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Clinical Implications of the Perception of Time in Attention Deficit Hyperactivity Disorder (ADHD): A Review

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Attention deficit hyperactivity disorder (ADHD) is a lifelong neurodevelopmental disorder that can affect many areas of the daily life of individuals and is associated with poor health outcomes and with debilitating deficits in executive function. Recently, increasing numbers of research studies have begun to investigate the associations between neural and behavioral manifestations of ADHD. This review summarizes recent research on the perception of time in ADHD and proposes that this symptom is a possible diagnostic characteristic. Controlled studies on time perception have compared individuals with ADHD with typically developing controls (TDCs) and have used methods that include the Zimbardo Time Perspective Inventory (ZTPI). Practical approaches to time perception and its evaluation have shown that individuals with ADHD have difficulties in time estimation and discrimination activities as well as having the feeling that time is passing by without them being able to complete tasks accurately and well. Although ADHD has been associated with neurologic abnormalities in the mesolimbic and dopaminergic systems, recent studies have found that when individuals with ADHD are treated medically, their perception of time tends to normalize. The relationship between ADHD and the perception of time requires greater attention. Further studies on time perception in ADHD with other abnormalities, including executive function, might be approaches that refine the classification and diagnosis of ADHD and should include studies on its varied presentation in different age groups.

MeSH Keywords: **Adult • Attention Deficit Disorder with Hyperactivity • Child • Time Perception**

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Background

Attention deficit hyperactivity disorder (ADHD) is the most common psychiatric disorder in childhood and is currently understood to be a lifelong disorder, with some differences in symptoms and manifestations among different age groups [1]. The new understanding of ADHD as a lifelong condition became official with the 2013 publication of the American Psychiatric Association Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) and the subsequent addition of adult ADHD as an official diagnosis that is not always associated with childhood ADHD [1]. ADHD tends to be defined by observable behavioral manifestations rather than by neurological markers. The symptoms of ADHD tend to be nonspecific and include general inattention, hyperactivity, impulsivity, and difficulty with self-control. The symptoms of ADHD can be divided into categories, or manifestations, which include inattention, hyperactivity, and impulsivity, and combined types, with symptom severity ranging from mild to severe [1]. For adult ADHD, there are some differences in certain aspects of the disorder when compared with childhood ADHD [1,2]. Impairment of higher executive function is greater in childhood ADHD when compared with adult ADHD, and in adult ADHD symptoms such as hyperactivity are internalized in adults as restlessness, unlike externalized behaviors are noted in children [2]. There are other behavioral and emotional issues in ADHD that are outside the DSM-5 criteria that have also been noted.

The variety of symptoms associated with ADHD are highlighted by the varied approaches to treatment that can include drug therapy, psychotherapy, or behavioral therapy that often results in improvements of secondary symptoms that fall outside the official diagnostic criteria, such as emotional dysregulation [2,3]. Despite the prevalence of ADHD in the general population being as high as 4% in the general population, there continues to be little public awareness of adult ADHD [4]. There can be a lack of awareness within clinical settings possibly because of the many comorbidities associated with ADHD, leading to masking of symptoms, misdiagnosis, and poor management outcome [4].

Methods of assessment of ADHD that use self-reported scales and questionnaires have been shown to be effective tools for symptomatic adults, which can increase patient awareness of their condition. ADHD is associated with a wide variety of comorbidities, and even if the condition remits, the individual is at risk of other problems, such as substance abuse or binge eating [5,6]. The lifestyles and comorbidities associated with ADHD can be lifelong and often result in very poor health outcomes, lower quality of life, and increased mortality rates [7,8]. Because less is known about adult ADHD compared with childhood ADHD, improved understanding of adult ADHD might lead to improvements in therapeutic approaches and

diagnostic criteria, which could improve the quality of life in the ADHD population.

ADHD is associated with a variety of other disorders not included in the official diagnostic criteria, such as emotional disinhibition, problems with memory, self-awareness, and motivation, and there are recognized differences in the perception of time [9]. The concept of time is a mental and biological construct that is innate in many living organisms and includes the perception of time, time sequencing, and time reproduction. The perception of time is directly associated with time processing, or the ability to record and estimate how much time is passing. In this review, the perception of time is defined in practical terms, and time processing and time perspective are discussed in terms of the focus and speed of processing of time perception.

ADHD, the Perception of Time, and Time Processing

The relationship between specific deficits in executive function, such as difficulties with emotive and behavioral inhibition, reduced working memory capacity, self-motivation, planning, and problem-solving, and their connection with ADHD is one that is becoming clearer to clinicians. The issues related to executive functioning and differences in the perception of time have been noted more often in children with ADHD, but are now also being studied in adults with ADHD [10,11]. The connection between executive dysfunction and ADHD has led investigators to hypothesize that the symptomatology of ADHD could be connected with a deficit in the perception of time [12,13].

