



HAL
open science

Time knowledge impairments in children with ADHD

A. de la Charie, F. Delteil, F. Labrell, P. Colas, J. Vigneras, Hugo
Câmara-Costa, Y. Mikaeloff

► To cite this version:

A. de la Charie, F. Delteil, F. Labrell, P. Colas, J. Vigneras, et al.. Time knowledge impairments in children with ADHD. Archives de Pédiatrie, 2021, 28 (2), pp.129-135. 10.1016/j.arcped.2020.11.008 . inserm-03896240

HAL Id: inserm-03896240

<https://inserm.hal.science/inserm-03896240>

Submitted on 22 Mar 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

Time knowledge impairments in children with ADHD

Short title: Time knowledge impairments in children with ADHD

A. De la Charie ^{1*}, F. Delteil ^{1,2}, F. Labrell ^{2,3}, P. Colas ¹, J. Vigneras ¹, H. Câmara-Costa, ², Y.
Mikaeloff ^{1,2}

- ¹ CRTLA (Centre de Référence des Troubles du Langage et des Apprentissages), Hôpital Kremlin Bicêtre, AP-HP (Assistance Publique Hôpitaux de Paris), le Kremlin-Bicêtre, France.
- ² CESP (U1178), Fac.de médecine-Univ.Paris-Sud, Fac.de médecine-UVSQ, INSERM, Université Paris-Saclay, 94805, Villejuif, France.
- ³ INSHEA (national higher institute for training and research on special needs education), Grhapes (EA 7287), Suresnes, France.

***Corresponding author:**

Auriane de la Charie : aurianedlc@gmail.com

Abstract

Background: A large number of studies have shown time perception impairment and reaction time (RT) variability in children with attention deficit hyperactivity disorder (ADHD), and have discussed the causes of such difficulties. However, very few studies have investigated time knowledge (i.e., the correct representation and use of time units) in children with ADHD.

Methods: We evaluated time knowledge in 33 children with ADHD, aged 8–12 years, who had consulted a reference center for learning disabilities in Paris, matched for age and gender with 33 typically developing (TD) children. We used a simple questionnaire-based survey and neuropsychological tests for cognitive and attentional skills.

Results: The acquisition of time knowledge was delayed in children with ADHD compared with TD children ($p < 0.01$). At the end of primary school, children with ADHD obtained time knowledge scores that were close to those of TD children at the beginning of primary school. In children with ADHD, time knowledge was significantly related to the working memory index ($p < 0.05$), but not to ADHD presentation (with or without hyperactivity).

Conclusion: This study shows time knowledge impairment in children with ADHD, and paves the way for new screening tests and rehabilitation focused on time knowledge and time-related skills, in order to improve patient care and autonomy.

Keywords: Attention deficit / hyperactivity disorder (ADHD); time knowledge; time perception; care; autonomy.

Highlights

The acquisition of time knowledge is delayed in children with ADHD compared with typically developing children. Rehabilitation focused on time knowledge could help improve patient care and autonomy.

1 Introduction

Two models of time processing have been proposed: the internal clock model, which postulates that estimating duration depends on the accumulation of temporal information in working memory [1], and the state-dependent network model, suggesting a qualitative – rather than quantitative – nonlinear and action-dependent coding of time [2]. The theory of “scalar time” is based on the hypothesis of an innate internal clock, in the form of a “pacemaker-accumulator” system, combined with a storage system involving short- and medium-term memory [3]. This temporal processing model connects conception of time with other cognitive functions, such as attentional skills toward events experienced, working memory to process the information received, and long-term memory to evaluate temporal concepts retrospectively. For some authors, the involvement of these executive functions in time perception is a key point in understanding the evolution of time perception in children according to their age [4]. This link between time perception and other cognitive functions, including working memory, is also reinforced by studies using functional neuroimaging to investigate brain structures activated by time-processing tasks [5].

Tasks that explore time perception can be divided into two groups according to whether or not a verbal answer using numbers and time units is required. For short time intervals (up to a few seconds), time perception in children has been investigated, following the “internal clock” model, using temporal reproduction or temporal discrimination tasks that do not use verbal encoding. These investigations have shown an increased performance with age during childhood, associated with an improvement in attention, working memory, and processing speed [6]. Exploring the perception of long durations (hours, days, years) requires verbal encoding. These “verbal” time tasks explore the correct representation and the correct use of time units, which have been defined as “time knowledge” (TK) studied in typically

developing (TD) children and in children treated for malignant cerebellar tumors [7,8]. It is thought that TK depends on two categories of factors: (1) academic knowledge and numerical skills, such as understanding of the principles of division (e.g., 1 day=24 h, 1 h=60 min, etc.); (2) factors related to action-perception coupling, enabling a correct “representation” of what 1 min, 1 h, etc. is exactly. For instance, 1 min can be seen as a representation of all actions that can be performed in 1 min, and this is an action-dependent encoding of time, as proposed by the state-dependent network model [2].

