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Original Article

Enhancing psychomotor skills in high school students using virtual reality

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Abstract:
Introduction: Many school-aged children and adolescents across Europe face coordination difficulties. Virtual reality, particularly through exergames, presents a promising solution by offering physical exercise and enhancing psychomotor skills while increasing overall physical activity levels. In this study, we assessed two key components of psychomotor skills: reaction time and eye–hand coordination in high school students. *Materials and methods:* The intervention program comprised tasks requiring motor and cognitive dual-task performance, focusing on motor coordination, attention, processing speed, focus, decision-making abilities, and memory within a virtual environment. The virtual reality exercises used Oculus Quest 2 developed by Meta (Facebook Technologies, LLC, 1 Hacker Way, Menlo Park, CA 94025, USA). *Results:* The results of the study showed statistically significant ($p < .05$) reductions in choice reaction time and improvements in eye–hand coordination between pre- and post-test in the experimental group. Additionally, there was a significant difference ($p < .05$) in post-test results of the AHWT and Deary–Liewald test between the experimental and control groups. *Discussion:* There are various mechanisms to explain the faster reaction time observed after the exergames intervention. This improvement may be attributed to enhanced concentration, increased alertness, and better muscle coordination in terms of speed and precision. Our results align with other literature demonstrating the potential of virtual reality (VR) to reduce reaction time and improve eye–hand coordination. *Conclusions:* Virtual reality training is more effective than real-world training for reducing choice reaction time and improving eye–hand coordination in high school students.
Keywords: exergames, Oculus, immersion, reaction time, eye-hand coordination

Introduction

We are in a period of human history where technology is at every turn. Most children and teenagers spend most of their free time playing various games on their phone, computer, Playstation or other cutting-edge devices. Although most studies blame these behaviors, being considered among the main causes of sedentary behavior among children and adolescents, we aim in our study to check if we can use technology as a double-edged sword and positively influence the quality of life of those mentioned above through it.

Approximately 5-6% of school-aged children and adolescents in Europe experience significant motor control and coordination difficulties. This is a serious problem because these children and adolescents are prone to sedentary behavior due to their lack of motor skills (Mahmoud et al., 2019; Mokmim & Jamiat, 2021).

Psychomotor development is very important for a teenager's motor and cognitive domains. Psychomotor skills play a key role in physical activity and sports participation in teenagers' day-to-day lives and can alter teenagers' behavior in a long-term commitment. (Trecroci et al., 2021) Improved coordination can translate into greater confidence and an increased likelihood of participating in physical activities. Students with motor coordination problems are less physically fit than students without problems (Smits-Engelsman et al., 2020). This has a clear effect on the health of the student and is directly related to the practice of physical activity (Ramón Otero & Ruiz Pérez, 2015). A good example of the usefulness of a good reaction time is when driving a car. Improving your reaction time can make you more alert, increasing the chances of avoiding or preventing a potential accident (Wang et al., 2015). Also a high level of physical fitness is important in labor market in almost any profession. (Manno, 2008; Kyrychenko et al., 2023)

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It`s being a known fact that children and teenagers like video games. Lately, there are more and more studies that use active video games or as they are also called exergames. Researchers are trying different ways to use them to positively influence the health of the subjects (Gao, 2017; Huang et al., 2017; Benzing & Schmidt, 2018). With the transition from sedentary to active games in recent experiments researchers observed significant benefits such as an increase in caloric expenditure, combating sedentary behavior and also these games showed improvement in athletic skills, coordination and reduction in reaction time (Staiano & Calvert, 2011; Rutkowski et al., 2021).

Virtual reality - technology can be a very important tool for researchers to use and to understand how this immersive technology can be used to improve the quality of life among people (Vaghetti et al., 2018; Zhou, 2020). Virtual reality has been defined as "the use of interactive simulations created with computer hardware and software to provide users with opportunities to engage with environments that look and feel similar to real-world objects and events (Lee et al., 2019)." According to Zhou (2020) - virtual reality technology creates immersive and highly controlled environments that seem to be real to users, replacing the sensory information we receive in the real world with stereoscopic visualization of the virtual world, audio feedback, and real-time synchronization of one's behaviors. (Zhou, 2020; de Back et al., 2020) A person using virtual reality equipment can look around the artificial world, move in it, and interact with virtual features or objects. The effect is typically created by VR headsets consisting of a head-mounted display with a small screen in front of the eyes (McClure & Schofield, 2020). Playing sports video games may be associated with higher levels of real-life sports involvement. For example, teenagers who play sports video games can find fun in them, learn the rules and strategy of various sports, and also experience the thrill of victory, thus increasing the chances of being involved in various sports in real life as well. (Adachi & Willoughby, 2015) Virtual reality through specific means - exergames or active video games, as they are also called, can be used as physical exercises and can represent a means to improve psychomotor skills and increase the physical activity of subjects (Gray, 2017; Barbosa et al., 2020).

