

# Playing Tetris in Virtual Reality Environment: Spatial Perception, Perceptual Speed and Visual Working Memory

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## משחק טטריס בסביבת מציאות מדומה: תפיסה מרחבית, מהירות תפיסתית וזיכרון עבודה חזותי

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### Abstract

This study examined whether playing Tetris in immersive virtual reality (VR) environments enhances cognitive abilities more effectively than playing on traditional computer screens. Specifically, the research investigated the impact of VR-3D versus computer-2D gameplay on the transferability of spatial perception, perceptual speed, and visual working memory, to non-game contexts. Seventy-two undergraduate students ( $M = 24.01$ ,  $SD = 1.77$ ) with no prior gaming experience were randomly assigned to either a VR or 2D computer group. Both groups played Tetris over four sessions. Pre- and post-tests assessed performance in card rotation, perceptual speed, and Corsi block-tapping tasks. Results revealed that while both groups improved in spatial perception and perceptual speed, the VR group demonstrated significantly greater gains. No significant improvement was observed in visual working memory in either group. Regression analyses indicated that group assignment significantly contributed to performance outcomes beyond baseline ability and demographic characteristics. These findings suggest that the immersive nature of VR facilitates deeper engagement and more effective cognitive processing, leading to enhanced spatial and perceptual performance. The study supports the potential of VR as a tool for targeted cognitive training in educational contexts, particularly for domains requiring spatial cognition. However, the limited effects on visual working memory highlight the need for task alignment and further exploration of domain-specific training in VR environments.

**Keywords:** virtual reality, cognitive training, Tetris, spatial perception, perceptual speed, visual working memory

### Literature review

The increased popularity of computer games has led scholars to explore their potential as educational tools. Many researchers argue that computer gameplay offers more effective skill

acquisition for children's future compared to traditional classroom instruction, especially in problem-solving, creativity, and cognitive flexibility (Carlson, 2023; Gao et al., 2020; Gee, 2017; Prensky, 2006; Rubalcaba, 2022).

Among the many computer games that have attracted the attention of researchers, Tetris, a classic spatial puzzle game, has been particularly recognized for its ability to improve cognitive abilities. One of the primary areas in which *Tetris* has demonstrated a significant impact is spatial cognition. The game of Tetris involves mentally rotating and positioning geometric shapes, a task that improves spatial reasoning as well as the ability to manipulate visual information (Sims & Mayer, 2002).

A central issue examined by many researchers is the extent to which cognitive skills developed during gameplay can be transferred to non-game contexts (Bediou et al., 2018; Lin et al., 2023; Plass et al., 2015). Recent advances in immersive technology, especially VR, offer new opportunities to explore this transfer process in more embodied and ecologically valid ways.

The rapid gameplay also encourages faster visual processing and decision-making skills (Dye, Green & Bavelier, 2009). Tetris players in computer 2D environment, demonstrate superior pattern recognition and quicker perceptual speed, translating into more efficient responses in similar tasks. Another salient cognitive benefit is the strengthening of visual working memory, as Tetris requires managing multiple elements simultaneously tracking shapes, predicting their place and orientation, and planning ahead. This multitasking enhances real-time management and control of information (Takacs & Kassai, 2019). Despite notable results, certain studies highlight limitations. For example, Pilegard and Mayer (2018) found that adding strategy instruction to traditional Tetris gameplay did not improve outcomes in spatial reasoning tasks outside the game, suggesting that low immersion or lack of context may limit skill transfer.

VR provides full-body engagement and sensory-rich environments, potentially amplifying learning processes through embodied cognition (Barsalou, 2008; Wilson, 2002; Johnson-Glenberg, 2018). In VR, students interact with objects in three-dimensional space, leveraging perceptual and motor systems more authentically. Empirical findings indicate that this immersion may strengthen spatial reasoning and memory retention compared to screen-based tasks (Cipresso et al., 2018; Kwon et al., 2023; Plancher et al., 2017; Queiroz et al., 2022; Riva & Wiederhold, 2022).

Crucially, VR deepens attentional resources and enhances the sense of "presence, which has been shown to reduce cognitive load and improve concentration, leading to superior performance in complex spatial and problem-solving activities (Makransky & Lilleholt, 2018 ; Makransky et al., 2019).

