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Total Reaction Time Performance of Individuals with Autism after a Virtual Reality Task

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Abstract

Evidence suggests that people with autism perform simple reaction time (RT) tasks differently than typically developing (TD) individuals. The current study examines this possibility by investigating the simple total reaction time (TRT) performance and examined effects of practice on a virtual reality motor task (VRMT) in participants with autism. Twenty-seven participants diagnosed with autism spectrum disorder (ASD) and twenty-seven TD participants completed a TRT test alternated with a VRMT. Significant increases in TRT measures were found post-practice with the VRMT only in the female autistic group. These findings suggest that the VRMT is a promising tool for improving visual RT functioning in autistic individuals.

Keywords: Autistic disorder; Reaction time; Developmental Disorder; Virtual Reality

Introduction

Autistic disorder is characterized by signs of sensory processing difficulties that may include over- or under-sensitivity to certain sensory experiences, abnormally high or low activity levels, poorly organized behavior, poor coordination and motor learning, or delays in language development or academic progress despite adequate intelligence [1].

Atypical movements in speed, coordination, posture, and gait have been observed across Autism Spectrum Disorder (ASD). Moreover, it is unclear whether atypical movements are uniformly distributed across the entire spectrum, and how the recently introduced clinical DSM-5 specifics of intelligence, associated conditions, language level, and severity are related to motor performance [2].

Children with autism often have difficulty performing skilled movements [3] and exhibit a host of motor disorders including poor coordination, deficient tool use and delayed learning of complex motor skills [4].

Considering the consistent clinical reports of impaired motor functioning in autism, motor examination may provide a window into the underlying neurobiological substrate of the disorder. Motor signs may serve as markers for deficits in parallel or neighboring brain systems that are important for control of socialization and communication. Measures of motor function tend to be more overtly observable than measures of more complex social and behavioral systems [3].

In a recent update of ASDs, the results indicate that co-morbidity is not exceptional, stressing the importance of assessing motor skills in children with ASD, because the lack of correct and complete diagnoses may negatively influence the choice of appropriate care. The early assessment of motor problems might have a positive influence on the psychological development of individuals with ASD, and if the motor weaknesses are taken into account, different interventions and treatments may be considered to address the problems [5].

Given the difficulties that this population may have, it is important to develop intervention strategies, facilitating daily life activities of individuals with autism. We suggest that virtual reality (VR) is a promising avenue for this population. VR is a new technology that allows users to interact with a scene in three dimensions generated by a computer during the execution of a certain task, providing increased visual, sensory, and auditory feedback [6].

With technological advances, several studies of its use have emerged, with many issues to be studied. Given this information, we question: does a workout in a virtual environment (virtual reality motor task (VRMT)) improve aspects, such as reaction time (RT), in this population?

In this context, RT is as a simple measure that contributes to the understanding of organizing, planning and preparing the performance of motor skills [7]. In addition, RT forms the basis of many cognitive tasks, abilities, and processes, and given that individuals with ASD do not always show evidence of information processing impairments on some processes that involve RT, further investigation of the role RT plays in individuals with ASD seems important [8].

Studies of children with autism reveal anomalous patterns of motor learning and impaired execution of skilled motor gestures. These findings robustly correlate with measures of social and communicative function, suggesting that anomalous action model formation may contribute to the impaired development of social and communicative (as well as motor) capacity in autism [9].

Despite these findings, a meta-analysis conducted by Ferraro [8] showed that, in 32 studies, there was little if any simple RT slowing associated with individuals with ASD. RT forms the basis of many cognitive tasks, abilities, and processes; thus, individuals with ASD do not always show evidence of information processing impairments in processes that involve RT.

Thus, considering the modernity of using VRMT in rehabilitation processes and the importance of measuring the influence in RT with ASD individuals, the aim of this study is to investigate whether practice in a VRMT can interfere with the RT of ASD individuals.

Method

Participants were 27 high-functioning patients with ASD between the ages of six and 22 (mean age 12.64, SD 3.47), and 27 TD, apparently healthy individuals, between the ages of 7 and 16 (mean age 11.63, SD 2.62). Individuals with any disability that prevented the realization of the activity, whether physical or related to a lack of understanding of the proposed activity, were excluded from the study.

Participants in each group (autistic or TD) were matched on age (a variation of two SD around the mean) and sex.

The autistic participants were recruited from GAPI - Special Education in São Bernardo do Campo, São Paulo, Brazil, which is a school for children and adolescents with pervasive developmental disorders. The TD individuals were recruited by convenience.

The diagnosis of autism was conducted by a child neurologist and/or psychiatrist and a multidisciplinary team of the institution through patient history, psychological assessment, neuropsychological assessment and evaluation of communication.

