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Reaction Time of Children with and without Autistic Spectrum Disorders

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Abstract

This study was conducted to evaluate and compare simple and choice reaction times for the comparison of perceptual-motor development levels found in children with and without autism. The participants of the study consisted of 24 children with autism and 10 typically developing (TD) children. Within the group of children with autism, only 10 were able to offer a full set data and four offered partial data. Data were collected through a computer-based procedure of reaction time test software, where the participant reacted by pressing a key on a laptop upon the appearance of one of the boxes turning yellow. Simple and choice reaction times appeared on the screen and were then recorded. The means and standard deviations were calculated for comparison and the data were evaluated from the results of a t-test. Significant differences were found among all reaction time tasks, whereas the group consisting of children with autism demonstrated slower reaction times and greater standard deviations compared with the typically developing/control group.

Keywords

Autism, Reaction Time, Perceptual-Motor Development, Motor Impairments, Physical Education

1. Introduction

For those without visual impairments, vision is the most dominant sense when performing motor skills or movements. Therefore, human motor development, learning, and behavior are dependent on the development of vision and the central processes required for motor responses. For many years, researchers have attempted to gain insight into the impairment that underlies the series of symp-

toms which characterize Autism Spectrum Disorder (ASD), such as impaired reciprocal social interactions and communication as well as repetitive, stereotyped patterns of behavior and restricted interests. A substantial number of children with autistic spectrum disorder (ASD) exhibit significant levels of attention deficit/hyperactivity disorder like symptoms: inattention, impulsivity, and hyperactivity [1] [2]. In addition, Autism and Asperger disorder have long been associated with movement abnormalities, although the neurobehavioural details of these abnormalities remain poorly defined. Clumsiness has traditionally been associated with Asperger disorder but not autism, although this is controversial. Others have suggested that both groups demonstrate a similar global motor delay [3].

Knowledge of reaction time is imperative when planning physical activities that entail quick decision-making and motor responses [4]. Individuals with slower perceptual-motor processes may not perform such activities to the same ability as those with typical processing and response times. The perceptual-motor process, as described by Winnick and Lavay [5], begins with sensory input, followed by sensory integration in the central nervous system, motor-behavioral output, and feedback, respectively. The reaction time is defined as the time between the onset of a stimulus and the beginning of the motor-behavioral output; reaction time becomes an objective measure in the perceptual-motor process from the sensory input to motor-behavioral output. Reaction time includes simple reaction time; it means one stimulus and one response known in advance and choice reaction time; it has more than one stimulus, with corresponding response alternatives. Thus, choice reaction time includes the stimulus identification and response selection. According to the study by Miller and Low [6], motor-behavioral preparation and output times were found to be equivalent in all forms of reaction time tests. With this implication and the assumption that all individuals in a study have typical sensory input processes, reaction time test can be used to measure the processing time of sensory integration in the central nervous system. The purpose of this study was to compare simple and choice reaction times of children with and without autism.

Unusual responses to sensory stimuli are seen in many children with autism. Rogers & Ozonoff [7] examined the empirical evidence for the widespread belief that sensory symptoms characterize autism and differentiate it from other disorders. Their study found that symptoms of hypo-responsiveness to sensory stimuli are more frequent and prominent in children with autism than in typically developing children, but there is no good evidence that these symptoms differentiate autism from other developmental disorders and there have been multiple failures to replicate findings.

Bogte, Flamma, Meere & Engeland [8] studied divided attention in adults with ASD by using a computerized variant memory recognition test, with two levels of cognitive load. Findings indicated that only the adults with ASD were slower, but those who used medication had greater divided attention deficits and specific difficulty reaching a binary decision in a memory search task. The results of stu-

dies by Wainwright-Sharp and Bryson [9] and Wainwright and Bryson [10] suggested that autistic subjects have problems in visual attention mechanisms. When the cue was presented 100 msec before target appearance, normal control subjects reacted faster on valid cued targets than on invalid cued targets; but autistic subjects did not show this cue validity effect. When the cue preceded the target by 800 msec, however, autistic adolescents showed a cue validity effect that was even larger than in control subjects. Keehn and Joseph [11] investigated modulation of attention by novel onset stimuli in children with ASD and IQ-matched typically developing children using a preview visual search task developed by Donk & Theeuwes [12]. The TD group exhibited faster reaction times (RT) to targets occurring as novel search elements, the ASD group performed similarly in target new and old conditions, indicating impaired attentional prioritization of novel onsets. However, Keehn and Associates [13] found that individuals with ASD have response time advantages during Embedded Figures Tests due to weak central coherence theory and enhanced perceptual functioning. Their study, consistent with prior Embedded Figures Test studies, found that children with ASD had accelerated response times, shorter fixations compared to the TD group.

