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The impact of a Full Immersive Virtual Reality intervention on children's reaction time

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Abstract

The purpose of this study was to examine whether there is a difference between a Full Immersive Virtual Reality-based and a typical training program, in female volleyball players aged 8-10 years old. In addition, the children's mood experience while playing Full Immersive Virtual Environments (FIVE) games compared to Typical Training (TT) was also investigated. Forty-eight female volleyball players were randomly divided into three individual groups of 16 players each, one Control Group (CG) and two experimental groups (FIVE, TT). The CG did not receive any structured RT training program, while the two experimental groups performed a specific RT training program for eight weeks, twice per week and 24 min per session. The "Reaction Test" of Vienna Test System was used to assess the RT of the participants at the pre-test, post-test and retention test. At the post-test, participants of two experimental groups completed the variable "mood experience" of the Greek version of the English self –report questionnaire of Ho, Lwin, Sng and Yee (2017). Two-Way (3X3) analyses of variance with repeated measures were conducted to determine the effect of training program groups and measurements across time on RT performance. Furthermore, an independent samples t–test was conducted to compare participants' mood experience between the FIVE and the TT groups. Analysis of the data illustrated that the post-test RT scores and the one-month retention test RT scores were remarkably greater than pre-test RT scores for both experimental groups and not for the CG. In addition, both experimental groups' scores on mood experience were high. Conclusively, findings suggest that the use of FIVE as an intervention is a valuable, feasible and pleasant approach in order to improve RT of female volleyball players.

Keywords: Full Immersive Virtual Reality; reaction time; mood experience; volleyball

1 Introduction

The role of Physical Education Scientists (PES) and coaches is the constant research for the right methods that are pleasant and valuable to participants, in order to achieve high performance in specific movements (skills). It is a fact that the level of capability of each individual in a skill is linked to the quantity and the quality of skill practicing (Schmidt & Lee, 1999). It is therefore necessary to identify the methods in which individuals could train their abilities, that affect skills improvement.

Virtual Reality (VR) is a global term that is very often used to describe a predominantly visual-based computer simulation of a real or imaginary environment (Craig, 2013) and is often ranked by how much immersion this technology can induce (Araiza-Alba, Keane, Chen, & Kaufman, 2021). Full immersive VR systems allow the user to be situated inside the computer-generated environment and to interact with the

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environment through physical gestures or movements (Araiza-Alba et al., 2021). A technology that can provide an immersive experience is a stereoscopic Head Mounted Display (HMD) with a head tracking device which is attached to the participant's head (Craig, 2013; Slater & Sanchez-Vives, 2016). This technology provides wide field of view, full stereoscopic imagery and translational and rotational viewpoint control. Specifically, HMD technology puts the displays close to the eyes (Slater & Sanchez-Vives, 2016) delivering two computer-generated images, one for each eye.

All the aforementioned, establish the VR as a powerful tool for the achievement of authentic experience, differing from other forms of human–computer interface since the user participates in the virtual world rather than uses it (Slater & Sanchez-Vives, 2016). Furthermore, full immersive VR is an innovative technology, which provides a different way of training as has been linked to numerous advantages, such as increasing motivation (Ryan, Rigby, & Przybylski, 2006) and reproduction of a realistic and controlled environment (Akbas, Marszatek, Kamieniarz, Polechonski, Stomka, & Juras, 2019). Moreover, another advantage of VR use is that VR can be used during lockdown period as we lived due to Covid -19 (Garcia, Birckhead, Krishnamurthy, Sackman, Mackey, Louis, Salmasi, Maddox, & Darnall, 2021; Siani & Marley, 2021) and finally can help athletes and players with injuries to maintain their Perceptual Abilities (PA) (Craig, 2013).

A high level of PA is required for successful sport performance, except of efficient execution of motor behavior (Kulpa, Bideau, & Brault, 2013; Mori, Ohtani, & Imanaka, 2002). PA refer to the ability to predict what is likely to happen prior to the event itself (Piras, Lobietti, & Squatrito, 2014). Reaction Time (RT) belongs to PA and refers to the quick and correct reaction. Specifically, depending on the number of stimuli and possible responses, the RT is classified into three categories the Simple Reaction Time (SRT), Choice Reaction Time (CRT) and Discrimination Reaction Time (DRT) (Rose, 1998). Therefore, the aforementioned dominates during the execution of many open skills or sports.

