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The Relationship between Impulsivity and Time Perception in Adolescents with ADHD

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Abstract

Introduction: Attention-deficit hyperactivity disorder (ADHD), is a mental neurodevelopmental disorder mainly characterized by inattention, hyperactivity, impulsivity, and impaired time perception.
Objectives: Our main goal was to determine the relationship between time perception and impulsiveness in adolescents with and without ADHD.
Methods: 156 adolescents with ADHD (mean age=16.52±1.63; male/female ratio=91.65) were placed in the case group and 198 mentally and physically healthy adolescents (mean age=16.84±1.49; male/female ratio=111.87) were placed in the control group. The performance of the subjects of the two groups was evaluated in the go/no go test and time perception task (time estimation and time production) and compared with each other. Furthermore, considering the group factor as a control variable, the partial correlation between the subscales of the go/no go test and the subscales of the time perception task were measured.
Results: Independent t-test showed significant differences between groups in terms of commission error, inhibition, reaction time, 10-, 20-, 40, and 80-second time estimation, and also 10-, 20-, 40-, and 80-second time production. Inhibition and reaction time were negatively correlated with all of the estimation time intervals and were positively correlated with all of the production times. Commission error was negatively correlated with all of the all of the production times and was positively correlated with all of the estimation time intervals .
Conclusions: Our results demonstrated that subjects with less response control ability had estimated the time intervals longer than their actual durations and had produced time intervals shorter than the requested time intervals in the time production task.

Keywords: ADHD, Impulsive behavior, Time Perception, Adolescent

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1. Introduction

Attention-deficit hyperactivity disorder (ADHD) is a mental neurodevelopmental disorder characterized primarily by symptoms of inattention, hyperactivity, and impulsivity, which are linked to a range of functional impairments (1). The symptoms appear before the age of 12, are present for at least six months, and cause problems in school, home, or recreational activities. The prevalence of ADHD in children and adolescents is estimated to range from 5.9% to 7.1%, depending on the diagnostic criteria. (2).

Impulsivity, the core symptom of ADHD from a psychological perspective, is defined by spontaneous risky actions and rapid decision-making due to a lack of response control. Barratt distinguished three dimensions of impulsivity as actions without thinking, quick decision-making and decreased sensitivity toward negative outcomes of behavior (3). In addition to ADHD, impulsivity has been demonstrated to exist in various psychiatric disorders linked to risky behaviors, such as bipolar disorder (4), drug addiction (5), and risky sexual behaviors (6).

From the neuropsychological point of view, impulsivity is viewed as a lower threshold for activation of immediate responses and can be understood as a lack of balance between the top-down and the bottom-up control of the behavior (7). The orbital frontal cortex (OFC) and the anterior cingulate cortex (ACC) are involved in the top-down control and in the prediction of expectancies of reward and punishment, while the limbic structures are involved in the bottom-up control of behavior (8).

Cognitive tempo, as the capacity of time estimation and time production, is shown to be related to impulsiveness (9). Impulsive individuals have been demonstrated to overestimate time intervals and therefore, under-produce time intervals. Evidence suggests that the biological clocks of individuals with high impulsivity may run faster than those with low impulsivity (10). Functional brain studies have revealed that the inferior frontal, parietal and medial frontal cortices, as well as the anterior insula, are significantly over-activated during time production in impulsive people and this activation pattern may be seen as a biological sign of cognitive time management in impulsivity (11).

Conversely, research has shown that teenagers with ADHD exhibit compromised time perception when compared to their peers without the disorder. For instance, research has shown that teenagers diagnosed with ADHD exhibit notably higher absolute discrepancy scores when performing time reproduction tasks, as well as experiencing more significant increases in these scores over time intervals compared to their peers in the control group (12). Toplak et al. (2003) reported that deficient duration discrimination and estimation have prominent effects on the temporal organization in adolescents with ADHD (13).

ADHD subjects act faster and make more errors in continuous performance tasks (14). Focusing on the stop-signal reaction time tasks, adolescents with ADHD have been shown to be slower to inhibit their incorrect responses than normal adolescents, and fail to cancel their “go” actions in a timely manner on the “no-go” trials in go/no-go tasks (15). Patients with ADHD tend to favor immediate rewards over larger delayed rewards when participating in delay-discounting tasks (16). Nielsen (2017) proposed that ADHD could be viewed as a "difference in temporal experience and rhythm" based on semi-structured interviews and observation. Additionally, individuals diagnosed with ADHD may experience affected prospective memory processing, which could directly influence their time perception.