Despite the growing body of research on game-based cognitive training, absent is a comprehensive examination of the mechanisms that underlie cognitive skill transfer across immersive and non-immersive environments. This study addresses this gap by empirically investigating how playing Tetris in VR versus a traditional computer setting influences the development and transfer of spatial, perceptual, and visual working memory skills.

## Methodology

The study focused on three cognitive domains: spatial perception, perceptual speed, visual working memory. An additional aim was to evaluate the transferability of these skills to tasks beyond the gaming environment.

## Participants

The study included 72 undergraduate students (43 male) enrolled in exact sciences programs at a major Israeli university, identified through a demographic questionnaire. Participants were recruited through on-campus posters and Facebook announcements targeting undergraduate students in the exact sciences. Participants were recruited only from exact sciences programs to create a more

homogeneous sample with similar spatial and analytical skills. This decision was made to reduce differences related to academic background and to improve internal validity when examining spatial and perceptual cognitive outcomes.

Eligibility criteria required participants to have minimal gaming experience (less than one hour per week) and no recent Tetris practice, in order to minimize prior exposure effects. The final sample size was sufficient to detect meaningful effects. Participants' ages ranged from 20 to 29 years ( $M = 24.01$ ,  $SD = 1.77$ ).

Participants were randomly assigned to either the VR or the 2D computer condition using a random allocation procedure. The first group ( $n = 36$ ; 20 male) played Tetris in a 2D computer environment, while the second group ( $n = 36$ ; 23 male) played in a 3D virtual reality (VR) environment using Oculus Quest headsets. Groups did not differ significantly in gender distribution,  $\chi^2(1) = .52$ ,  $p = .471$ , or prior Tetris experience,  $\chi^2(1) = .08$ ,  $p = .772$ , indicating balanced conditions. However, a t-test revealed a significant age difference,  $t(70) = 2.11$ ,  $p = .038$ , with VR participants slightly older; age was therefore used as a covariate in analyses.

All participants received \$100 for approximately three hours of participation across four sessions. The study was approved by the Ethics Committee of the School of Education at Bar-Ilan University, and all participants provided written informed consent.

## Materials

**Virtual Reality.** Immersive VR enables users to experience first-person 360° virtual environments via headset and controllers, fostering immersion, presence, and embodiment (Villalba et al., 2021). Participants played *Tetris Effect: Connected* using an Oculus Quest 2 headset while seated in a 2x2 m safe zone. The game was custom developed in Unity 3D, identical in mechanics to the 2D version, differing only in presentation format. Players rotated and placed blocks using Oculus controllers, promoting embodied visuomotor interaction (Johnson-Glenberg, 2018; Parong & Mayer, 2021)

**Game Intervention.** *Tetris Effect* follows the traditional logic of the classic Tetris game. Players must position the falling geometric shapes (tetrominos) to complete full horizontal lines, which then disappear. As the game progresses, the shapes fall faster and the challenge increases. The game also includes visual and musical effects that synchronize with the rhythm of play, creating an engaging and immersive experience (Mayer, 2014; Sibert, 2019). All participants played the same version of *Tetris Effect: Connected*.

## Computer-use Experience Questionnaire

Participants completed a short self-report questionnaire assessing general computer use and familiarity with digital technologies. The questionnaire included items related to frequency of computer use, prior experience with digital games, and familiarity with Tetris. It was used to describe the sample and to ensure minimal prior gaming experience, in accordance with the inclusion criteria.

**Cognitive Measures.** Three standardized cognitive tests were administered before and after the intervention:

**Card Rotation Test** (Ekstrom et al., 1976). A paper-based test of mental rotation ability. Participants judged whether rotated figures matched a target figure. The test included 80 items and lasted 3 minutes. It measures spatial perception and has reliability values between .75 and .85.

**Number Comparison Test** (Ekstrom et al., 1976). A paper-based test measuring perceptual speed. Participants compared pairs of numbers and marked the differing ones within 90 seconds. The test includes 48 comparisons and shows reliability between .80 and .90.

**Corsi Block-Tapping Task** (Mueller & Piper, 2014). A computerized test of visuospatial working memory. Participants observed sequences of colored squares and reproduced them in the correct order. Sequence length ranged from three to eight squares. Reported reliability ranges from .70 to .85.

