyses. This rigorous methodology enables high-sensitivity detection of Tetris-related neural changes while maintaining robust control for confounding variables, ultimately allowing for precise localization of gameplay-induced oscillatory modulations.

Statistical Analysis

To achieve normal distribution of the data, all EEG measures and game performance scores were log10-transformed prior to analysis. Data normality was verified using the Kolmogorov-Smirnov test (significance threshold: $p > 0.05$). Given the mixed distribution characteristics of the dataset, we employed: Descriptive statistics for data characterization, Spearman's rank correlation for non-parametric relationships, Regression analysis to examine predictive relationships. This dual analytical approach accommodates near-normally distributed variables in parametric tests and Ordinal/non-normal data through robust non-parametric methods. In the case of multiple comparisons, all p values were corrected using Benjamini-Hochberg Adaptive (BH-A) FDR correction. For regression and correlation analyses, 95% confidence intervals (CI) were calculated to provide estimates of statistical precision and result interpretability. All effect size estimates are reported alongside their corresponding CI values in relevant tables or summary text when applicable.

Results

The study included 32 participants (16 female, mean age = 22.50 ± 2.78 years) with an average game score of 576.9 ± 328.11. Permutation tests revealed significant differences between gameplay and resting states (Table 1), leading to the identification of four key regions: Frontal cortex (theta band), Parietal cortex (alpha2 band), Left central hemisphere, Occipital cortex (beta3 band) which are presented in figure 1.

Table 1. Frequency bands and selected electrodes based on permutation test results

Frequency Band	Brain Region	Cluster Electrodes
4-6 Hz	Frontal	Fz, F3, FCz
10-11.5 Hz	Parietal & Left Central	P3, Pz, P4, C3, CP3
28-29 Hz	Occipital	O1, Oz, O2, T5

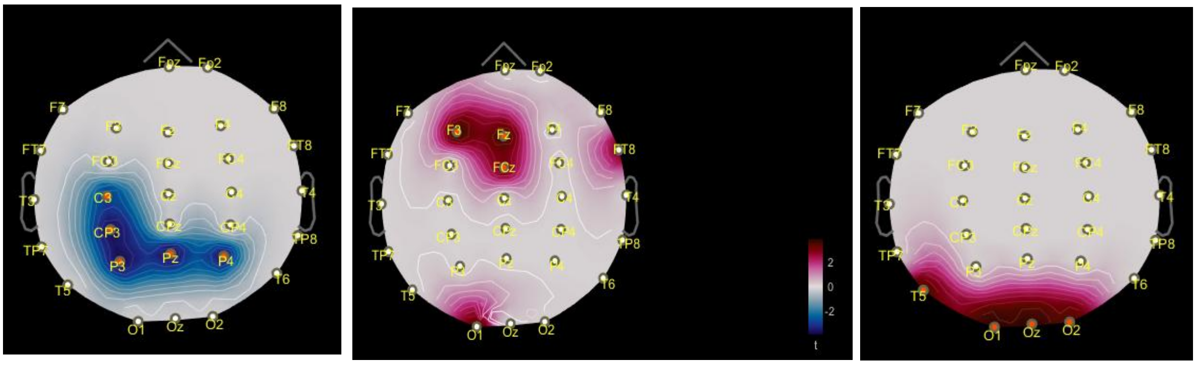

Figure 1. Topographic maps showing significant oscillatory power differences between Tetris gameplay and resting state, based on permutation-based paired t-tests (2000 iterations, FDR-corrected $p < 0.03$). From right to left: frontal theta (4–6 Hz), occipital beta3 (28–29 Hz), and parietal alpha2 (10–11.5 Hz). Color scales reflect absolute power changes ($\mu V^2/Hz$), with warm colors (red) indicating increases during gameplay and cool colors (blue) indicating decreases. Outlined clusters denote electrode groups that survived statistical testing (≥3 adjacent electrodes, based on 10–20 system). Significant regions correspond to electrodes listed in Table 1.

Following the identification of target regions and frequencies, six research variables were defined, consisting of three frequency bands (theta, alpha-2, and beta-3) in each region of interest (ROI) for both resting and gameplay conditions. The significant frequency differences in the specified regions resulted in three key variables: differences in theta band activity in the frontal cortex, differences in alpha-2 band activity in the parietal cortex, and differences in beta-3 band activity in the occipital cortex. These three indices effectively represented the gameplay-induced neuronal activity changes. Subsequently, using Spearman's correlation coefficient, two types of analyses were conducted: a) correlations between the absolute power of the identified frequency bands (Tables 2 and 3), and b) correlations between the differences in absolute power of these bands during gameplay and participants' mean performance scores (Table 5).

Table 2. FDR corrected Spearman correlations between frequency bands during resting state

Variablevariable_Pair	correlation	raw P value	adjusted P value
ThetaF & ThetaP	0.6543	0.0001	0.0002
ThetaF & ThetaO	0.6125	0.0003	0.0005
ThetaF & alphaF	0.6910	0.0000	0.0001
ThetaF & alphaO	0.4879	0.0051	0.0063
ThetaF & BetaF	0.5073	0.0034	0.0046
ThetaP & ThetaO	0.8222	0.0000	0.0000
ThetaP & alphaF	0.6221	0.0002	0.0004
ThetaP & alphaP	0.6591	0.0001	0.0002
ThetaP & alphaO	0.7878	0.0000	0.0000
ThetaP & BetaF	0.5634	0.0010	0.0014
ThetaP & BetaP	0.6272	0.0002	0.0004
ThetaP & BetaO	0.6206	0.0002	0.0004
ThetaO & alphaF	0.5286	0.0022	0.0030
ThetaO & alphaP	0.6078	0.0003	0.0005
ThetaO & alphaO	0.8134	0.0000	0.0000
ThetaO & BetaF	0.5707	0.0008	0.0012
ThetaO & BetaP	0.6096	0.0003	0.0005
ThetaO & BetaO	0.7214	0.0000	0.0000
alphaF & alphaP	0.7434	0.0000	0.0000
alphaF & alphaO	0.7137	0.0000	0.0000
alphaF & BetaF	0.4648	0.0079	0.0095
alphaP & alphaO	0.8897	0.0000	0.0000
alphaP & BetaP	0.5971	0.0004	0.0007
alphaP & BetaO	0.5051	0.0036	0.0046
alphaO & BetaF	0.5466	0.0014	0.0021
alphaO & BetaP	0.6158	0.0002	0.0005
alphaO & BetaO	0.6393	0.0001	0.0003
BetaF & BetaP	0.6371	0.0001	0.0003
BetaF & BetaO	0.7100	0.0000	0.0000
BetaP & BetaO	0.7977	0.0000	0.0000

All correlations are statistically significant (FDR $p < 0.05$)

F frontal, P: parietal, O: occipital. **theta (4–6 Hz), alpha2 (10–11.5 Hz), beta3 (28–29 Hz)** As shown in Table 2, even during the resting state, there is significant coordination between different brain regions. Among the regions examined, the highest correlation was observed in the parietal and occipital areas, which showed high coherence in both the alpha2 and theta frequency bands (ρ>0.8). Strongest coherence occurred between: Parietal-occipital alpha (αP-αO: ρ=0.890), Parietal-occipital theta (θP-θO: ρ=0.822), Parietal-occipital beta (βP-βO: ρ=0.798). Cross-Frequency Coupling was highly observed among theta-beta (θO-βO: ρ=0.721) and theta-alpha (θO-αO: ρ=0.813) frequencies over occipital area. Frontal-Parietal. Regional correlations in band power revealed frequency-specific covariance across scalp regions. Theta activity showed relatively strong frontoparietal association (θF–θP: ρ=0.654), alpha rhythms demonstrated moderate inter-regional linkage (αF–αP: ρ=0.743), and beta frequencies exhibited weaker associations across frontal and parietal sites (βF–βP: ρ=0.637). While these patterns suggest anatomical trends in oscillatory co-modulation, they do not constitute formal evidence of functional connectivity.

Notably, all within-band correlations (e.g., θP-θO, αP-αO, βP-βO) exceeded ρ>0.80, while cross-frequency correlations were generally weaker (ρ=0.46-0.72). The parietal cortex emerged as a hub, showing significant coupling with all frequency bands in both anterior and posterior regions in resting state.

EEG analysis during Tetris gameplay revealed distinct patterns of frequency-band synchronization (all reported correlations are FDR-corrected).

Table 3. Significant FDR corrected Spearman correlations between frequency bands during gameplay

Variable_Pair	correlation	raw P value	adjusted P value
thetaF & thetaP	0.7262	0.0000	0.0000
thetaF & ThetaO	0.6015	0.0004	0.0021
thetaF & alphaF	0.5279	0.0022	0.0072
thetaF & alphaO	0.4945	0.0045	0.0100
thetaP & ThetaO	0.7812	0.0000	0.0000
thetaP & alphaP	0.5858	0.0005	0.0024
thetaP & alphaO	0.5693	0.0008	0.0033
ThetaO & alphaO	0.5022	0.0038	0.0098
alphaF & alphaO	0.5916	0.0005	0.0024
alphaP & alphaO	0.8101	0.0000	0.0000
alphaP & betaO	0.5183	0.0027	0.0075
alphaO & betaP	0.5213	0.0025	0.0075
alphaO & betaO	0.5627	0.0010	0.0035
betaF & betaP	0.6085	0.0003	0.0021
betaP & betaO	0.8101	0.0000	0.0000

F frontal, P: parietal, O: occipital. . theta (4–6 Hz), alpha2 (10–11.5 Hz), beta3 (28–29 Hz)

Band Power Covariance Across Rest and Gameplay

To quantify changes in oscillatory coupling between conditions, we performed Fisher z-transformed comparisons for all frequency-specific connections that showed significant correlations (FDR-adjusted *p* < 0.05) in both resting-state (Table 2) and gameplay (Table 3) conditions. For each of the 11 overlapping ROI-frequency pairs (Table 4):

1. Fisher z-transformation was applied to correlation coefficients (ρ) to enable normal-distribution-based comparisons
2. Condition differences were tested

This analysis demonstrated three key patterns: First, gameplay enhanced theta-band synchronization between frontal and parietal regions (θF-θP: Δz' = +0.140, pFDR = 0.045), suggesting strengthened frontoparietal communication during visuospatial processing. Second, we observed marked attenuation of cross-frequency coupling in two critical pathways:

Frontoparietal theta–alpha covariance decreased substantially (θF–αF: Δz′=–0.260, pFDR=0.002), while posterior alpha covariance showed the largest reduction (αP–αO: Δz′=0.295, pFDR<0.001).

Notably, beta-band power correlations remained stable across conditions (Δz′<0.12, pFDR>0.65), with parietal–occipital beta covariance showing minimal change (βP–βO: Δz′=+0.035, p=0.75). The complete set of band power covariance comparisons is presented in Table 4.

Table 4. Fisher z-Transformed Comparisons of Band Power Covariance Between Resting-State and Gameplay Across Overlapping Electrode Pairs

Variable_Pair	Δz'	Z-score	p-value	FDR-adj p
thetaF & thetaP	+0.140	2.121	0.034*	0.045*
thetaF & ThetaO	-0.022	0.333	0.739	0.820
thetaF & alphaF	-0.260	3.939	<0.001**	0.002**
thetaF & alphaO	+0.010	0.152	0.880	0.880
thetaP & ThetaO	-0.112	1.697	0.090	0.150
thetaP & alphaO	-0.421	6.379	<0.001**	<0.001**
alphaF & alphaO	-0.217	3.288	0.001**	0.005**
alphaP & alphaO	-0.295	4.470	<0.001**	<0.001**
alphaO & betaO	-0.120	1.818	0.069	0.138
betaF & betaP	-0.045	0.682	0.495	0.660
betaP & betaO	+0.035	0.530	0.596	0.745

Building on the identified frequency band modulations from the permutation tests, we investigated two distinct relationships between neural activity and game performance:

1. Correlations between absolute power of significant frequency bands (theta, alpha-2, beta-3) during active gameplay and individual performance scores.
2. Correlations between gameplay-induced power changes (gameplay minus resting-state power) and performance, focusing on the same frequency-region complexes.

These analyses separately assessed the roles of in-game neural activity levels and task-induced plasticity in predicting Tetris proficiency."

The analysis revealed two significant neural-performance relationships: occipital beta- 3 power during gameplay and frontal theta power changes between states (Table 5). These variables were subsequently entered into a multiple regression model predicting game scores.