Raymaekers, Van Der Meere, and Roeyers [1] found that adults with high functioning autism (HFA) exhibit problems with response inhibition when go/no-go stimuli were presented rapidly, but not when stimuli were presented slow. It was found that performance in adults with HFA was the same as in the control group in the condition with a slow and medium presentation rate, but that it decreased in the condition with a fast presentation rate: many errors of commission were made in this condition. Raymaekers, Van Der Meere, and Roeyers [14] later investigated inhibition of proponent responses in children with HFA and its possible association with inattention, impulsivity, or hyperactivity symptomatologies using an immediate arousal task. They found that the HFA group outperformed the control group, indicating neither arousal regulation deficit nor response inhibition deficit. In addition, Gastgeb, Strauss, & Minshew [2] studied the effect of exemplar typicality on reaction time and accuracy of categorization on autism individuals. They found that individuals with autism responded more slowly than matched controls to atypical exemplars at all ages.

The purpose of the current study was to examine the reaction time of children with and without autism. More specifically, it compares the simple right hand reaction time, simple left hand reaction time, choice right hand reaction time, and choice left hand reaction time between children with autism and children of typical development.

2. Method

2.1. Participants

A total of 34 children participated in the study. The group with autism consisted of 17 males and 7 females between the ages of seven and thirteen. The students with autism were participants of an adapted physical education clinic at a uni-

versity in northeastern Ohio. Here, each sport science/physical education candidates provides adapted physical education to individual students from four different schools in northeastern Ohio. Information regarding the clinic was sent to the children's parents, who signed and returned a consent form prior to their child being admitted into the clinic and study. Also, the children were asked to participate and their verbal consent was required for participation in the study. After completing all tasks and trials, the participants and parents were free to ask questions regarding the tasks and procedures. A school team which included the parents determined that the children met IDEA eligibility for autism. In addition, among the 24 participants, eighteen children with autism were also evaluated by their teachers using Childhood Autism Rating Scale [15] (CARS2). Among these 18 children, 10 were not able to complete the reaction time tests, these individuals also had high scores on the CARS2. The IQ scores were the estimates of the teachers based on the students' performance in the classrooms. The control group was selected from physical education classes within the same school district as the group with autism. The control group consisted of a total of 10 typically developing students. This group consisted of seven males and three females between the ages of ten and twelve. All participants had normal or corrected-to-normal vision and no history of ophthalmological problems (**Table 1**).

Table 1. Results of CARS2-HF assessment of participants with autism.

	Sex	IQ	Raw score	t-score	Percentile
1	m	80<	35.5*	53	62
2	m	60<	51.5*	70	97>
3	f	60<	49.5*	70	97>
4	m	60<	43.5*	63	90
5	m	60<	55*	70	97>
6	f	60<	42*	62	88
7	f	60<	52*	70	97>
8	f	60<	41*	61	86
9	m	60<	53*	70	97>
10	f	60 - 80	34.5	51	54
11	m	80<	42	62	88
12	f	80<	22	32	4
13	m	80<	38	57	76
14	m	80<	52*	70	97>
15	m	80<	28	42	21
16	f	80<	26	38	12
17	m	80<	47	70	97>
18	m	80>	23	33	5

*Unable to complete reaction time tests.