Volleyball is an open sport with a variable environment, that is to say, difficult to predict. Consequently, the motor performance is directly related to the capacities of foreseeing and answering the alterations that happened in the environment (Fontani, Lodi, Felici, Migliorini, & Corradeschi, 2006; Fontani, Maffei, Cameli & Polidori, 1999). The ability to recall and recognize an evolving pattern of play is the strongest predictor of anticipatory skill. Therefore, the high level of PA is a very determining factor for volleyball players' performance (Zwierko, Osiński, Lubiński, Czepita, & Florkiewicz, 2010). In addition, many studies indicate that volleyball players have shorter SRT (Barcelos, Morales, Maciel, Azevedo, & Silva, 2009; Zwierko et al., 2010), CRT (Zwierko et al., 2010) and DRT (Barcelos et al., 2009) compared to non –athletes.

RT is influenced by a number of factors, such as training and age (Tzetzis & Lola, 2015). Furthermore, many researchers argue that systematic typical training can shorten RT (Ando, Kida, & Oda, 2002; Πολιτόπουλος, 2015), others that systematic typical training can increase RT (Brisswalter, Arcelni, Audiffren, & Delignieres, 1997; Williams, Pottinger, & Shapcott, 1985) and others that systematic typical training can exert no effect to RT (Brisswalter et al., 1997; Tsorbatzoudis, Barkoukis, Dadis, & Grouios, 1998). Studies in the literature have indicated an improvement on SRT (Balkó, Rous, Balkó, Hnízdil, & Borysiuk, 2017; Wang, 2009; Χατζηθεοδώρου, 2008) and CRT (Balkó et al., 2017) after exercising with typical training. Moreover, volleyball players have shorter SRT (Barcelos et al., 2009; Zwierko et al., 2010), CRT (Zwierko et al., 2010) and DRT (Barcelos et al., 2009) than non –athletes.

Except of typical training programs, VR –based training programs can, also, improve attention skills (Satyen & Ohtsuka, 2001; Green & Bavelier, 2003) such as RT suggesting an alternative way of developing them. After engagement with VR –based training program, children with cerebral palsy reduced RT (Pourazar, Mirakhori, Hemayattalab, & Bagherzadeh, 2018), people with intellectual disabilities reduced CRT (Standen & Ip, 2002) and elderly improved balance and SRT (Bisson, Contant, Sveistrup, & Lajoie, 2007). Additionally, research has shown that the VR engagement can enhance the mood experience, as has found to be an enjoyable experience (Byrne & Furness, 1994; Goodyear, Skinner, Mckeever, & Griffiths, 2021; Ijaz, Wang, Ahmadpour, & Calvo, 2017; Liu, Wang, Tang, & Liu, 2020;), fun to play (Evans, Naugle, Kaleth, Arnold, & Naugle, 2021; Lee & Park, 2020; Taylor, 1997), as well as mood improvement (Lieberman, 2006; Russell & Newton, 2008; Vidal-Balea, Blano –Novoa, Fraga –Lamas, & Fernandez –Carames, 2021), especially younger ages (Osberg, 1995).

The afore-presented review of the literature suggests that the few FIVE –based interventions that have been conducted thus far with a view to improving RT development: a) were mainly targeted at children or adolescents with clinical conditions and not at healthy young athletes (Pourazar et al., 2018; Standen & Ip, 2002, b) did not provide any evidence on the long-term effects of FIVE on RT development and c) to the best of the authors' knowledge, no study to date has addressed the use of the newer generation FIVE exergames as a form of exercise for the development of RT in young healthy athletes, examining both short-term and long-term effects of this use on children's RT development. The study presented in this paper is original, as attempts to fill in this gap in the research literature.