## Procedure

The experiment was conducted across four sessions over two weeks, with one session every 3–4 days. In the first session, participants completed a short questionnaire on computer-use experience (5 minutes), followed by the pre-training phase of three cognitive tests: the card rotation test (6 minutes), the perceptual speed test (3 minutes), and the Corsi block-tapping task (5–8 minutes).

Afterward, participants played Tetris for 30 minutes, aiming for the highest possible score. In the next three sessions, both groups (2D computer and VR 3D) played Tetris for 30 minutes each. In the final session, participants completed the post-training phase of the same cognitive assessments. All sessions were held at similar times of day in a quiet university room to reduce fatigue and maintain consistency. Participants were seated in both environments.

## Findings

Preliminary analyses confirmed that the data met the assumptions for parametric testing. Accordingly, two-way mixed ANCOVAs were used to examine group differences across time points. Prior to examining the main hypotheses, one-way ANCOVAs tested baseline (T1) differences in card rotation, number comparison, Corsi block-tapping, and Tetris performance, controlling for age. No significant group differences were found (see Table 1).

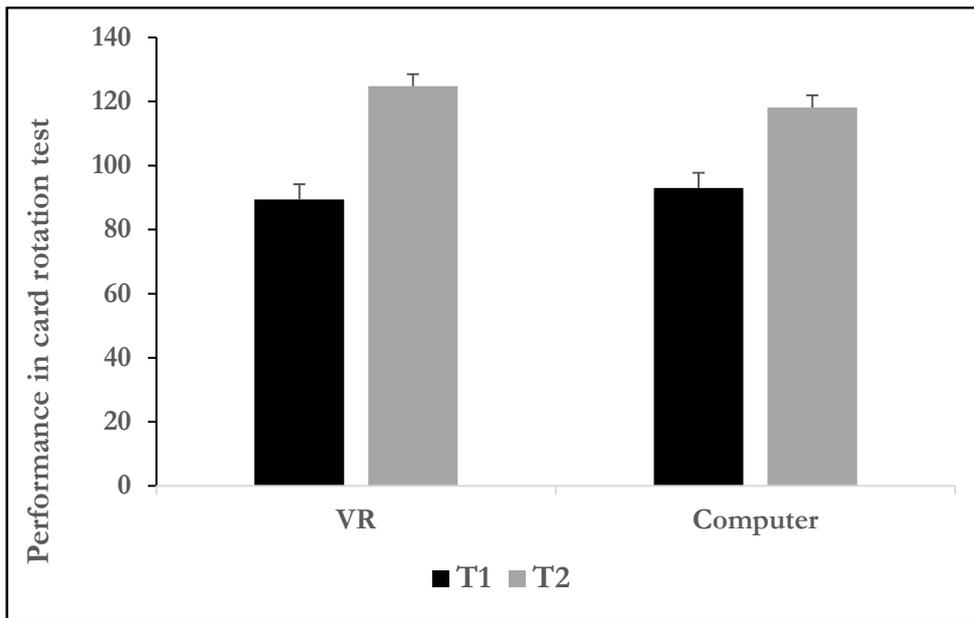
**Table 1.** Mean, SD, mean estimated values, and F-values of the students' performance on card rotation, number comparison, and Corsi block tapping tests, as well as the scores in the Tetris game at T1, controlling for students' age

Computer ( <i>n</i> = 36)			VR ( <i>n</i> = 36)			F-values			CI
<i>M</i>	<i>SD</i>	<i>M.E</i>	<i>M</i>	<i>SD</i>	<i>M.E</i>	<i>F</i>	<i>p</i>	$\eta_p^2$	
<b>Card rotation test</b>									
91.81	28.10	92.98	90.58	28.48	89.41	.27	.602	.00	[-10.04, 17.20]
<b>Number comparison</b>									
22.97	4.69	22.90	23.81	4.24	23.88	.82	.369	.01	[-3.16, 1.19]
<b>Corsi block tapping - Span Length</b>									
5.89	0.91	5.91	5.96	0.87	5.94	.01	.904	.00	[-.46, 41]
<b>Corsi block tapping – Total score</b>									
68.22	26.68	68.93	71.00	24.21	70.29	.05	.828	.00	[-13.72, 11.01]
<b>Tetris game score</b>									
13,480	6,817.80	13,898.76	15,286.64	6,986.41	14,867.96	.35	.556	.01	[-4239.07, 2300.67]