TK during childhood improves with academic learning of words and numbers at school. Time orientation and awareness of the present hour, day, month, year, or season are the first steps toward conventional TK. According to Friedman, from the age of 5 years, children develop a list-based representation of time, relying on lexical working memory; then, at about 7 years of age, the concept of “cycles” in daily life events appears, with the notion of order and the recurrence of chronological sequences, related to logical reasoning and the ability to recognize series; finally, at around 10 years of age, children discover a spatial representation of time that enables them to understand the relationships between time units and to estimate the “distance” between days, weeks, months, and seasons [9]. At about the same age, children develop “diachronic thinking” or the ability to conceptualize events that are unfolding, i.e., to understand the passing of time and the link with sequences of events. Being able to represent the span of a lifetime and to understand the irreversibility of growth for humans stems from this ability. Indeed, an accurate estimation of age gaps between human beings seems to be a difficult task for young children [7]. Finally, with regard to tools measuring time, telling the time on a clock is a complex cognitive activity that relies on several domains of competence, such as mathematics, language, visual-spatial skills, and conceptual representations [10].

The etiology and pathophysiology of attention deficit with hyperactivity disorder (ADHD) are still debated [11]. ADHD is characterized by attention deficit and/or psychomotor hyperactivity and impulsivity. There are three subtypes of ADHD presentation: mixed, predominant inattention, or predominant hyperactivity/impulsivity [12]. The link between ADHD and executive function disorders is a regular topic in ADHD studies. For some authors, the symptoms of children with ADHD result first from disability in understanding time conceptions and chronology [13]. In addition, studies related to time conception in TD children have shown that prospective time perception is influenced by the ability to pay attention [4], and a link between impulsivity and alteration in time conception is also found in

some pathologies involving impulsivity, such as bipolar disorder, alcoholism, and substance abuse [14]. Supported by the findings of health support workers, the hypothesis of an alteration in time conception in children with ADHD has thus been envisaged in several studies [15–17]. Finally, children with ADHD are less accurate in reproducing durations (seconds to minutes), which is a task involving working memory, this being observed regardless of age, type of stimulus (auditory, visual, or mixed), and duration (500 ms to 90 s) [15,16]. This difficulty in reproducing durations seems to increase with the duration of the stimulus (3, 6, 12, 24 s) [16].

Concerning TK, a Swedish team evaluated time conception in healthy children, and studied the relationship between time conception and autonomy in children with ADHD, autism spectrum disorder, mild or moderate mental retardation, myelomeningocele, or brain injury [18]. Significant correlations were found between children's time conception and self-evaluated autonomy by children, but also between children's time conception and the evaluation by fathers of their children's daily time management. However, the heterogeneity of the study populations and the lack of specific results for children with ADHD tend to make the interpretation of the findings for children with ADHD difficult. Thus, alterations in time conception in children with ADHD have been mentioned in many studies, and the pathophysiological mechanisms responsible for these disorders have been discussed. Overall, the development of TK (defined as the correct representation and use of time units) in children with ADHD, despite its relevance to everyday clinical practice and to the autonomy of a child, has been the object of little or no research. The first aim of the present study was to investigate the presence or absence of TK difficulties in children with ADHD, using a validated TK tool. The second aim was to examine which factors (such as age, ADHD presentation, cognitive functions, academic skills, and comorbidities) are associated with TK.

2 Methods

The clinical data collection and psychological tests were those recommended for children with ADHD in France [19]. Clinical data were collected from parents and children in the course of a multidisciplinary evaluation, and from questionnaires or reports completed by teachers and health professionals (speech therapists, psychologists). The evaluation of attention and the psychometric neuropsychological assessments were conducted by trained neuropsychologists. Informed consent to participate was obtained from both parents, following the ethics committee recommendations, and the study protocol was approved by Kremlin Bicêtre University Hospital Ethics Committee (PP 15-015).

2.1 Participants

2.1.1 Children with ADHD

Children attending a consultation in the CRTLA (*Centre de Référence des Troubles du Langage et des Apprentissages*) of the Kremlin Bicêtre Hospital in Paris, France, and presenting the following criteria were included: (1) age 8–12 years; (2) diagnosis of ADHD using the *Diagnostic and Statistical Manual of Mental Disorders*, 5th edition (DSM-V) by a neuropsychiatrist [12]; (3) intelligence quotient (IQ) in the standard range or above the norm for age (IQ >70) according to Wechsler's Intelligence Scale, 4th edition (WISC-IV) or Wechsler's Preschool and Primary Scale of Intelligence, 3rd edition (WPPSI-III). An associated specific learning disorder was not a criterion for exclusion. Exclusion criteria were disorders of psychiatric origin, absence of psychometric assessment of IQ, and methylphenidate treatment.