The purpose of this study was to examine whether there is a difference between two RT intervention programs in female volleyball players aged 8-10 years old: a Full Immersive Virtual Reality-based and a RT typical training program. In addition, the children's mood experience while playing FIVE games compared to TT was also investigated. The study involved three groups: the FIVE group, the TT group, and a CG. The children's RT was assessed through RT tests before the interventions (pre-test), after the intervention sessions (post –test) and one month following the interventions (1-month retention test). More specifically, the study examined the following research questions:

(1) Are there any differences in mean RT test scores between the FIVE, the TT and the CG?
(2) Do children, on average, report differently on the RT test for the pre-test, post-test and 1-month retention test measurements?
(3) Do the differences in means for the RT test between the FIVE, the TT and the CG vary between the pre-test, post-test and 1-month retention test measurements?
(4) Does the average amount of children's mood experience differ between the FIVE and the TT groups in the post –test?

The study can offer the international research community useful guidance regarding the effectiveness or ineffectiveness of FIVE as vehicle for improving RT development and conferring mood experience during RT training among female young volleyball athletes.

2 Method

2.1 Method

Research involved forty–eight (n=48) female volleyball players. The age of players ranged from 8 to 10 years old (Mean 9.27±0.77 yrs) and they had been playing volleyball for at least a year. The sampling frame used for this study was self-selected sampling. Participants were randomly divided into three individual groups of 16 children each, one Control Group (CG) and two experimental groups (FIVE and TT). Prior to group assignments, children whose parents had expressed interest in participating in the study were screened to ensure that they were willing to participate, after being informed regarding the study requirements and being checked against the inclusion and exclusion criteria. Inclusion criteria were: aged 8 to 10 years at start of study, able to attend all the classes of the intervention program and able to use FIVE. The exclusion criterion was a current clinically severe illness or disorder making it impossible to perform the intervention program. Informed consent was obtained from each parent prior to a child's voluntary participation in the study.

2.2 Procedure

Prior to data collection, the parent permission forms and the child assent forms regarding participation in the study were gathered. Once all permissions were obtained, pre-tests were conducted. A random assignment was then performed to create a CG and two experimental groups for the study (FIVE and TT). The CG did not receive any structured RT training program, while the two experimental groups (FIVE and TT) performed a specific RT training program for eight weeks, twice per week, 24 min per session. Post-tests assessments were conducted at the end of the intervention sessions, where the participants of two experimental groups completed the variable "mood experience" of the Greek version of the English self –report questionnaire of Ho and colleagues (2017) (Appendix A). The retention test assessments were conducted one month after the interventions. The overall study design is presented in Figure 1.