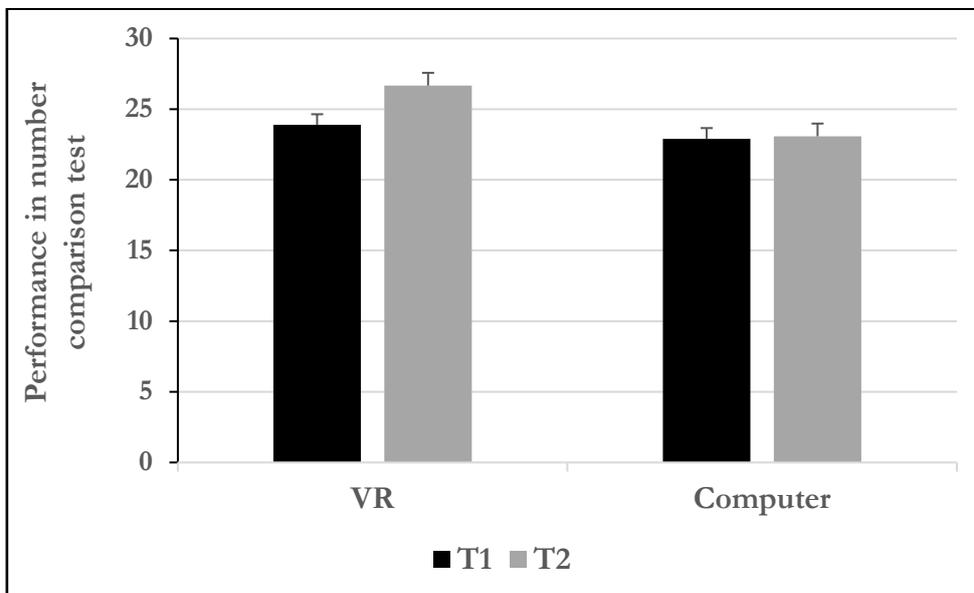
**M.E = Mean Estimated; CI = The confidence interval.**

To examine changes over time, 2x2 mixed ANCOVAs were conducted with group as a between-subjects factor and time as a within-subjects factor.

Significant group  $\times$  time interactions emerged for the card rotation and number comparison tests [ $F(1,69) = 6.98, p = .010$ ;  $F(1,69) = 6.86, p = .011$ ], indicating greater improvement among students in the VR condition. Paired t-tests revealed significant gains in card rotation performance, which assesses spatial perception, in both groups, with higher improvement in VR ( $d = 1.68$  vs.  $2.14$ ). For the number comparison test, measuring perceptual speed, only the VR group showed significant improvement ( $d = .68$ ). No changes were found for the Corsi block-tapping test which measures visual working memory capacity (see Figures 1–2). Table 1 presents the descriptive and inferential statistics at baseline, whereas Figures 1–3 are included to visually demonstrate performance changes across sessions and to highlight group differences in performance over time.

