Using Virtual Reality for Motor and Psychomotor Skill Development: A Systematic Review

Ștefan MOROȘANU[a*], Vlad Teodor GROSU[b]

[a]*Babeș-Bolyai University, Faculty of Physical Education and Sport, Cluj-Napoca, Romania*
[b]*Technical University of Cluj-Napoca, Cluj-Napoca, Romania*

Abstract

The properties of a virtual reality training program can take many forms. The program can present a digital environment on a computer monitor and participants can interact with this environment using a keyboard and mouse. Alternatively, participants can wear an HMD using motion sensors that track human body movements.

The purpose of this review is to synthesize the evidence for the effectiveness of virtual reality as a tool for developing motor and psychomotor skills. The studies that were included in the systematic review were searched in August 2022, on the following specialized literature platform: PubMed, ScienceDirect, Google Scholar. The initial search identified 451 articles, but only 9 of these articles met inclusion and exclusion criteria. Six studies used VR HMD (head-mounted display) and that made VR interventions more immersive, three studies used less immersive VR devices.

The findings from these 9 articles are encouraging and provide initial support for the notion that motor and psychomotor skills can be improved with a VR training programme. The short number of studies included in this review suggests that is a great need of research who investigates the capability of VR technology to improve motor or psychomotor skills.

Keywords: *virtual reality, HMD, reaction time, motor skills, psychomotor skills.*

[*] Corresponding author. Tel.: 0721338426;
E-mail address: stefan.morosanu@ubbcluj.ro

1. Introduction

Since the 1960s, the term virtual reality (VR) has been used to describe a number of very different technologies, both software and hardware, such as the Sensorama Simulator, online virtual light (e.g., Second Life), multiplayer online games (MMORPGs such as World of Warcraft), surgery simulators, Cave Automatic Virtual Environments (CAVEs), as well as head mounted headsets (HMDs). (Jensen & Konradsen, 2017; Howard, Gutworth & Jacobs, 2021)

VR is defined as the three-dimensional digital representation of a real or imaginary space with interactive capabilities (Zyda, 2005). A few additions should be made to this definition.

First, users navigate their digitally represented three-dimensional digital environments called avatars. Users can view their avatar from a third-person perspective or be completely unaware of their avatar's appearance, taking a first-person perspective (Didehbani, Allen, Kandalaft, Krawczyk & Chapman, 2016).

Second, VR programs can be used for training, gaming, telecommunications, or any other purpose (Howard et al., 2021).

VR programs can be relatively simple. These may include unrealistic graphics, few interactive opportunities, and typical computer hardware (monitor, keyboard, and mouse). However, VR programs can also be extremely complex. These may include real graphics, an interactive world, and advanced computer hardware (eg, head-mounted-display (HMD), motion sensors) (Howard et al., 2021).

For decades it has been debated whether virtual reality has the potential to revolutionize education. The argument is that VR can be used for simulation-based education, where students can practice new skills in a simulated environment that allows for correction, repetition and eliminates risk. Despite high hopes, these ideas were based more on speculation than practice, and outside of dedicated training simulators for surgeons, pilots and military personnel, VR technology has not been used to a level where it could be applied in education and training in general (Jensen & Konradsen, 2017).

This changed in 2013, when the first versions of an HMD from the company Oculus Rift introduced a new generation of VR technology at a price accessible to the general public.

Over the next few years, a host of competitors released their own HMD, making this new technology even more accessible to the public for both research and educational purposes (Ragan et al, 2015).

The properties of a virtual reality training program can take many forms. The program can present a digital environment on a computer monitor and participants can interact with this environment using a keyboard and mouse. Alternatively, participants can wear an HMD using motion sensors that track human body movements. Participants may even use a combination of immersive and non-immersive hardware, such as using a computer monitor to view their environment and custom input devices to provide input (eg, surgical instruments with sensors). (Howard et al., 2021).

In all of these applications, researchers have shown that VR training programs offer promising results (Moglia et al., 2016; Vaughan, Dubey, Wainwright, & Middleton, 2016)

The purpose of this review is to synthesize the evidence for the effectiveness of virtual reality as a tool for developing motor and psychomotor skills. It is necessary to first determine whether VR is an effective tool to improve real-world skills by reviewing articles that demonstrate real-world transfer.

2. Methods

2.1. Search strategy

The studies that were included in the systematic review were searched in August 2022, on the following specialized literature platform: PubMed, ScienceDirect, Google Scholar. To search for these studies, we used the following terms, but also combinations between them: "virtual reality", "head-mounted display", "motor skills", "psychomotor skills", "reaction time", "eye-hand coordination".