2.1.2 Typically developing (TD) children

TD children were recruited at school and matched individually for age (± 3 months) and gender with children with ADHD. They belonged to a larger series of 105 school-aged children enrolled in general education classrooms [7,8,20]. Both parents gave their informed consent for children to participate in the study, and teachers were instructed to recruit children with no special educational needs, no history of schooling delay, and without any reported learning, behavioral, or neurological disorders [7,8,20]. Furthermore, as children's TK changes considerably between the beginning and the end of the primary school, the group TD children was divided into two age categories: from second to third grade (first part of primary school), and from fourth to sixth grade (second part of primary school).

2.2 Data collection

2.2.1 Diagnosis of ADHD and associated specific learning disorders

The diagnosis of ADHD was made in a school and family-suggestive context, on the basis of the DSM-V criteria [12]. Results from the behavioral questionnaires developed by Conners [21] and Achenbach [22] and from standardized neuropsychological attention tests such as the Neuro-Psychological battery (NEPSY II) [23], the Test of Everyday Attention for Children (TEA – Ch) [24], and the Continuous Performance Test, version II (CPT II) [25] were also taken into account at the time of the children’s inclusion in the study. During the neuropediatric examinations, an assessment of learning abilities was made using the standardized EDA battery (*Evaluation Des fonctions cognitives et des Apprentissages* [26]). The children’s level in language, reading and written expression, mathematics as well as their coordination skills were assessed to confirm any diagnosis of associated specific learning disorders (about language, reading and writing expression, mathematics, developmental coordination).

2.2.2 Neuropsychological attention tests: index retained for analysis

To assess the link between attention parameters and ZK in children with ADHD, we used the Conners Continuous Performance Test – Version II (CPT II [25]). Participants were asked to press a keyboard spacebar whenever a letter appeared on the screen, and not to press the spacebar when the letter “X” appeared. This test allows for the computation of a Confidence Index, which was selected for the purpose of the present study. This index represents an indicator of the probability that a respondent’s profile resembles that of a clinical ADHD profile [25]. Index values greater than 70% suggest strong evidence for clinical classification.

2.2.3 Time Knowledge Questionnaire (TkQ): content and scoring

The TK questionnaire (TkQ) that we used in our study has the advantage of assessing TK in children in a simple, quick (10 min), and standardized manner, combining: (1) conventional TK, such as time orientation (day/month/year), time sequences (months/seasons), relationship between time units (seconds, minutes, hours), telling the time on a clock; (2) the estimation of periods (months/years), using the contexts of birthdays and life cycles; and (3) the estimation of the passing of time (duration of interview). Normative data were obtained for the general population from previous studies [7,8,20].

The TkQ is composed of seven items. The “Time Orientation (OR)” item includes five questions, assessing whether the children are able to describe the moment of the interview: “What day is it today?”; “What time is it?”; “What month, year, season are we in?” Regarding the notion of time of day, the answer is considered correct if the children accurately indicate the right part of the day (morning or afternoon). For the “Time Sequences (SEQ)” item, the children are asked to say which month comes after March, and to give months and seasons in chronological order. For months in order, the answer is correct even if children make one mistake. The “Time Units (TU)” item includes four questions, each carrying 1 point. The first three questions are designed to compare two durations: a minute versus a second, a week versus a month, and a month versus a year. The fourth question concerns the number of hours making up a day. For the first four questions in the “Clock (CLO)” item, children have to choose among five analogue clocks the one corresponding to time given by examiner. For the last question, children have to estimate how many minutes is it to 2 o’clock, looking at an analogue clock showing 1 h and 35 min. The children are then shown four pictures in the “Ages of Life (AGE)” item, representing a baby, a child, a young man, and an older man. The three questions focus on the time required to go from one age to another, i.e., baby to child, child to young adult, and young adult to old man. Each answer is rated 0, 1, or 2 points.

Scoring is based on responses by 20 adults: from baby to child, the average was 6.3 years (SD = 1, 8), with a range of 4–10 years; from child to adult, the average was 22.4 years (SD = 3, 3), range 15–30 years; from young adult to old man, the average was 36.1 years (SD = 8, 7), range 20–55 years. When the children’s responses are within these intervals, they score 2 points. One point is given if the answer lies within the following intervals: range of 2–3.99 or range of 10.01–15 years for baby–child, range of 5–14.99 or range of 30.01–40 years for child–adult, and range of 55.01–90 years for young/old adult. No point is awarded for the “don't know” response or for values outside the ranges mentioned. The scores for the “Cyclic Time (CYC)” or “birthday” items are based on the answers to two questions: “How many months (and days) is it since your last birthday?”; “How long (months, days) is it to your next birthday?” For these two durations between the day of the interview and the previous or next birthday, no point is awarded for “don't know” answers or for answers of more than 12 months. One, 2, or 3 points are given for mistakes exceeding 3 months, between 1 and 3 months, and less than 1 month, respectively. Finally, at the end of the interview, the examiner asks the children: “How long have we been here together?” The score for this “Current Time (CUR)” item is defined in relation to an algorithm based on the difference between the logarithm of real time and the time given by the children.