Properly structured, dosed and planned this form of training could be a viable option to improve psychomotor skills. It is a proven fact that by improving psychomotor skills children will do more sports, with better skills the confidence in their own abilities increases (Diamond, 2012; Page et al., 2017). According to the results of the Syvaoja study, a high level of objectively measured moderate or vigorous physical activity was associated with good performance on the reaction time test, which measures children's reaction time and speed of response to a visual target. (Syväoja et al., 2014; Gidu et al., 2022)

In our study we focused on improving two important components of psychomotor skills: reaction time and eye-hand coordination. Reaction time is defined as the time interval between the appearance of a stimulus and the initiation of a response to it. Usually expressed in milliseconds (Garg et al., 2013; Akhani et al., 2015). Good reaction time allows us to be efficient when it comes to responding to external stimuli and situations such as sports, playing, driving or avoid falling. There are three types of experiments based on reaction time (Luce, 1986):

1. Simple reaction time: it requires a single response to a single stimulus (e.g. pressing a key on a computer when hearing a beep);
2. Recognition reaction time: requires a response only when certain stimuli appear (pressing a key on a computer only when the letter "x" appears on the screen, not when another letter appear;
3. Choice reaction time: the response must be appropriate to the stimulus (pressing the "space" key when the letter "x" appears on the screen and pressing the "enter" key when the letter "z" appears on the screen.

Eye-hand coordination can be defined as the ability to perform activities that require the simultaneous use of eyes and hands (Mayer & Caminiti, 2018). This is a complex cognitive skill, because it requires the hands to be guided according to the stimuli that the eyes receive (Rutkowski et al., 2021).

Little is known about the synaptic mechanisms behind visuomotor integration that underlie and are relevant to the coordinated transformation of movements. Despite this fact, there are quite a few studies in specialized literature that demonstrate the possibility of improving eye-hand coordination (Binkofski & Buccino, 2018; Patel & Bansal, 2018; Batmaz et al., 2020). In the cerebral cortex, functionally equivalent domains and their connections sculpt multiple systems, which are identified by combining information from anatomical connectivity and functional properties. These information processing systems encode different functions, which are, in order, visual processing, grasping the object and manipulating it, and recognizing the intention and actions of others (Mayer & Caminiti, 2018; Battaglia-Mayer & Caminiti, 2018).

Largely unexplored is understanding how the development of multiple health-related variables can synergistically impact each other to either positively or negatively influence health.

It is a known fact that psychomotor skills can be improved with real-world training. Our question is whether psychomotor skills can be improved in a virtual environment. This study aimed to analyze the effects of virtual environment training on the improvement of psychomotor skills such as reaction time and eye-hand coordination in high school students. The purpose of the study is to investigate the exercise program in the virtual environment in a relatively short period of time - 12 weeks, to track the effects on the eye-hand coordination and reaction time in high school students.

Material & methods

Participants

Sixteen children who met inclusion-exclusion criteria were selected from a high school in Cluj-Napoca. Their ages ranged from 17 to 19 years old. They were randomly selected into two equal number groups. Group 1 (n=8) (virtual reality – experimental group) including 4 males and 4 females managed virtual reality exergames. Group 2 (n=8) (control group) including 4 males and 4 females participate only in physical education lessons from school's curriculum.

Inclusion-exclusion criteria were:

-clinically healthy condition;

-only 11th and 12th grade students;

-not to be engaged in any sports or other organized form of physical exercise, not being trained in the use of video games.

The participants were informed about the risks of participating in the research, we also received the written consent of the students, respectively from parents or legal guardian in the case of minor students. The study adhered to the Declaration of Helsinki, ethical approval was obtained from The Scientific Council of the Babeș-Bolyai University of Cluj-Napoca on request submitted under the reference number: 1/ 03.01.2023.

Intervention

This intervention program involves motor and cognitive double-task performance, demanding motor coordination, attention, processing velocity, focus, decision-making capacity and memory to interact with a virtual environment. The intervention program had a duration of 12 weeks, with a frequency of twice a week, with 40 minutes for each session. In the ***Virtual reality exercises program*** we used HMD's Oculus Quest 2 created by Meta (Facebook Technologies, LLC. 1 Hacker Way, Menlo Park, CA 94025, USA). Participants from the control group participated only in physical education lessons from the school's curriculum. The intervention program took place in the gymnasium of the high school.

