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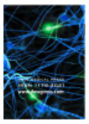

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REVIEW

Detecting Time Concept Competence in Children with Autism Spectrum and Attention Disorders

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Abstract: The importance of time concept in human existence is "ancient history" celebrated in the biblical book Ecclesiastes. Indeed, our time-sensitive mechanisms are literally carved into our biology and neurology on a molecular level, gifting us with neural clocks. However, time in human consciousness is not the time indicated by physical clocks: time is a subjective reality in our psychological makeup due to the nature of the temporal neural mechanisms and unique properties of physical time. Nonetheless, subjective time requires anchoring to physical time which permeates our language, endeavors, and entire existence, a process hinging on time-related skills such as estimates and measures of passage and duration of time. Moreover, accurate time reading, a critical adaptive life-skill, is imperative for effective function in all societal activities. Because it embodies the complexity of the time construct, it is central to instruction of time concept in primary education. It is often measured in children by clock drawings, a cognitive integrative skill with errors pointing to neuroanatomical differences impacting the integrity of executive function. Time competence in children with atypical neurobiological development and high prevalence, as in autism spectrum disorders (ASD), and attention disorders (ADHD), is often compromised, calling for investigation of its function. This thematic review article aims to: 1) discuss the complexity of time concept and its underlying bio-neurological mechanisms, 2) elucidate difficulties children with ASD and those with ADHD exhibit in temporal development, and 3) demonstrate the use of a set of clinical tools in uncovering temporal competence and ecological executive function in two children with ASD, and a child with ADHD, using a clock drawing task and error analyses; children's time knowledge questionnaire; a behavior rating parent questionnaire examining ecological executive function, and parent open-ended questions related to their children's time difficulties. A discussion, directions, and a take-home message round out the article.

Keywords: ASD, ADHD, time competence detection, clinical tools, intervention

Introduction

The importance of time in human existence is "ancient history" as portrayed in Ecclesiastes[1] "… a time for every purpose under heaven …" This biblical celebration of cyclical time is marked by beginnings and endings of sequential and predictable recurring time phenomena in nature that determine human behavior and existence universally, while time concepts, woven into the fabric of all human languages, allow revisiting events no longer in existence or contemplating events that do not yet exist and may never exist. Indeed, our biological time-sensitive mechanisms are literally carved into our biology and neurology on a molecular level – gifting us with a circadian clock, a biological neural clock system central in the study of *chronobiology*[2] that responds to external events such as the rise and fall of daylight, while others are tuned to internal biological and neurological processes measured by small timescales in minutes and fractions of seconds. In effect, a *second* forms the base unit in measures of physical time in exceedingly accurate physical timekeeping devices, attesting to the importance of time in modern human existence.[3] While these small timescale neural structures were studied extensively and are well known, what was unknown until recently is how the brain encodes our time experiences and memories that may last anywhere from milliseconds to hours.[4]

The following sections focus on how subjective time is experienced, and difficulties it may pose in anchoring to physical time. An attempt at explaining the exceptional complexity of *time* follows. Next, the article elucidates the

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development of temporal sensitivity emphasizing the innateness of this attribute and its further development contingent on brain maturation, in contrast to the acknowledged difficulty teaching the time concept to typical children and adolescents. This is followed by descriptions of difficulties with temporal competence in children with atypical neurodevelopment and especially salient are those with high prevalence such as ASD[5] and those with ADHD[6] – a disorder often comorbid in ASD.[7] The focus here is on their temporal challenges and related weaknesses and includes a proposal urging that temporal competence integrity investigations become an integral component of these high risk children's clinical assessments to inform timely appropriate interventions. Following this, a set of clinically useful tools for detecting time competence are described, and their effectiveness in detecting children's time competence demonstrated with results from three children with high risk for time competence challenges: two with ASD with dissimilar ages and severity, and one with ADHD. The discussion section includes, directions in evaluation and treatment of compromised temporal competence, call for changes in assessment and intervention with ASD children and families, and a take-home message.