2.3 Statistical analysis

The statistical analysis was performed using SAS version 9 software. We used: (1) descriptive statistics (percentages for categorical variables, means, standard deviations, and ranges for continuous variables); (2) tests of association between two variables, including the chi-square test, Student’s *t* test, and Pearson’s correlation coefficient; (3) linear regression (proc GLM and proc REG on SAS), to explore the role of different factors on time questionnaire total

scores (age, gender, IQ and cognitive skills, presence of learning disorder, ADHD presentation).

3 Results

3.1 Description of the study population

A total of 33 children with ADHD consulting the Kremlin Bicêtre Hospital CRTLA, between December 1, 2014 and May 31, 2015 were included. The descriptive characteristics of this population are summarized in Table 1. Mean age was 9.4 years old (SD = 1.0). Concerning medical records, six (18%) children had a history of minor neonatal problems: prematurity (35 weeks, $n=2$; 36 weeks, $n=3$), oligohydramnios without prematurity ($n=1$). No children were extremely premature, and no neonatal infectious diseases were reported. Five (15%) children had surgery for recurrent otitis. Primary school class distribution was as follows: two (6.1%) children in second grade, with one of them in a special needs school, 14 (42.4%) in third grade, seven (21.2%) in fourth grade, eight (24.2%) in fifth grade, and two (6.1%) in sixth grade. Most of the children with ADHD in our study had DSM-V ADHD inattentive presentation: 20 (60.6%) children had ADHD combined presentation, and 11 (33.3%) children had “pure” ADHD inattentive presentation. For 21 (63.6%) children who underwent the CPT II test, 17 (81%) had a positive CPT II index of confidence, and the mean CPT II index of confidence was 78.8% (SD = 14.5). Achenbach’s questionnaire was administered to 22 (66.7%) patients, and their ADHD mean score was 67 (SD = 8.5). Finally, for patients with hyperactivity, the mean index of hyperactivity according to the Conners questionnaire was 72.3 (SD = 12.9).

3.2 Comparison between children with ADHD and TD children

The TD population in our study was taken from a cohort of 105 children included in a survey in 2012: 57 (46%) girls and 48 (46%) boys, aged 6.2–11.1 years. In total 33 children were selected matching their age and gender with those of the 33 children with ADHD (Table 2). There was no significant difference in age, gender, or school grade between the group of children with ADHD and TD children.

Table 3 shows the TkQ results comparing children with ADHD and TD children, by age group. The age effect was significant for all subtests except orientation. The group effect (ADHD vs. TD children) was significant for all subtests ($p < 0.0001$ for subtotal and total TkQ scores). The age group interaction was significant for the time units (TU) and ages of life (AGE) subtests ($p = 0.003$) and for the total score ($p = 0.005$), with a greater difference between children with ADHD and TD children in the younger age group than in the older age group. The mean TkQ total score of children with ADHD in the fourth to sixth grades was lower than the average TkQ total score of TD children in second and third grades (30.1 vs. 33/39). Finally, it is interesting to note that variability in performance was greater in children with ADHD than in TD children ($SD = 7.6$ vs. 3.4) in both age groups. Figures 1 and 2 show the significant difference between children with ADHD and TD children of the same age in the acquisition of TK.

In the younger age group (second and third grade), children with ADHD failed more frequently in the TU test compared with TD children. Whereas the younger children in the TD group gave correct answers to almost all of the four questions of the TU test (average score 3.9/4), children with ADHD in the same age range responded correctly to less than three questions on average (score 2.8/4). Estimates in the AGE item also highlighted difficulties for younger children with ADHD. Their average score for this item was half that of the TD group

(2.6 vs. 5.3/6). Younger children with ADHD also had difficulties answering questions on the CYC and the birthday items. The average score of the younger children with ADHD was 2.5 whereas younger TD children scored an average of 4.4/6. Finally, concerning the CUR item, the average score of the younger children with ADHD was half that of the TD children of the same age (4.1 vs. 8.5/10).

3.3 Factors associated with the TkQ total score in children with ADHD

There was no significant association between scores for inattention and hyperactivity-impulsivity and the TkQ total score ($p > 0.50$). Nor was there any significant association between the CPT II index of confidence for ADHD $> 70\%$ and the TkQ total score ($p = 0.58$). Concerning Wechsler IQ, the TkQ total score was significantly linked to the Verbal Comprehension Index score ($r = 0.38$, $p < 0.05$) and the Working Memory Index score ($r = 0.48$, $p < 0.05$). These correlations were no longer significant after correction for multiple comparisons. Overall, 14 (42.4%) children with ADHD had reading and written expression disorders, 12 (36.4%) had developmental coordination disorder, and 11 (33.3%) children presented difficulties in mathematics according to the EDA assessment. There was no significant association between having one of these comorbidities and the TkQ total score.

4 Discussion

Our study shows TK impairment in young children with ADHD, compared with TD children matched for age and gender.