Included studies are in English only. The publication date we have chosen for these studies is the range 2015-2022. The criteria according to which the studies were included are the following: the included studies must be experimental or quasi-experimental; studies published in English; each study must include a healthy population; The criteria according to which the studies were excluded are as follows: studies that do not refer to the development of motor or psychomotor skills; studies that refer to rehabilitation.

2.2. Article selection

After searching the above-mentioned specialist platforms and using the keywords and their combinations, 451 studies were found. After the duplicates were eliminated, 442 remained. After going through the abstract, 20 studies remained, which were read entirely. Of these, 11 were excluded because they did not fit the inclusion criteria (did not include healthy population, did not develop motor or psychomotor skills). Finally, 9 studies were included to be analyzed and discussed later.

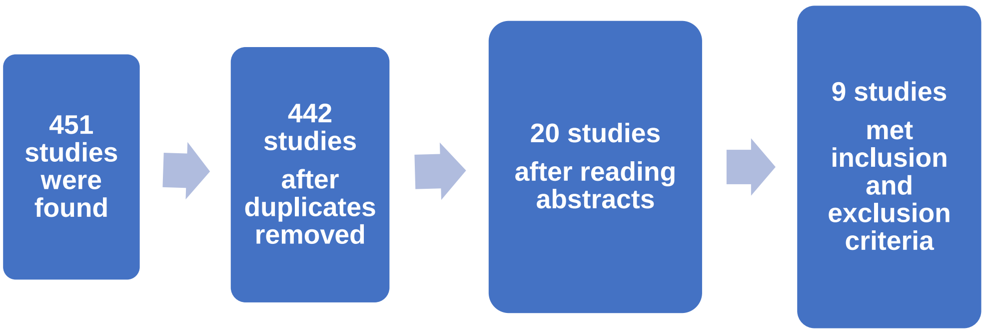

Figure 1. Selection process of the study

3. Results and discussion

3.1. Descriptions of studies

Eleven out of twenty were excluded because they did not met the inclusion and exclusion criteria such as: they did not develop motor or psychomotor skills, they did not use a healthy population. Out of the nine studies there is a combined total numer of 552 participants. The studies were published between 2015 and 2021. In the nine studies included in this review, sample sizes ranged from 6 to 24. The length of the VR intervention was between one day session to 9 months.

Six studies out of nine used intervention and control group. Barbosa (2020), Rutkowski et al. (2021) and Tharani, Shah, Kothari & Shah (2020) implemented a single-group pre-post study design. Three studies used athletes in their studies (Amprasi, Vernadakis, Zetou & Antoniou, 2021; Gray, 2017; Petri, Bandow, Masik & Witte, 2019) the other six studies used students.

The shortest intervention was only one session long (Drew et al., 2020) and verified if participant who train dart throwing abilities in a VE will improved real world dart throwing abilities. The longest intervention was nine months long and verified potential improvement in motor skill competence after a VR programme (Sunyue ye, Lee, Stodden & Gao, 2018).

Six studies used VR HMD (head-mounted display) and that made VR interventions more immersive, three studies used less immersive VR devices.

Table 1. Summary of included articles.

Authors	Participants	Intervention design	Evaluation	Results
Amprasi et al. (2021)	n=48 Age=8-10 Sex: Male=0 Female=48	Three groups: FIVE, TT, CG Duration:6 weeks, biweekly, 24 minutes each time	WBRT Tests and instruments:WBRT(Takei Instruments)	WBRT improved in both FIVE and TT group compared to CG.
Barbosa (2020)	n=17 Age=9-13 Sex: N/A Male= N/A Female= N/A	Single group, Duration: one exergames session	SRT CRT Tests and instruments: Reaction Time® v. 2. 0 software	Children reduced SRT after exergames session.
Drew et al. (2020)	n=41 Age=18-N/A Sex: Male= 22 Female= 19	Two groups: VR ,RW Duration: one session	Dart throws Tests and instruments: 100 dart throws	VR training was not effective for real world performance.
Gray (2017)	n=80 Age=17-18 Sex: 80 Male= 80 Female=	Four groups: VE, VE+extra sessions, extra	Baseball batting Tests and instruments: 8 batting test	Players in the VE adaptive group showed significant