Given that impulsivity is one of the main symptoms of adolescents with ADHD, and also taking into account the fact that impulsiveness may be due to the impaired perception of time, our main goal in this study was to determine the relationship between time perception and impulsiveness in adolescents with ADHD, compared to healthy adolescents. Obviously, the results of this study could clarify the effect of time perception in the incidence of impulsive behavior in adolescents with ADHD and can pave the way for future studies to find diagnostic endophenotypes and therapeutic approaches.

2. Methods

This study used a correlational method.

2.1. Participants

156 adolescents with ADHD who visited Owj clinic in Gorgan, Iran, from 2016 to 2018, participated in this study by their parents' informed consent. The age of the participants was in the range of 14-19 years. All patients were evaluated by two experienced psychiatrists and their disorder was confirmed. It was also found that none of the patients had any other neurological or mental disorder. Furthermore, the study involved 198 adolescents, aged 15 to 19 years, who were in good mental and physical health. None of the individuals had any substance abuse issues.

2.2. Measures

2.2.1. Go/No-Go Task

The go/no-go tests are commonly utilized for assessing impulsivity. Individuals are instructed to execute a task when presented with specific stimuli (go stimuli) and to refrain from doing so when presented with a different set of stimuli (no-go stimuli). Performance effectiveness is measured based on accurate responses, omission and commission errors, and reaction time. Omission errors are indicative of inattention symptoms, whereas commission errors are believed to indicate deficiencies in response control. Reaction time refers to the duration between the stimulus presentation and the individual's response (17).

2.2.2. Time Perception Task

2.2.2.1. Time Estimation

The subjects were tasked with estimating time intervals of 10, 20, 40, and 80 seconds. Each interval was shown twice in a random order to avoid participants using their own pacing as a reference for time. While performing the test, the participants were diverted by reading random numbers, ranging from 1 to 9, presented on a computer monitor. The average difference between the estimated time and the specified time after two attempts was computed for each person.

2.2.2.2. Time Production

Participants were asked to produce 10, 20, 40, and 80 s time intervals by pushing the start and end buttons. The mean of the difference between the produced time and the requested time after each trial was calculated for each individual.

2.2.2.3. Long-Term Time Estimation

Upon completion of the time perception task (approximately 10 minutes), participants were requested to gauge the overall duration from the commencement of the experiment to its conclusion. The estimated times provided by the participants were then compared to the actual elapsed time.

2.3. Data analysis

To depict the demographic traits and participants' scores, central and dispersion measures were employed. A comparison of the female/male ratio between the case and control groups was conducted utilizing Fisher's exact test. The scores of both groups were analyzed through independent t-tests with a significance level set at 0.05. The correlation between all subscales of the go/no-go test and the time perception task was determined using the Pearson coefficient.

3. Results

The age range of the case group was 14 to 19, with a mean of 16.52±1.63, and the age range of the control group was 15 to 19, with a mean of 16.84±1.49. According to the independent t-test, the mean age of the two groups did not show statistical significance (P=0.055).

In the case group, there were 91 males and 65 females, while in the control group, there were 111 males and 87 females. According to Fisher's exact test, the male/female ratio did not show a significant difference between the two groups (P=0.746).

In the case group, the mean scores of the go/no-go test subscales, in terms of omission error, commission error, inhibition, and reaction time were 1.82±0.93, 3.9±1.39, 34.32±1.74, and 2.00±0.46, respectively. In the control group, the mean scores of omission error, commission error, inhibition, and reaction time were 2.04±1.52, 2.05±1.39, 35.89±2.09, and 2.42±0.50, respectively (Figure 1). Independent t-test showed that there were significant differences between the two groups in terms of commission error (P<0.001), inhibition (P<0.001), and reaction time (P<0.001).