Our study population included 79% of boys, close to figures for ADHD given in the literature: 77% in Europe and 85% in France [19]. The mean age of the children was 9.5 years, corresponding to the mean age at diagnosis in France [19]. The intellectual profile of our ADHD population, with a significant difference between the Verbal Comprehension Index (VCI) and Perceptual Organization Index (POI) in favor of VCI, has been found in other studies and has been associated with developmental coordination disorder comorbidity [27]. The children in our population were recruited in a learning disorder reference center in Paris. Learning disorders are a common gateway for ADHD diagnosis, and 30–50% of children with ADHD have learning disorders [19]. Furthermore, 73% of ADHD families report the initiating of diagnostic procedures in the context of difficulties encountered in school [19], and teachers are often in the front line for reporting children with ADHD difficulties (78.3% of children with ADHD) [28]. Therefore, our study population seems to provide a representative sample of children with ADHD in relation to the population diagnosed in France. Concerning associated learning disorders, 42% of the children with ADHD in our study presented additional reading and written expression disorders. Indeed, reading and written expression disorders are frequent among children with ADHD (from 25 to 40%) [29]. No correlation was found between Achenbach's ADHD score and the CPT II index of confidence for ADHD. The Conners and Achenbach questionnaires show good internal validity and have been used in several studies of children with ADHD. However, the French Health Authority (*Haute Autorité de Santé*) specifies that “questionnaires are useful in assessment processes but are not sufficient to diagnose ADHD” [19].

According to Barkley, the symptoms of children with ADHD result first from difficulties in understanding time conception and chronology [13]. TK has not been specifically studied in children with ADHD [16]. A strength of our study is the use of a specific TkQ that is a standardized assessment tool for TK in children. Its relevance has been objectified in several previous studies of TD children as well as diseased children [7,8,20]. The present study has shown a very significant gap between children with ADHD and TD children of the same age in the acquisition of TK. This confirms the existence of time conception difficulties in children with ADHD. The gap between children with ADHD and TD children was more marked among younger children in second and third grades, suggesting that ADHD is associated with a delay in the acquisition of TK at the beginning of primary school. We also noted similar scores for children with ADHD at the end of primary school and TD children at the beginning of primary school in many TkQ subtests such as OR, SEQ, and TU.” For the items AGE and interview duration or CUR, the results obtained for older children with ADHD were even lower than those obtained for younger TD children. Thus, the delay in the acquisition of time conception in children with ADHD persists at the end of primary school, although children with ADHD seem to be able to acquire certain aspects of time conception. Among the time questionnaire items, the understanding and use of time markers was one of the most frequently failed skills by children with ADHD compared with TD children of the same age. Time orientation (current full date and time of day), time sequences (months and seasons), and using time units (seconds and minutes, number of hours in a day) are particularly difficult for children with ADHD. Correct use of these time markers requires written language abilities, skills in mathematics and especially the ability to compare quantities, as well as working memory. Estimating a person’s age and the age gap between two people also seems to be difficult for children with ADHD. Thus, it is difficult for these children to estimate long periods (in years). Once again, this skill mainly involves

mathematical ability: analog time representation (e.g., positioning a number on a line) and mental arithmetic. Working memory is also mobilized in this exercise. The children in our study also found it difficult to count months since their last birthday and months until their next birthday. In addition to knowing the months of the year in order, this test involves conventional TK, i.e., number of days in a month, and number of months in a year. Once again, the answer requires working memory in the form of mental arithmetic. Finally, the children with ADHD made more mistakes in estimating interview duration than did the TD children of the same age. This item reflects verbal and digital forms of retrospective time perception assessment, and mobilizes working memory. To sum up, children with ADHD failed mostly in the items that require primarily verbal abilities, mathematical skills, and working memory.

The present study shows links between the time questionnaire total score and the Working Memory Index (WMI). Using time markers (seconds, minutes, hours, days of the week, months, seasons) seems to be particularly related to working memory ($p < 0.01$). Therefore, time conception difficulties in children with ADHD could be related to working memory capacities. Concerning the psychometric assessment of children with ADHD, our study also found a significant association between the VCI and the time questionnaire total score. Indeed, to succeed on the time questionnaire, children have to understand questions that are asked orally by the examiner before they can respond. Thus, specific time vocabulary must be known (“months,” “seasons,” “seconds,” “minutes”). This link therefore appears to be related to the way in which children’s TK is assessed in the study rather than to a causal link with the time conception disorders in ADHD.

Finally, our study did not find any link between ADHD presentation and time conception skills. Hyperactivity–impulsivity co-occurring with attention problems does not seem to affect

skills in the conception of time. However, a limitation of our study concerned the low number of children for this subgroup analysis. In the current literature, the results of studies on the links between ADHD presentation and time conception remain contradictory, but most of them have found no significant links [15,16]. Further studies with bigger samples and aimed at comparing “pure” inattentive ADHD with combined or “pure” hyperactive–impulsive ADHD could determine more formally the reality of any link between ADHD presentation and time conception skills in these children.