Subjective Time Experience

Recent studies at the Norwegian neuroscience centre Kavli[4] uncovered a *Neural Clock* behaving as a dynamic system that is bound to our life experiences thus measuring *subjective time*. Using rat models, the researchers found clusters and circuits of neurons in specific areas of the hippocampus (a sea-horse shaped structure deep in the temporal lobe) that represent time through encoding the *sequential* order of experiences that give rise to *episodic memory*,[8] a finding corroborated with human hippocampal studies.[9] Although the hippocampal role in episodic memory and semantic memory interdependence is known,[10] the focus in this article is on episodic memory solely so that elaborations on semantic memory are excluded. Episodic memory is the recall of personal experiences and discrete episodic memories, ie, separation and integration of sequences resulting from dynamic processes of on-going changes in context.[11] Episodic memory formation includes the "what", the "where", and the "when" of events, along with the sensory[12] and emotional context in which it was experienced.[13] The researchers note that the resulting flow of the experience measures *subjective time* which may be perceived as passing faster or slower than that shown by clocks.

In addition, the Kavli lab experiments[4] demonstrated that the nature of the experiences determined timing efficiency: wide range activities with self-directed options, eg, choice of movement direction, honed sequential temporal efficiency, while a procedure with structured repetitive activities and forced choice options, although yielded good understanding of segments of the experience, resulted in poor understanding of the event as a whole (implicating inadequate synthesizing ability). These experiments confirmed the neural networks' plasticity by showing changes that occurred in the neurology due to the experienced event, altered the neural circuit, and this in turn impacted on how time is perceived, indicating a *reciprocal dynamic system*. Moreover, the researchers found that immediate neighboring areas of the time networks responsible for encoding *spatial* information are activated simultaneously. In effect, memory of personal past experiences that took place at specific times and places are preserved in these circuits of neurons and molecules, along with the experienced emotions embedded in each memory.[14]

Contribution of Emotions to Episodic Memory

Although emotions were known to impact learning and memory, their role in episodic memory, highlighted more recently by researchers,[14] revealed episodic memories are preferentially selected by duration for different types of storage, and the episodic long-term memories are the ones remembered more frequently, and in greater detail for events that are highly stressful and intense. Emotional arousal, therefore, seems to be the jump start for the formation of an episodic memory, and is also activated during its retrieval, inducing the feeling of *déjà vu*, ie, a relived experience. The emotional component not only determines whether and how an episode will be recalled, but, interestingly, includes the sensory modality (eg, auditory, visual, or integrated) in which it was embedded.[15] Sensory information, note researchers,[12] seems to contribute to the physical cues needed for memory retrieval. A dimensional framework explaining the emotional component of episodic memory was put forth by researchers.[16] In it, emotional states are conceptualized along two primary dimensions spanning the scope of emotional behavior by valence, from unpleasant to pleasant, and by arousal or degree of stimulation it elicits, from unstimulating to exciting. Other researchers[17] confirmed that emotional events are remembered more often and more clearly than emotion neutral episodes. Furthermore, negative events are more likely to increase encoding of sensory detail and memory consolidation leading to successful retrieval, so that the *relived* event will resemble more closely the original experience. In short, successful episodic memory retrieval can be predicted by the cognitive and neural processes that are engaged during its encoding, as well as by the *recapitulation* or review of these processes during retrieval. However, the process of reviewing an event is not static but rather dynamic so that in subsequent retrievals of the event, memory vividness and details may be altered, explain researchers.[18]

Short Time Intervals

The subjective experience of short time intervals, a central topic in many studies of *prospective* time (likely to happen), is explained with the *temporal-relevance* and *temporal-uncertainty* model[19] to account for how, in the face of constant bombardment of sensory information, individuals determine where to allocate their limited memory resources. Successful allocation requires accurate *temporal judgments*, an essential adaptive response to a dynamic system dealing with constantly changing information from internal and external stimuli. Prospective time or ongoing events require knowledge of the duration of the event, and so are relevant to the observer. Prospective time judgment, explains the author, depends on the *degree of meaningfulness* assigned to an event and *the amount of attentional resources* devoted to it, so that those with high relevance require a greater amount of attentional resources. The quality of the relevant events influence how we experience time, eg, if pleasurable, time seems to "fly" or contract in duration, whereas in fear evoking events, time seems to "freeze" or dilates – the *temporal relevance* of the event, as well as its *temporal uncertainty* of when it will end, are both high. Temporal expectations, therefore, seem to determine how the event is experienced, a finding supported by other researchers.[20] In short, the relative meaningfulness of events to the person determine their temporal relevance and, as events are constantly changing, so are their temporal relevance, confirming the high subjectivity of temporal experiences. Researchers caution,[21] however, that attentional allocation may be divided by ongoing events, resulting in depletion of prospective time attention resources and consequently altering the accuracy of the subjective experience.