This study was approved by the ethics committee at the ABC medical school under number CAEE: 39396814.9.1001.0082 – approved on 20/01/2015 – number 980.629.

Instrument

The TRT_S2012 Software [10] was used to measure total reaction time (TRT) with a simple stimulus. RT is a simple measure that includes the time in milliseconds between the onset of the stimulus and the beginning of a motor response. The RT is a sensitive variable that provides a refined investigation of neuropsychological functioning: one important yardstick for health [7].

Simple RT involves the participant making a single response to a stimulus, and the instructions in such a task would state that, when the participant sees the stimulus, they need only press the spacebar on the computer [8]. Participants pressed the spacebar as soon as possible after the presentation of visual stimuli. The stimulus consisted of filling a square of 2.4 x 2.4 cm, whose place was marked with a thin black line around it (Figure 2-A). The inter-stimulus interval varied systematically from 1,500 to 6,500 ms to avoid anticipation effects, and they were presented in the same sequence for all participants. Anticipations (when the participant pressed the space bar before the onset of the stimulus) were recorded by the software with a -1 value.

Procedures

The participants were positioned comfortably in a chair adjusted according to size and needs along with a footrest so that they were positioned properly to enable task execution. Prior to testing, each participant received standardized instructions concerning the general nature of the experiment. Following the instructions, participants performed five practice trials to ensure they understood the instructions.

Following the practice trials, participants were given 14 test trials. After the execution of the first 14 TRT executions, the participant moved to another computer, where a motor task with the use of a VR interface was applied. After that, they performed another 14 test trials [Figure 1].

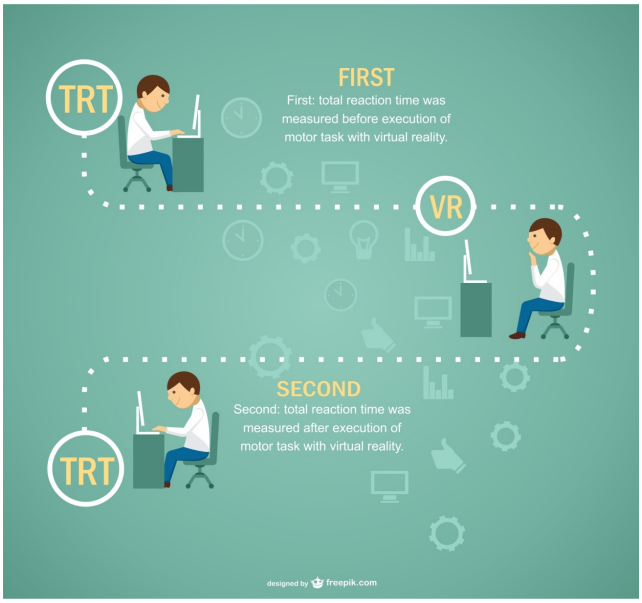

Figure 1: Task statement performing two blocks of total reaction time tasks, interspersed with a motor task with virtual reality. TRT- Total reaction time; VR- Virtual reality

Virtual Reality Task

During the VRMT, all individuals played with gaming software created in partnership with the Information Systems group of the School of Arts, Sciences and Humanities, EACH-USP using the Kinect interface from Microsoft. The task consisted of a computer screen that presented a set of 10 balls in a vertical line representing a timing coincident task (Figure 2-B). The participants were instructed to place the preferred hand on a virtual mark projected on a computer screen using the Kinect system. Once the first top cube turned on, the individual had to move his or her hand to touch the target key represented by movement in front of the Kinect system exactly at the moment the bottom target cube turned on. Different sounds were provided as feedback for a hit or miss during the performance (see [11]). All participants performed this task for about 20 minutes.

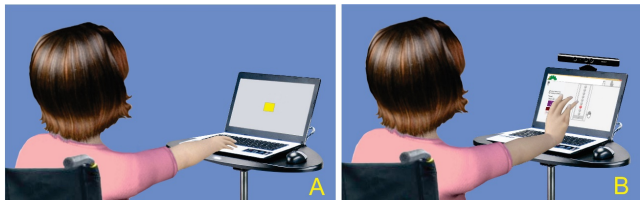

Figure 2: Children performing a total reaction time task (A) and a virtual reality motor task (B).

Data Analysis

The mean TRT under each condition was calculated for each participant. Responses of greater than two or more SDs (in individual results) were excluded from the TRT analysis. This represented 3.77% of the total 1,512 TRT measures.

Preliminary analyses would determine whether any gender differences (male vs. female) existed in terms of groups. A Mann–Whitney U test was conducted to compare means in two independent samples: autistic group vs. TD group, and male vs. female (in each group).

A Wilcoxon signed rank test was used to compare means in related samples: the first 14 TRT execution vs. the second 14 TRT executions in each group.