2.2. Instruments

All tasks within this study were computer-based task and used a Dell Latitude D630 laptop computer. The laptop's monitor had a diagonal length of 14 inches, 1440 × 900 pixel resolution, 32 Bits color quality, and 60 Hertz refresh rate. The laptop was installed with reaction time test software, developed by one of the authors using LabVIEW (National Instruments, Austin, TX). A grey screen with right and left boxes was presented. The square boxes measured approximately ¾ inches at each side. Participants were instructed to press the right response key as soon as the right box turned yellow. During simple reaction time tests, only the box that corresponded to the performing hand turned yellow. Therefore, the left box never turned yellow during the right hand reaction time test. For the adapted physical education clinic, a standard, metal chair and desk was used, where the participants were able to adjust for their own comfort. The control group used their physical education teacher's desk and chair, which was also appropriate for meeting the participant's comfort needs. Prior to administering any tasks, the students were asked if they were comfortable to perform the tasks.

2.3. Procedures

The procedures of this study took place within and during physical education classes. Students were asked to sit in a chair within arms reach of the computer. The computer desk was faced toward a wall, away from the gym activities. The participants were able to visually attend to the task at hand, but had to filter out any auditory stimuli throughout their class. The students were given procedural instructions prior to each of the three sets of tests. Procedures began with the students performing ten simple reaction time test trials with their right hands. Participants were asked to place their right index finger on the right response key, which was F9. A verbal cue informed the students when the test will start. A run continually button was used to automatically reset each trial. After 10 trials were completed, the administrator manually ended the task. If the student responded prior to the box turning yellow, no reaction time was measured or recorded. The test was immediately reset to begin another trial. After ten trials were completed from the right hand, the simple reaction time test was repeated on the left side. Students performed left hand simple reaction time tests by pressing the left response key, which was F4, with their left index finger when the left box turned yellow. After ten recorded trials of left hand reaction time test, the choice reaction time test was administered. Participants were instructed to place their right index finger on the right response key and their left index finger on the left response key. The choice reaction time test consisted of either the right or left boxes turning yellow at random. Students had to respond with the right hand when the right square turned yellow and with the left hand when the left square turned yellow. The choice reaction time test was administered until ten choices right and ten choice left reaction time measures were recorded. All reaction times for a single hand that exceeded ten trials were not recorded.

3. Results

Although 24 children with autism participated in the study, only 10 were able to complete all the reaction time tasks and provide a full set of data. Four children were able to provide partial data and the remaining ten were unable to perform the tasks. For the simple reaction times, both groups demonstrated faster mean reaction times and lower standard deviations with the right hand than that with the left hand. However, the group with autism had significantly ($p < 0.0001$) slower mean reaction times and greater standard deviations compared to the typically developing group in both simple reaction time tasks. For the simple right reaction time task, the group with autism had a mean of 663 ms with a standard deviation of 206, whereas the typically developing group had a mean of 312 ms and a standard deviation of 24. Similar results were found in the simple left reaction time task. The group with autism had a mean of 703 ms and a standard deviation of 224 compared to the mean reaction time of 336 ms and standard deviation of 43 within the typically developing group. Choice reaction times were significantly ($p < 0.0001$) slower and standard deviations were greater among both groups than the simple reaction times. Unlike the simple reaction time tasks, there was no distinct advantage between the choice right and choice left reactions times. Again, the group with autism had significantly slower mean reaction times and greater standard deviations compared to the typically developing group during the choice reaction time measures. The mean choice right hand reaction time for the group with autism was 732 ms, whereas the typically developing group's mean was 390 ms. Even greater differences were found in the standard deviations within the choice right hand measures. The group with autism's standard deviation was 595 compared to typically developing group's standard deviation of 43. Similar results were found in the choice left reaction time measures. The mean choice left hand reaction time for the group with autism was 765 ms with a standard deviation of 635 compared to the typically developing group's mean of 377 ms and standard deviation of 44 (see Table 2).