Authors	Participants	Intervention design	Evaluation	Results
		sessions RBT, NT Duration: 6 weeks, 2 ses/week, 45 minutes each		improvements for 7/8 of the batting performance.
Petri et al. (2019)	n=15 Age=13-17 Sex: Male=10 Female=5	Two groups: VR, CG Duration:8 weeks, 10 minutes, once a week	Reaction time Tests and instruments: (Contemplas, Kempten, Germany, 100 Hz).	VR training improved participants anticipation.
Rutkowski et al. (2021)	n=14 Age=14-19 Sex: Male=6 Female=8	Single group Duration:once a day for 5 days, 15 minutes each time	Reaction time Hand-eye coordination Tests and instruments:PTT Ruler-drop test TMT test	Hand–eye coordination and reaction time showed significant improvement.
Sunyue ye et al. (2018)	n= 261 Age=7-9 Sex: Male=127 Female:134	Two groups:IG, CG Duration: 9 month, biweekly, 25 minutes each	MSC	CG demonstrating greater improvement, compared to the IG at MSC tests.
Tharani et al. (2020)	n=10 Age=18-24 Sex: Male=N/A Female=N/A	Single group Duration:4 weeks, 3 days/week, 20 minutes per session	Auditory and Visual reaction time Tests and instruments: Inquisit 5.0v software was used on a laptop.	Auditory and Visual reaction time reduced post-intervention.
Vernadakis et al. (2015)	n=66 Age=6-7 Sex: Male= 36 Female: 30	Three groups: XBOX, TA, CG Duration: 8 weeks, biweekly, 30 minutes each.	FMS Tests and instruments: TGMD-2	Post-test FMS scores for both experimental groups are higher compared to control group.

n- number
FIVE- full immersvive virtual environment
TT- typical training
CG- control group
WBRT- whole body reaction time
SRT- simple reaction time
CRT- complex reaction time
RW- real world
VE- virtual environment
RBT- real batting practice
NT- normal training
VR- virtual reality
IG- intervention group
MSC- motor skill competence
PTT- plate-tapping test
TMT- trial-making test
N/A- not available
TA- traditional aproach
FMS- fundamental motor skills
TGMD-2- test of gross motor development 2

3.2. Findigs

The study of Amprasi et al. (2021) suggests methods to improve reaction time, providing a useful tool for Physical Education teachers and coaches in order to improve reaction time in a different way. The study revealed that, regardless of whether it was full immersive virtual environment(FIVE) or traditional training (TT), reaction time improved and retained in in comparison to a control group receiving no-training (Amprasi et al., 2021).

Barbosa (2020) intervention reduced SRT, showing an improvement on visual perception and action. Moreover, activities increased HR in relation to rest, which could be used to break sedentarism.

VR training programme of Rutkowski et al. (2021) improved the hand–eye coordination and reaction time of musicians, which may lead to the faster mastering of a musical instruments.

Gray (2017) demonstrated that training in VR can be good not only for the musicians but for athletes also: ′′Training in a VE can be used to improve real, on-field performance especially when designers take advantage of simulation to provide training methods (e.g., adaptive training) that do not simply recreate the real training situation′′(Gray, 2017).

Petri et al. (2019) find that subtracting reaction times from the first reaction of the responding athlete is an appropriate method to analyze changes in perception and anticipation due to training in VR. These new findings can be used in karate training to improve motor learning in beginners to enhance performance.

3.3. Summary and future research

In this review, we evaluated research measuring the effectiveness of using virtual reality to improve motor or psychomotor skills. Whether participants was students (Barbosa, 2020; Rutkowski et al., 2021; Sunyue ye et al., 2018; Tharani et al., 2020; Vernadakis et al., 2015) or athletes (Amprasi et al., 2021; Gray, 2017; Petri et al., 2019) this studies demonstrated that a VR training programme can improve motor and psychomotor skills. The only study from this review who doesn`t showed motor or psychomotor skills improvement was Drew et al. (2020), maybe because of the short duration.

Notably, studies like Petri, et al. (2019) using real international successful karate kumite athletes, all of them with the black belt degree (1st - 4th Dan) to build an avatar which was used in the intervention program.

The short number of studies included in this review suggests that is a great need of research who investigates the capability of VR technology to improve motor or psychomotor skills.

References

Amprasi, E., Vernadakis, N., Zetou, E., & Antoniou, P. (2021). Effect of a Full Immersive Virtual Reality Intervention on Whole Body Reaction Time in Children. *International Journal of Latest Research in Humanities and Social Science (IJLRHSS), 4,8:*15-20.

Barbosa, E.G. (2020). Virtual Reality-Based Exercise Reduces Children's Simple Reaction Time. *International Journal of Sports Science, 10(5):* 112-116.