Overall, this is one of the first studies presenting evidence of a significant difference in TK between children with ADHD and TD children. These results should encourage future research to investigate TK while taking into account the role of ADHD and its comorbidities (e.g., developmental coordination disorder, learning disabilities), executive function and cognitive difficulties, number processing and calculation problems, as well as language-related difficulties.

5 Conclusion

International guidelines for children with ADHD mention difficulties in managing time and daily activities in school, and recommend psychomotor rehabilitation and/or teaching strategies for adults caring for children with ADHD [19,30]. Nevertheless, none of them addresses time conception difficulties in children with ADHD compared with TD children of the same age, and no standardized scale is available to healthcare professionals to assess the different time conception skills. As a result, these difficulties are not screened for and are not taken into account in the care of children with ADHD. Children with disabilities encounter difficulties in daily functioning related to time conception problems: organization and planning difficulties, as well as empowerment difficulties [18]. Compared with previous studies on time conception in children with ADHD, our study has the advantage of proposing

an easy, practical, and relevant standardized tool to objectify and track time conception difficulties in children with ADHD.

Acknowledgments

We wish to thank all CRTLA members for their participation in patient care.

Disclosure

The authors declare that they have no competing interest.

References

- [1] Gibbon J, Church RM, Meck WH. Scalar timing in memory. *Ann N Y Acad Sci* 1984;423:52–77.
- [2] Karmarkar UR, Buonomano DV. Timing in the Absence of Clocks: Encoding Time in Neural Network States. *Neuron* 2007;53:427–38.
- [3] Wearden J. Origines et développement des théories d’horloge interne du temps psychologique. *Psychol Fr* 2005;50:7–25.
- [4] Zélanti PS, Droit-Volet S. Cognitive abilities explaining age-related changes in time perception of short and long durations. *Journal of Experimental Child Psychology* 2011;109:143–57.
- [5] Buhusi CV, Meck WH. Relative time sharing: new findings and an extension of the resource allocation model of temporal processing. *Phil Trans R Soc B* 2009;364:1875–85.
- [6] Droit-Volet S. Time perception in children: A neurodevelopmental approach. *Neuropsychologia* 2013;51:220–34.
- [7] Labrell F, Mikaeloff Y, Perdry H, et al. Time knowledge acquisition in children aged 6 to 11 years and its relationship with numerical skills. *Journal of Experimental Child Psychology* 2016;143:1–13.
- [8] Labrell F, Câmara-Costa H, Kieffer V, et al. Time knowledge difficulties following treatment for malignant cerebellar tumors. *Child Neuropsychol* 2018;24:524–40.
- [9] Friedman WJ. The development of children’s understanding of cyclic aspects of time. *Child Dev* 1977;48:1593–9.
- [10] Burny E, Valcke M, Desoete A. Towards an agenda for studying learning and instruction focusing on time-related competences in children. *Educational Studies* 2009;35:481–92.
- [11] Broyd SJ, Demanuele C, Debener S, et al. Default-mode brain dysfunction in mental disorders: A systematic review. *Neuroscience & Biobehavioral Reviews* 2009;33:279–96.
- [12] American Psychiatric Association, American Psychiatric Association, editors. *Diagnostic and statistical manual of mental disorders: DSM-5*. 5th ed. Washington, D.C: American Psychiatric Association; 2013.
- [13] Barkley RA, Koplowitz S, Anderson T, et al. Sense of time in children with ADHD: effects of duration, distraction, and stimulant medication. *J Int Neuropsychol Soc* 1997;3:359–69.
- [14] Rubia K, Halari R, Christakou A, et al. Impulsiveness as a timing disturbance: neurocognitive abnormalities in attention-deficit hyperactivity disorder during temporal processes and normalization with methylphenidate. *Phil Trans R Soc B* 2009;364:1919–31.
- [15] Noreika V, Falter CM, Rubia K. Timing deficits in attention-deficit/hyperactivity disorder (ADHD): Evidence from neurocognitive and neuroimaging studies. *Neuropsychologia* 2013;51:235–66.
- [16] Smith A, Taylor E, Warner Rogers J, et al. Evidence for a pure time perception deficit in children with ADHD. *J Child Psychol & Psychiat* 2002;43:529–42.
- [17] Sonuga-Barke EJS, Taylor E, Sembi S, et al. Hyperactivity and Delay Aversion?I. The Effect of Delay on Choice. *J Child Psychol & Psychiat* 1992;33:387–98.
- [18] Janeslätt G, Granlund M, Kottorp A. Measurement of time processing ability and daily time management in children with disabilities. *Disability Health J* 2009;2:15–9.

