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Virtual Reality-Based Exercise Reduces Children's Simple Reaction Time

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Abstract Evidence has been showing the benefits of virtual reality-based exercise (exergames) on children's cognitive and behavioural performance. The objective of this research is to investigate the acute effect of one session of virtual reality - based exercises on children's simple and complex reaction time. This investigation comprised 17 basic school students (10±11 yrs.) from a school of Montes Claros, Minas Gerais, Brazil. One exergames session has been conducted using the package Wii Sports Resort: games: Sword Play Speed Slice and Table Tennis. Students were assessed pre and post session: 1. Heart rate (HR) at rest and during the activities measured by Heart Rate Monitor; 2. Reaction time and choice time in seconds, obtained with Reaction Time Task v.2.0 software. Paired t-Test ($p \leq 0,05$) was performed to compare dependent variables (pre and post session). Additionally, Cohen's d effect size estimation was used to assess differences. Students reduced simple reaction time from 1.04 ± 0.22s to 0.93 ± 0.19s after exergames session ($t = 2.39$, $df = 16$, $p = 0.02$), with a moderate effect size (Cohen's $d = -0.48$), showing an increasing on data processing velocity. Choice time remained unchanged (pre = 1.26 ± 0.50 s; and post = 1.06 ± 0.19 s) ($t = 0.89$, $df = 16$, $p = 0.38$), with small effect size (Cohen's $d = -0.39$). During exergames HR varied from 75 to a 129 bpm (36 to 61% of $HR_{Maximum}$ – light to moderate). A single exergames session reduces acutely simple reaction time of basic school students.

Keywords Cognition, Active video game, Physical activity

1. Introduction

Cognitive functions are structured brain activities that allow learning and the formulation of human behaviour. It can be divided into memory, attention, language, temporal and spatial perception, data processing velocity and executive functions (Tomporowski et al., 2011).

The most significant manner of stimulating cognitive functions is through the learning of new abilities and task solving (Donnelly et al., 2016). During child development, cognition is stimulated through movements and environment exploration (Ferreira-Vasques & Lamônica, 2015). The learning of new motor tasks demands a cortical- subcortical management, which stimulates the consolidation of either neural cognitive and motor circuits (Monteiro-Junior et al., 2016).

Evidence has been showing the relationship between physical activity and basic school children 's learning performance (Tomporowski et al., 2011; Davis et al., 2011; Donnelly et al., 2016). A recent study has shown that moderate intensity exercise improves significantly children's cognition, especially executive planning functions, inhibitory control, operational memory, among others (Samuel et al., 2017). Therefore, to perform activities that stimulate children's movement might be a useful strategy to stimulate children's cognitive improvement.

Currently, virtual reality connected to exercises (exergames) has been gaining prominence in the scientific community. This intervention involves motor and cognitive double - task performance, demanding mainly, motor coordination, attention, focus, processing velocity, memory and decision making to interact with virtual environment (Pichierri et al., 2012). Exergames, besides holding an overview on the promotion of physical activity, could be used to boost cognitive processes and motivation on the

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educational scope, thus presenting results on students' future social life, moral and aesthetics (Granic et al., 2014). However, it is not clear if short-term stimuli might acutely improve children's cognition.

Therefore, this study aimed the analysis of the acute effect of one virtual reality-based exercise session upon the Simple Reaction Time (SRT) and Complex Reaction Time (CRT) in children.

2. Methods

Participated in the study 17 basic schoolchildren (3rd to 5th grades, aged between 9 and 13 yrs.) of a public school located on Montes Claros, Minas Gerais, Brazil's Southeast region. Participants were allocated to the study by convenience. All participants participated voluntarily in this research, after their parents or guardians have signed the Informed Consent. Participants also signed the Informed Consent to participate in the research.

Individuals met the inclusion criteria (enrolment at basic school 1 and exhibit preserved communication skill) and exclusion criteria (not allowed by parents or guardians, exhibit diagnosed behavioural disorder, neurologic and/or cardiovascular diseases). The study was approved by the Ethics Committee of the State University of Montes Claros (n.1.970.139/2017).