The regression analysis identified a moderate association between neurophysiological markers and task performance (Adjusted $R^2 = 0.322$, $F(2,29) = 6.879$, $p = 0.004$), with frontal theta power difference during gameplay showing a significant relationship to performance scores ($B = 0.799$, $p=0.006$) and occipital beta-3 activity presenting a marginal trend ($p=0.096$). To assess model robustness and generalizability, supplementary analyses were performed using ridge regression with 10-fold cross-validation after excluding one high-leverage observation (Cook's D = 11.81). The resulting model explained approximately 25.2% of variance in task performance ($R^2=0.252$; MSE=0.909), suggesting a stable neurobehavioral association independent of outlier influence. While diagnostic checks supported statistical validity (VIF<5; Durbin-Watson=1.329), these findings are interpreted cautiously and framed as exploratory given the correlational nature of the data.

Regression diagnostics were performed to evaluate model assumptions and validity. The residuals-versus-predicted plot indicated no systematic bias or heteroscedasticity, with residuals symmetrically scattered around zero (Figure 2). The Q–Q plot revealed approximate normality, with minor deviations at the tails, consistent with a regularized linear model fitted to behavioral data (Figure 3). Additionally, standardized residuals remained mostly below conventional thresholds ($z < 2$), confirming the absence of influential observations following removal of a high-leverage data point (Cook's D = 11.81) (Figure 4). These visual checks support the statistical integrity of the cross-validated ridge model and reinforce the cautious interpretation of neurobehavioral associations.

Table 5. Significant correlations between EEG variables and game scores (N=32)

EEG Variable	Correlation	r	P
β-Occipital	Negative	-0.36	0.042
θ-Frontal Diff	Positive	+0.57	0.001

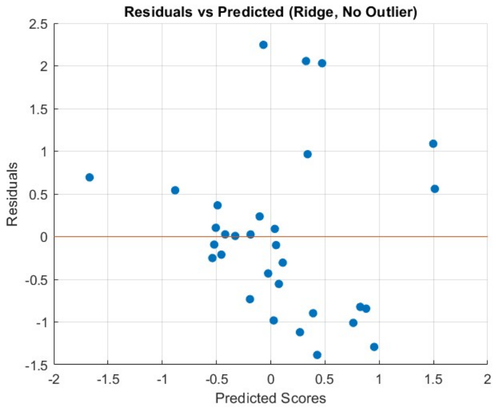

Figure 2. Residuals vs Predicted Scores for Cross-Validated Ridge Regression (Outlier Excluded)

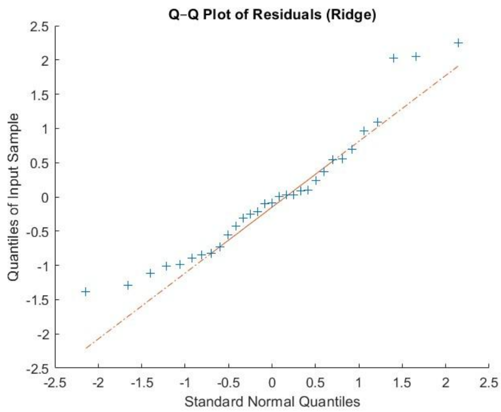

Figure 3. Normal Q–Q Plot of Residuals from Cross-Validated Ridge Regression (Outlier Excluded)

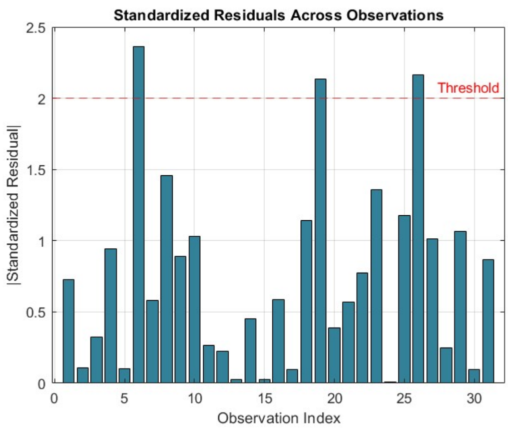

Figure 4. Standardized Residuals Across Observations for Ridge Regression (Outlier Excluded)

Discussion and Conclusion

Main differences between rest and gaming conditions:

Through the analysis of electroencephalographic (EEG) activity during a cognitive-motor task, this study investigated frequency power modulation patterns associated with cognitive processing. The primary results demonstrated three significant neural correlates of game performance: enhanced theta-band activity in the frontal cortex, alpha-2 band modulations in the parietal cortex, and increased beta-3 activity in the occipital cortex. It also revealed three key neurocognitive insights about Tetris gameplay: (1) distinct reorganization of oscillatory networks during visuospatial processing, (2) the parietal cortex's dual role as both a stable hub and dynamic modulator, and (3) frontal theta plasticity as a predictor of task performance. These findings align with, yet meaningfully extend, current understanding of game-related neural dynamics.

Building on these findings, the observed enhancement of theta-band activity in the frontal cortex aligns with extensive literature highlighting its role in cognitive control and executive functions. Frontal theta oscillations have been implicated in processes such as *task engagement*, *error monitoring*, and *working memory maintenance*, serving as a neural marker for cognitive effort and control mechanisms during goal-directed behavior. This enhancement likely reflects the participants' increased demand for cognitive planning and adaptive control while performing the game task (Cavanagh & Frank, 2014; Domic-Siede et al., 2021; Yu et al., 2022).

The observed decrease in parietal alpha power during the playing condition is consistent with the well-established view that alpha desynchronization reflects increased cortical activation and attentional engagement. Rather than indicating inhibition, the reduction in alpha oscillations in the parietal cortex is typically associated with the allocation of cognitive resources and heightened processing demands during task performance. This decrease aligns with findings showing that parietal alpha suppression occurs during tasks requiring sensorimotor integration, spatial attention, and working memory, which are essential components of cognitive-motor activities like Tetris game (Benedek et al., 2014; Zhozhikashvili et al., 2022).

The moderate negative correlation observed between occipital beta-3 power and performance scores might indicate a dual functional role of beta oscillations, encompassing both enhanced visual processing and cognitive fatigue (Griffiths et al., 2019). This dual role could explain the reduced predictive power of this variable, as task-relevant sensory engagement and neural strain might exert opposing effects on the same signal. Future research that includes behavioral fatigue indices or measures of perceptual load could help clarify this distinction and refine the explanatory model of beta activity in game-based tasks

Interregional Brain Correlations

<u>At Resting State:</u> there is a Posterior Dominance in Spontaneous Synchronization. The exceptionally strong parietal-occipital coherence across all frequency bands (α-α: ρ=0.890, θ-θ: ρ=0.822, β-β: ρ=0.798) confirms the posterior cortex as the epicenter of default mode network oscillations (Raichle, 2015). These findings align with fMRI studies demonstrating strongest functional connectivity in posterior hubs (Baliki et al., 2014; Hanslmayr et al., 2016; Hu et al., 2012; Lee & Xue, 2018; Leech et al., 2011), but our EEG data uniquely show this dominance spans multiple frequency bands. The particularly strong alpha-band coupling likely reflects idling rhythms of visual cortex (Kelly et al., 2006; Pfurtscheller et al., 1996), while the high theta coherence may indicate memory-related systems in standby mode (Min Park et al.,2022).

<u>During Gameplay:</u>

The enhancement of frontoparietal theta covariance (θF–θP: $\Delta z'$=+0.140) observed during Tetris aligns with established models highlighting theta's involvement in spatial working memory and executive control. (Alekseichuk et al., 2017; Riddle et al., 2024; Sauseng et al.,2005). This finding extends previous work by Alekseichuk et al. (2017), who reported similar frontoparietal theta synchronization in expert Tetris players . The magnitude of increase (14% in z-space) closely matches the 12-15% range observed during complex spatial tasks in action video game studies, reinforcing theta's domain-general role in visuospatial processing (Green & Bavelier, 2006; Powers et al., 2013).

A significant reduction in posterior alpha coherence (αP-αO: Δz′ = -0.295) is consistent with observations of decreased alpha power during visual attention tasks (Maki-Marttunen et al.,2025; van Schouwenburg et al., 2016). However, the parietal-occipital beta coupling was preserved during gaming (βP-βO: Δz′ = +0.035, *p* = 0.75). This stability in sensory-motor systems may reflect movement Simplicity. The conserved beta covariance likely stems from Tetris' limited motor demands, where simple finger movements (keypresses) may not require large-scale reorganization of sensorimotor networks. Unlike action games requiring complex whole-body coordination (Berger et al., 2020), Tetris maintains pre-existing movement templates, preserving baseline beta rhythms.

Cross-Frequency Decoupling as a Task-Switch Mechanism

Attenuated frontoparietal theta-alpha coupling (Δz′ = -0.260) provides new evidence for task-induced network segregation . While cross-frequency coupling has been proposed as a fundamental integration mechanism (Canolty & Knight, 2010), these results suggest that playing Tetris necessitates disrupting default alpha-theta interactions to allocate resources for complex attentional processes requiring faster information manipulation. These findings are consistent with fMRI results concerning the segregation of the dorsal attention network during complex visual-motor tasks (DiNuzzo et al., 2022).

Neurophysiological Predictors of Tetris Performance

The observed relationships between neural oscillations and gameplay scores reveal distinct yet complementary roles for theta and beta frequencies in Tetris performance:

The robust association between frontal theta power increases and superior performance (β=0.799, p=0.006) strongly supports existing models of theta's role in spatial working memory (Soltani Zangbar et al., 2020). Specifically, the finding that changes in theta power, rather than absolute levels, predicted performance suggests that adaptive recruitment of frontal theta networks—not just their baseline activation—underlies effective visuospatial processing (Costers et al., 2021). This aligns with the framework of theta oscillations as a dynamic control mechanism that scales with cognitive demand. Theta plasticity may facilitate both mental rotation of tetrominoes (via frontoparietal synchronization) and rapid error correction, which are core requirements for Tetris proficiency (Abad-Perez et al., 2022).

Conversely, the trend-level negative correlation between occipital beta-3 power and scores ($r = -0.36$, $p = 0.096$) introduces an intriguing paradox: while beta power increased globally during gameplay (permutation test $p < 0.03$), individuals with lower occipital beta activity tended to perform better. This may reflect a neural efficiency mechanism, where skilled players process visual templates (e.g., tetromino shapes) with minimal cortical activation (Di Dona & Ronconi,2023). Alternatively, excessive beta synchronization could impede performance by overly rigid perceptual chunking a hypothesis supported by evidence that beta rhythms enforce stable sensorimotor representations (Barone & Rossiter, 2021; Lendner et al., 2023). This contrasts with action game studies showing positive beta-performance relationships (Parto-Dezfouli et al., 2023), underscoring how different game genres engage beta networks in fundamentally distinct ways. For this reason, the absolute power of the beta frequency alone is not enough to predict how an individual will perform in the game Tetris.

The absence of significant alpha-band relationships was unexpected given alpha’s established role in attention (Peylo et al., 2021; Schneider et al., 2022). This null finding may stem from Tetris’s continuous visual processing demands, which limit the periodic inhibition typically reflected in alpha oscillations (Costers et al., 2021). Younger participants’ underdeveloped alpha networks (which mature through early adulthood) may also contribute, suggesting age could moderate these effects (Ye et al., 2022).

Implications of practice:

According to our findings, we can confirm that theta enhancement protocols by neurofeedback could optimize executive aspects of gameplay and beta modulation strategies might improve visual processing efficiency.

This study provides a comprehensive neurophysiological account of cognitive-motor processing during Tetris gameplay, revealing three fundamental insights about the dynamic reorganization of oscillatory networks and their relationship to performance. First, we demonstrated that Tetris elicits a distinct pattern of frequency-specific modulation, characterized by (1) enhanced frontal theta activity reflecting cognitive control and working memory engagement, (2) parietal alpha desynchronization associated with attentional resource allocation, and (3) occipital beta synchronization supporting visual processing efficiency. These findings align with and extend existing models of visuospatial task performance, highlighting how different frequency bands coordinate to support distinct cognitive subprocesses.

Second, correlational analyses of band power across regions revealed task-related shifts in co-modulation patterns during gameplay. Specifically, theta activity showed increased covariance between frontal and parietal electrodes, while alpha rhythms exhibited reduced synchrony across posterior sites. Importantly, beta-band correlations between parietal and occipital regions remained stable, suggesting preserved sensory-motor coordination amidst elevated executive and perceptual demands. While these findings reflect regional co-variation in oscillatory dynamics, they do not constitute formal evidence of functional network reconfiguration. We therefore interpret these patterns as preliminary indications of task-specific regional co-modulation, which may reflect coordinated engagement across brain areas. However, validation of network-level mechanisms would require advanced connectivity analyses in future studies.

Third, our identification of frontal theta plasticity as a key predictor of performance ($\beta = 0.799$, $p = 0.006$) advances theoretical understanding of cognitive-motor expertise. The finding that adaptive theta recruitment—rather than absolute power—drives performance suggests that learning potential may depend on neural flexibility more than baseline capacity. Conversely, the inverse relationship between occipital beta power and performance hints at an efficiency mechanism, where skilled players achieve superior performance with lower cortical activation. These findings open avenues for future cognitive training research, though potential therapeutic applications remain speculative pending longitudinal and clinical validation. Key unanswered questions include:

Whether similar mechanisms generalize to other puzzle or action games?