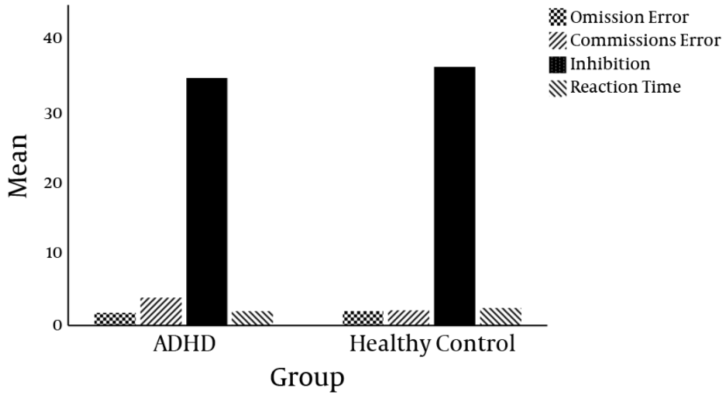

Figure 1. The Mean Scores of the Go/No-Go Test Subscales, in Terms of Omission Error, Commission Error, Inhibition, and Reaction Time, in the Case and Control Groups.

The mean differences between the actual time intervals and the estimated time intervals by the ADHD subjects were 0.46±1.67, -0.02±3.29, 0.49±4.84, and 1.07±6.40 for the 10 s, 20 s, 40 s, and 80 s intervals, respectively. The mean differences in the control group were -0.89±1.37, -0.77±2.74, -1.62±4.05, and -2.47±5.41 for the 10 s, 20 s, 40 s, and 80 s intervals, respectively (Figure 2. A). Independent t-test showed that there were significant differences between the two groups for the 10 s (P<0.001), 20 s (P=0.023), 40 s (P<0.001), and 80 s (P<0.001) intervals.

The mean differences between the actual production times and the produced times by the ADHD subjects were -0.50±0.94, -1.10±1.33, -0.32±1.81, and -0.65±3.62 for the 10 s, 20 s, 40 s, and 80 s production times, respectively. The mean differences in the control group were -0.05±0.65, 0.19±1.35, 2.05±1.71, and 0.10±3.43 for the 10 s, 20 s, 40 s, and 80 s production times, respectively (Figure 2. B). Independent t-test showed that there were significant differences between the two groups for the 10 s (P<0.001), 20 s (P<0.001), 40 s (P<0.001), and 80 s (P=0.046) production times.

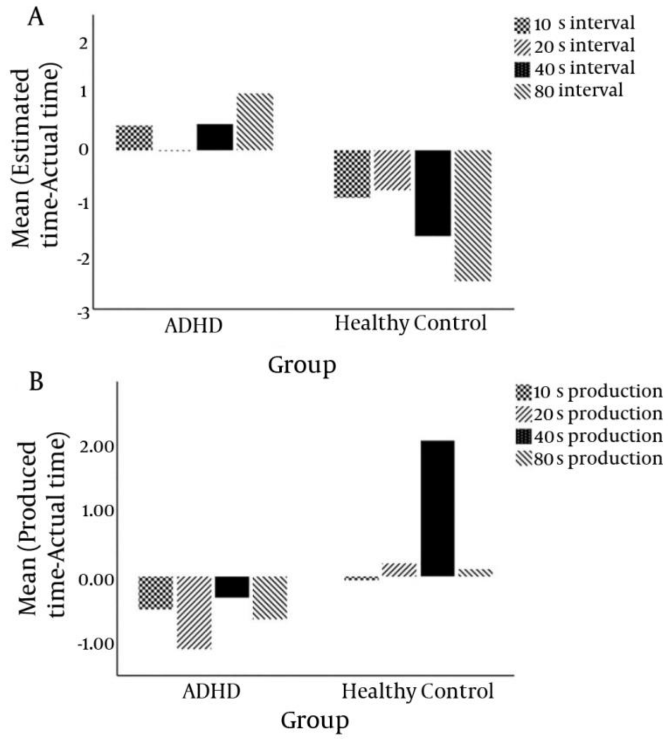

Figure 2. The Mean Differences between the Actual Times and the Estimated/Produced Times by the Two Groups.

The mean total time spent from the beginning of the experiment to the end was estimated 592.00±70.87 by the case group and was estimated 570.30±71.02 by the control group. The estimated values were significantly different between the two groups (P=0.005).

The partial correlation analysis between the subscales of the go/no-go test and the subscales of the time perception task, controlled for the group variable showed that there were significant negative correlations between the inhibition and the estimation times (for all the time intervals), and there were significant positive correlations between the inhibition and the production times (for all the production times) (Figure 3. A).