The short time measuring structures and episodic memory highlight the great subjectivity of temporal experiences. Nonetheless, these require intact physical–biological neural pathways, with functional connections to a myriad of networks and structures to collect all sensory inputs, determine their meaningfulness, form temporal judgments, and in turn determine their relevance for allocating sufficient attentional resources. All these processes require *temporal synchrony* in order to anchor the subjective time experience to the physical time as measured by various means and instruments, a formidable task indeed given the complexity of time,[22] an entity that is difficult to define, and cannot be seen but can be measured and its passage felt as it leaves tracks in its wake. The presence of atypical or compromised neurobiological systems and connections in individuals would be predictive of challenges in achieving optimal function in *synchronous temporal processing*.

Time: An Exceedingly Complex Concept

The concept of time is enormously complex as time in human consciousness is not the time indicated by physical clocks but rather a subjective reality in our psychological makeup due to the underlying time related neurology, and time's complex properties. Although time study is central in the physics disciplines, and despite being one of the basic properties of the universe, physicists tend to agree that it is a most difficult to understand attribute.[23] Setting aside interdisciplinary controversies regarding what time is,[24] *time* is defined by science as the forward unidirectional progression of events which always move through present to future and cannot move backwards toward events in the past.[25] The unidirectional movement of time is due to *entropy*, a measure of disorder of a system, explained in physics by the *Second Thermodynamic* law applied to the phenomenon of time:[26] movement of the thermodynamic wave is from low to high disorder or *entropy* (from Greek: turning toward) – resulting in a unidirectional "arrow of time", always moving forward from the present toward the highly disordered future events.

Our modern understanding of time is largely due to Einstein's *Special Relativity Theory* (SRT) and the later *Theory of General Relativity* (GRT) – these propelled our understanding of time and space from Newtonian times to the modern era.[27] The SRT, meant to describe small scale phenomena, explains the author, was based on two foundational premises:

1) the invariance of the speed of light – An electromagnetic vibrating wave traveling at an astounding constant speed of 186,000 miles/second no matter the location, and capacity to cover vast space distances described with *light years* (5.88 trillion miles/light year), and 2) the laws of physics are universal, ie, the same for all observers, no matter their location or motion. Based on his ”thought experiments” (*Gedankenexperiment*), Einstein showed that simultaneous flashing lights can occur at different times for observers in motion from those who are stationary, not because the speed of light varies, but because time itself varies relative to the location and motion of the observer, a thought that gave rise to the *Relativity of Simultaneity* principle.

The *GRT*, meant to describe large scale processes, addresses gravity, a formidable force in the universe accounting for the attraction of spatial bodies to each other. The power of gravitational waves, assert astrophysicists in recent investigations, impact periodically the dimensions of the very fabric of the universe by stretching and compressing time-space, causing slight shifts of earth's position relative to stars.[28] The GRT theory was also meant to describe formation and explosion of stars, and reveal the origin of the universe, notes the author.[27] Nonetheless, the relativity theory experiments reshaped our understanding of both time and space. Unlike Newtonian space viewed as an immovable large flat surface while time flows, space too is relative and varies simultaneously with time according to the observer's experience: for a stationary person observing a moving body time flows more slowly or *dilates*, and the moving body appears shorter or *contracts*. Accordingly, time and space are interchangeable, and form *timespace* (a concept contributed by Minkowski, Einstein's mathematics teacher), adding the fourth dimension of our understanding of the universe (ie, length, breadth, depth, and timespace). In addition, it accounts for a curved timespace due to gravitational pull of large cosmic bodies when these are close.

The GRT provides highly complex mathematical equations to explain the shape of timespace behavior according to matter or energy. Many of the equations were tested and predictions were confirmed, eg, the universe is expanding, and the time dilation phenomenon actually affects accuracy of time keeping devices such as *Global Positioning System* (GPS), instruments that provide us with positioning, navigation, and timing services[29] because it impacts the incredibly accurate *atomic clocks* (with only a 1 second error in 100 million years)[3] on which GPS instruments rely. In-depth discussions of the various components of GRT are beyond the scope of this article, they are, nonetheless, immensely interesting as they can explain "the behaviour of individual bodies and of the entire universe" (p.17).[27]