- [19] Haute Autorité de Santé. Recommandation de bonne pratique : Conduite à tenir en médecine de premier recours devant un enfant ou un adolescent susceptible d'avoir un trouble déficit de l'attention avec ou sans hyperactivité. 2014.
https://www.has-sante.fr/jcms/c_1362146/fr/conduite-a-tenir-en-medecine-de-premier-recours-devant-un-enfant-ou-un-adolescent-susceptible-d-avoir-un-trouble-deficit-de-l-attention-avec-ou-sans-hyperactivite
- [20] Labrell F, Câmara Costa H, Perdry H, et al. The Time Knowledge Questionnaire for children. *Heliyon* 2020;6.
- [21] Conners CK. Conners 3rd Edition Manual. Toronto, Ontario, Canada: Multi-Health Systems Inc; 2008.
- [22] Achenbach TM, Edelbrock CS. Manual for the child behavior checklist and revised child behavior profile. Burlington, VT: T.M. Achenbach; 1983.
- [23] Korkman M, Kirk U, Kemp S. NEPSY-II: Bilan Neuro-Psychologique de l'enfant. 2nde ed. Paris: Edition Centre de Psychologie Appliquée; 2012.
- [24] Manly T, Robertson IH, Anderson V, et al. The Test of Everyday Attention for Children (TEA-Ch). Bury St Edmunds, England: Thames Valley Test Company; 1999.
- [25] Conners CK. Continuous Performance Test version II. North Tonawanda, NY: North Tonawanda, NY: Multi-Health Systems; 2000.
- [26] Billard C, Touzin M. EDA évaluation des fonctions cognitives et apprentissages (nouvelle BREV). Isbergues: Ortho édition; 2012.
- [27] Loh PR, Piek JP, Barrett NC. Comorbid ADHD and DCD: Examining cognitive functions using the WISC-IV. *Research in Developmental Disabilities* 2011;32:1260–9.
- [28] Hodgkins P, Setyawan J, Mitra D, et al. Management of ADHD in children across Europe: patient demographics, physician characteristics and treatment patterns. *Eur J Pediatr* 2013;172:895–906.
- [29] Willcutt EG, Betjemann RS, McGrath LM, et al. Etiology and neuropsychology of comorbidity between RD and ADHD: The case for multiple-deficit models. *Cortex* 2010;46:1345–61.
- [30] Canadian Attention Deficit Hyperactivity Disorder Alliance (CADDRA). Lignes directrices canadiennes sur le TDAH. Toronto, Ontario: CADDRA; 2010.

Table 1: Characteristics of children with ADHD

Baseline characteristics	
<i>n</i>	33
Age (mean \pm SD)	9.4 \pm 1.0
Gender male, <i>n</i> (%)	26 (78.8)
Right-handed, <i>n</i> (%)	29 (87.9)
Wechsler scales, mean \pm SD (range)	
VCI	103 \pm 12 (88–132)
POI	89 \pm 14 (60–119)
WMI	91 \pm 12 (70–115)
PSI	93 \pm 14 (71–118)
Associated specific learning disorder, <i>n</i> (%)	22 (66.7)
ADHD characteristics	
DSM V ADHD presentation, <i>n</i> (%)	
inattentive	11 (33.3)
hyperactive	2 (6.1)
combined	20 (60.6)
CPT II index for ADHD	
<i>n</i> (%)	21 (63.6)
Mean \pm SD	78.8 \pm 14.5
Significantly positive index, <i>n</i> (%)	17 (81.0)

Abbreviations: VCI: Verbal Comprehension Index; POI: Perceptual Organization Index;
WMI: Working Memory Index; PSI: Processing Speed Index;
ADHD: Attention deficit hyperactivity disorder;
DSM: *Diagnostic and Statistical Manual of Mental Disorders*;
CPT II: Continuous Performance Test version II;
SD: standard deviation.

Table 2: Comparison of age, gender, and grade between children with ADHD and typically developing children (TD)

Group		ADHD <i>n</i> = 33	TD <i>n</i> = 33
Age*, mean ± SD		9.4 ± 1.0	9.5 ± 0.9
Gender, <i>n</i> (%)	M	26 (78.8)	26 (78.8)
	F	7 (21.2)	7 (21.2)
Grade, <i>n</i> (%)	Second	2 (6.1)	0
	Third	14 (42.4)	13 (39.4)
	Fourth	7 (21.2)	11 (33.3)
	Fifth	8 (24.2)	9 (27.3)
	Sixth	2 (6.1)	0

**p* 0.62

Abbreviations: M: Male; F: Female; SD: standard deviation; ADHD: attention deficit hyperactivity disorder; TD: typically developing children.