Strong positive relationships were observed between the commission error and the estimation times across all time intervals, while strong negative relationships were found between the commission error and the production times for all production times (see Figure 3.B).

Significant adverse associations were observed between the reaction time and the estimation times across all time intervals, while notable favorable associations were found between the reaction time and the production times for all production times (refer to Figure 3. C). The outcomes of the partial correlation analysis between the subscales of the go/no-go test and the subscales of the time perception task, adjusted for the group variable, are depicted in Figures 3.

Table 1. The Partial Correlation Analysis between the Subscales of the Go/No-Go Test and the Subscales of the Time Perception Task, Controlled for the Group Variable.

			Omission Error	Commission Error	Inhibition	Reaction Time
Time Estimation (s) (Estimated Time-Actual Time)	10	r	-0.023	0.452	-0.331	-0.376
		p	0.667	0.000	0.000	0.000
	20	r	-0.016	0.445	-0.331	-0.367
		p	0.771	0.000	0.000	0.000
	40	r	-0.015	0.447	-0.336	-0.373
		p	0.780	0.000	0.000	0.000
	80	r	-0.017	0.448	-0.332	-0.372
		p	0.747	0.000	0.000	0.000
Time Production (s) (Produced Time-Actual Time)	10	r	-0.037	-0.479	0.396	0.403
		p	0.485	0.000	0.000	0.000
	20	r	-0.062	-0.374	0.342	0.305
		p	0.243	0.000	0.000	0.000
	40	r	-0.013	-0.345	0.291	0.315
		p	0.811	0.000	0.000	0.000
	80	r	-0.008	-0.345	0.287	0.315
		p	0.888	0.000	0.000	0.000
Long Term Estimation (s)	About 10 min (600 s)	r	0.033	0.357	-0.306	-0.329
		p	0.532	0.000	0.000	0.000

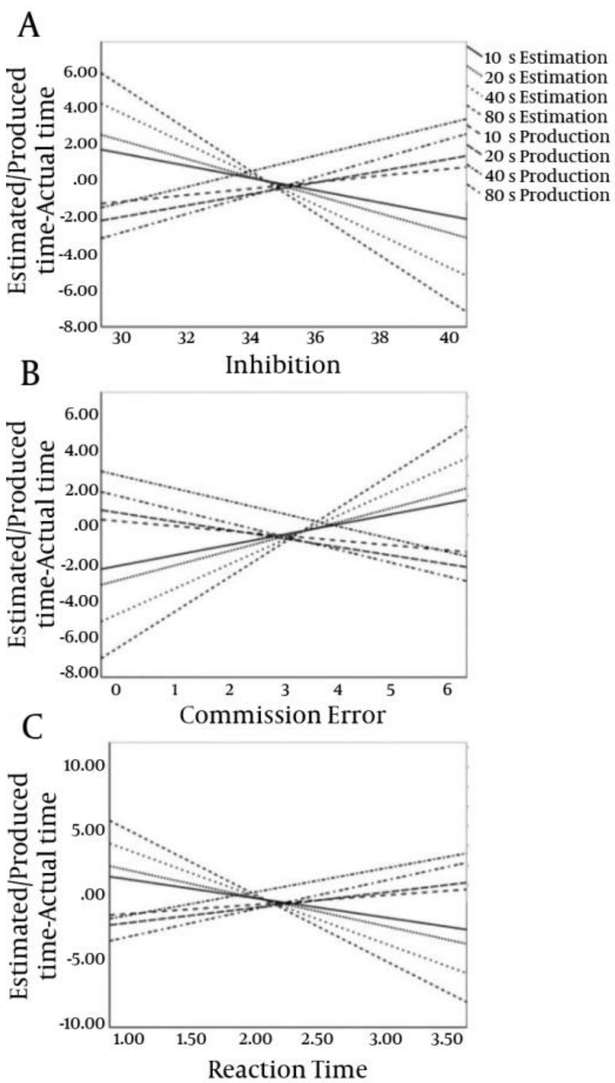

Figure 3. The Results of Partial Correlation Analysis between the Subscales of the Go/No-Go Test and the Subscales of the Time Perception Task, Controlled for the Group Variable.