The same tests were conducted to assess whether there was a significant difference in the number of anticipations (the reaction was prior to the appearance of the stimulus).

Results

The results are listed in Table 1. The mean response time of the participants in the autism group required to perform the first 14 TRT was 737.91 ms, whereas the mean response time of the participants in the TD group was 385.51 ms. As can be seen, the difference between the groups was statistically significant, U=89.00, z=-4.77, p=.000, r=-.65. The mean response time for the second 14 TRT performance was significantly higher in the autism group (M=711.12) than in the TD group (M=452.29), U=170.00, z=−3.37, p=.001, r=−.46, suggesting that the TD group was faster than the autism group. This means that, in general, TD participants are significantly quicker in TRT performance than autistic participants.

The performance in the second TRT execution was significantly less than the first execution in the autism group, *T=99.00, p<.05, r=-.29* (Figure 3). The autism group improved their performance in TRT in the second execution, after training with a VRMT.

The performance in the second TRT execution was significantly higher than the first execution in the TD group, *T=309.00, p<.01, r=.39*.

The number of anticipations performed by the autistic group (M=1.15, SD=1.61) was significantly higher than in the TD group (M=.52, SD=1.19) in the first TRT block *U=89.00, z=−4.77, p<.001, r=−.65*. In the second TRT block, the number of anticipations was not significant between the two groups.

The number of anticipations was not significantly different between the first and the second TRT block in the autistic group (*T=53.00, p>.05, r=-.06*) and the TD group (*T=40.50, p>.05, r=.09*).

	Autism Group n = 27		Typically Developing Group n = 27		
	Mean (SD)	Mdn	Mean (SD)	Mdn	*p*
Age	12.64 (3.47)	13.00	11.63 (2.62)	12	0.293
Gender (M:F)	21:06	-	21:06	-	
1st. 14 TRT	737.91 (382.41)	543.27	385.51 (65.60)	363.08	<.001
2nd. 14 TRT	686.55 (378.09)	512.38	452.29 (209.13)	395.29	<.01
p^w	<.05		<.01		
1st. Anticipation	1.15 (1.61)	1.00	.52 (1.19)	0	<.05
2nd. Anticipation	1.22 (1.55)	1.00	.56 (.89)	0	>.05
p^w	.685		.486		

Table 1: Performance of autistic and typically developing groups in a total reaction time task in two execution blocks. The groups performed the two blocks interspersed with a motor task with virtual reality. SD= Standard Deviation; Mdn= Median; p= Mann–Whitney U test; M= Male; F= Female; pw= Wilcoxon signed rank test

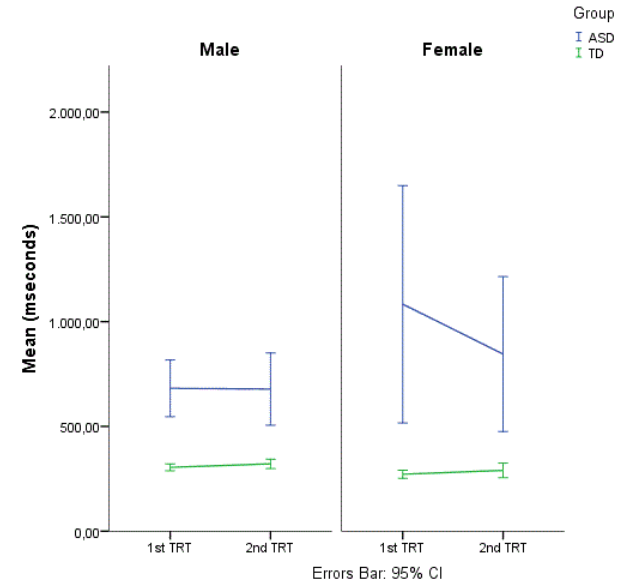

Figure 3: Mean total reaction time performance in two blocks. Groups trained in a virtual reality motor task before second total reaction time blocks.

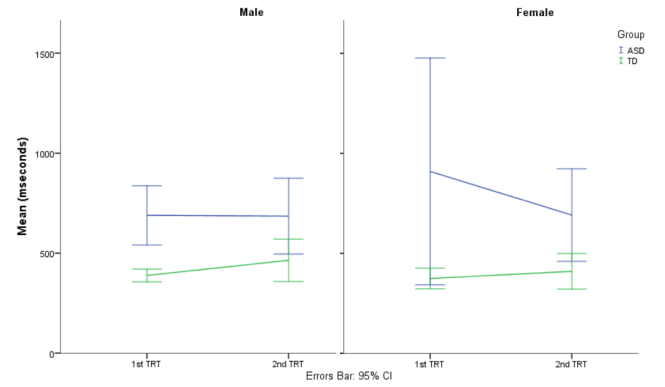

Figure 4: Mean total reaction time performance in two blocks separated by sex. Groups trained in a virtual reality motor task before the second total reaction time block.