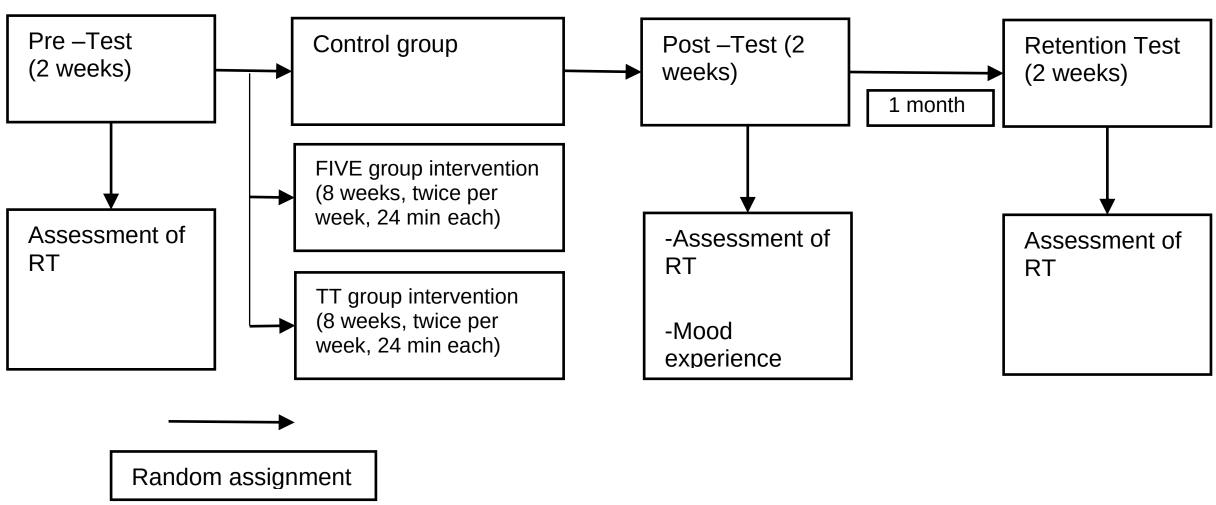


Figure 1. The overall study design

2.3 Instruments

2.3.1 Reaction Time tests

2.3.1.1 Simple Reaction Time test

The “Reaction Test” of the Vienna Test System (Schuhfried, 1989) was used to evaluate SRT in visual stimulus. Children had to react to the appearance of a visual stimulus (red light) by pressing the red button with the index finger of their dominant hand. The number of the reactions /answers and the RT in seconds were recorded. The attempts that were given were two trials and 13 regular. The variable evaluated was the average RT of 13 attempts (sec). The degree of test reliability for SRT was r= .98 (Schuhfried, 1989).

2.3.1.2 Choice Reaction Time test

The “Determination Test” of the VIENNA Test Instrument System (Schuhfried, 1996) was used for the evaluation of the CRT. Children were sitting in front of a computer monitor and had to respond to each of the seven visual and two auditory stimuli displayed. The visual stimuli were five circles of different colors. The auditory stimuli were two white circles with two different frequency sounds, each corresponding to left and right leg (2400-2000 Hz/ min). The frequency of stimuli was determined by the response rate of each child. The test started after the training phase and lasted four minutes. The variable evaluated was the mean response time of the correct answers (msec). The degree of test reliability for CRT was r= .89.

2.3.1.3 Discrimination Reaction Time test

The “Reaction Test” of the Vienna Test System WTS 630 was used for the evaluation of DRT. The assessment of DRT included one response of two visual stimuli. Children were sitting in front of a computer monitor and had the index finger of their dominant hand on the start button. Each time the visual stimulus (yellow light) appeared on the monitor, the children had to press the yellow button as fast as possible with the index finger of their dominant hand. Prior to the test, children had 9 trials (in five stimuli had to respond) and then recorded the number and the mean of the reaction time of 19 attempts (in 9 stimuli had to respond). The variable evaluated was the mean response reaction time of responses (msec). The degree of test reliability for DRT was r= .90.

2.3.2 Questionnaire

The variable “mood experience” of the Greek version of the English self –report questionnaire of Ho et al. (2017) was used. The Greek version of this questionnaire was translated and tasted for validity and reliability from Syropoulou, Amprasi, Karageorgopoulou and Giannousi (2017). The variable “mood experience”, that used, measured using an inventory of four emotive responses toward games adapted from Ryan et al. (2006) and Diener and Emmons (1984). Children were asked to rate whether four adjectives (active, energetic, excited, and lively) described their experience on a 5-point scale, anchored on “does not describe” (1) to “accurately describes.” The Cronbach's alpha for mood experience was 0.86.

2.4 Statistics

To perform analyses of the study's data, the SPSS 23.0 (Statistical Package for the Social Sciences) for Windows was used. Prior to analysis, data were screened for violations of statistical assumptions, and no violations were detected (Green & Salkind, 2013). A two-way (3X3) analysis of variance (ANOVA) with repeated measures was conducted to evaluate the effect of training programs and measurements across time on RT performance. The dependent variable was RT (simple, choice, discriminant) test scores. The within-individuals factors were training program groups with three levels (FIVE, TT and CG) and time with three levels (pre-test, post-test and one –month retention test). The Training programs x Time interaction effect, as well as the Training programs and Time main effect, were tested using the multivariate criterion of Wilks's lambda (L). Significant differences between the means across time were tested at the 0.05 alpha level. An effect size was computed for each analysis using the eta-squared statistic (η^2) to assess the practical significance of findings. Cohen's guidelines were used to interpret η^2 effect size: 0.01=small, 0.06=medium and 0.14=large (Cohen,1988). Furthermore, an independent samples t –test was conducted to compare participants' mood experience between the FIVE and the TT groups. The dependent variables were the mood experience scores.