Means

Exergames require psychomotor skills like eye-hand coordination and quick reaction time (Staiano & Calvert, 2011). The exergames used in our intervention were Reakt, Thrill of Fight, OHShape and Eleven Table Tennis. According to the game's creators, "REAKT Performance Trainer is the first virtual mental skills training system. Based on technology originally developed for athletes, REAKT will make your brain work faster with intense training and competition modes" (Neurotrainer, 2021). Table tennis is characterized by perceptual uncertainty and time constraints. As a dynamic sport, it involves a constantly changing visual environment. Studies have shown that table tennis players have faster reaction times than non-table tennis players (Akhani et al., 2015; Assar et al., 2022).

Another means used is the active video game The Thrill of Fight, which represents boxing in the virtual environment. During a fight, subjects are constantly reacting to each other. Every dodge, punch and step taken by the opponent requires a quick reaction. For this reason, to fight, the participants must remain constantly focused on the opponent's movements and make quick decisions according to the circumstances (Polechoński & Langer, 2022). Skill-related components include speed, agility, strength, balance, coordination, and reaction time (Çakmakçı et al., 2019). Based on these, we included boxing in the virtual environment in the program to improve reaction time and eye-hand coordination.

Measures

The participants were tested before and after the application of the intervention program. For the evaluation of choice reaction time, we used Deary-Liewald Reaction Time Test (Deary et al., 2011) and for the evaluation of eye-hand coordination, we used Alternate-Hand Wall-Toss Test (Mackenzie, 2009).

For this experiment we chose to measure choice reaction time, we used the choice reaction time part of the Deary-Liewald test when four white squares are positioned in a horizontal line in the middle of the computer screen, set against a blue background. Four keys on a standard computer keyboard correspond to different squares. The position of the keys corresponds aligned with the position of the squares on the screen: the "z" key corresponds to the leftmost square, the "x" key to the second square from the left, the "comma" key to the second rightmost square, and the "period" key to the farthest square right. The stimulus is represented by the appearance of a cross within one of the squares. A cross appears randomly in one of the squares and the participants must respond as quickly as possible by pressing the corresponding key on the keyboard. The inter-stimulus interval varies between 1 and 3 s and is randomized within these limits (Deary et al., 2011).

Alternate-Hand Wall-Toss Test is a test of eye-hand coordination. A sign is placed 2 meters from the wall. The participant sits behind the line and faces the wall. A tennis ball is thrown with one hand towards the wall and must be caught with the opposite hand when returning from the wall. The ball is then thrown back to the wall and caught with the original hand. The test continues for 30 seconds (Mackenzie, 2009).

Statistical analysis

Descriptive statistics and t-test were conducted for comparison of subject characteristics between both groups. Independent T test was conducted to compare mean values of the measured variables between both groups and paired t test was conducted to compare between pre and post treatment mean values of the measured variables in each group. The level of significance for all statistical tests was set at $p < 0.05$. All statistical tests were performed through the statistical package for social sciences (SPSS) version 29 for windows (IBM SPSS, Chicago, IL,USA).

Results

A total of sixteen high school students, 8 females and 8 males, aged from 17 to 19 years old were included in this study. The participants were randomly chosen into two groups, the control group (CG), and the experimental group (EG), 4 females and 4 males respectively.

Reaction time was reduced and eye-hand coordination was improved in EG between baseline test and post-test. The differences were found statistically significant ($p<0.05$). (Table 1).

Table 1. Comparison between pre- and post-test in experimental group (EG).

Experimental Group (EG)		N	Mean	Std. Deviation	Mean Difference	t	df	p-value
Reaction time (AHWT Test)	Pre-test	8	24.75	3.012	-3.375	5.974	7	<.001*
	Post-test	8	28.13	2.696				
Eye-Hand coordination (Deary-Liewald Test)	Pre-test	8	412.38	35.238	31.375	7.961	7	<.001*
	Post-test	8	381.00	34.822				

*Significant differences p<0.05

Choice reaction time was reduced and eye-hand coordination was improved in CG. However, these differences were not found significant (Table 2).

Table 2. Choice reaction Time and Eye-Hand Coordination values between pre- and post-test in control group.

Control Group (CG)		N	Mean	Std. Deviation	Mean Difference	t	df	p-value
Reaction time (AHWT Test)	Pre-test	8	24.25	2.605	-.625	-1.667	7	.070
	Post-test	8	24.88	2.900				
Eye-Hand Coordination (Deary-Liewald Test)	Pre-test	8	416.50	37.394	4.125	1.729	7	.064
	Post-test	8	412.38	33.419				

N, number of subjects; t, t-value; df, degrees of freedom; p, p-value

There was not a significant difference ($p >.05$) in pre-test between experimental group and control group in reaction time and eye-hand coordination (Table 3). However, significant differences ($p <.05$) were found in reaction time and eye-hand coordination in post-test between EG and CG (Table 4).

Table 3. Comparison of pre-test between experimental and control group.