A study that compared children with ADHD and typically developing controls (TDCs) showed that children with ADHD had difficulties in prospective memory time tasks [14]. When a time-based prospective memory task was administered to an ADHD group and a TDC group, the performance of the ADHD group was significantly worse when compared with the TDC group, and they had more difficulty in remembering items from the task, with deficits in working memory and with inattention [14]. Other studies have shown that time tasks tend to result in the effect of cognitive overload in subjects with ADHD, which could lead to a significant disadvantage in everyday life and impede performance at school or work [15]. Based on these recent studies, it may be hypothesized that the perception of time is a mediating factor between ADHD and deficits in executive functioning and can result in significant difficulties for people with ADHD.

The psychiatrist and researcher Gabor Maté hypothesized that individuals with ADHD perceive that time is slipping by, and

this causes distress that leads to inattention or hyperactive and impulsive behaviors [16]. Studies that have investigated the relationship between ADHD and the perception of time have focused primarily on children and adolescents [13,17]. In 2005, Toplak and Tannock identified pronounced differences in adolescents with ADHD in time discrimination and perception, which led them to hypothesize that individuals with ADHD have severe impairments related to the perception of time and that they might have neurological causes [18]. Further studies showed that children with ADHD had deficits in the perception of time, time sequencing, and time reproduction when compared with TDCs. Other investigators also found differences between teenagers with ADHD and a control group for the estimation of time, particularly for longer intervals of times. The ADHD group did poorly on a continuous performance task, but there were no significant differences in working memory [19]. Barkley et al. reported the finding of a normalizing effect of ADHD medications on the perception of time as well as on core symptoms of ADHD [14]. When children with ADHD were tested on time tasks, the ADHD group who were medicated performed much better, even when distractions were added, compared with the unmedicated group [14].

Subsequent research studies have specifically investigated particular subtypes or presentations of ADHD, and have compared individuals with ADHD in inattentive symptoms (I) with those with combined (C) symptoms and TDCs [17]. In Puerto Rican children with ADHD (I) and (C), no significant differences were found in time estimation between the ADHD groups and TDCs, but impairment was noted for time reproduction tasks when the ADHD groups were compared with the TDCs [17]. Investigators have hypothesized that temporal reproduction is a cognitive endophenotype associated with executive dysfunction in ADHD, which might have specific genetic implications [20]. This hypothesis was tested in a small study on adults with ADHD in the United States and individuals with ADHD had difficulties in time estimation and replication tasks when compared with the non-ADHD controls [21]. Also, anatomical differences were noted in structural magnetic resonance imaging (MRI) scans, and there was increased grey matter volume in the cerebellum of the ADHD group [21]. These investigators hypothesized that there was a correlation between the cerebral anomalies and differences in the perception of time in the group with ADHD [21].

Recent structural studies of the cerebellum have confirmed previously reported anatomical differences in subjects with ADHD, as well as other regions of the brain, giving rise to new explanations for ADHD involving differences in white and grey matter and connectivity abnormalities [22,23]. Regarding time processing, researchers in Germany found several differences in cerebellar functioning in children with ADHD [24]. This study compared three groups, children with ADHD, children with clear

cerebellar lesions or dysfunction, and a control group [24]. Each study group was assigned time-processing exercises, including visual threshold and time estimation exercises [24]. The results of the study showed that children with cerebellar dysfunction and those with ADHD had impaired performance when compared with the controls, which indicated that cerebellar dysfunction affected time processing and time perception [24]. Also, Valko et al. found that time processing abnormalities were consistent in the various presentations of ADHD and in both the childhood and adulthood forms of ADHD [25]. A study conducted in China noted large differences in time processing and discrimination in children with ADHD [26]. This study evaluated a task to detect visual stimuli from sub-threshold to threshold of conscious appraisal of the stimulus and asked subjects to estimate the time that had gone by and to note when the stimulus was present [26]. In this study, children with ADHD took a significantly longer time to detect the threshold change and were more easily distracted during the task [26].