We assessed HR, cognitive tests and subjective perception of virtual games. HR was monitored at rest, during exergames performance and immediately after the intervention. We used a HR monitor GPulse® (Taichung City, Taiwan). To rest assessment, participant remained seated the quietest possible for five min, while we inputted the last HR value. After, participants started the activity.

SRT and CRT are directly associated to attention and executive functions, inhibitory control, decision making and cognitive flexibility (Jakobsen et al., 2011). Thus, cognitive functions were evaluated according to STR and CTR. We used Reaction Time® v. 2. 0 software, which presented until eight letters of the alphabet on the screen (A, S, D, F, H, J, K, L), colours (grey, pink, yellow, red, blue, orange, green and purple) and numbers (1, 2, 3, 4, 5, 6, 7, 8). Each letter on the screen had its corresponding key on the keyboard. To evaluate STR, letter H was selected, while to CTR were selected four letter options, DFHJ, to remain on the screen. One of these letters randomly appeared on the screen display top centre. Participant was guided to remain attentive, and when a letter came into sight, it should press the corresponding key the fastest possible. Time was estimated by the software in seconds. A previous familiarization was conducted before the session. Immediately after cognitive assessment, participants responded a questionnaire reporting their satisfaction with exergames and that if they would like to have these activities in school classes. Reaction Time® v. 2. Software 0 was designed by the Group of Studies and Research in Development and Motor Learning of the State University of Londrina.

Participants performed individually a virtual reality-based exercise session. Games used were: "Sword Play Speed Slice" and "Table Tennis", both from Wii Sports Resort package, Nintendo Wii (table 1).

Table 1. Exergames Description

Package	Game	Description
Wii Sports Resort	1. Sword Play Speed Slice	Participants stand up holding the Wii Motion (control with accelerometer) in the virtual environment. Participants are represented by an avatar (virtual character) grasping a sword. There is a virtual referee who throws objects in front of the avatar, and immediately after the throwing arrows appear on the screen pointing to the direction the objects must be cut. To win, participant must cut the largest quantity of objects, before the opponent, in the right direction.
Wii Sports Resort	2. Table Tennis	This virtual game simulates table tennis. Participants are represented by avatars, one in each extremity of the table. The screen is divided in the middle to allow each participant to have a better sense of space. Movements are similar to a real table tennis, with the same goal: pass the ball to the opponent's field, it touches the table and the opponent is unable to play it back.

We verified normality and homoscedasticity of the data to perform the parametric test. Therefore, Paired t-Test was conducted to compare reaction time and choice time pre and post exergame session. Significance level was established $p \leq 0.05$ and we used SPSS 22. Additionally, Cohen's effect size was calculated to estimate pre and post intervention differences assuming the following classification: trivial (0-0.19), small (0.2-0.39), moderate (0.4-0.79), and large (≥0.8) (Cohen, 1992).

3. Results

Participants mean age was 9.71±1.27 yrs., and 16 individuals were dominant right-handed. Children reduced reaction time from (1.04 ± 0.22 s) to (0.93 ± 0.19 s) after exergames session ($t = 2.39$, $df = 16$, $p = 0.02$) (Table 2), with a moderate effect size (Cohen's $d = -0.48$), showing an improvement on data processing velocity. Although the reduction of choice time, no statistical difference was found on this variable in the comparison between pre (1.26 ± 0.50 s) and post session (1.06 ± 0.19 s) ($t = 0.89$, $df = 16$, $p = 0.38$). A small effect size was found on the reduction of choice time (Cohen's $d = -0.39$). HR during exergames shifted from 75 to 129 bpm (36 to 61% of HR_{max}, light to moderate intensity). The children, when questioned if they had a good time and if they would like to have exergames activity in the Physical Education classes, all of them responded affirmatively, except one. Mean time of game was 9.65±1.33 min.

Table 2. Descriptive results (mean ± standard deviation) and inference of variables analyzed

	Pre	Post	*p*	Cohen's d	Classification
SRT	1.04 ± 0.22	0.93 ± 0.19	0.02	-0.48	Moderate
CRT	1.26 ± 0.50	1.06 ± 0.15	0.38	-0.39	Small
HR	97.59 ±10.88	102.94 ±11.03	-	-	-

SRT: Simple Reaction Time, CRT: Complex Reaction Time, HR: Heart Rate.