4. Discussion

The primary objective of this research was to investigate the correlation between time perception and impulsivity among adolescents diagnosed with ADHD compared to those without the condition. Our findings revealed that individuals in the ADHD group exhibited poorer performance across all subscales of the go/no-go test in comparison to the control group. Specifically, omission and commission errors were notably higher in the ADHD group, while inhibition and reaction time were significantly lower when compared to the control group. These results align with previous studies conducted in this area.

For example, it has been indicated that the commission error is significantly higher in the ADHD group than the healthy group and methylphenidate can improve the go-no go performance of these patients by decreasing their tendency to make impulsive errors (18). Also, it has been argued that response inhibition is the primary deficit in ADHD (19). Also, it has been reported that the errors of commission are significantly correlated with the symptom of hyperactivity–impulsivity in ADHD patients (20).

In an effort to find out the neural causes associated with the inability to control the response in ADHD subjects, Suskauer et al. (2008) provided functional brain imaging evidence that adolescents with ADHD demonstrate significantly less activation than did the typically developing controls within the frontal networks in the pre-supplementary motor area, which are important for motor response selection (21). Furthermore, recently, Baijot et al. (22) investigated the electroencephalographic dynamics and inter-trial coherence linked to the event-related potential triggered by go/no-go visual stimuli, in adolescents with ADHD (22). Their findings revealed an impaired ability in adolescents with ADHD in conserving the brain oscillations associated with the processing of visual stimuli.

In the second phase of the study, we evaluated time perception in the two groups and compared their performances. Our results demonstrated that adolescents with ADHD generally had perceived the time intervals more than that actually were, and in the process of time production, they had produced shorter time intervals than what should be produced. So overall, it can be concluded that adolescents with ADHD perceive the passage of time faster than healthy subjects.

In this regard, Smith et al. (23) reported that adolescents with ADHD are impaired in their time discrimination and estimate time intervals longer and respond earlier in reproduction task when compared with controls (23). They suggested that deficient time perception in ADHD may impact the motor timing and reduce the precision of their motor activity. Toplak et al. (24) indicated that basic timing mechanisms are impaired in ADHD (24), and Gooch et al. (25) reported that adolescents with ADHD exhibit impairments in time perception compared to adolescents without ADHD (25).

Although the cause of the disturbance in the perception of time in patients with ADHD is still not well known, however, several hypotheses have been raised in this regard.

Scalar timing theory (26) proposed that timing is regulated by a complex underlying mechanism, involving an internal clock consisting of a pacemaker and an accumulator functionally connected to each other, as well as memory and decision mechanisms (26). Hurks et al. (27) pointed out towards parallel networks for regulating attention and impulse inhibition, so that in the event of damage of one component, another one will be affected as well (27). Walg et al. (28) provided evidence that difficulties in mental set-shifting extend to temporal processing in adolescents with ADHD (28).

In the last phase of the study, we observed that subjects with less response control ability had estimated the time intervals longer than their actual durations and had produced time intervals shorter than the requested time intervals in the time production task. Although evidence has suggested that the abnormal time perception and impaired response control in adolescents with ADHD both reflect underlying attentional mechanisms (29,30), however, in this study, we cannot confirm this, because we observed no significant difference between the case and the control groups in terms of omission errors, which in turn represent attentional deficits.

A limitation is this study was that we used adolescents as statistical sample. However, using children and adults in future studies can provide more comprehensive view on the effects of impulsivity on time perception in ADHD. In addition, larger sample size in future studies can be more effective.

4.1. Conclusions

Therefore, in summary, and based on the results of this study, it seems that, contrary to the previous hypotheses, processes involved in the regulation of attention do not significantly overlap with the processes involved in the perception of time. Future studies on larger and more homogeneous populations, as well as functional studies of the brain, can better determine the mechanisms underlying the correlation between impulsivity and time perception and may show the direction of this relationship.

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Footnotes

Authors' Contribution: This study was carried out solely by the corresponding author.

Conflict of Interests: The researcher confirms that there is no conflict of interests in this study with any participant.

Data Availability: The data that support the findings of this study are openly available upon request from the corresponding author.

Ethical Approval: Approval for this study was obtained from the university. The author confirms that all steps . The requirements of this study comply with ethical guidelines. Participants were informed about the characteristics of the study and gave written informed consent.

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