The hypotheses of this study were:

H1. The three groups of children (FIVE, TT, CG) will not differ significantly on measure of RT at pre-test.

H2. The children in both experimental groups (FIVE and TT) would improve and retain their RT, in contrast with those in the CG.

H3. The effect of the FIVE training approach on mood experience would be stronger than that of the TT approach.

3 Results

3.1 Initial measurements

A One –Way Analysis of Variance was conducted to evaluate Hypothesis I (that the three groups of participants would not differ significantly on measure of three categories of RT at pre-test). Indeed, there were no significant initial differences between the three groups in the mean RT test scores, SRT: $F_{(2,45)}=0.386$, $p>.05$, CRT: $F_{(2,45)}=3.103$, $p>.05$ and DRT: $F_{(2,45)}=0.569$, $p>.05$.

3.2 Reaction time results

Two –Way Analysis of Variance (ANOVA) with repeated measures was conducted to evaluate the Hypothesis II (that participants in both the FIVE and the TT groups would improve and retain their RT, in contrast with those in the CG). The hypothesis was corroborated.

Table 1. Pre, Post and Retention test of SRT, CRT and DRT.

		FIVE *n*=16		TT *n*=16		CG *n*=16	
		M	*SD*	*M*	*SD*	*M*	*SD*
SRT (msec)	Pre –test	.56	.07	.58	.08	.57	.08
	Post –test	.51	.07	.51	.09	.58	.08
	1 –month ret test	.53	.08	.51	.09	.57	.08
CRT	Pre –test	1.69	.14	1.58	.14	1.61	.12
(msec)	Post –test	1.54	.21	1.51	.16	1.61	.14

	1 –month ret test	1.43	.19	1.39	.17	1.64	.16
DRT (msec)	Pre –test	.72	.21	.77	.10	.76	.10
	Post –test	.65	.12	.69	.14	.78	.11
	1 –month ret test	.66	.13	.66	.12	.73	.21

3.2.1 Simple Reaction Time

There was no significant main effect on SRT, $F_{(2,45)}$=2.646, p>.05, partial η^2 = .105, while the training programs × mean of SRT interaction effect was significant, *Wilks'Λ* =.854, *F*(2,44)= 3.760, *p* <.05, partial η^2 = .146. The univariate test associated with the Group's main effect was not significant as well, *Wilks'Λ* =.866, *F*(4,88) = 1.639, *p* >.05, partial η^2 = .069. Pairwise comparisons using t-test with a LSD adjustment revealed significant mean differences in SRT between pre –test and post –test test (*MD* = .076, *p*< .05, 95% CI: .009 to .143) and between pre –test and retention test (*MD* = .069, *p*< .05, 95% CI: .006 to .131) in TT group. As shown in Figure 2, the post-test in SRT scores and the 1-month retention test in SRT scores were remarkably lower than pre-test in SRT scores for both experimental groups, but not for CG.