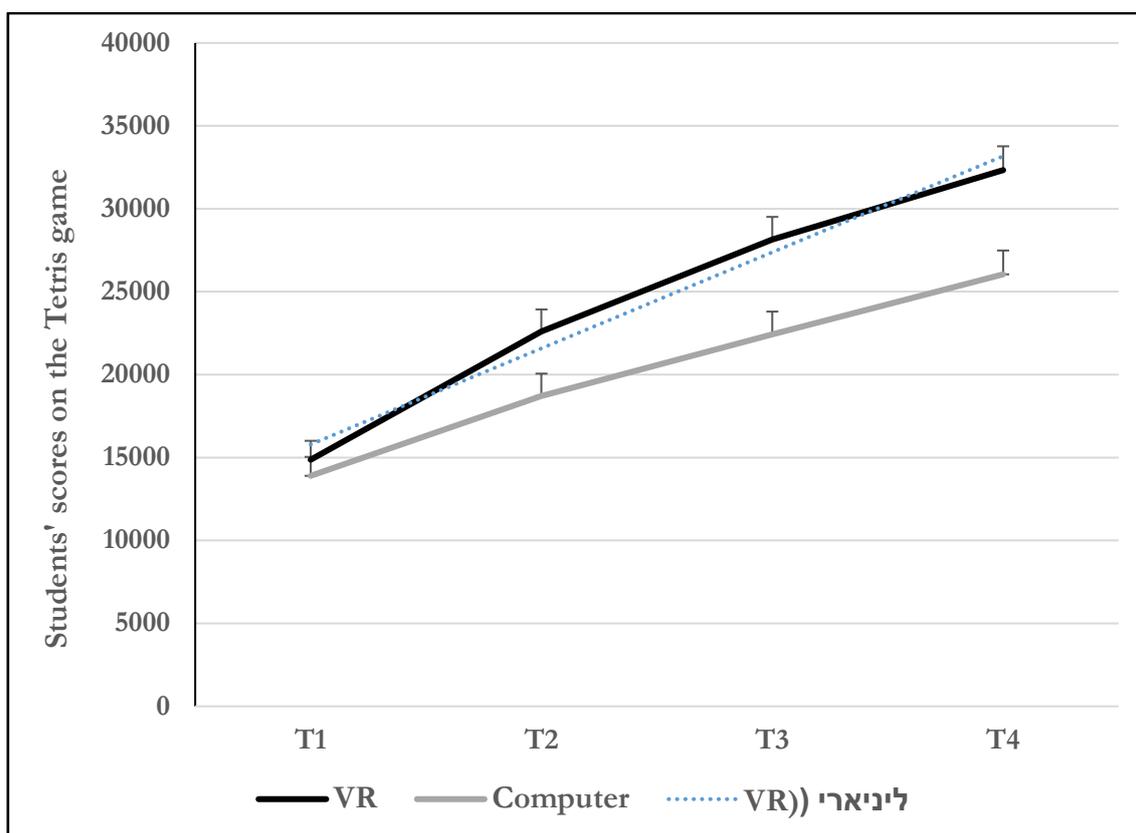


**Figure 1.** Mean estimated (and S.E.) of the performance on spatial perception test across time points.



**Figure 2.** Mean estimated (and S.E.) of the performance on perceptual speed test across time points.

A 2×4 mixed ANCOVA on Tetris scores showed a significant main effect of group [ $F(1,69) = 6.13, p = .016$ ] and a significant group × time interaction [ $F(3,207) = 5.76, p < .001$ ], reflecting greater improvement over sessions in the VR group (see Figure 3).



**Figure 3.** Mean estimated (and S.E) of the scores on the Tetris game across time points.

To explore the relationships among the different cognitive measures, correlation analyses were conducted. Results indicated positive associations among the three cognitive tests and between card rotation and Tetris performance, stronger in the VR group ( $Fisher Z = 2.61, p = .009$ ). Hierarchical regression analyses further showed that age and baseline performance significantly predicted final outcomes, while group assignment uniquely explained additional variance in card rotation, number comparison, and Tetris performance at post-test.

## Discussion

The objective of the current study was to examine the degree to which playing a VR version of the classic spatial puzzle game Tetris, offering enhanced depth perception and embodied interaction, would lead to measurable improvements in spatial and perceptual skills beyond the gaming context. The results revealed that most hypotheses were supported. No significant improvement was found in visual working memory.

Significant differences emerged in spatial perception improvements between the VR and computer groups, as measured by the Card Rotation Test. Although both groups showed progress, the VR group demonstrated greater enhancement, supporting the interpretation of near transfer, since the cognitive operations practiced during gameplay were reflected in the test performance. The effects were limited to tasks sharing cognitive demands with the game, and the study was not

designed to test far transfer. Future research should distinguish more clearly between these types of transfer (Sala & Gobet, 2017).

These findings support the hypothesis that playing Tetris in an immersive 3D VR environment enhances cognitive skills such as spatial perception and may facilitate their application in real-life contexts. They align with prior research (Chavez & Bayona, 2018; Coban et al., 2022), suggesting that virtual environments can improve spatial abilities. The substantial VR-related improvement can be attributed to the enhanced depth, embodiment, and interactivity of VR, which promote spatial reasoning compared to 2D computer gameplay.

A significant group  $\times$  time interaction also appeared in the Perceptual Speed Test, where only VR participants showed improvement. This finding supports the hypothesis that VR's multisensory environment enhances response speed and pattern recognition, enabling faster real-life information processing. These results are consistent with Wiesing et al. (2020), who suggested that 3D engagement in VR promotes faster perceptual responses.