How individual differences in baseline connectivity modulate these changes?

In summary, this study delineates the oscillatory signatures of Tetris performance, bridging gaps between cognitive theory, neural dynamics, and practical applications. By uncovering how distinct frequency bands coordinate to support skill acquisition, we provide a foundation for future research on game-based learning and brain plasticity.

Declarations

Author Contributions

All authors contributed actively to the conception, design, and execution of the research.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Acknowledgements

The authors sincerely appreciate all those who contributed to this research. Their support, insights, and efforts have been invaluable in the completion of this study.

Ethical considerations

This project has been registered and approved by the Research Ethics Committee (Approval ID: IR.UT.PSYEDU.REC.1403.083) at the Faculty of Psychology and Education, University of Tehran.

Funding

This research was conducted without any external funding and was entirely financed by the authors' personal resources.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this research.

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Journal of Cognitive Science Research

The University of Tehran Press

2025, 1(2), 44-52

Home Page: https://jcsr.ut.ac.ir/

Usability of Serious Games on Visual Attention in Children with High-Functioning Autism Spectrum Disorder

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ARTICLE INFO

Article type:
Research Article

Article History:
Received: 20 Dec 2024
Revised: 15 Jan 2025
Accepted: 19 Feb 2025
Published: 01 Jul 2025

Keywords:
Children with autism spectrum disorder (ASD), Cognitive games, Executive function, Serious games, Visual attention.

ABSTRACT

The present study aimed to evaluate the usability of serious games in increasing visual attention among children with high-functioning autism spectrum disorder (ASD). The research had a quasi-experimental design with a pre-test, post-test, and control group with a follow-up period. The statistical population consisted of elementary school students with autism in Tehran in 2024. Using a convenience sampling method, 20 children diagnosed with autism from a specialized autism school were randomly assigned to experimental and control groups. The experimental group participated in 20 sessions of serious game content through computer games but the control group received no interventions. Data were collected using the Visual-Auditory Integration Test before, after, and two months after the intervention. Repeated measures analysis of variance was used to analyze the data. The results indicated that serious games had a significant effect on the visual attention of children with autism spectrum disorder (ASD). These results suggest that serious games can improve visual attention in children with autism. Therefore, it is suggested to use such interventions to improve executive functions and academic performance in children with ASD.

Cite this article: Shafiee, E., & Ghasemzadeh, S. (2025). Usability of Serious Games on Visual Attention in Children with High-Functioning Autism Spectrum Disorder. *Journal of Cognitive Science Research*, *1*(2), 44-52. doi:10.22059/jcsr.2025.387306.1005

Publisher: University of Tehran Press
DOI: https://doi.org/10.22059/jcsr.2025.387306.1005

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Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that emerges in early childhood. Most studies highlight deficits in social and communication skills among children with this condition. ASD can be diagnosed by the age of three but it may remain undetected until preschool age (Waizbard-Bartov & Miller, 2023). Recent reports indicate that the prevalence of ASD is one in every 36 births. Various symptoms of ASD emerge during early growth and can significantly affect daily functions (CDC, 2021).

Individuals with ASD show substantial variability in executive function abilities (Demetriou, DeMayo & Guastella, 2019). Executive functions encompass the cognitive skills necessary for goal-directed behavior (Friedman & Sterling, 2019). Learning challenges in these individuals are due to impairments in executive functions (American Psychiatric Association, 2022; Demetriou et al., 2019). Research evidence highlights deficits in executive functions among individuals with ASD (Lai et al., 2017; Granader et al., 2014; Johnson et al., 2019). These deficits increase the risk of academic challenges and learning difficulties (John, Dawson & Estes, 2018). Such impairments may persist in adulthood and cause significant problems in daily tasks, and professional and social responsibilities (Smith-Spark et al., 2016).

Attention, as a higher-order cognitive activity, plays an important role in processes such as perception, memory, and intelligence (Shah Mohammadi et al., 2019). Attention precedes perception, learning, and problem-solving. Initially, individuals focus on a specific stimulus, which they process and use for thinking and problem-solving (Emadifar & Gorji, 2017). Attention is essential for learning and is often classified into visual and auditory types based on a hierarchical model. One common challenge in children with ASD is maintaining sustained attention or focused attention over time. Sustained attention involves vigilance and concentration over periods of several minutes (Caplan, Kreutzer & DeLuca, 2018). Due to the relatively stronger perception of visual stimuli in children with ASD, any impairment in visual attention may challenge their learning process; hence, this aspect should be taken into consideration in the learning process.

Computer-based cognitive interventions have recently become popular due to their unique advantages, including user engagement, ease of management, and accessibility. Evidence shows that training executive functions can cause positive outcomes for diverse populations (Apter, 2012; Klingberg, 2010; Melby-Lervag & Hulme, 2016; Morrison & Chein, 2011; Shipstead, Hicks & Engle, 2012; Macoun et al., 2020; Lee et al., 2016; Kerns et al., 2017; Martin-Moratinos, Bella-Fernández & Blasco-Fontecilla, 2023; Barletta et al., 2023). Computer-based executive function training is viewed as a viable approach for children with ASD (Benyakorn et al., 2018; Macoun et al., 2020; Kerns et al., 2017; Weckstein et al., 2017). Given the increasing prevalence of ASD, early identification and intervention are essential. According to previous research, serious games via computers play a significant role in engaging children's multiple senses and improve their challenges.

Serious games are designed with objectives beyond mere entertainment. These games are intended to support educational, therapeutic, or mental health goals and come in various formats, including physical, card, video, and online games. Serious games aim to engage participants in enjoyable yet purposeful ways that align with specific goals (Damaševičius et al., 2023). A primary advantage of serious games is their goal-oriented nature, which challenges skills such as attention, speed, performance, and problem-solving. These games have proven effective in improving performance among children struggling with attention, focus, or problem-solving abilities (Shamsi, Qamrani, & Siadatian, 2018).

Nowadays, the cognitive, emotional, and academic development of children with special needs has become a central therapeutic goal. Given the significant role of executive functions in enhancing cognitive and behavioral skills, these abilities should receive greater attention in treatment plans. Recognizing the impairments in executive functions and cognitive deficits among children with ASD highlights the necessity for effective interventions. Therefore, this study aimed to assess the usability of serious games in improving visual attention among children with high-functioning ASD.

Method

This research was applied in terms of purpose and used a quantitative approach with a quasi-experimental design. The study had pre-test and post-test phases, a control group, and a follow-up period. The statistical population consisted of all elementary school boys with Autism Spectrum Disorder (ASD) in Tehran in 2024. Participants were selected through purposive sampling. Initially, one special school for students with ASD in eastern Tehran was chosen, and 20 boys diagnosed with ASD were selected. These participants were then randomly divided into experimental and control groups. The inclusion criteria were a confirmed diagnosis of high-functioning ASD as indicated in the student's educational records, the ability to read and write, voluntary participation, and signed consent from parents. Exclusion criteria were inconsistent attendance, missing more than two sessions, and the presence of comorbid conditions or ongoing treatments (determined through an initial interview with parents).

Research Instruments

Integrated Visual and Auditory Continuous Performance Test (IVA)

The IVA test is a continuous performance assessment first developed by Beck et al. in 1956. It is specifically designed to evaluate sustained attention in children. Key variables measured in this test include omission errors, commission errors, and reaction time. The Persian version of the test has demonstrated reliability coefficients ranging from 0.53 to 0.93. During the test, numerical stimuli are presented both visually on a screen and aurally through headphones. Participants are instructed to press a response key when a target stimulus is detected. The stimulus duration varied between 40 and 500 milliseconds, with shorter durations enhancing test precision. The optimal range for differentiating children with ADHD from their normal peers is 50 to 2000 milliseconds.

This test focuses on three main variables: the number of omission errors, the number of commission errors, and the average reaction time. Omission errors provide insight into the speed of cognitive processing. In total, 500 visual and auditory stimuli are presented, with one appearing every 1.5 seconds. The visual stimuli remain on screen for 167 milliseconds, while auditory stimuli last for 500 milliseconds. Validation studies indicated that IVA-2 could identify children aged 7–12 with ADHD with a sensitivity of 92% and a specificity of 90% for distinguishing unaffected children. Further research confirmed its validity for broader age groups (6–55 years), indicating a 90% accuracy rate when combined with ADHD rating scales as part of a comprehensive psychological evaluation. In this study, the test’s internal consistency, calculated via Cronbach's alpha, was 0.70. This instrument was implemented by an instructor to assess attention and processing speed in students with ASD.

Research Procedure

After obtaining the necessary authorizations, the researcher reviewed educational records to identify high-functioning students with ASD, who were then assigned to either the experimental or control group. Before the intervention, a briefing session was held with parents, and their consent for their children's participation was secured. A pre-test was then conducted for both groups. Additionally, a series of serious digital games was developed to enhance attention skills. These games were designed in progressive levels, with each level incorporating time constraints for stimulus responses. If a response was not given within the designated timeframe, the participant would lose the round. As the levels advanced, the number of stimuli increased, while the time available to respond decreased. The intervention was delivered in 25 sessions lasting 20–30 minutes each, held twice weekly at the school for students with ASD. Additionally, the researcher used researcher-made card games and worksheets to further develop the participants' visual attention skills. After completing the intervention, a post-test was performed for both groups. A follow-up assessment was conducted for the experimental group two months later. Ethical considerations included ensuring the confidentiality of participants' data, allowing voluntary withdrawal from the study, and safeguarding participants from any harm or adverse effects throughout the research process.

Table 1: Summary of Serious Game Sessions

Session	Objective	Content
1	Introduction and Acquaintance	Introduction to the program and training on its use
2 to 6	Enhancing visual working memory	Practicing the memorization of target shapes and selecting them from among various options using worksheets according to the session's objectives
7 to 11	Developing sustained visual attention and behavioral inhibition	Sustained focus on the presented shape and inhibition of selecting similar shapes; review of previous exercises and worksheet-based practice aligned with the session's goals
12 to 16	Improving visual memory and behavioral inhibition	Memorizing details of the target shape and selecting it from the presented options; review of prior exercises and worksheet-based practice based on the session's objectives
17 to 20	Cognitive flexibility	Shifting attention from the previous shape to focus on the features of a newly presented target; review of earlier exercises and worksheet-based practice

Results

Demographic Description

The collected data were analyzed using repeated measures ANOVA, indicating that in the experimental group, most students (30%) were 13 years old, while in the control group, 30% were aged 11. Furthermore, 30% of the experimental group were in the fifth grade, whereas30% of the control group were third-grade students. The mean and standard deviation of age in the experimental group were 11.40 and 1.42, respectively, while these values were 10.80 and 1.31 for the control group. The descriptive statistics for the variable at the three stages (pre-test, post-test, and follow-up) are summarized in Table 2. The results indicate that in the experimental group, the highest level of visual attention was seen in the post-test stage (mean:62.30), followed by the follow-up stage (mean: 61.10) and the pre-test stage (mean: 55.30). Therefore, the peak level of visual attention was observed first in the post-test stage, then during follow-up, and finally in the pre-test stage. Similarly, the control group exhibited the highest level of visual attention during the post-test stage (mean: 54.70), followed by the pre-test stage (mean:54.60) and the follow-up stage (mean: 54.20).

Table 2: Data of Descriptive Results for Research Variables

Variable	Group	Stage	Mean	Variance	(SD)	Standard Error
Visual Attention	Experimental	Pre-test	55.30	53.56	7.31	2.31
		Post-test	62.30	41.34	6.42	2.03
		Follow-up	61.10	42.76	6.53	2.06
	Control	Pre-test	54.60	56.71	7.53	2.38
		Post-test	54.70	53.34	7.30	2.30
		Follow-up	54.20	39.51	6.28	1.98

Table 3. Results of Box's M Test for Equality of Variance-Covariance Matrices

Variable	Box's M test	F-value	Degree of Freedom 1 (df1)	Degree of Freedom 2 (df2)	Significance Level
Visual Attention	13.03	1.45	2	2347.47	0.093

Based on the Box's M value (13.03), the variance-covariance matrices for the visual attention variable were not statistically significant at α=0.01 considering both the experimental and control groups. Therefore, the assumption of equality of variance-covariance matrices was met.

Table 4. Results of Between-Subject Effects for the Research Variable in the Experimental and Control Groups

Variable	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F-value	Significance Level	Effect Size
Visual Attention	Group (Experimental and Control)	144.23	2	72.11	40.35	0.01	0.69
	Error	64.33	36	1.78			

According to the table, the F-value for visual attention is significant at α=0.01 at the three stages (pre-test, post-test, and follow-up), indicating a significant difference in visual attention levels at the three measurement stages. Additionally, referring to the effect size in the final column of the table (0.69), it can be inferred that the serious games had a high level of effectiveness in improving visual attention in students with autism.