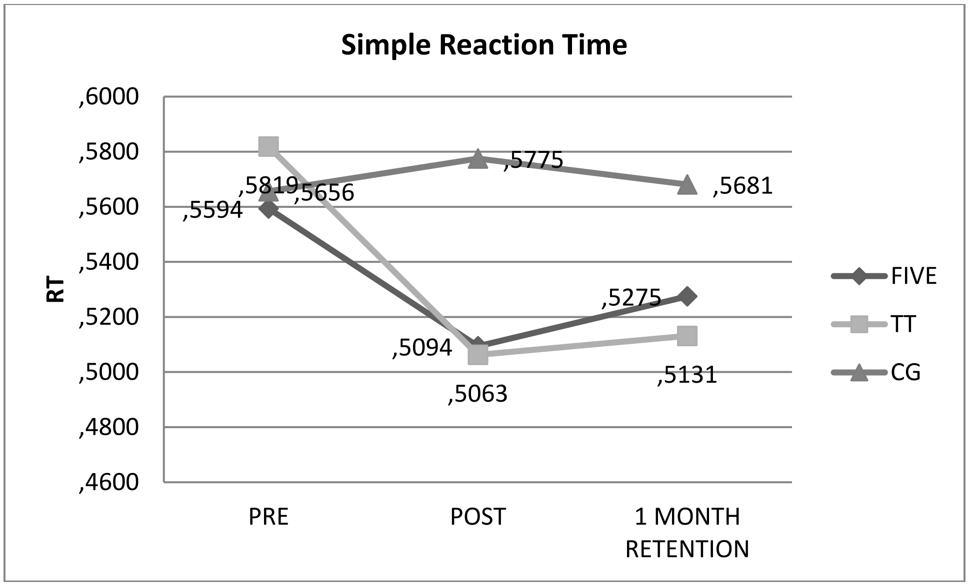


Figure 2. Performance on all measurements across time of the SRT ability test of the three groups.

3.2.2 Choice Reaction Time

A significant main effect was noted for CRT *F*(2, 45) = 4.041, *p* <.05, partial η^2 = .152 while the training programs × CRT interaction effect was significant, *Wilks'Λ* =.642, *F*(4,90) = 5.454, *p* <.05, partial η^2 = .199. The univariate test associated with the Group's main effect was significant as well, *Wilks' Λ* = .594, *F*(2,44) = 15.049, *p* <.05, partial η^2 = .406. Analyzing the interaction on the CRT for each level of the independent variable, a significant effect of the repeated factor Time was found for the FIVE group, *Wilks' Λ*= .566, *F*(2, 44) = 16.890, *p* <.05, partial η^2 = .434 and the TT group, *Wilks' Λ = .692, F*(2, 44) = 9.814, *p* <.05, partial η^2 = .308. Pairwise comparisons using t-test with a Bonferroni adjustment revealed significant mean differences in CRT between pre –test and post –test (*MD* = .153, $p < .05$, 95% CI: .049 to .256), between pre –test and retention test (*MD* = .256, $p<.05$, 95% CI: .147 to .364) and between post –test and retention test (*MD* = .103, $p< .05$, 95% CI: .004 to .202) in FIVE group. Similarly, significant mean differences in CRT were found between pre-test and retention test (*MD* = .189, $p <.05$, 95% CI: .080 to .297) and between post –test and retention test (*MD* = .127, $p <.05$, 95% CI: .028 to .226) in TT group. As shown in Figure 3, the retention test RT was remarkably higher than pre-test CRT scores for both experimental groups, but not for CG.

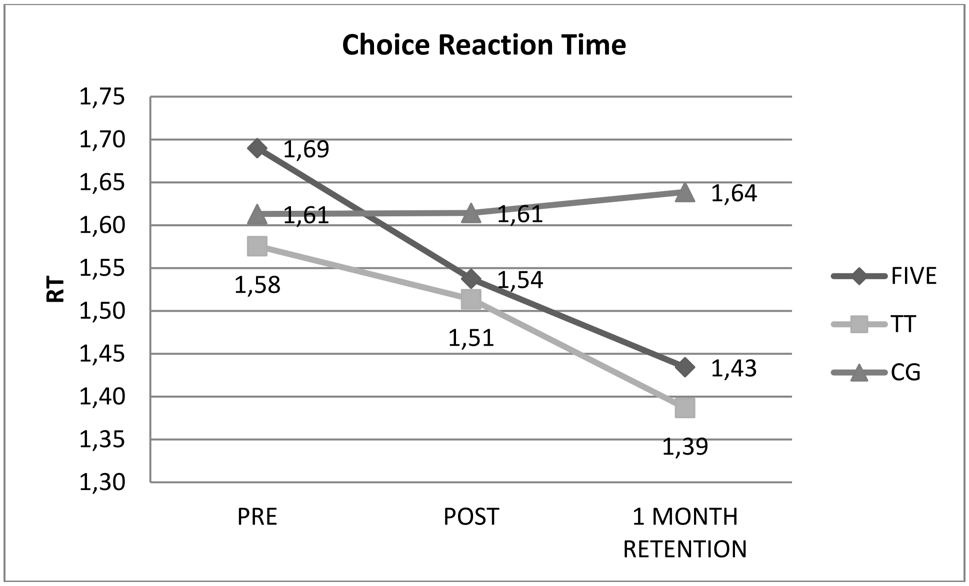


Figure 3. Performance on all measurements across time of the CRT ability test of the three groups.