Contrary to expectations, no significant differences emerged between groups in visual working memory, as measured by the Corsi Block-Tapping Test. Neither group improved over time, contrasting with Krokos et al. (2019), who found VR to enhance memory retention. This discrepancy may stem from differences in task type: Tetris, despite its spatial demands, might not strongly engage visual working memory. Their results support the specific transfer view, suggesting that cognitive skills practiced in the gaming environment do not necessarily generalize beyond it. Alternatively, visual working memory improvements may require longer or more varied training than provided here (Nozari & Martin, 2024; Soveri et al., 2017).

In contrast to Pilegard and Mayer (2018), the present study supports the transfer of general skills view within VR, particularly regarding spatial perception and perceptual speed, as the VR group showed improvement in both domains. This improvement likely stems from the robust cognitive processes activated in VR.

Performance analysis also showed that participants in the VR group achieved significantly higher Tetris scores, suggesting more efficient transfer of in-game cognitive skills to real-life analogues. While both groups improved over the four sessions, the VR group exhibited greater gains.

The positive correlations between Tetris performance and spatial perception, especially in the VR group, indicate that VR enhances cognitive mechanisms crucial for both gameplay success and real-world spatial reasoning. These results are consistent with prior work (Dallant & Iacono, 2024; Lindstedt & Gray, 2020) and with studies supporting the specific-transfer-of-general-skills theory (Mayer, 2019; Vedeckina & Borgonovi, 2021; Yen & Chiu, 2021). Overall, these findings reinforce the conclusion that playing Tetris in a VR environment can strengthen cognitive skills both within and beyond the gaming context.

A key methodological strength of this study was the integration of immersive VR gameplay with pre- and post-intervention cognitive assessments using validated standardized measures in a structured four-session protocol. This design offers greater rigor compared with many previous VR studies, thus strengthening its contribution to game-based transfer research (Makransky & Mayer, 2022).

## Conclusion

The present study adds to the expanding body of research examining the cognitive benefits associated with virtual reality. The results suggest that virtual reality has the potential to improve spatial perception, perceptual speed, and performance in specific tasks, such as Tetris, while its effect on visual working memory remains unclear. In this study, we found that the use of VR contributed to the improvement in cognitive processes not only within the game but also in tasks beyond the game, due to the robust cognitive processes active in VR. With the ongoing advancement of VR technology, its application in educational and training environments holds promise for improving cognitive skills

and task performance in ways that conventional computer environments may not. This study highlights the educational potential of Tetris, demonstrating that cognitive skills developed during the game can transfer to non-game contexts. It provides valuable insights into how video games, when properly structured, can be tools for cognitive development.