4. Discussion

This study analysed the acute effect of one virtual reality-based exercise session (exergames) on children's cognitive function. The 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.

SRT can be divided into two distinct phases: in the first phase, called pre-motor or pre-tension, the stimulus decoding occurs until the awareness of the first muscle electric activities performed by the peripheral nervous system; in motor or tension phase (second phase) muscle cells start the process of muscle contraction until the first movement. Vernadakis et al., (2015) investigated the training effects with exergames over motor variables, such as object control. These researchers have concluded that these findings hold a relationship with the immersive capacity of videogames, which allows the player an enlarged feedback, i.e., a visual feedback over the score. Therefore, it is believed that visual stimulus of virtual reality, represented by gameplay feedback, is a sufficiently strong stimulus to operate changes in SRT.

SRT is an important variable associated to the ability of processing information (Moradi & Esmaeilzadeh, 2017). Researches have been showing that physical exercise enables an improvement on cognitive performance and the reduction of reaction time (Chaddock et al., 2010; Voss et al., 2011). Only one exercise session can present positive results on the improvement of cognitive performance (Johnson et al., 2016). An investigation with adolescents has shown that acute physical activity with exergames holds a high level of cognitive involvement, which provides better results on the performance of cognitive flexibility when compared to the same activity with the same intensity, but with videogames holding a low level of cognitive involvement (Benzing et al., 2016). The investigation sustains that acute physical exercise improves the executive function in children, adolescents and adults (Verburgh et al., 2014), which emphasizes the importance of exercise over the cognition.

As exergames demand a double task, they provide an increasing on brain activity related to attention and memory (Delbroek et al., 2017). This effect, the result of interaction with the virtual environment, can provide an improvement on students' cognitive development (Staiano & Calvert, 2011; Flynn et al., 2014; Benzing et al., 2016). Cortical modulation is associated to the acute changes on brain blood flow (Hoffmann et al., 2018), which can correlate with a better acute cognitive performance. Hence, despite the need of further researches that investigate neurobiological and neuro physiological mechanisms involved on the exergames use, we suggest that acute neurofunctional effects might occur.

Vaghetti et al., (2017) investigated in a systematic review the use of exergames in school environment. Findings have showed that, although scarce studies had assessed the effect of exergames on the cognitive aspects, the use of this kind of virtual reality at school can boost physical activity levels, change anthropometric variables and increase motivation in Physical Education classes, contributing for positive cognitive results in school performance.

Tasks required by exergames are open motor skills, on most part of the games, and demand the players higher executive functions, which might be related to a higher cortical stimulus. (Monteiro-Junior et al., 2016; Choi et al., 2015). Hence, the findings of this study evidence a potential use of this kind of intervention, as an additional resource in school Physical Education classes.

Exergame is a new, low- cost technology that holds a great fascination upon users (O'leary et al., 2011; Maillot et al., 2012). The perception mechanism supplied by virtual environment can stimulate sensor-motor skills. The use of exergames as a technical- pedagogical resource connected to modern technology can draw attention and enhance academic performance (Staiano et al., 2012; Flynn et al., 2014; Ferreira & Francisco, 2017). The literature emphasizes that exercise with virtual reality might significantly work in the prevention of obesity (Lu et al., 2012; Staiano et al., 2013; Trost et al., 2014), which is a serious problem of public health. An investigation with obese children has depicted that a session with exergames can improve cardiovascular response (Da Costa et al., 2017). Consequently, interventions with this technology could reduce other health problems at school.

In the literature, there are studies investigating the effect of computer games on reaction time (Corbetta et al., 2015), but there are few studies investigate the effect of exergaming on reaction time.

5. Conclusions

One session of exergames increased the simple reaction time of basic school children, maintaining the effort with light to moderate intensity. The practical applications as an outcome of this study indicate that the decrease in reaction time represents changes in neuromuscular coordination and consequently improve the performance in the task. It brings new perspectives to stimulate cognitive functions in children but the study should be replicated.

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