3.2.3 Discrimination Reaction Time

There was no significant main effect for DRT, $F_{(2,45)}$=2.825, p>.05, partial $\eta^2 = .112$, while the training programs × DRT effect was also not significant, $F_{(1.865,83.913)} = 3.183$, $p = .05$, partial $\eta^2 = .066$. The univariate test associated with the Group's main effect was not significant as well, $F_{(4,90)} = .872$, $p >.05$, partial $\eta^2 = .037$. As shown in Figure 4, the post-test in DRT scores and the 1-month retention test in DRT scores were lower than pre-test in DRT scores for both experimental groups but were not statistically significant. Accordingly, neither for CG.

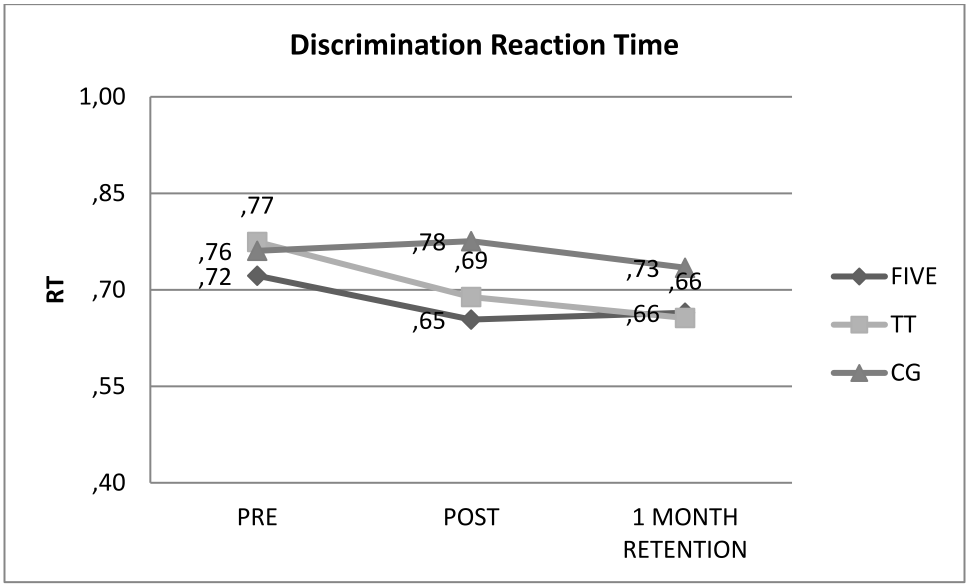


Figure 4. Performance on all measurements across time of the DRT ability test of the three groups.

3.3 Mood experience results

An independent-samples t –test was conducted to evaluate the Hypothesis III that the effect of the FIVE training on mood experience would be stronger than that of TT. The test was not significant, $t_{30} = 0.472$, $p = 0.640$, and, thus, the results do not support the hypothesis (Table 1).

Table 1 The results of independent samples t –test for mood experience

	FIVE		TT				
	M	SD	M	SD	T	P	α Cronbach
Mood experience	4.58	.597	4.66	.287	.472	.640	.86
Indicate how you feel after each exercise session.:							
1. Active	4.56	1.094	4.38	.806	.552	.585	
2. Energetic	4.50	.816	4.69	.479	.792	.434	
3. Excited	4.56	1.094	4.75	.447	.635	.530	
4. Lively	4.69	.479	4.81	.403	.799	.431	

As shown in Figure 5, mean score on mood experience was the same for both groups (FIVE and TT).

Figure 5 Differences in the “mood experience” of the experimental groups

4 Discussion

The purpose of this study was to examine whether there is a difference between two RT intervention programs, in female volleyball players aged 8-10 years old: a Full Immersive Virtual Reality-based and a RT typical training program. Before, after and one -month after the interventions, the children’s RT was measured. In addition, after the intervention, in post –test, the children's mood experience while playing FIVE games compared to TT was also investigated.