4. Discussion

The study examined the simple and choice reaction times of children with and without autism for the application and evaluation of a child's perceptual motor development. Significant differences were found among all reaction time tasks,

Table 2. Means and SD of RT (in millisecond) for children with autism and children of typical development.

group	Simple right mean (SD)	Simple left mean (SD)	Choice right mean (SD)	Choice left mean (SD)
Autism	663.93	703.02	732.99	765.3
n = 14	(206.12)	(224.93)	(595.17)	(635.57)
Typical	312.95***	336.54***	390.74***	377.76***
n = 10	(24.10)	(43.91)	(43.90)	(44.65)

***$P < 0.0001$.

the group consisting of children with autism demonstrated slower reaction times and greater standard deviations compared to the typically developing/ control group. Based on mean scores, the group consisting of typically developing individuals demonstrated reaction times nearly twice as fast as the group of children with autism. Both groups showed slower reaction times in the choice reaction time task compared to the simple reaction time tests. Noticeable differences were also found between the reaction times of the right and left hands within autism group. The autism group had slower reaction times with the left hand than the right hand, whereas the typically developing group had score that were more random. In addition, the delayed reaction time associated with autism could be underestimated because there were a number of autistic children who could not complete the task; we would assume that their reaction behavior is more impaired. Additionally, the data indicated a distinct pattern of reaction time for autistic and typical students where the dominant side (right hand side) reacted faster than non-dominant side (left hand side) for both SRT and CRT.

The slower reaction time from the group with autism may have been directly related to deficits in the perceptual motor process. Some researchers take the view that a deficit in executive function (EF) is central in autism spectrum disorders [16] [17]. In Landry, Mitchell, & Burack, study [18], the difficulties of participants with ASD on endogenous orienting were said to occur at the response selection level, not the perceptual level. However, the differences in mean reaction times among all tasks ranged from about 350 msec to 387 msec, implying deficiencies at both the response and perceptual levels. The choice reaction time tasks did require motor reprogramming, but due to the similar ranges in mean reaction time differences between the two groups among all tasks, the results did not coincide with the results of Rinehart, Bradshaw, Brereton, & Tonge [3], which suggested that individuals with autism and Asperger disorder have a normal ability to execute movements in motor reprogramming paradigm.

Research that correlated attention deficit/hyperactivity disorder (ADHD) and ASD symptomatology with response inhibition scores indicated that difficulties in response inhibition could be associated with ADHD characteristics, rather than ASD characteristics [19] [20] [21]. Therefore, inconsistent findings may occur in response inhibition task score among children exhibit significant levels of ADHD-like symptoms while other children with ASD do not. Since a deficit in response inhibition is seen by many as the key deficit in ADHD [22], studies focusing on ASD and response inhibition should control for ADHD-like symptoms [14], which this study did not. The tasks in this study required the participants' divided attention for the best possible reaction time scores. According to Bogdashina [23], a limited divided attention capacity may contribute to failures in establishing and maintaining joint attention, a specific problem in ASD.

The prevalence of motor impairments may have also been a factor in why the group with autism demonstrated significantly slower reaction times than the typically developing group. In a retrospective clinical record reviewed by Ming, Brimacombe & Wagner [24], results suggested that fine motor control and pro-

gramming deficits are common co-occurrence of children with ASD in this cohort. The reduced prevalence of motor deficits in older children suggests improvement over time, whether through natural progression, results of interventional therapy, or the combination of the two [24]. Therefore, younger children, such as the adolescents in this study, may not have received the services to improve their fine motor skills, which may be contributing factors in this study's tasks. It may be hypothesized that if due to motor impairments, older children would improve on their reaction times toward more typical levels.

Based on the results of studies of Wainwright-Sharp and Bryson [9] and Wainwright-Sharp and Bryson [10], when cues presented 100 msec before target appearance, normal control subjects react faster on valid cued targets than on invalid cued targets; but autistic subjects do not show this cue validity effect. When the cue preceded the target by 800 msec, however, autistic adolescents showed a cue validity effect that was even larger than in control subjects. This study did not use any cues. The next trial took place directly after the previous response. The time between trials ranged from 10 to 30 seconds.

Results of this study found that individuals with autism were significantly slower in response to the reaction time tests comparing to the typically developing children. The results found similar trends with other studies related to autism and reaction time [3] [12] [18] [25]-[35]. The significant delay in these tasks can be attributed to inattentiveness, slow neurological response, clumsiness, as well as the delays in motor movement development. Future study can be conducted to compare these results to older individuals of autism and also older individuals of autism that had received remedial intervention of physical therapy and other fine motor skills training to examine the developmental effect on reaction time.