The TRT of autistic female participants was lower in the second (M=691.39) than the first TRT block (M=909.50), but not significantly so (*T=4, p>.05, r=-.39*), indicating a possible influence on performance after training with VRMT (Figure 4). Male autism also showed no significant difference after training with VRMT (*T=67.00, p>.05, r=-.26*). This comparison (first block, M=688.88 vs. second block, M=685.17) shows a small to medium effect. Therefore, although non-significant, the effect of training with VRMT was a fairly substantive effect.

Female performance in the TD group was better in the first (M=374.24) compared to the second TRT block (M=410.10), but not significantly so (T=18.00, p>.05, r=.45). Male performance in the TD group was significantly better in the first (M=388.73) compared to the second TRT block (M=464.34) (T=187.00, p<.05, r=.38.)

The male ASD group (M=688.88) had significantly worse performance in the first TRT block than the TD group (M=388.73) (U=64.00, z=-3.94, p=.000, r=-.61). The same occurred for the second TRT block, in which the male ASD group (M=685.17) had significantly worse performance than the TD group (M=464.34) (*U=120.00, z=-2.53, p<.05, r=-.39*).

The female ASD group (M=909.50) had significantly worse performance in the first TRT block than the TD group (M=374.24) (*U=1.00, z=-2.72, p<.05, r=-.79*). The same occurred for the second TRT block, in which the female ASD group (M=691.39) had significantly worse performance than the TD group (M=410.10) (*U=3.00, z=-2.40, p<.05, r=-.69*).

Discussion

This study investigated the performance of TRT in ASD and TD participants after using a VRMT. The results showed that individuals with autism disorder had the ability to respond to movements in this motor task, and the training of VR improved the performance in TRT, but only for female individuals with autism; this difference was not significant for male or TD individuals. However, individuals with autism were slower and presented more anticipations (press the keyboard space bar before the appearance of a yellow square) than TD individuals in all phases of the experiment, which suggested that individuals with autism may show greater executive functional deficiencies than TD individuals (i.e., set shifting) [12].

This result did not reflect the results of Rinehart et al. [13], where the pattern of anticipation was not reflected in the autism group's preparation time, and movement preparation was characterized by a "lack of anticipation" in autistic individuals.

The significant differences between groups showed that the TD and male autistic participants performed the task best in the beginning, and that the continued execution of more than 14 attempts in the second block seemed to have a discouraging effect, resulting in a significant reduction in performance. This became more evident when we noticed that the female ASD group showed an improvement in performance in the second execution of the TRT task. Probably for the female ASD group, the task difficulty was greater and provided motivation to improve performance.

These results differ from those reported by Lai et al. [14] where males with ASD performed worse than TD males, but females with and without ASD performed comparably. The authors also argued that this sex difference within ASD suggested that performance in visuospatial attention to detail may characterize men, but not women, with ASD. Perhaps the reduced number of female participants in our study can explain this difference.

Differences in visuo-spatial or cognitive task performance were not replicated in males with high-functioning autism when compared with TD controls [15]. However, the authors stated that caution was warranted in the interpretation of the results; with only 13 participants in each group, the statistical power was necessarily low. Having only six females in each group in our study may have indicated a trend that was not confirmed in a larger group.

Our results indicated that VRMT could have a positive effect in ASD, stressing the importance of new technological approaches in providing better RT and motor skills in children with ASD. Early assessment and intervention of motor problems might have a positive influence on the psychological development in individuals with ASD. If the motor weaknesses are taken into account, different interventions and treatments may be considered to address the problems [16].

Although our results did not show significant differences in the performance of the ASD group according to age, Landry and Parker [17] showed that the potential impact of slowed orienting in childhood, adolescence, or adulthood needed to be further examined. Thus, given the limited number of studies and variability of designs, it is imperative that future studies approach the question developmentally, testing children as young as possible on identical tasks, and including a wider age range and tasks that are appropriate for even the youngest children.

Besides the relatively small number of female participants, there are other limitations of our sample selection that are important to present. First, we did not evaluate the symptom severity diagnosis of our participants with autism and, therefore, have no means to evaluate if it predicts any of the measures of performance. Second, we did not exclude participants who were taking medications. Thus, we cannot be certain if some types of medication affected the overall TRT of the participants with autism. However, our primary findings reflect the pattern of performance and there is no reason to believe that any of the medications influenced the overall pattern of performance [18]. Finally, our participants had a wide range of mental abilities, which

seems to have some influence on overall performance speed on these tasks.

Conclusion

The findings suggested that children with ASD could operate the VR system and use it in the intervention program. More, importantly, autistic female participants showed improvements in TRT performance after the use of a VRMT.

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