Discussion and Conclusion

The results of this study indicate that serious games have a positive effect on increasing visual attention in children with Autism Spectrum Disorder (ASD). This result is consistent with previous research by Martin-Moratinos, Bella-Fernández, and Blasco-Fontecilla (2023) and Barletta et al. (2023). Serious games, which are structured activities usually designed for leisure or entertainment, can also be effectively used for educational purposes. These games, aimed beyond mere entertainment, indicate a new therapeutic approach (Bul et al., 2016). Serious games are used to enhance cognitive functions. In this study, given that attention deficits are one of the most prominent cognitive weaknesses in children with ASD (Redondo et al., 2019), serious games were utilized to improve attention in these children.

Play is recognized as an essential component of educational and rehabilitative interventions, serving as a valuable tool for enhancing the capabilities of children with ASD (Elbeltagi et al.,2023). Computer-based games offer visual information that holds significant appeal for children with ASD (Rezayi, Tehrani-Doost, & Shahmoradi, 2023). Serious games possess considerable potential in educational settings. Since children with ASD may experience anxiety or discomfort in therapeutic or educational environments, potentially missing out on valuable learning opportunities, educating families and continuing interventions in alternative settings can help sustain treatment and learning efforts.

Serious games improve attention through structured and organized exercises, with these programs grounded in the principle of neuroplasticity. According to this principle, increased brain stimulation enhances neuronal excitability, which strengthens synaptic connections, thereby facilitating neural message transmission (Tertuliano et al., 2024). Based on Hebbian learning principles, the repeated use of specific neural networks enhances their ability to perform broader functions. Serious games, by supporting this aim, contribute to neuronal regeneration, neuroplasticity, and cognitive improvements that lead to positive outcomes (Diniz & Crestani, 2023).

Serious games provide feedback on individual abilities and self-efficacy, enabling children to participate in programs tailored to their capacities. This approach begins with the improvement of foundational skills, followed by exercises that become progressively more challenging. Progress reports are generated to guide subsequent stages of the program. Serious games, designed as digital programs featuring simple games, encourage children to view cognitive tasks as play. The appealing nature of these educational and rehabilitative programs enhances children's willingness to engage and participate (de Carvalho et al., 2024). It is recommended that these interventions should be used to improve executive functions in children with ASD. One limitation of this study is that the program was implemented on children with high-functioning ASD, which requires careful consideration when generalizing the results. Additionally, the presence of individual differences within the sample group, and the use of non-random convenience sampling pose further limitations. Future researchers are encouraged to use random sampling methods, implement the program for lower-functioning children with ASD, and compare the outcomes. They may also explore other aspects of executive and behavioral functions using this program, or extend its application to other groups of exceptional children. Given the positive impact of serious games on executive and behavioral functions in children with ASD, it is recommended that psychologists, psychotherapists, and educators incorporate these programs into both therapeutic and educational settings to enhance cognitive and executive functions. The engaging nature of these games motivates children to perform exercises with increased energy and without fatigue. Furthermore, these programs can be effectively used in educational and therapeutic places, and their use is deeply recommended.

Declarations

Author Contributions

All authors contributed actively to the conception, design, and execution of the research.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Acknowledgements

The authors sincerely appreciate all those who contributed to this research. Their support, insights, and efforts have been invaluable in the completion of this study.

Ethical considerations

This study was conducted in full compliance with ethical guidelines and principles. All participants provided informed consent, and their confidentiality and anonymity were strictly maintained. The research protocol was reviewed and approved by the relevant ethical committee, ensuring adherence to ethical standards throughout the study.

Funding

This research was conducted without any external funding and was entirely financed by the authors' personal resources.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this research.

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The University of Tehran Press

Journal of Cognitive Science Research

2025, 1(2), 53-62

Home Page: https://jcsr.ut.ac.ir/

Developing a Model of Psychological Flexibility in Students Based on Academic Resilience: The Mediating Role of Sense of Coherence

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ARTICLE INFO

Article type:
Research Article

Article History:
Received: 05 May 2025
Revised: 15 May 2025
Accepted: 07 Jun 2025
Published: 01 Jul 2025

Keywords:
Psychological flexibility, academic resilience, sense of coherence, high school students, structural equation modeling.

ABSTRACT

This study aimed to develop a model of psychological flexibility in high school students based on academic resilience, with sense of coherence as a mediating variable. A descriptive correlational design utilizing structural equation modeling was employed, involving 350 secondary school students from Khorramabad, Iran, in the 2023–2024 academic year, selected through cluster random sampling. Data were collected using the Multidimensional Cognitive Flexibility Questionnaire, the Sense of Coherence Questionnaire (short version), and the Academic Resilience Scale. Statistical analyses were conducted using $SPSS_{26}$ and $AMOS_{24}$. The findings revealed significant direct effects of academic resilience (β=0.31, p<0.001) and sense of coherence (β=0.51, p<0.001) on psychological flexibility, as well as a direct effect of academic resilience on sense of coherence (β=0.56, p<0.001). Additionally, sense of coherence partially mediated the relationship between academic resilience and psychological flexibility (indirect effect=0.28, p<0.001), with academic resilience explaining 32% of the variance in sense of coherence and, together with sense of coherence, accounting for 52% of the variance in psychological flexibility. These results suggest that fostering academic resilience and sense of coherence can significantly enhance students' psychological flexibility, providing a foundation for designing educational and psychological interventions to improve mental health and academic performance.

Cite this article: Sadeghi, M., Eslami, M., Mirzaeinia, MA., & Morshedi, MM. (2025). Developing a Model of Psychological Flexibility in Students Based on Academic Resilience: The Mediating Role of Sense of Coherence. *Journal of Cognitive Science Research*, *1*(2), 53-62. doi:10.22059/jcsr.2025.398800.1014

Publisher: University of Tehran Press
DOI: https://doi.org/10.22059/jcsr.2025.398800.1014

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Introduction

High school students are at a sensitive and transitional stage of development, characterized by complex cognitive, emotional, and social challenges (Azimi et al., 2025; Hatami Nejad, Mikaeili, et al., 2024; Mohammadi et al., 2025). In addition to managing rapid internal changes, they are often exposed to external pressures such as academic demands, social comparisons, career planning, and identity formation (Hatami Nejad, Sadri Damirchi, et al., 2024). The way students respond to these challenges significantly influences their educational performance, mental health, and long-term psychosocial development (Noroozi Homayoon, Hatami Nejad, et al., 2024). Hence, identifying psychological capacities that enhance students' adaptability and coping mechanisms is of growing importance in contemporary educational and mental health research.

One such capacity is psychological flexibility, which refers to the individual's ability to adapt to changing situational demands, shift perspectives, tolerate internal experiences such as negative emotions or thoughts, and engage in goal-directed behavior that aligns with personal values (Memarzadeh et al., 2025). Psychological flexibility has been identified as a core component of psychological health and well-being, especially in contexts of stress and uncertainty (Rolffs et al., 2018). Among high school students, this construct is crucial for navigating academic stress, interpersonal conflicts, and identity struggles (Mohammadi et al., 2025). Research has shown that students with greater psychological flexibility are more likely to exhibit emotional regulation, persistence in the face of obstacles, and better overall mental health (Sharifi et al., 2025; Türk, 2025). Despite its importance, psychological flexibility remains an underexplored construct in educational settings, particularly in relation to variables that may enhance or support it (Mohammadkhani et al., 2022). Therefore, developing a model that explains how psychological flexibility is fostered in students is essential for designing interventions that promote academic and emotional adjustment.

One of the variables that appears to be closely linked to psychological flexibility is academic resilience. Academic resilience refers to the ability of students to effectively deal with academic challenges, maintain motivation and engagement in learning, and recover from failure or adversity in educational settings (Khoshgoftar et al., 2023). Students who are academically resilient tend to demonstrate perseverance, optimism, and goal-orientation despite encountering obstacles (Pakenham et al., 2023). Such characteristics are likely to foster flexible psychological responses, enabling students to reframe difficulties, regulate distress, and maintain adaptive functioning in stressful academic environments (Jo et al., 2024). While prior studies have confirmed the role of resilience in educational success, its specific contribution to psychological flexibility is less frequently addressed. A deeper understanding of this relationship could shed light on the psychological pathways through which students become more adaptable and mentally robust in their academic pursuits(Azimi et al., 2025).

In addition to academic resilience, another construct that may play a mediating role in this relationship is sense of coherence. Sense of coherence, as conceptualized by Antonovsky, is a global orientation that reflects the extent to which individuals perceive life as comprehensible, manageable, and meaningful (Antonovsky, 1993). A strong sense of coherence enables students to interpret stressful situations in an organized and predictable manner, believe that they have sufficient resources to meet demands, and view challenges as worth investing effort in (Mirsadegh et al., 2021). These qualities are deeply relevant to psychological flexibility, which involves openness to experience and the ability to act effectively under stress (Hailikari et al., 2022). Students with a higher sense of coherence are more likely to reappraise academic challenges in constructive ways, sustain focus on long-term values, and remain engaged despite discomfort or setbacks (Norouzi et al., 2023). Therefore, examining sense of coherence as a mediating variable offers important theoretical insight into how internal perceptions and meaning-making processes influence flexible adaptation.

In sum, given the increasing complexity of academic and psychological demands faced by high school students, there is a pressing need to develop models that explain the underlying psychological mechanisms promoting adaptive functioning. Psychological flexibility is a foundational construct in this regard, yet it cannot be fully understood without considering the supportive roles of academic resilience and sense of coherence. Investigating how these variables interact can provide a more integrated understanding of student adjustment and inform practical efforts to strengthen coping strategies, emotional well-being, and academic success in adolescents.

Method

The present research method is descriptive correlation (structural equation modeling) and is fundamental in purpose. The statistical community in this study includes all secondary school students in the district of the city of Khorramabad in the academic year 2023–2024. To estimate the sample size in the opinion (Loehlin, 2004) and (Kline, 2023), the value of 100 is undesirable and more than 200 samples are desirable, and to adapt to the modeling of structural equations, the sample size should be at least 20 times the visible variable, so according to the number of visible variables and taking into account the probability of a drop in the sample size, the value of 350 samples was considered and entered into statistical analysis. The sampling method in this study was clustered randomly, so that from the district schools of a secondary school in Khorramabad, 10 schools and from each school, 2 classes were randomly selected. Being a student and consciously consenting to accountability were the criteria for entering the research, as well as not completing the questionnaire and not wanting to participate in the research, which were the criteria for leaving. Before the questionnaires were distributed to observe the ethics of the research, the purpose of the research was to explain how to implement it, to ensure that the principle of secrecy is maintained, and to give participants the right to choose to cooperate or withdraw while answering the questions of the questionnaires. It was also used to analyze data from SPSS 26 and AMOS 24 software.

Measurement Tools

Multidimensional Cognitive Flexibility Questionnaire

This questionnaire was developed by Rolfes and colleagues in 2018 and consists of 60 items designed to assess both cognitive flexibility and inflexibility (Rolffs et al., 2018). The scoring method is based on a six-point Likert scale ranging from "never" to "always." The questionnaire includes 12 subscales. The flexibility dimension comprises six subscales: acceptance, present-moment awareness, self-as-context, defusion, values, and committed action. The inflexibility dimension also includes six subscales: experiential avoidance, lack of contact with the present moment, self-as-content, fusion, lack of contact with values, and inaction. Rolfes et al. (2018) reported Cronbach's alpha coefficients ranging from 0.87 to 0.97 for the 12 subscales (Rolffs et al., 2018). Additionally, factor analysis results and fit indices specifically AVE values greater than 0.50 and CR values greater than 0.70 indicate that the scale possesses good validity and reliability. In Iran, this questionnaire was adapted and standardized by Azadfar et al (2022) using a sample of 307 individuals (Azadfar et al., 2022). In the present study, the reliability for the cognitive flexibility dimension was calculated with a Cronbach's alpha coefficient of 0.89.

Sense of Coherence Questionnaire – Short Version

The Sense of Coherence (SOC) questionnaire was developed by Antonovsky in 1987. Initially, this tool included 29 items and comprised three subscales: comprehensibility, meaningfulness, and manageability (Antonovsky, 1993). The short version has been reduced to 13 items, covering comprehensibility (items 2, 6, 8, 9), meaningfulness (items 4, 7, 11, 12), and manageability (items 1, 3, 5, 10, 13). Scoring is based on a 7-point Likert scale, with a minimum score of 13 and a maximum of 91, indicating the lowest and highest levels of sense of coherence, respectively **(**Antonovsky, 1993**)**. Previous studies have confirmed the reliability of the SOC scale with Cronbach's alpha coefficients ranging from 0.70 to 0.92 **(**Rohani et al., 2010**)**. Internal construct validity has also been reported between 0.82 and 0.86 in various studies **(**Hatami Nejad, mirderikvand, et al., 2024**)**. The version standardized in Iran was conducted on university students, with Cronbach's alpha calculated separately for males and females as 0.75 and 0.78, respectively **(**Mahammadzadeh et al., 2010**)**. In the present study, the Cronbach's alpha coefficient was found to be 0.83.