Table 3: Time Knowledge Questionnaire (TkQ): comparison of children with ADHD and typically developing children (TD), according to age

	Score max	Second and third grades		Fourth and fifth grades		All children		<i>p</i>		
		ADHD (<i>n</i> = 16)	TD (<i>n</i> = 13)	ADHD (<i>n</i> = 17)	TD (<i>n</i> = 20)	ADHD (<i>n</i> = 33)	TD (<i>n</i> = 33)	<i>p</i> (age)	<i>p</i> (group)	<i>p</i> (interact)
OR total	5	4.1 (1.2)	4.8 (0.3)	4.4 (0.7)	4.9 (0.3)	4.2 (1.0)	4.9 (0.3)	0.282	0.001*	0.43
SEQ total	3	1.6 (0.8)	2.3 (0.8)	2.1 (1.1)	2.6 (0.6)	1.8 (1.0)	2.4 (0.7)	0.072	0.008*	0.475
TU total	4	2.8 (1.1)	3.9 (0.2)	3.8 (0.4)	3.9 (0.3)	3.3 (0.9)	3.9 (0.2)	0.004*	0.0001*	0.003*
CLO total	5	3.1 (1.0)	3.8 (0.8)	4.2 (0.7)	4.7 (0.4)	3.7 (1.0)	4.3 (0.7)	<0.0001*	0.0063*	0.668
Total 1	17	11.6 (2.6)	14.9 (1.7)	14.5 (2.0)	16.0 (1.0)	13.0 (2.7)	15.6 (1.4)	<0.0001*	<0.0001*	0.0723
AGE total	6	2.6 (2.2)	5.3 (0.6)	4.6 (1.6)	4.8 (1.4)	3.6 (2.1)	5.0 (1.2)	0.057	0.0004*	0.0032*
CYC total	6	2.5 (2.3)	4.4 (1.6)	4.6 (1.5)	5.4 (1.0)	3.6 (2.2)	5.0 (1.3)	0.0004*	0.002*	0.203
Total 2	12	5.1 (3.4)	9.7 (1.8)	9.2 (2.3)	10.2 (1.8)	7.2 (3.5)	10.0 (1.7)	0.0003*	<0.0001*	0.0047*
CUR total	10	4.1 (3.6)	8.5 (1.6)	6.4 (2.9)	8.9 (1.3)	5.3 (3.4)	8.7 (1.4)	0.036*	<0.0001*	0.13
Total TkQ	39	20.7 (7.0)	33.0 (3.8)	30.1 (5.1)	35.1 (2.9)	25.5 (7.6)	34.3 (3.4)	<0.0001*	<0.0001*	0.0045*

Values are means (Standard Deviation). *p*: according to the age; according to the clinical group; according to the interaction of the two parameters. ADHD: attention deficit hyperactivity disorder; OR: orientation; SEQ: sequences; TU: Time Units; CLO: Clock knowledge; AGE: Ages of life; CYC: Cyclic time; CUR: Current time.

Total 1: sum of OR, SEQ, TU and CLO scores. Total 2: sum of AGE and CYC scores.

* *p* < 0.05

Figure 1: Time knowledge total score for children with ADHD and typically developing children (TD): beginning of primary school

ADHD: attention deficit hyperactivity disorder

Figure 2: Time knowledge total score for children with ADHD and typically developing children (TD): end of primary school

ADHD: attention deficit hyperactivity disorder

Figure 1

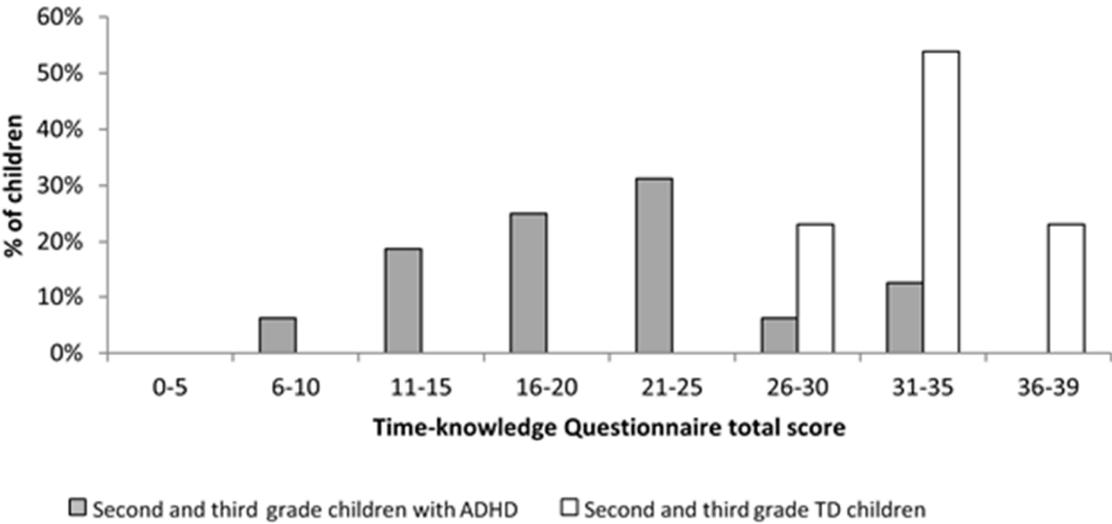


Figure 2 :