5. Implications to Physical Education

The speed of cognitive processing changes with age. Adult experts might surpass children with their knowledge. Slowing processing also occurs with aging. However, older adults with active lifestyles who participate in an activity and acquire considerable experience can perform at a high level of information processing. Exercises would maintain better cognitive and motor functioning than nonexcisers [4]. During the cognitive stage of learning, the comfortable pace is set up for the learners in the learning process; in addition; if the psychomotor motions such as swing, throwing, turning, kicking, can slow down for the learners, learning can be more effective.

Reaction times improved after aerobic exercisers [36]. If possible, planning exercises such as jogging, cycling, swimming on the regular bases, according to the research, these exercises can be helpful on improving individual's reaction time.

When teaching students with autism, educators need to keep in mind the attention and the details that are required to deliver instruction for teaching and learning for this special population of students. In particular, their social beha-

vior and communication deficits in the classroom setting may have a far reaching effect in participating in the class effectively. This limitation (deficits in social behavior and communication) may have the special implication for students participating in physical education setting where social behavior and communication are important components for success of these students. Hovey [37] suggests that when teaching students with autism, teachers in physical education must pay special attention to fitness and movement activities as these students are not in the par with the typical students. There are strong indications that there are many multi-facets [37] [38] [39] benefits in participating in physical activities by students with autism. To meet the fitness goals for autism students, Hovey [37] had provided the six-step process to assist physical education teachers for design, task selection, pre-test, individualization and evaluation.

Teaching motor skills for autism students poses the additional challenge to the physical education teachers. According to Haywood and Getchell [4], knowledge of reaction time is imperative when planning physical activities that entail quick decision-making and motor responses. The data from this study provide and shed additional light on how autism students react to stimulus presented to them which has a broader implication to teaching motor skills to these students. The data of simple reaction time (SRT) and choice reaction time (CRT) provides specific directions to design special (motor learning) curriculum for autism students that may enhance their ability to learn and be successful in acquiring motor skills. The data of SRT and CRT indicate that the autism subjects react twice as slower than the typical subjects to the presented stimulus. Thus indicating that they are slow in information processing as it relates to information processing theory [40] [41] and also in motor programming a motor response to the required movement [42]. To address this limitation of the autism students physical education teachers must deliberately modify motor skills/activities and instruction to meet the needs of these students in order for them to be successful in the planned motor skill/activities. Such motor skills/activities must be developmental appropriate [43] [44]. The planned developmental appropriate motor skills/activities must be designed and based on what these students can successfully accomplish, enjoy and get motivated to participate. Getting the autism students to actively and successfully participate in the class is half the battle to the road of effective teaching and success of these students. Although it is possible to generate curricula and use large group instruction to teach, it is generally recognized that teaching one-on-one (tutoring, small class size) produces the best results in terms of learning [45] [46].

The difficulty level of the task must be taken into consideration when planning a lesson by starting motor skills/activities from simple to complex, close to open and slow to fast movements. Sometimes these motor skills/activities including the equipments will have to be modified to meet the needs of these students. Here is an example that illustrates how an activity and the equipment where modified to give autism students more time to process incoming information, so that; they can generate an appropriate motor response to catch the ball.

For illustrative purposes activity that was selected was very simple to enhance eye-hand-coordination. The activity was to drop (at chest height) and catch the ball. Any air-foam inflatable ball may be used; they come in 9" and 13" diameter. Start with the bigger ball and as the students get proficient one can change to smaller ball to do this activity, thus, increasing the degree of difficulty for these students. These balls can vary the size and bounce by adding more or less air into it. Well inflated ball will have a higher and livelier bounce for fast-paced activities and conversely less inflated ball will bounce slower. The data of this study indicated that the autism students reacted twice slower than the typical students. Using less inflated ball for this activity will provide more time for autism students to process the information and react accordingly to catch the ball. Thus helping them to react according to their own ability and making them successful at catching the dropped ball. The less inflated ball will bounce slower and will provide ample time for them to react and catch the ball. By modifying this activity the task was made easy for the students to experience success.

6. Limitations

The participants in the current study were not matched by age so there were participants with autism who were younger than those without autism. A previous study [24] found that reaction times improved with age. The slower reaction time of children with autism found in the current study may have been related to the participants in younger age as well. These variables may be controlled for better comparison of the subjects in the future studies.

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