Pre-Test	Group	N	Mean	Std. Deviation	Mean Difference	t	df	p-value
Reaction time (AHWT test)	Experimental	8	24.75	3.012	.500	.355	14	.364
	Control	8	24.25	2.605				
Eye-Hand coordination (Deary-Liewald test)	Experimental	8	412.38	35.238	-4.125	-.227	14	.412
	Control	8	416.50	37.394				

N, number of subjects; t, t-value; df, degrees of freedom; p, p-value

Table 4. Comparison of post-test between experimental and control group.

Post-Test	Group	N	Mean	Std. Deviation	Mean Difference	t	df	p-value
Reaction time (AHWT test)	Experimental	8	28.13	2.696	3.250	2.322	14	.018*
	Control	8	24.88	2.900				
Eye-Hand coordination (Deary-Liewald test)	Experimental	8	381.00	34.822	-31.375	-1.839	14	.044*
	Control	8	412.38	33.419				

*Significant differences p<0.05

Dicussion

There are different mechanisms to explain faster reaction time after exergames intervention. This may be due to improved concentration, alertness and improved muscle coordination speed and precision (Garg et al., 2013).

The results from our study is in character with other studies from literature which demonstrate the possibility of using virtual reality (VR) means to reduce reaction time and also to improve eye-hand coordination (Barbosa et al., 2020; Tharani et al., 2020; Amprasi et al., 2021; Rutkowski et al., 2021).

Amprasi et al. (2021) used a fully immersive virtual environment (FIVE) to improve reaction time. Different from our study this study used young athletes-volleyball players, all females(n=48) their ages ranges beetwen 8 to 10 years old. Duration of the study was 6 weeks with a frequence of two trainings per week, 24 minutes each time. Playstation4 was the VR platform used by subjecsts of the FIVE group. The study revealed reduction in reaction time. (Amprasi et al., 2021) VR training programme of Rutkowski et al. (2021) demostred that VR programmes are not only for athletes but for musicians also.

They revealed an improvement in hand–eye coordination and a reduced reaction time after the intervention program. The authors said that an improvement in hand–eye coordination and a faster reaction time could help the musicians in mastering the instruments. (Rutkowski et al., 2021) Barbosa et al. (2020) showed that virtual reality can be used to break sedentarism. They observed that activities in virtual environment increased participants heart rate. They also reavealed an improvement in simple reaction time after intervention program. Interestingly, according to Adachi & Willoughby (2015) playing sports video games may be associated with higher levels of real-life sports involvement. (Adachi & Willoughby, 2015; Barbosa et al., 2020)

Petri et al. (2019) creates an avatar based on real international successful karate kumite athletes, to build the avatar the five karate experts conducted several attacks. Each attack was recorded for the creation of the virtual attacker. 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.

Several reaction times were subtracted to analyse the movement of the attacker to the time of the recognition by the reacting athlete to find out relevant movement stages which contain anticipatory cues. These new findings can be used in karate training to improve motor learning in beginners to enhance performance. (Petri et al., 2019)

Another virtual reality based study, single group designed with a duration of 4 weeks, 3 days/week, 20 minutes per session found post-intervention reduction in auditory and visual reaction time (Tharani et al., 2020).

Gray (2017) used a virtual environment based on baseball batting. The participants in the study were 80 male baseball players with age ranges between 17 to 18 years old. This study demonstrates that practice of baseball batting in a virtual environment could transfer the perceptual-motor skills to real baseball performance. Virtual environment training, lead to significant improvements in 7/8 of the batting performance assessments. (Gray, 2017) Like we have seen above the majority of studies used athletes.

However, this study shows that a well-structured 12-week virtual reality program can improve high school students' eye-hand coordination and reaction time. Besides the small number of participants and the relatively short time dedicated to the intervention, the present study has other limitations, such as the lack of medium and long-term verification of the subjects' participation in different physical activities, if the intervention program had the effect of a greater involvement in physical activities. Future studies should focus on these issues.

Conclusions

The day-by-day improvement of technology helps researchers study its effects on humans. The emerging technology of virtual reality allows us to explore how to better promote a healthy and active lifestyle among people. Real-world training and virtual environment training with exergames showed to be effective strategies for improving psychomotor skills such as reaction time and eye-hand coordination in high school students. However, virtual reality training with exergames was more effective in reducing choice reaction time and improving eye-hand coordination than physical education lessons from the school's curriculum in high school students.

Virtual reality programs properly structured, dosed, and planned are a viable option to improve psychomotor skills.

The researchers must focus their work on large numbers of populations for a better understanding of the effects of virtual reality programs on reaction time, eye-hand coordination, and other psychomotor skills.

Through our study, we managed to demonstrate that an exercise program in virtual reality can improve the reaction time and eye-hand coordination of high school students. Future studies must focus on the practical establishment of these improvements, their effects must be clearly established, if they contribute to increasing the physical activity of students.

Conflicts of interest - Authors declare don´t have any conflicts of interest.

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