Didehbani, N., Allen, T., Kandalaft, M., Krawczyk, D., & Chapman, S. (2016). Virtual reality social cognition training for children with high functioning autism. *Computers in Human Behavior, 62*, 703–711.

Drew, S.A, Awad, M.F., Armendariz, J.A., Gabay, B., Lachica, I.J. & Hinkel-Lipsker, J.W. (2020). The Trade-Off of Virtual Reality Training for Dart Throwing: A Facilitation of Perceptual-Motor Learning With a Detriment to Performance. *Front. Sports Act. Living 2:*59. doi: 10.3389/fspor.2020.00059.

Finco, M.D., Reategui, E., Zaro, M.A., Sheehan, D.D., & Katz, L. (2015). Exergaming as an alternative for students unmotivated to participate in regular physical education classes. *Int. J. Game-Based Learn., 5*, 1–10.

Gray R. (2017). Transfer of Training from Virtual to Real Baseball Batting. *Front. Psychol. 8*:2183. doi: 10.3389/fpsyg.2017.02183

Howard M.C, Gutworth M.B, & Jacobs R.R. (2021). A meta-analysis of virtual reality training programs. *Computers in Human Behavior, 121*, 106808.

Jensen, L., & Konradsen, F. (2017). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies, 23*, 1515–1529.

Mayer, A.B., & Caminiti, R. (2018). Parieto-frontal networks for eye-hand coordination and movements. *Handb. Clin. Neurol., 151*, 499–524.

Moglia, A., Ferrari, V., Morelli, L., Ferrari, M., Mosca, F., & Cuschieri, A. (2016). A systematic review of virtual reality simulators for robot-assisted surgery. *European Urology, 69*(6), 1065–1080.

Neumann, D.L., et al. (2018). A systematic review of the application of interactive virtual reality to sport. *Virtual Real., 22*, 183–198.

Petri, K., Bandow, N., Masik, S., & Witte, K. (2019). Improvement of early recognition of attacks in karate kumite due to training in virtual reality. *Journal Sport Area 4(2):* 294-308.

Ragan, E. D., Bowman, D. A., Kopper, R., Stinson, C., Scerbo, S., & McMahan, R. P. (2015). Effects of field of view and visual complexity on virtual reality training effectiveness for a visual scanning task. *IEEE Transactions on Visualization and Computer Graphics, 21*(7), 794–807. DOI:10.1109/TVCG.2015.2403312.

Rutkowski, S., Adamczyk, M., Pastuła A., Gos E., Luque-Moreno, C., & Rutkowska, A. (2021). Training Using a Commercial Immersive Virtual Reality System on Hand–Eye Coordination and Reaction Time in Young Musicians: A Pilot Study. *Int. J. Environ. Res. Public Health, 18*, 1297. doi:10.3390/ijerph18031297.

Shin, D. (2018). Empathy and embodied experience in virtual environment: To what extent can virtual reality stimulate empathy and embodied experience? *Computers in Human Behavior*, *78*, 64–73.

Sportillo, D., Avveduto, G., Tecchia, F., & Carrozzino, M. (2015). Training in VR: A preliminary study on learning assembly/disassembly sequences. *2nd International Conference on Augmented and Virtual Reality, 9254*, 332-343.

Sunyue, Y., Lee J.E., Stodden, D.F. & Gao, Z. (2018). Impact of Exergaming on Children's Motor Skill Competence and Health-Related Fitness: A Quasi-Experimental Study. *J. Clin. Med., 7,* 261; doi:10.3390/jcm7090261.

Tharani, S.A., Shah, M.R., Kothari, P.H., & Shah, V. (2020). Effect of Virtual Reality Games on Stress, Anxiety and Reaction Time in young Adults: A Pilot Study. *International Journal of Health Sciences and Research, 10*, 4:156-161.

Vaghetti, C.A.O., Monteiro-Junior, R.S., Finco, M.D., Reategui, E., & Silva da Costa Botelho, S. (2018). Exergames experience in physical education: A review. *Phys. Cult. Sport. Stud. Res.*, *78*, 23–32.

Vaughan, N., Dubey, V., Wainwright, T., & Middleton, R. (2016). A review of virtual reality based training simulators for orthopaedic surgery. *Medical Engineering & Physics, 38*(2), 59–71.

Vernadakis, N., Papastergiou, M., Zetou, E. & Antoniou P. (2015). The impact of an exergame-based intervention on children's fundamental motor skills. *Computers & Education 83:*90-102.

Zyda, M. (2005). From visual simulation to virtual reality to games. *Computer*, *38*(9), 25–32.