Individuals with ADHD do not always have significantly worse performance on time perception threshold tasks when compared with controls. There are times when individuals with ADHD better detect emotional stimuli. In an extensive study on the perception of time that was related to emotional stimuli, together with neutral stimuli, subjects with ADHD scored significantly higher when compared with TDCs, but only for emotional stimuli, and were also better at interpreting positive and negative emotional effects of the stimuli than were TDCs [27]. The findings of this study suggested that when a neutral task related to time discrimination was assigned, those with ADHD scored lower and had some difficulties, but when emotional stimuli were included, those with ADHD did better than the TDCs and appeared to be more focused [27]. Furthermore, situational stimuli such as interactions and overall pictures were more easily interpreted by children with ADHD [27]. Also, in 2015, Raz and Dan showed that adults with ADHD had worse performance in recognition of facial expressions but were more proficient than controls in situational analysis [28]. However, none of the participants from the ADHD group were medicated during the study [28]. The influence of medications used in the treatment of ADHD, such as methylphenidate, was found to have a positive effect on the perception of time but, of interest, the same effect was found when monetary rewards were offered [29]. The investigators in this study hypothesized that this finding was due to dopaminergic deficits or abnormalities in subjects with ADHD, as the offer of a monetary reward could also induce a spike in dopamine [29].

The simplest way to assess time processing is to use time estimation, which is the ability to state an approximate amount of time passed without using a watch or a timer. In studies in children, researchers in Germany found that those with ADHD did substantially worse than NDC children in time estimation [30].

Children with ADHD either overestimated the time passed, for example approximating 20 minutes for a ten-minute task, or minimized the time passed, to a much greater extent than controls [30]. The authors concluded that impaired perception of time was a significant component of ADHD, and further investigation into the prevalence of this symptom was needed [30]. A small study in Brazil assessed the effect of music on time processing and estimation and compared children aged between 6–14 years who had ADHD and who were treated with methylphenidate, with children with ADHD who were unmedicated, and TDCs [31]. In this study, music was used with a time estimation exercise and showed that both ADHD groups had impaired performance when compared with controls for time estimation, but that those who were medicated had slightly better estimation times compared with the controls [31]. Music reduced the symptoms of inattention of both the medicated and unmedicated groups with ADHD [31].

The literature suggests that people with ADHD perform poorly on specific timed replication tasks that rely heavily on controlling impulsiveness and focus on processes of attention [13]. These factors appear to be present when dealing with neutral tasks such as being able to recognize an image on a screen after only a brief exposure that lasts milliseconds [13]. However, individuals with ADHD have been shown to be able to detect emotionally relevant stimuli better than controls, and are also quicker to detect situational stimuli and to understand them correctly [13]. In general, there are perceptual time perspective differences that should be noted in ADHD, and a temporal perception deficit in the range of milliseconds in ADHD may affect other functions such as perceptual language skills and motor timing, which can substantially influence every aspect of life in children with ADHD and possibly persist into adulthood [13]. However, there are limited published studies on the topic of time perception in adults with ADHD.

Another aspect of time that seems to be impaired in ADHD is processing speed. Processing speed generally refers to how quickly things can be done [32]. However, in clinical research and in clinical practice, a wide variety of rapid tasks and measures are used to assess processing speed, including simple reaction time, scanning speed, and visual motor speed [33]. Several of the tasks designed to measure processing speed require a correct or accurate response, such as the Processing Speed Index from the Wechsler Intelligence tests. Tasks involving processing speed can vary widely in terms of complexity, from simple recognition and output speed to more complicated tasks requiring cognitive interference control [34]. A consensus definition of processing speed as a neuropsychological construct has not yet been reached, although it is considered to be a secondary aspect of ADHD that can be quite limiting to those affected. In a landmark study from 2006, children and adolescents with ADHD demonstrated significantly slower

processing speeds across an extended battery of rapid tasks that required either verbal or motor output [35]. While processing speed appears to be slower in many children and adolescents with ADHD, exactly how processing speed deficits manifest in daily functioning, and its relationship to the perception of time has not been well established [35].

Deficits in processing speed, as defined and measured by the Wechsler Intelligence Scale for Children (WISC), have been documented across many pediatric conditions, including ADHD [36]. Studies have investigated the neuropsychology of pediatric ADHD and have established that processing speed is slower in children and adolescents with ADHD [35,36]. When compared with controls, young people diagnosed with ADHD presenting with predominant symptoms of inattention showed deficits across several processing speed measures, including motor speed output, set shifting speed, and verbal output speed [35]. In addition to these phenomena in the perception of time, it is also important to investigate time perspectives and to develop a more practical understanding of the phenomena that non-clinicians can understand and implement in their lives.