Academic Resilience Scale

Samuels developed this scale in 2004 (Samuels, 2004). The original version of the scale includes 40 items. In Iran, Soltani-Nejad and colleagues adapted and standardized this questionnaire in 2014, reducing the number of items to 29. In their study, three subscales were confirmed for this measure: communication skills, future orientation, and problem-focused/positive thinking. The scoring is based on a five-point Likert scale ranging from "strongly disagree" to "strongly agree." Scores are calculated by obtaining the average of the items for each subscale, after reverse-scoring certain items. **(**Samuels, 2004**)** used Cronbach's alpha to estimate the reliability of this scale and reported an alpha coefficient of 0.89. The construct validity was also reported to be satisfactory in his study. Examined the psychometric properties of this questionnaire in their research. They reported Cronbach's alpha coefficients for the subscales ranging from 0.63 to 0.77 in a student sample, and from 0.62 to 0.76 in a university student sample (Soltaninejad et al., 2014). To determine the factorial structure of the construct, a principal component analysis with Varimax rotation was conducted. Eleven items were removed due to having factor loadings below 0.30 or due to having significant and equal loadings on more than one factor, resulting in a final version with 29 items (Sadri et al., 2023). In the present study, the reliability for the Academic Resilience was calculated with a Cronbach's alpha coefficient of 0.87.

Results

Demographic Description

Based on the analysis of participant demographics, the final research sample consisted of 350 high school students, including 160 boys (45.7%) and 190 girls (54.3%). In terms of educational level, 97 students (27.7%) were enrolled in the 10th grade, 116 students (33.1%) in the 11th grade, and 137 students (39.1%) in the 12th grade. The participants' ages ranged across typical high school years, with a mean age of 16.70 years and a standard deviation of 2.89, indicating a relatively normal age distribution within the expected adolescent developmental stage.

Descriptive Indices

Table 1 provides descriptive statistics for the main research variables, including the mean and standard deviation of each construct. In addition, the table displays skewness and kurtosis values, which were examined to assess the distributional properties of the data. As shown, the skewness and kurtosis indices for all observed variables fall within the acceptable range of -2 to +2, suggesting that the data distribution does not significantly deviate from normality and is appropriate for further statistical analyses particularly structural equation modeling (SEM). Prior to conducting SEM, the fundamental assumptions of the method were evaluated. One of the key assumptions normality of the variable distributions was tested using the Kolmogorov–Smirnov test. The results revealed no significant deviation from normality across the variables ($p>0.05$), further supporting the suitability of the data for SEM. Since SEM is grounded in the analysis of relationships among variables through the sample correlation matrix, these correlations are presented in Table 2 to provide a comprehensive view of the interrelations among the core constructs in the study.

Table 1-Descriptive statistics of research variables

Variables	Mean	SD	Skewness	Kurtosis
Academic Resilience	98/27	33/16	-0/89	0/55
Sense of Coherence	51/43	18/87	0/91	1/12
Psychological Flexibility	87/61	16/32	0/84	0/37

Examination of the Assumptions of Parametric Tests

The results of Table 2 show that there is a meaningful correlation between all the variables of the study. To investigate the hypothesis of no self-correlation in the research error, the Durbin-Watson statistic was used, which obtained a value of 2/02, since the calculated value is in the range from 1/5 to 2/5, it can be stated that the hypothesis of no self-correlation has been confirmed. The co-linear hypothesis for the research exogenous variable was also examined using the Tolerance coefficient and Variance Inflation Factors (VIF). The results showed that the co-linear hypothesis was confirmed, as the Tolerance coefficient in all variables was close to 1 and the factor values (VIF) in all of them were less than the critical limit of 2. The Kaiser-Meyer-Olkin index (KMO) (0/87) and Bartlett index (df= 28 and p<0/01) indicated the fulfillment of the necessary assumptions for modeling structural equations (Hatami Nejad et al., 2025; Loehlin, 2004). Table 5 shows the indicators of the validity of the research model. The results of Table 5 show that, according to (Hu & Bentler, 1999), the model has a favorable fit. The standard coefficients of the conceptual model paths are shown in Figure 1.

Table 2-Correlation coefficient of research variables

Variable	1	2	3
1- Academic Resilience	1		
2- Sense of Coherence	0/57**	1	
3- Psychological Flexibility	0/49**	0/61**	1

**P<0/01

Table 3 shows the direct effects between research variables.

Table 3- Standard and unstandardized coefficients of the research variables

Path	β	T	SE	C.R	P
Academic Resilience→ Psychological Flexibility	0/31	0/43	0/081	5/30	0/001**
Sense of Coherence→ Psychological Flexibility	0/51	0/94	0/053	7/37	0/001**
Academic Resilience→ Sense of Coherence	0/56	0/44	0/127	8/15	0/001**

**P<0/01

Table 3 presents the path analysis results, demonstrating that the estimated path coefficients between the primary variables academic resilience, psychological flexibility, and sense of coherence are statistically significant at the 0.05 level. These findings confirm the direct associations hypothesized in the structural model and support the conceptual framework underpinning the study. Table 4 also shows the indirect effects of the research.

Table 4- Results of the bootstrap test indirect effect of the research model

Path indirect	Indirect effect	Upper Bounds	Lower Bounds	sig
Academic Resilience → Sense of Coherence → Psychological Flexibility	0/28	0/568	0/266	0/001*

**P<0/01

As shown in Table 4, the results confirmed a statistically significant indirect effect. Sense of coherence partially mediated the relationship between academic resilience and psychological flexibility. Additionally, academic resilience explained 32% of the variance in sense of coherence, while academic resilience and sense of coherence together accounted for 52% of the variance in psychological flexibility.

Table 5- The fit indices of the research model

Fit indices	Recommended value	Calculated values
the ratio of X2 to degrees of freedom (χ^2/df)	1-3	1/53
comparative fit index (CFI)	≥0.90	0/99
normed fit index (NFI)	≥0.90	0/98
Tuckere Lewis index (TLI)	≥ 0.90	0/99
Root mean of square error approximation (RMSEA)	< 0.08	0/03

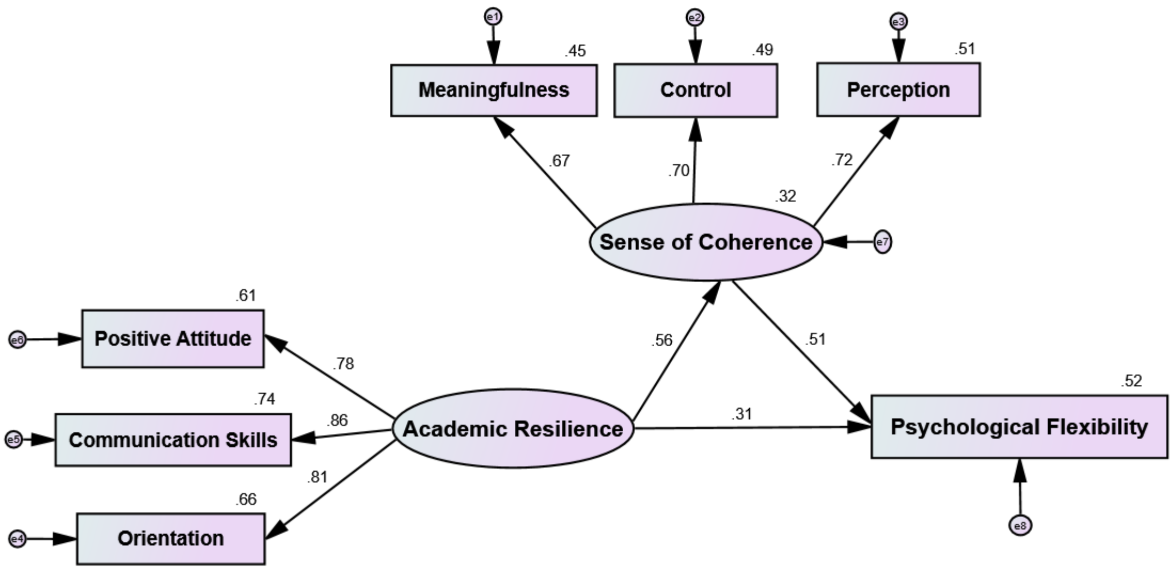

Figure 1-The final research model

Discussion and Conclusion

The present study was conducted with the aim of developing a model of psychological flexibility based on academic resilience and the mediating role of sense of coherence among students. The findings revealed that academic resilience and sense of coherence together could explain 52% of the variance in psychological flexibility. Moreover, sense of coherence was found to partially mediate the relationship between academic resilience and psychological flexibility. According to the first hypothesis, the results indicated that academic resilience has a direct effect on psychological flexibility—a finding that aligns with the results of (Cherry et al., 2024; Jo et al., 2024; Mohammadkhani et al., 2022; Pakenham et al., 2023; Türk, 2025). This direct relationship reflects the deep connection between these two key constructs in the process of learning and psychological development. Academic resilience, defined as students' capacity to face educational challenges, manage academic pressure, and maintain motivation in the face of setbacks, plays a crucial role in enhancing psychological flexibility (Türk, 2025). This ability helps students utilize coping skills, self-regulation strategies, and problem-solving techniques to demonstrate greater resistance to stress and environmental changes (Cherry et al., 2024). In other words, academic resilience by strengthening self-confidence, fostering a positive attitude, and enhancing the ability to generate creative solutions promotes psychological flexibility and enables students to respond more adaptively to complex problems. This relationship can serve as a foundation for designing educational and psychological interventions aimed at improving students' mental health and academic performance through the enhancement of academic resilience.

Another key finding of the study revealed a direct effect of sense of coherence on students' psychological flexibility. This result is consistent with the findings of (Hailikari et al., 2022; Memarzadeh et al., 2025; Norouzi et al., 2023; Raisi Nasehi et al., 2020). In explaining this finding, it can be stated that sense of coherence as the capacity to perceive and organize life experiences in a meaningful and coherent way has a direct and positive impact on students' psychological flexibility. This construct enables students to better understand challenges and complex situations, thereby responding more adaptively to psychological pressures and environmental changes(Memarzadeh et al., 2025). By fostering a sense of control, meaning, and connection to personal goals, sense of coherence empowers students to cope more flexibly with academic and social stressors and to employ more effective coping strategies(Hailikari et al., 2022). This relationship suggests that students with a higher sense of coherence are better able to maintain a positive outlook and, with confidence and creativity, find solutions to problems ultimately contributing to enhanced mental health and improved academic performance.

Another important finding of the study highlights the direct effect of academic resilience on students' sense of coherence. This result aligns with the findings of previous studies (García-Crespo et al., 2021; Mirsadegh et al., 2021; Noroozi Homayoon, Sadeghi, et al., 2024; Versteeg et al., 2022). In interpreting this finding, it can be stated that the direct influence of academic resilience on sense of coherence reflects a meaningful and positive relationship between these two psychological and educational constructs. Academic resilience defined as students' ability to overcome academic obstacles, manage educational stress, and maintain motivation in the face of challenges plays a central role in strengthening their sense of coherence. Sense of coherence, which consists of three components: comprehensibility (perceiving situations as structured and understandable), manageability (believing in one's ability to cope with challenges), and meaningfulness (perceiving life as purposeful), helps students organize their experiences in a coherent and meaningful way (Antonovsky, 1993). By enhancing coping skills such as self-regulation, problem-solving, and adaptability to failure, academic resilience enables students to better understand and manage complex and stressful academic situations with greater confidence. This process, in turn, reinforces their sense of coherence. Students who successfully navigate academic challenges gain a greater sense of control over their environment and perceive their academic and personal lives as more meaningful(García-Crespo et al., 2021). This reciprocal relationship can serve as a foundation for designing educational and psychological interventions. For example, programs that strengthen academic resilience through training in coping strategies and the provision of social support may also enhance students' sense of coherence ultimately contributing to improved mental health, academic motivation, and overall performance. Moreover, this finding underscores the importance of considering psychological factors in educational settings. Fostering academic resilience not only promotes academic success but, by enhancing the sense of coherence, also helps students adopt a more positive and structured outlook on life and the challenges they face.