## References

- Barsalou, L. W. (2008). Grounded cognition. *Annu. Rev. Psychol.*, *59*(1), 617-645.
- Bediou, B., Adams, D. M., Mayer, R. E., Tipton, E., Green, C. S., & Bavelier, D. (2018). Meta-analysis of action video game impact on perceptual, attentional, and cognitive skills. *Psychological bulletin*, *144*(1), 77.
- Carlson, S. M. (2023). Let me choose: The role of choice in the development of executive function skills. *Current directions in psychological Science*, *32*(3), 220-227.
- Chavez, B., & Bayona, S. (2018). Virtual reality in the learning process. *Advances in Intelligent Systems and Computing*, 1345–1356.
- Cipresso, P., Giglioli, I. A. C., Raya, M. A., & Riva, G. (2018). The past, present, and future of virtual and augmented reality research: a network and cluster analysis of the literature. *Frontiers in psychology*, *9*, 2086.
- Coban, M., Bolat, Y. I., & Goksu, I. (2022). The potential of immersive virtual reality to enhance learning: A meta-analysis. *Educational Research Review*, *36*.
- Dallant, J., & Iacono, J. (2024). How fast can we play Tetris greedily with rectangular pieces?. *Theoretical Computer Science*, *992*, 114405.
- Dye, M. W., Green, C. S., & Bavelier, D. (2009). The development of attention skills in action video game players. *Neuropsychologia*, *47*(8-9), 1780-1789.
- Gao, F., Li, L., & Sun, Y. (2020). A systematic review of mobile game-based learning in STEM education. *Educational Technology Research and Development*, *68*, 1791-1827.
- Gee, J. P. (2017). *What video games have to teach us about learning and literacy*. Macmillan.
- Johnson-Glenberg, M. C. (2018). Immersive VR and education: Embodied design principles that include gesture and hand controls. *Frontiers in Robotics and AI*, *5*, 375272.
- Krokos, E., Plaisant, C., & Varshney, A. (2019). Virtual memory palaces: immersion aids recall. *Virtual reality*, *23*(1), 1-15.
- Kwon, S. H., Park, J. K., & Koh, Y. H. (2023). A systematic review and meta-analysis on the effect of virtual reality-based rehabilitation for people with Parkinson's disease. *Journal of neuroengineering and rehabilitation*, *20*(1), 94.
- Lindstedt, J. K., & Gray, W. D. (2020). The "cognitive speed-bump": How world champion Tetris players trade milliseconds for seconds. In *CogSci*.
- Makransky, G., & Lilleholt, L. (2018). A structural equation modeling investigation of the emotional value of immersive virtual reality in education. *Educational Technology Research and Development*, *66*(5), 1141-1164.
- Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction*, *60*, 225-236.
- Makransky, G., & Mayer, R. E. (2022). Immersive virtual reality and learning: A review. *Educational Psychology Review*, *34*, 101-118.
- Mayer, R. E. (2019). Computer games in education. *Annual review of psychology*, *70*(1), 531-549.
- Nozari, N., & Martin, R. C. (2024). Is working memory domain-general or domain-specific?. *Trends in cognitive sciences*, *28*(11), 1023-1036.
- Pilegard, C., & Mayer, R. E. (2018). Game over for Tetris as a platform for cognitive skill training. *Contemporary Educational Psychology*, *54*, 29–41.
- Plancher, G., Barra, J., Orriols, E., & Piolino, P. (2017). The influence of action on episodic memory: A virtual reality study. *The Quarterly Journal of Experimental Psychology*, *70*(12), 2353-2365.

- Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational psychologist, 50*(4), 258-283.
- Prensky, M. (2006). *Don't bother me mom—I'm learning*. St. Paul, MN: Paragon House.
- Queiroz, A. C., Fauville, G., Herrera, F., Leme, M. I., & Bailenson, J. N. (2022). Do students learn better with immersive virtual reality videos than conventional videos? A comparison of media effects with middle school girls. *Technology, Mind, and Behavior, 3*(3).
- Riva, G., & Wiederhold, B. K. (2022). What the metaverse is (really) and why we need to know about it. *Cyberpsychology, behavior, and social networking, 25*(6), 355-359.
- Rubalcaba, L. (2022). Understanding innovation in education: A service co-production perspective. *Economies, 10*(5), 96.
- Sala, G., & Gobet, F. (2017). Does far transfer exist? Negative evidence from chess, music, and working memory training. *Current Directions in Psychological Science, 26*(6), 515-520.
- Sims, V. K., & Mayer, R. E. (2002). Domain specificity of spatial expertise: The case of video game players. *Applied Cognitive Psychology, 16*(1), 97-115.
- Soveri, A., Antfolk, J., Karlsson, L., Salo, B., & Laine, M. (2017). Working memory training revisited: A multi-level meta-analysis of n-back training studies. *Psychonomic bulletin & review, 24*(4), 1077-1096.
- Takacs, Z. K., & Kassai, R. (2019). The efficacy of different interventions to foster children's executive function skills: a series of meta-analyses. *Psychological bulletin, 145*(7), 653.
- Vedechkina, M., & Borgonovi, F. (2021). A review of evidence on the role of digital technology in shaping attention and cognitive control in children. *Frontiers in Psychology, 12*, 611155.
- Wiesing, M., Fink, G. R., & Weidner, R. (2020). Accuracy and precision of stimulus timing and reaction times with Unreal Engine and SteamVR. *PloS one, 15*(4), e0231152.
- Wilson, M. (2002). Six views of embodied cognition. *Psychonomic bulletin & review, 9*(4), 625-636.
- Yen, H. Y., & Chiu, H. L. (2021). Virtual reality exergames for improving older adults' cognition and depression: a systematic review and meta-analysis of randomized control trials. *Journal of the American Medical Directors Association, 22*(5), 995-1002.