ADHD and Time Perspectives

The existing research on the perception of time, time sequencing, and time reproduction provides useful insights and tools for further understanding ADHD from more than one perspective. These findings may add to the neurological findings, including the role of cerebellar abnormalities and differences in grey matter with time processing in people with ADHD. Several studies have also attempted to describe and capture individual differences in the perception of time, focusing on how the attention of the individual is focused on time perspectives, such as future, past, and present. Concepts such as balanced time perspective or future time perspective have been discussed and explored in the literature [37,38]. These psychosocial constructs are often embedded in the culture, with a melancholic focus on the past or positive setting of goals for the future, leading to postponement in pleasures of the present [37,38].

A standardized measure used to assess time perspective and aid future applications of research in practice is the Zimbardo Time Perspective Inventory (ZTPI) [39]. Carelli and Wiberg have shown the ZTPI to have strong external validity and demonstrated that it could be integrated therapeutically in everyday situations [39]. They proposed further research on the therapeutic potential of the ZTPI in adults with ADHD [39]. This ZTPI method estimates the intensity with which respondents focus their perception on the past, present, and future, and whether their time perspective tends to have a positive or negative value and balance. The five dimensions of the ZTPI include: the Past Positive dimension associated with positive

reminiscence or memories of the past; the Past Negative dimension that assesses the degree to which unpleasant or traumatic past experiences influence the life of the individual; the Present Hedonism dimension that includes living in the moment, and pleasure seeking; the Present Fatalism dimension that expresses the conviction that lives are not controlled by free will but by fate and luck; and the Future Dimension that assesses the degree to which individuals are goal oriented, focusing on accomplishments and responsibilities to other people, similar to the traditional protestant work ethic [39]. These five dimensions can be assessed individually or in their mutual relationship and balance, as individuals may be unbalanced and anchored primarily to one dimension such as present hedonism, or balanced between the various dimensions [39]. Zimbardo and Boyd have indicated that various types of disorders can be attributed to imbalances in the perception of time [40]. For example, individuals with post-traumatic stress disorder (PTSD) are anchored in the Past Negative orientation, which supports the view that the environment and experiences can alter the perception of time [40].

From the symptoms and lifestyle that they generally display, individuals with ADHD seem to be stuck in the present. More specifically, individuals with the Impulsive presentation of ADHD exhibit the time perspective of the Present Hedonism dimension in the ZTPI, due to lifestyles and comorbidities associated with ADHD [41]. These comorbidities include impulsive gaming and addictive use of social media, as well as more classically known addictions such as nicotine and cocaine addiction [41]. Similarly, investigators have found that individuals with bipolar disorder who are in the manic phase or with manic tendencies tended to display more present time perspectives when compared with controls [42].

Clinical Implications

Understanding and integrating the concepts of time within the clinical setting could be advantageous both in terms of diagnostic and treatment plans for individuals with ADHD. There are differences in executive functioning that are often crucial in ADHD. Executive functioning is a neuropsychological construct that includes the ability to engage in goal-directed, purposeful, future-oriented, problem-solving behavior [14,43]. Each of these aspects occurs in a limited period. Difficulties with the perception of time can lead to difficulties in the planning aspect of any remedy for executive dysfunction, such as the use of a calendar, scheduling the appropriate amount of time to complete an assignment, and setting short-term goals.

Furthermore, problems with processing speed can make many tasks more cumbersome and take longer to complete. Despite the lack of conceptual clarity surrounding these issues,

the perception of time could prove to be highly clinically relevant. It is important to better understand the functional consequences and relevant outcomes associated with deficits in the perception of time in combination with ADHD to facilitate the clinical care of young people with ADHD. Clinicians might focus on these areas to obtain a clearer picture of a patient's everyday life, and the issues associated with the concept of time might be integrated to assess the severity of the symptoms of ADHD.

Walig et al. conducted a study using the Wechsler Intelligence Scale for Children version IV (WISC-IV) and found that there were ways of integrating some of the WISC-IV time processing tasks to diagnose ADHD better [44]. They noted consistencies in time deficits in those with a confirmed diagnosis of ADHD rather than individuals suffering from some of the symptoms but at a low level, whom the authors referred to as 'pseudo-ADHD' [44]. In previously reported studies by these authors, the findings showed that adults with strong symptoms of ADHD had unique lifestyles and habits that might make diagnosis and treatment planning easier, and the perception of time could be viewed in similar terms as far as asking the right questions for diagnosis and including time treatments [45]. The inner clock of people with ADHD seems to run faster than in normal individuals, and this can be useful in diagnostics and can be integrated into treatment. Furthermore, tasks that for individuals without ADHD are perceived as repetitive or uninteresting are perceived as dragging on much longer for those with ADHD. In terms of practical solutions, this can be assisted in therapy by providing specific rewards for such tasks to lead to a better outcome for the activity [14,46].