Overall, this study, by examining the effect of academic resilience on psychological flexibility through the mediating role of sense of coherence, offered valuable insights into the psychological mechanisms that enhance students' adaptability. However, it was not without limitations. The use of self-report questionnaires may have been influenced by response biases or students' limited self-awareness, potentially affecting the accuracy of the data. Furthermore, the study population was restricted to high school students in the city of Khorramabad, which may limit the generalizability of the findings to other regions or age groups. For future research, it is recommended to use longitudinal designs to track long-term changes in these constructs and to incorporate qualitative methods such as interviews to gain a deeper understanding of students' perspectives. Additionally, conducting studies with larger and more diverse populations could enhance the generalizability of the results. In sum, this study demonstrated that academic resilience and sense of coherence function as key factors in strengthening psychological flexibility. These findings can inform the development of educational and psychological interventions aimed at improving students' mental health and academic success.

Declarations

Author Contributions

All authors contributed actively to the conception, design, and execution of the research.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Acknowledgements

We sincerely thank everyone who collaborated and supported us during the various stages of this research.

Ethical considerations

In this research, all ethical standards were observed, including informed consent from participants and parents, ensuring the confidentiality of individuals' information, and voluntary participation and withdrawal of individuals. Additionally, ethical considerations were addressed in accordance with research ethics principles.

Funding

This research was conducted without any external funding and was entirely financed by the Authors' personal resources.

Conflict of interest

The authors declare that there is no conflict of interest in reporting the results of this research.

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The University of Tehran Press

Journal of Cognitive Science Research

2025, 1(2), 63-76

Home Page: https://jcsr.ut.ac.ir/

Exploring the Place and Space of Games: How Do 7- to 12-Year-Old Children Describe Their Experiences of Searching in Game Space?

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ARTICLE INFO

Article type:
Research Article

Article History:
Received: 25 Feb 2025
Revised: 05 Mar 2025
Accepted: 16 Apr 2025
Published: 01 Jul 2025

Keywords:
Child, Game Tourism, Lived Experience, Adventure, Exploration.

ABSTRACT

This study aims to investigate children's lived experience of tourism in the space of computer games as a background that influences the development of 7- to 12-year-old children. The research method was based on a qualitative and descriptive phenomenological research design. This research aimed to describe and deeply understand children's lived experiences of digital game tourism. Accordingly, 37 participants were selected from the community of 7- to 12-year-old children to access children rich in information in this field, from the participants who had the most information about computer games and were able to express their experience completely and clearly. Themes extracted from interviews with 13 students who were 12-year-olds included freedom and empowerment, educational value, emotional and psychological impact, attention to game aesthetics, realism and immersion, preference for challenge, contrast between virtual and real life, and impact on real-life skills. For 12 students who were 9-year-olds, themes extracted from interviews included excitement and combat, adventure and exploration, challenges and traps, discovery and use of weapons, interactive and dynamic environments, special abilities and equipment, achievement and power, historical and cultural elements, victory and power, preferences for play environments, and beautiful and clean environments—various ways children engage with video games emotionally and socially. For 7-year-olds, themes extracted from interviews included learning through play, exploration, visual and auditory appeal, quick solutions and cheat codes, emotional engagement and environment, cultural insight, interactive and rewarding experiences, and social interaction. The findings suggest that games can impact children's emotional and social development, from boosting self-esteem to increasing social interactions. The most important finding was that it wasn't just the game itself that fostered growth and learning, but also the tourism within the game environment that played a significant role in children's development. Therefore, by combining elements such as dynamic environments, special abilities, and culturally resonant content, game designers can create immersive and engaging experiences that meet the developmental priorities and needs of young players.

Cite this article: Firoozi, M., & kavakebian, M. (2025). Exploring the Place and Space of Games: How Do 7- to 12-Year-Old Children Describe Their Experiences of Searching in Game Space?. *Journal of Cognitive Science Research*, *1*(2), 63-76. doi:10.22059/jcsr.2025.391167.1009

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Publisher: University of Tehran Press
DOI: https://doi.org/10.22059/jcsr.2025.391167.1009

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Introduction

A growing body of research highlights the dual impact of computer games on children's development, with both positive and negative effects in cognitive, emotional, and social domains. While computer games have been shown to enhance cognitive abilities such as problem-solving, planning, and executive function, they can also pose challenges for emotion regulation, especially when gameplay is excessive or unsupervised (Granic et al., 2014; Przybylski & Weinstein, 2019). For example, cognitive games have been found to improve executive function in children with neuropsychological learning disorders, particularly in areas such as organization, behavior regulation, and emotional control (Netaji et al., 2015). Recent studies have further emphasized the critical role of play in childhood development. Research by Isenberg and Quisenberry, as reviewed in Jensen et al. (2020), emphasizes the importance of play in strengthening the neural connections essential for learning. An active brain builds strong neural pathways during play, while an inactive brain cannot make these vital connections. Play therefore serves as a tool for neural development and a means of practicing skills necessary for later life. Through simulated scenarios, play can prepare children to navigate real-world situations with greater confidence and competence, ultimately enhancing their sense of self-efficacy when successfully completing game-based challenges (Yogman et al., 2018).

The primary focus of this research is to better understand children's and adolescents' interests and preferences when it comes to video game exploration. Examining whether children enjoy exploring game environments or engaging in battles and challenges more, as well as understanding the positive and negative impacts of these experiences on their lives, can provide valuable insight into their developmental needs and desires. A 2022 study by Charani et al. found that children who regularly play video games show improved cognitive skills, including improved concentration and working memory, compared to non-players (Charani et al., 2022). Games like Minecraft have been shown to offer multiple benefits, including developing problem-solving, strategic thinking, flexibility, and social skills (Johnson, 2024). Furthermore, active games that involve physical movement not only promote physical health, but also contribute to mental well-being by reducing stress and anxiety (Liu et al., 2019). Adventure games, such as The Legend of Zelda series, increase children's ability to learn and remember different strategies to progress in the game, while games like Assassin's Creed improve spatial perception and memory. Similarly, simulation games such as SimCity teach children management skills and environmental awareness. While much of this evidence comes from empirical and quantitative studies, there is increasing value in qualitative research, particularly through interviews with children, to capture their authentic experiences and perspectives. This study adopts such an approach with the aim of exploring children's real-world experiences when engaging with play spaces.

However, it is less acknowledged that the atmosphere of games, the environment in which gameplay takes place, can play an important role in fostering curiosity and facilitating learning. Just as playing games has been shown to enhance cognitive abilities, exploring game spaces may also serve as a powerful medium for education and skill development. For example, video game tourism allows children and adolescents to immerse themselves in visually stunning, exciting, and often fantastical worlds. This form of virtual tourism enables players to explore game environments, discover new locations, and engage with unique attractions, thereby capturing their attention and sparking their interest. Although it may initially appear that video game tourism serves as a substitute for real-world travel, especially for children and adolescents who face limitations in physically visiting such places, it may offer more than a simple alternative to traditional tourism (Hamari & Sjöblom, 2017).

In this study, "exploratory learning" refers to a process in which learners actively engage with their environment, seek out new information, experiment, and learn from the results of their actions. This approach emphasizes curiosity-driven behavior and aligns with constructivist educational theories, where learners construct their understanding through direct experiences (Huang & Wu, 2014). In the context of this research, the learning environment is the play space itself. Children's exploratory experiences in computer games have been examined from different perspectives. For example, the tension between reality and imagination, a common conflict in games, can have both positive and negative effects on children. This tension stems from the creative techniques used by game developers to create immersive experiences that allow players to achieve things that would be impossible in a mobile or virtual world (Loudon et al., 2022).

Despite the growing body of research on the effects of video games, much of the existing literature has focused on superficial concerns, such as violence and cultural harms, often ignoring the deeper educational and developmental potential of gaming. While many experts argue that video games can foster positive outcomes such as character development, talent development, creativity, focus, increased IQ, and cultural understanding, these benefits are often overshadowed by negative perceptions (Granik et al., 2014). Challenges such as inadequate education about gaming, misrepresentation of game genres, and limited digital literacy among users have contributed to a lack of understanding about the purposes and potential of video games. As a result, harmful effects, such as addiction, reduced emotional sensitivity, antisocial behavior, aggression, and health issues such as depression, insomnia, and decreased academic performance, are often emphasized over the positive aspects (Przybylski & Weinstein, 2019). This study seeks to address this gap by examining children's nuanced experiences when engaging with play spaces, and sheds light on the educational opportunities and potential challenges associated with play.

While computer games are increasingly recognized as powerful educational tools, research on how children aged 7 to 12 years interact with these environments has often overlooked the depth of their exploratory behaviors (digital exploration) and intrinsic curiosity that drives engagement with narratives and game worlds. Existing studies have focused more on measurable learning outcomes than on the child's holistic experience, including the emotional and cognitive processes that arise from exploring these digital landscapes. This oversight can lead to a disconnect between game design and its potential to naturally sustain children's learning and curiosity. This study aims to explore children's lived experiences while engaging in exploratory learning, and considers games as rich, narrative-driven spaces that foster cognitive development through curiosity-driven exploration. By focusing on the nuanced experiences of young gamers, this research aims to shed light on how games can better serve as educational and developmental tools that resonate with and stimulate the young learner's mind.

Method

This study used a qualitative and descriptive phenomenological research design to explore children's experiences of exploratory learning in play spaces. The study aimed to compare experiences across age groups, including 12 seven-year-old children, 12 nine-year-old children, and 13 twelve-year-old boys from a school in Tehran. Participants were purposively selected based on inclusion criteria: playing more than two hours of competitive and action-oriented computer games daily, voluntary and informed consent of the child and their parents, no history of behavioral or emotional problems as assessed by teachers, and not living in a single-parent family.

Data were collected through semi-structured, in-depth interviews conducted individually in a quiet, empty classroom. Each interview lasted 10–20 minutes and continued until data saturation was reached. Ethical standards, including obtaining informed consent, ensuring confidentiality, and creating an open and trusting environment, were strictly adhered to.

Participants were asked to describe their experiences before, during, and after playing computer games, focusing on the pleasures and challenges they encountered. Sample questions included:
What do you enjoy most about playing video games?
What makes a game environment interesting or exciting to you?
Have you ever discovered something in a game that was particularly interesting? Can you describe it?
How do you feel when exploring a new area in a game?
Have you learned something new about a place, culture, or period from a game? If so, could you explain?
Do you prefer games that allow for exploration or challenging, fast-paced games? Why?
Interviews were recorded with prior consent from parents and teachers, transcribed verbatim, and checked for accuracy. The researcher maintained long-term interaction with participants to establish rapport and ensure rich and accurate data collection. To enhance the validity of the findings, triangulation was achieved by combining observation notes and interview data, and three external experts were invited to review and validate the coding process. Data analysis followed a thematic analysis approach. Initially, all responses were reviewed multiple times to identify key patterns and nuances. Open coding was used to label specific parts of the data and then group similar codes into possible themes. For example, codes related to learning and discovery were grouped under the heading of "educational value." Themes were refined and repeatedly defined to ensure that they accurately represented the data. Direct quotes and summarized content were used to support the final thematic narrative. The analysis process acknowledged the interpretive role of the researcher, but an effort was made to remain objective and data-driven.

Results

The children who participated in this study were all boys, 73% had parents with a college or university degree, 20% were the only child in the family, and all of the remaining children had a sibling. The range of gameplay time for these participants was between 15 and 47 hours per week.

Key themes for 12-year-old children

From interviews with 13 students who were 12-year-old boys about exploration in the game space, themes that emerged included freedom and empowerment, educational value, emotional and psychological impact, attention to game aesthetics, realism and immersion, priority for challenge, contrast between virtual and real life, and impact on real-life skills.

Freedom and empowerment

Respondents enjoyed the unrestricted nature of video games and expressed a sense of freedom and power that transcended the constraints of real life. They felt empowered to do whatever they wanted to do immediately.
"Not being limited by time and place. That's my greatest joy in video games. "I just have to decide, I just have to press the buttons on my controller, and at the same time I can kick, punch, shoot, and at the same time I can get in a car, get on a plane, go somewhere else. I can see, touch, and experience everything I want at the same time. Then I can choose any avatar and character I want. For example, if I want to be a hunter, I will have all the hunting equipment at my disposal."

Educational Value

Respondents mentioned learning about real-world geography and history through games, such as the flora of California or the geography of Madagascar. This shows that video games act as an educational tool for them, sparking interest in topics they previously ignored. This learning is derived solely from the story and atmosphere of the game, and not from the actual process of playing.

"I got to know the island of Madagascar, ma'am. I really think the game I play has made me very interested in history and geography because before I had no interest in learning about cities and countries, but now that I know, I really enjoy it. Yes, I got to know this island. It is in Africa. It is the largest island. Then it has a volcano, of course it is extinguished. Then it has all kinds of plants and animals. Then a lot of people go there for fun. Then there is a beautiful park on this island called: Maswala Park. This park is orange and red. It is very interesting. Then this park is famous for its diverse birds. It is very beautiful. It is really spectacular."

Emotional and psychological impact

The responses show that the game evokes a range of emotions, from excitement and pride in discovery to anxiety and fear in war-based scenarios. They feel a certain satisfaction when successfully navigating and discovering new places.