Volleyball players receive a lot of stimuli during training and games and they have to react to each of them, quickly and correctly, differently each time. That’s why CRT is considered particularly important in open skills, such as volleyball (Youngen, 1959). Actually, volleyball players have shorter CRT than non-athletes, as volleyball players have faster signal transmission on perceptual or/and central stages of information processing (Zwierko et al., 2010). The results of this study revealed that both experimental groups (FIVE and TT) improved their CRT in contrast to CG who had not any improvement. These results were expected, as are in agreement with those of previous studies. Indicatively, according to Balkó et al. (2017), CRT can be improved through appropriate intervention. Furthermore, athletes have the ability to focus attention in a spatially selective manner so they can facilitate the perception of stimuli.

Moreover, the results of this survey, showed that athletes of two experimental groups (FIVE and TT) reduced the SRT. This is in accordance with Balkó et al. (2017) and Wang (2009) who claimed that SRT can be improved through practice. In addition, athletes who practiced with TT –based RT training program improved their SRT more than athletes who practiced with FIVE –based RT training program. Maybe because the training program that followed TT group was came from volleyball, a fact that made the athletes more familiar, as they have been playing volleyball for at least a year.

Furthermore, DRT is considered very important in planning the tactics to be followed by the team (Barcelos et al., 2009), where athletes have to react only to pre –agreed actions, ignoring the rest. That is why experienced volleyball players, 13-20 years old, have shorter DRT than beginners, younger’s (Barcelos et al., 2009). In this survey, DRT was not improved in any experimental group. Maybe, because volleyball athletes, in that age, do not follow tactic training.

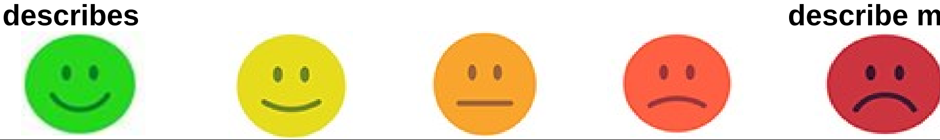
The fact that FIVE group improved CRT, is a very important point of the research, which contributes to its innovation, as in the existing literature, there have not been researches that have used FIVE in order to improve CRT. After all, these games are based on sports and also allow physically active, embodied play that imitates on-screen action, thus, offering players opportunities to actually practice sports and exercise their body (Papastergiou, 2009). In addition, the fact that they reproduce a realistic and controlled environment (Akbas et al, 2019) constitute FIVE a useful tool and can be suggested as an additional method to PES and coaches of practicing CRT in addition to TT practice. Besides volleyball athletes had a positive mood expression for this training method.

In conclusion, full immersive (VR) is an innovative tool, which can be used from PES and coaches in order to improve RT. This new method provides individualized training of abilities regardless of the time and place, against a chosen opponent (Akbas et al., 2019). In this way, full immersive VR could contribute to the further training and development of abilities, being a useful tool to PES and coaches in order to improve abilities and consequently participants' skills. In addition, it will be interesting to see whether future advances in VR can make this technology more accessible to everyone, and whether it will be able to provide a novel, exciting way of enhancing athlete and player performance (Craig, 2013). Future research should be conducted (possibly in younger or older children) to determine if FIVE games can improve other PA, such as anticipation reaction time or depth perception. Also, the same research should be conducted in young athletes of individual or other team sports.

A possible limitation of the test is the fact that the measurement procedure (reaction to a light) was different than if the measurement procedure included volleyball content. It is documented that the athletes are better in only their sport environment. Another limitation is that there was used laboratory measurement environment rather than real sports environment testing, where the results may differ.

Appendix A

Please indicate how you feel on the following words after each exercise session.



	Accurately describes				**Does not describe me**
Active	**5**	**4**	**3**	**2**	**1**
Energetic	**5**	**4**	**3**	**2**	**1**
Excited	**5**	**4**	**3**	**2**	**1**
Lively	**5**	**4**	**3**	**2**	**1**

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