Coaching in executive function is frequently used as a treatment for ADHD. A newly formulated paradigm in neuropsychology is termed perceptual microgenesis, which incorporates experiences and neurological processes in the brain as a complex evolving organ that includes the complexities of time perception [47,48]. Therefore, a condition such as ADHD could be seen from the perceptual microgenesis point of view and the disordered perception of time would be a logical component of this state [47,48]. A common technique used in student examinations is to ask students to estimate the length of time to perform a task, or to decide what they can accomplish in a given period. While the students are completing the task, it is also quite common to provide an estimate of how many minutes remain. This technique is used for students with ADHD, yet it assumes that they have an intact perception of time, but this is an unfair assumption that may make estimation and time monitoring inapplicable for many students with ADHD [32].

The overall corrective effect of ADHD medication, as demonstrated by Barkley et al., on time tasks and other executive functions, is of great importance as it gives a holistic view of

a complex disorder that has yet to be fully understood and investigated [14]. The so-called secondary symptoms of ADHD could provide clearer clues to its neurological basis and help in future approaches to treatment [14]. Also, the ZTPI could be used to help diagnose ADHD or institute treatment plans and improve outcome for patients that also include time perception, such as symptom management, balancing time perspectives and developing effective time management skills.

Conclusions

Further studies are needed to investigate the relationship between ADHD and the abnormal perception of time. Investigations on time perception in ADHD with other abnormalities, including executive function, might be approaches that refine the classification and diagnosis of ADHD according to its varied presentations in different age groups, including new developments in the management of symptoms and the role of psychotherapy.

With advances in neuroimaging techniques, it may be possible to understand disorders of perception and behavior in terms of differences in brain structure and function in individuals with ADHD when compared with normally developed controls (NDCs). These findings may lead to the development of new drug treatments for ADHD. Improvements in medical treatment of ADHD require improvements to be made beyond the classical view of ADHD as being defined solely by dopamine deficiency and increased dopamine transporter density (DTD). The differences in the perception of time point to possible differences in communication between different parts of the brain, including the hippocampus. Future developments in the diagnosis and management of ADHD require the identification of diagnostic and therapeutic biomarkers to improve current diagnostic approaches that are based on behavioral observation and often rely on self-reported assessments from individuals who may have ADHD.

Recognition of altered perception of time in ADHD is of clinical importance. Clinicians should ask their patients questions regarding the perception of time when asking questions about behavior and lifestyle. Approaches that integrate time-based treatment and behavioral coaching might be incorporated into cognitive behavioral therapy (CBT) with the understanding of the importance of the balanced perception of time in overall quality of life as part of psychotherapy for ADHD. There is also a need for clinicians to see ADHD in a broader perspective beyond the American Psychiatric Association Diagnostic and Statistical Manual of Mental Disorders, Fifth

Edition (DSM-5) criteria. There are aspects of ADHD that are associated with executive functioning, including the perception of time, which are just as important to note and just as debilitating to the people with ADHD. In terms of non-clinical implications, the findings on ADHD and the perception of time suggest that specific accommodations should be made for individuals with ADHD in the school setting. For example, in the United States, from elementary schools to universities, more time is being given for individuals with ADHD, to complete their examinations or assignments. The authors of this review article believe that, worldwide, educators could significantly help students with ADHD by implementing measures that acknowledge reduced time perception.

Parents who have children with ADHD-like symptoms, including these symptoms that often go unnoticed, which may include differences in the perception of time, working memory difficulties, and difficulties in self-control, at the appropriate age the might ask their children how they experience time. Time perception would be appropriate for parents to assess prior to bringing their child to be assessed for possible ADHD. Drugs that are used to treat ADHD, such as methylphenidate have a normalizing effect on the differences in the perception of time in subjects with ADHD. Although this finding is important, the best clinical outcomes for the management of ADHD are psychopharmacological treatments in conjunction with psychotherapy. The findings on time perception could be used to individualize therapy and coaching for better time management and to teach individuals to create schedules and routines. These kinds of interventions are worth pursuing in all age groups. Although children are the most likely age group to be diagnosed with ADHD, it should not be forgotten that adults are also living with ADHD. The implementation of therapy and drugs for adults could substantially improve their quality of life, help in their work and relationships, and help them to avoid negative health outcomes that are associated with ADHD when not adequately treated.

The findings from this review have indicated that further studies are needed on the perception of time, especially in adults. Further studies would provide a valuable addition clinical knowledge and might improve the understanding the nature of ADHD, raise awareness of the condition, and help develop effective treatments that are more holistic to manage symptoms and improve the quality of life for people with ADHD.

Conflict of interest

None.

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