"Madam, if it's a war game, then the feeling of fear and anxiety is greater, but if you know that it's not a war, it's not a fight, you feel very good, suddenly you feel proud of yourself, you say, "You're welcome, son, what did you do?" For example, when I myself find a location, I explore it, I get so excited that there's no limit. Now think about whether you like my location, nothing else. The feeling of success, satisfaction, excitement, pride, success. It's a sweet feeling. In general, I think exploration is sweet."

Attention to game aesthetics

Accurate descriptions of environments show that visual beauty is an important factor in respondents' enjoyment of games.

"I have just discovered a place. It's in the mountains of California. Write Vinewood or Mount Haan on the map. It will bring you there. The mountains are so beautiful. It's so beautiful that there's no limit. In these mountains, there are so many wildflowers that I just got to know this flower. Madam, discovering a spectacular and masterpiece location is very enjoyable and relaxing for me.

Realism and immersion

The aesthetics and realism of game environments play an important role in the interaction of respondents. They appreciate realistic graphics, natural elements, and music that enhance the gaming experience. The inclusion of familiar cultural elements, such as Iranian music, adds to the sense of immersion.

"The locations I discovered were really beautiful and I think the reason is because they were close to reality. Their size, color, volume, dimensions, and overall graphics are fantastic! It is very important that the game music is in harmony with the game and pleasant. I myself play a game. When I get into the car, it is interesting that Iranian music is playing, even though the game is American, that is, made in America, but Iranian music is playing or I get into a taxi, the radio is playing in Persian. Well, this is what attracted the gamer a lot. The first time I was shocked, I turned up the music and saw that it was really Iranian. Game music can have a great impact on attraction.

Priority for Challenge

While exploration is valued, respondents also prefer games that involve challenges and fast-paced action, indicating a desire for a balance between exploration and game mechanics.

"Well, in fast-paced and challenging games there is exploration. Then I really like exploration. You just have to be careful because you might be in danger. But Ms. Rai, I like speed games because they are exciting. I said from the beginning that I like competitive games more. I enjoy them. Because I feel strong, I have a lot of strength, I can give me power, it gives me confidence, I feel satisfied, I am proud of myself. These feelings are not few, they are very enjoyable. That is why my vote and decision and choice is speed games."

Contrast between virtual and real-life

Respondents often compare their gaming experiences with real life and use virtual achievements and environments to compensate for perceived limitations in the real world.

"Well, in online games you can make friends from different cities, then form a group, set goals to defeat the enemy, but what about in the real world? How can you make friends from different cities? Plan with them to win, succeed."

Impact on real-life skills

Respondents believe that gaming has improved their real-life skills such as attention to detail, language skills, and social interactions.

"My social connection with people has increased a lot because I am always talking to them, we create scenarios, we find goals, we plan to win. Overall, my attention has increased a lot, my enthusiasm has increased, it has improved my management and leadership because even at school I am the team leader, I see how different I have become and I have become better."

Main themes for 9-year-olds

From interviews with 12 9-year-old boys about exploration in the game space, the themes that were extracted included the main themes of excitement and struggle, adventure and exploration, challenges and traps, weapon discovery and use, interactive and dynamic environments, special abilities and equipment, achievement and power, historical and cultural elements, victory and power, preferences for the game environment, and beautiful and clean environments.

Excitement and struggle

Respondents were exposed to the adrenaline and excitement of struggle and action in games. They enjoy strategic gameplay that involves attacking and defeating enemies, which adds an exciting element to their gaming experience.

"Ma'am, are you telling the truth? Let's fight, let's attack, let's loot, it's so much fun, it's exciting. If it's not like that, it's not fun, but if it's a war, it's stressful, it's fun. Then you shout in the game. It's exciting. "

Adventure and Exploration

They are eager to explore new places, even in a virtual setting, such as the detailed landscapes of New York City in games. This type of exploration allows them to experience the grandeur and excitement without leaving home and increase their knowledge of the world in a fun way.

"I was introduced to New York City in a game. Wow, how beautiful and big is this city? Someone just said that this is one of the largest cities in Korea. But unfortunately, this beautiful city was attacked by monsters. Its parks are very beautiful. When my friend said that it was attacked, I remembered its beautiful buildings. It is a very beautiful city. "

Challenges and Traps

The presence of constant challenges and traps in games keeps the respondents engaged and focused and provides an exciting experience that is valuable to them.

"Wow, having a trap from top to bottom, left to right, every corner is a challenge. Wow, this game is very interesting to me. It is exciting. Hey, be careful. Hey, there is a challenge in front of me. Wow, great. "

Discovering and using weapons

Discovering and using different types of weapons in games is exciting for them. It adds a layer of complexity and fun to the gameplay, especially when these elements allow them to experiment with different strategies and outcomes.

"I bought a bunch of guns and rifles in an assault game with my coins, then one of the guns was really cool. Look, with a gun, when you shoot, a bullet is fired, but with this gun, when I fired, suddenly a small bullet was fired. Wow, I was so excited. It was awesome. I had never seen that gun before. I took a picture of the gun and showed it to my dad and he said it was called a shotgun. In short, I discovered the shotgun, which I didn't know at all."

Interactive and dynamic environments

Respondents mentioned games with environments rich in interactive elements, such as traps and challenges that keep them alert and engaged.

"In the overall environment, there should be a map. Spectacular and cool maps. Then when we have a competition, for example, there should be fruit and food that is a bonus, and whoever eats it first will have more life and more strength, so that the environment is exciting and every moment is a challenge."

Special abilities and equipment

Discovering unique abilities or equipment in games, such as characters with special vision or powerful weapons, greatly enhances their gaming experience. These features contribute to a sense of superiority and excitement.

"One of my new and exciting discoveries was that some of the characters have really, really weird eyes, meaning they can scan enemies through walls. So if I can catch a character like that one day, wow, weird lady, I feel superior and powerful."

Achievement and Power

Winning and feeling powerful are very important to their enjoyment. They get a lot of satisfaction from overcoming challenges and proving their power in the game world.

"The feeling of power. The feeling of accomplishment. The excitement. The joy of victory because I can. I can do it. I am strong. I am a winner."

Historical and Cultural Elements

They find games that incorporate historical and cultural contexts appealing, such as games set in the Sassanid era or exploring ancient cities like Bukhara. These elements provide depth that enriches the gaming experience.

"Yes, ma'am, I remember playing a war game that was during the Sassanid era, and our Persian race was one of the most powerful. Then there were even a lot of elephants, all of which were war elephants for our race. Then there was a war in Bukhara, where the king of Bukhara was Khosrow Anushirvan, who was like the famous king of Sassanids. In short, we fought and we won."

Victory and Power

Winning battles in games and feeling powerful is important to this respondent. These experiences help with feelings of success and self-esteem, and increase the enjoyment and satisfaction of the game.

"When we won the Bukhara war, I was very happy. I felt satisfied. I felt like a hero. My self-confidence also increased because I went and proudly told all my friends that I had won. "

Game Environment Preferences

Unlike some gamers who prefer aesthetic environments, these respondents enjoy darker, more challenging settings that align with action and combat, indicating a preference for more intense and gritty backgrounds.

"I don't think it matters, you know why, ladies? Girls say it's important to have pink and hearts, but I don't think it matters, boys love dark and dangerous and warlike environments."

Beautiful and Clean Environments

Clean and aesthetically pleasing environments in games make a big difference to their experience. They prefer environments that are neat and well-designed, which helps them feel more energized and ready to engage.

"My environment should be beautiful and clean so that the game is more enjoyable. Ma'am, I'm really sensitive about cleanliness. If my environment is clean and nice, I'll have more energy to study, do my work, and so on. That's why I like my environment to be beautiful and full of exploration and discovery areas in the game."

Main themes for 7-year-old children

From interviews with 12 7-year-old boys about exploration in the play space, the themes that were extracted included the main themes including learning through play, exploration, visual and auditory appeal, instant solutions and cheat codes, emotional and environmental engagement, cultural insight, interactive and rewarding experiences, social and community engagement

Learning through play

Participants emphasized the desire to learn new things through play, especially from games that contain educational content such as stories or scenarios that they can explain to others, such as teachers and family, and reinforce their learning, they find attractive.

"My dear teacher, I like playing to learn new things, to learn a good story. When I play, I will explain to you later, to explain to my mom, to encourage me, to give me a prize."

Exploration

Like the first participant, this child also shows a strong interest in exploring new environments and places through games, expressing curiosity about places beyond their immediate surroundings and even thinking about future visits or living arrangements based on these explorations.

"Yes, very much so because I like to learn about new places. I don't just like to know this city I live in. I like to know more places. Maybe it's nicer there, right, ma'am? When I grow up, I'll go and live there."

Visual and auditory appeal

Participants are significantly influenced by the aesthetic and auditory aspects of games. They prefer vibrant and colorful environments and enjoy good background music, indicating a sensitivity to the sensory quality of games that enhances their gaming experience.

"Madam, I like the game environment to be beautiful, and colorful. Ma'am, it was a game that was all black and gray. Wow, I didn't like it because of the color. Then it should have a nice song, not because the song is ugly and you have to go and turn off the song settings."

Quick fixes and cheat codes

Discovering cheat codes or quick wins in games excites these participants and gives them a sense of power and mastery over the challenges of the game. It also introduces a practical component to the game, where they learn shortcuts and strategies to improve their game performance.

" Madam, because I go to English class and I know the alphabet, my cousin gave me a bunch of codes. For example, when your car breaks down if you type this car code, your car will suddenly be fixed, or if you get hit, if you type this health code to avoid going to the hospital, you will be healthy. Suddenly, I was so happy when I discovered these codes. I can't believe it. Everything is so easy and fast."

Emotional Interaction and Environment

Games that create a pleasant and engaging atmosphere are preferred. Participants enjoy scenarios that involve real interactions, such as driving a bus through a beautiful landscape, which not only increases their enjoyment but also provides a simulated experience of travel and exploration.

"Madam, there is a game called Bus Driving where you have to pick up a bunch of passengers and then drive through beautiful roads to get to where the passengers want to go. The game is very beautiful. Madam, the roads are very beautiful. Whenever I picked up a passenger and wanted to drop him off, I felt like I was going on a trip because the streets and roads are really beautiful."

Cultural Insight

Learning about different cultural greetings and behaviors from games enriches their understanding of the world and showcases the game as a tool for cultural education.

"My cousin plays from morning till night. I was sitting in front of her once. She was picking her team for a fight. When they were ready, they all started rubbing their noses and foreheads. I thought they were fighting. I asked my cousin why they were fighting. He said, "No, people here rub their noses and foreheads when they want to say hello. It was very interesting to me. I always remember that my cousin and I used to laugh when we said hello and then did this."

Interactive and rewarding experiences

Participants appreciate games that reward their progress with in-game currency and enable them to make in-game purchases. This indicates a preference for games that reward investment and effort.

"Madam, there is a game called Bus Driving. You have to pick up a lot of passengers, then drive through beautiful roads. You get to the place where the passengers want to go. There you drop everyone off. Of course, some get off on the way. But in general, for every passenger you deliver safely, you get a coin. When you have more coins, you can buy a higher-model bus or change its color. I like to buy a red bus, so I try to pick up a lot of passengers and drive carefully to deliver them safely so that I can get more coins."

Social and community interaction

Participants enjoy sharing their game experiences with their families and show that the game acts as a bridge for family interaction and social bonding.

"Madam, my kind teacher, I like the game to learn new things, to learn a good story. When I play, I explain it to you and then to my mom so that you can encourage me and give me a prize."

In qualitative research, adults are usually interviewed, but this study showed that if children are asked about topics, they are knowledgeable about, they answer questions with care, interest, and detail, and interviews can reveal part of their psychological world even with younger children. These findings were part of a larger study that also included 11- and 8-year-old children, but due to the breadth of the findings, it was not possible to report them in the form of an article.

Discussion and Conclusion

The findings of this study provide valuable insights into how 7- to 12-year-old boys experience and understand exploratory learning in play, particularly through the lens of video games. Themes extracted from the 12-year-old interviews included freedom and empowerment, educational value, emotional and psychological impact, attention to game aesthetics, realism and immersion, preference for challenge, contrast between virtual and real life, and impact on real-life skills. These findings highlight the multifaceted nature of game-based learning and its potential to influence children's emotional, cognitive, and social development.

The sense of freedom and empowerment reported by participants is consistent with the existing literature on the motivational aspects of video games. Ryan, Rigby, and Przybylski (2006) emphasize that the autonomy offered by video games is a key factor in their appeal, as it allows players to experiment with their identities and actions in a risk-free environment. Boys in this study had a strong appreciation for the open-ended nature of video games, where they could immediately act out their desires and explore a variety of roles. This finding underscores the importance of designing educational games that balance structured learning objectives with opportunities for endless exploration. The educational value of video games, as highlighted by participants, is consistent with research demonstrating the potential of games to foster interest in academic subjects. For example, Squire (2011) found that games such as Civilization can enhance players' understanding of history and geography by immersing them in interactive, narrative-driven environments. Boys in this study reported gaining knowledge about real-world locations, such as Madagascar, and developing an interest in topics that had previously been uninteresting to them. This suggests that video games can serve as powerful tools for stimulating curiosity and facilitating self-directed learning.

The emotional and psychological impact of gaming, from excitement and pride to anxiety and fear, reflects the all-encompassing nature of video games. McGonigal (2011) argues that games evoke strong emotional responses by providing meaningful challenges and opportunities for mastery. Participants' descriptions of their emotional experiences during play highlight the dual role of games as both fun and exciting. This emotional engagement can be applied in educational contexts to create memorable learning experiences that resonate with children on a deeper level.

The participants' emphasis on game aesthetics and realism is consistent with research on the role of visual and auditory elements in enhancing immersion. Jannett et al. (2008) found that realistic graphics and relevant cultural content significantly contribute to players' sense of presence in virtual environments. Boys in this study appreciated the visual beauty of game environments and the inclusion of familiar cultural elements such as Persian music. These findings suggest that combining high-quality visuals with culturally resonant content can enhance the appeal and educational value of games for diverse audiences.

The preference for challenging, fast-paced games reflects participants' desire to balance exploration and action. This finding is consistent with the concept of "flow" (Csikszentmihalyi,1990), in which optimal engagement occurs when challenges are well-matched to players' skill levels. By combining exploratory and competitive elements, game designers can create experiences that cater to a wide range of player preferences and learning styles.

Participants' comparisons between virtual and real-life experiences highlight the compensatory role of video games. Turkel (2011) discusses how virtual environments can provide a sense of achievement and social connection that may not be present in real life. Boys in this study used games to overcome perceived limitations, such as making friends from different cities and working together on common goals. This suggests that games can serve as a platform for developing social skills and fostering a sense of community, especially for children who may face challenges in traditional social settings. Participants' belief that gaming improves their real-life skills, such as attention to detail, language skills, and social interactions, is supported by research on the transfer of skills from virtual environments to the real world. Granik, Lobel, and Engels (2014) found that video games can enhance cognitive abilities such as problem-solving and spatial reasoning, as well as social skills such as teamwork and communication. These findings underscore the potential for games to contribute to holistic development.

The findings of this study provide a detailed understanding of how 9-year-old boys experience and understand exploratory learning in play spaces. Themes extracted from the interviews thrill and struggle, adventure and exploration, challenges and traps, weapon discovery and use, interactive and dynamic environments, special abilities and equipment, achievement and power, historical and cultural elements, victory and power, preferences for play environments, and beautiful and clean environments highlight the diverse ways children engage with video games emotionally and socially. These findings are consistent with and extend existing research on game-based learning and its impact on children's development.

The participants' emphasis on adrenaline and the thrill of combat aligns with research on the motivational aspects of video games. Przybylski, Rigby, and Ryan (2010) argue that the thrill of overcoming challenges and engaging in strategic gameplay is a key driver of player engagement. Boys in this study described combat as a key element of their enjoyment and emphasized the importance of incorporating action-oriented mechanics into educational games to maintain interest and motivation.

Participants' enthusiasm for exploring virtual environments, such as detailed New York City landscapes, reflects the educational potential of video games. Jay (2007) emphasizes that games can serve as "situated learning environments," where players acquire knowledge through exploration and interaction. Boys' descriptions of discovering new places and learning about their features suggest that games can stimulate curiosity and provide a fun and engaging way to learn about the world.

The presence of challenges and traps in games was an important factor in attracting participants. This finding supports the concept of "flow" (Csikszentmihalyi, 1990), in which optimal engagement occurs when challenges are well-matched to players' skill levels. The boys' enjoyment of overcoming obstacles and navigational traps underscores the importance of designing games that balance difficulty and reward to maintain engagement and enhance problem-solving skills. The excitement associated with discovering and using weapons in games highlights the role of novelty and complexity in enhancing gameplay. This is consistent with Malone's (1981) theory of intrinsic motivation, which identifies challenge, curiosity, and fantasy as key elements of engaging learning environments. The boys' descriptions of experimenting with different weapons and strategies suggest that games can provide a safe space for exploration and mastery of new skills.

Participants' appreciation of interactive and dynamic environments highlights the importance of responsive game design. Jannett et al. (2008) found that interactive elements, such as traps and challenges, significantly increased players' sense of immersion and engagement. Boys' enjoyment of games with rich, interactive environments suggests that such features can make learning more engaging and memorable.

The discovery of special abilities and equipment was a source of excitement and empowerment for participants. This finding is consistent with research on the role of rewards in motivating gameplay (Ryan, Rigby, & Przybylski, 2006). Boys' descriptions of feelings of superiority and power when acquiring unique abilities highlight the potential of games to enhance self-esteem and foster a sense of achievement.

Participants' emphasis on winning and feeling powerful underscores the importance of mastery and competence in gaming experiences. Desi and Ryan's (2000) self-determination theory identifies competence as a fundamental psychological need that drives motivation. Boys' satisfaction in overcoming challenges and proving their strength suggests that games can provide a sense of accomplishment that leads to increased self-confidence and self-efficacy.

Participants' interest in games with historical and cultural contexts highlights the potential for games to serve as educational tools. Squire (2011) found that games such as Civilization can enhance players' understanding of history and culture by immersing them in interactive, narrative-driven environments. Boys' descriptions of games set in the Sassanid era and ancient cities such as Bukhara suggest that such content can enrich their learning experiences and foster a deeper understanding of history and culture.

Participants' enjoyment of winning battles and feeling powerful reflects the emotional rewards of the game. McGonigal (2011) argues that games provide a sense of achievement and victory that may not be present in real life. Boys' descriptions of feeling like heroes and sharing their victories with friends suggest that games can enhance social interactions and self-esteem.

Participants' preference for darker, more challenging environments contrasts with aesthetic preferences often associated with younger children. This finding is consistent with research on gender differences in game preferences (Hartman & Klimt, 2006), which suggests that boys are more drawn to action and competitive games. Boys' enjoyment of challenging and challenging settings highlights the importance of designing games based on the preferences of their target audience.

While participants preferred action-oriented environments, they also appreciated clean, aesthetically pleasing settings. This finding suggests that visual design plays an important role in enhancing the gaming experience. (2008) emphasize that high-quality graphics and immersive environments contribute to players' sense of presence and engagement. Boys' appreciation of beautiful environments underscores the importance of balancing aesthetic appeal with gameplay mechanics.

The findings of this study provide a detailed understanding of how 7-year-old boys experience and understand exploratory learning in game spaces. Themes extracted from the interviews—learning through play, exploration, visual and auditory appeal, quick solutions and cheat codes, emotional and environmental engagement, cultural insight, interactive and rewarding experiences, and social interaction—highlight the multifaceted ways in which video games

engage young children cognitively, emotionally, and socially. These findings are consistent with and expand on existing research on game-based learning and its impact on early childhood development.
The participants' emphasis on learning through play aligns with Vygotsky's (1978) social constructivist theory, which argues that play is a critical context for cognitive and social development. Boys in this study described how games with educational content, such as stories and scenarios, allowed them to reinforce their learning by explaining it to others. This suggests that games can serve as effective tools for strengthening communication skills and retaining knowledge, especially when they encourage children to articulate their experiences.
Participants' eagerness to explore new environments through games reflects the natural curiosity of young children. Jay (2007) emphasizes that games can serve as "situated learning environments," where players acquire knowledge through exploration and interaction. Boys' descriptions of discovering new places and imagining future visits highlight the potential for games to broaden children's horizons and instill a sense of wonder about the world.
Participants' sensitivity to the aesthetic and auditory aspects of games underscores the importance of sensory engagement in early childhood. Research by Janet et al. (2008) suggests that high-quality graphics and immersive sound design significantly enhance players' sense of presence and enjoyment. Boys' preference for vibrant, colorful environments and pleasant background music suggests that sensory appeal is a key factor in maintaining their interest and engagement.
The excitement associated with discovering cheat codes and quick solutions reflects participants' desire for mastery and control. This is consistent with Malone's (1981) theory of intrinsic motivation, which identifies challenge and curiosity as key drivers of engagement. Boys' enjoyment of using cheat codes to overcome challenges suggests that games can build a sense of empowerment and encourage problem-solving skills even at an early age.
Participants' preference for games that create a pleasant and engaging atmosphere highlights the emotional impact of play. McGonigal (2011) argues that games evoke strong emotional responses by providing meaningful challenges and opportunities for mastery. Boys' descriptions of driving a bus through beautiful scenery suggest that games can provide simulated experiences that are both enjoyable and emotionally rich.
Participants' interest in learning about different cultural greetings and behaviors through games highlights the potential for games to serve as a tool for cultural education. Squire (2011) found that games like Civilization can enhance players' understanding of history and culture by immersing them in interactive, narrative-driven environments. Boys' descriptions of cultural interactions in games suggest that such content can foster curiosity and an appreciation for diversity.
Participants' appreciation for games that reward progress with in-game currency is consistent with research on the role of rewards in motivating gameplay (Ryan, Rigby, & Przybylski, 2006). Boys' enjoyment of earning coins and in-game purchases suggests that games can provide a sense of achievement and encourage goal setting and perseverance.
Participants' enjoyment of sharing their gaming experiences with family members highlights the social dimension of gaming. Granik, Lobel, & Engels (2014) found that video games can enhance social skills such as teamwork and communication by providing opportunities for shared experiences. Boys' descriptions of explaining game content to their families suggest that games can serve as a bridge for family interaction and bonding.
A comparison of findings across three age groups—7-year-olds, 9-year-olds, and 12-year-olds—reveals both developmental consistency and age-specific differences in how children experience and understand exploratory learning in play. Across all age groups, themes of exploration, challenge, and sensory appeal emerge as central to their play experiences. For example, 7-year-olds express a strong desire to learn through play and explore new

environments, and they often describe a fascination with vibrant visuals and rewarding mechanics. Similarly, 9-year-olds emphasize the thrill of combat and adventure, while 12-year-olds emphasize their freedom and ability to navigate the expansive game world. This suggests that, regardless of age, children are drawn to games that offer opportunities for exploration, mastery, and sensory engagement. However, the complexity and depth of their engagement changes with age. Younger children (ages 7) focus more on immediate rewards, such as in-game coins or cheat codes, and simpler interactions, such as driving a bus through beautiful landscapes. In contrast, older children (ages 9 and 12) show a greater appreciation for strategic challenges, historical and cultural context, and the emotional and psychological impact of games, reflecting their cognitive and emotional development.

Another key difference is in the social and emotional dimensions of gaming. While 7-year-olds enjoy sharing their gaming experiences with family members and see gaming as a means of social bonding, 9- and 12-year-olds demonstrate a more nuanced understanding of social interactions in gaming. For example, 9-year-olds describe the excitement of competing with friends and forming teams to achieve goals, while 12-year-olds reflect on the contrast between virtual and real-world social interactions, using gaming to compensate for perceived limitations in their offline lives. In addition, older age groups (9 and 12 years old) demonstrate greater awareness of the educational and cultural value of gaming, such as learning about geography, history, or cultural practices, while 7-year-olds focus more on the immediate pleasure of discovery and sensory appeal. These differences illustrate how as children grow older, play experiences become more complex and multifaceted, reflecting their cognitive abilities, social awareness, and emotional maturity. Overall, the findings underscore the importance of designing games with the developmental needs and priorities of different age groups in mind, ensuring that games remain engaging, educational, and socially enriching throughout childhood.

The contrast between virtual and real-life experiences, as well as the compensatory role of games, suggests that video games can serve as valuable tools for addressing social and emotional challenges. By harnessing the educational and motivational aspects of games, educators and game designers can create innovative learning environments that inspire curiosity, creativity, and collaboration.

Future research should examine the experiences of more diverse samples, including girls and children from different cultural and socioeconomic backgrounds, to gain a comprehensive understanding of the impact of game-based learning. Additionally, longitudinal studies can examine the long-term effects of play on academic achievement, social development, and emotional well-being. By continuing to explore the intersection of play, education, and storytelling, we can open up new opportunities to engage and empower the next generation of learners.

Declarations

Author Contributions

All authors contributed actively to the conception, design, and execution of the research.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Acknowledgements

The authors sincerely appreciate all those who contributed to this research. Their support, insights, and efforts have been invaluable in the completion of this study.

Ethical considerations

This study was conducted in full compliance with ethical guidelines and principles. All participants provided informed consent, and their confidentiality and anonymity were strictly maintained. The research protocol was reviewed and approved by the relevant ethical committee, ensuring adherence to ethical standards throughout the study.

Funding

This research was conducted without any external funding and was entirely financed by the authors' personal resources.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this research.

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