Development of Temporal Concepts and Their Cognitive-Linguistic Roots

Timing Capacity an Innate Gift

Human infants are endowed with timing capacity from birth, as their brains are adapted to processing sequential events in unison with their temporal correlates. However, this innate capacity is shaped further by experience and brain maturation.[30] In fact, the developmental trajectory of time discrimination capacity hinges on brain maturation, as do all cognitive perceptual developments. Consequently, children exhibit better temporal perceptual discrimination skills or *temporal sensitivity* with age, a development that progresses until early adulthood. Studies have shown,[31] for example, that temporal sensitivity to short durations (0.5–30 seconds) occurred earlier and depended on short-term memory span, while temporal sensitivity for longer durations was explained with attention in executive functions (EF). Both, therefore, were attached to attentional resources development. A set of experiments[32] with children aged 5, 8, and young adults showed that time sensitivity was best predicted by *brain information processing speed*, with faster speeds accounting for higher temporal sensitivity performance, while working memory, seen earlier as the "major player" in this development, contributed less to the participants' performance variability. Interestingly, temporal sensitivity development occurred earlier in the auditory modality than the visual. This phenomenon, researchers noted,[33] occurs in millisecond time range discrimination tasks while, in longer time durations, the modality-specific event transitions to cognitive timing mechanisms and processes or *temporal cognition*.

Integration of Temporal Abilities with Cognitive-Linguistic Capacities

Temporal Cognition refers to our abilities to perceive, estimate, and keep track of time, a highly complex set of skills involving lower level perceptual processes, and higher order cognitive linguistic capacities.[34] Researchers[35] observe that development of temporal concepts and terms hinges on understanding and talking about time, grasping the differences between past, present, and future, and developing reasoning ability about sequence of events. The researchers reviewed studies to uncover children's development of time with a focus on linguistic factors in both temporal language production and comprehension, and cognitive processes examining temporal judgment and temporal reasoning. The resulting differences in acquisition age, explain the authors, were mainly due to methodological differences, ie, while psycholinguistic studies relied on tense production, the cognitive developmental studies asked for differentiation of past and future events as evidence for temporal comprehension. Understanding temporal markers in language, reiterate the researchers, rests on maturation of cognitive skills to be able to differentiate time terms, and map them to linguistic expression.

In sum, time in particular is difficult to grasp, and relies heavily on language, our fundamental symbolic system for conceptual representation. The cognitive-linguistic components are braided and difficult to disentangle in tasks but, in fact, children's temporal comprehension unfolds in parallel with their cognitive and linguistic developments while the interaction between them tends to propel temporal development further.[35] It is clear from these findings that acquisition of temporal concepts requires intact cognitive and linguistic developments, and effective integration to develop adequate temporal competence, a finding that may inform clinicians' practice.

Instruction of Time in Education: A Difficult to Teach Concept

Some researchers[36] define time in pragmatic terms as "a component of a measuring system" used to sequence events, and compare their duration and gaps between them. Time competence is then demonstrated by the acquired skill of clock reading, measuring time intervals and recording its duration, using calendars, timelines, and so on. In primary education, note the authors, clock reading is seen as a central skill in time-related instruction as it embodies "the complexity of time conceptions in general." Time concepts are an integral part of practically all school subjects, however, they are centred on mathematics as part of measurement skills. It is closely tied to clock reading, a cognitively loaded competence, which remains important throughout the primary grades, and hinges on integration of complex skills: numeracy and its various subskills including fractions knowledge, time-related vocabulary, understanding that relative time and absolute time are expressed differently but reference the same time, and showing a specific time on their own drawing of a close facsimile of a clock. This involves attending to all components of a clock, understanding the importance of the arrangement of numbers for showing the required time and time intervals, comprehending that each number has two values, hours and minutes, etc, and all hinge on intact memory. Children are taught to read both digital and analog clocks – these are cognitively more demanding than digital clocks as they allow determining time both in relative and absolute terms.[37] Nonetheless, children with math challenges, for example, are equally stymied in understanding either type of clock.[38] The researchers confirm[36] there is no agreement as to what curriculum works best in time concept instruction, but all agree that it is a difficult concept to teach.

In secondary education for example, instructors in geography, earth, and environmental sciences grapple with teaching time. They ask, *can it be fully realized and taught*?[39] A major obstacle is the increase in the cognitive load when teaching complex concepts with new terminology. The concept of time and how to explain it is indeed an onerous task as, besides its complexity, it varies greatly according to the discipline in which it is embedded, and often outside students' vocabulary, conceptual repertoire, and experience or background knowledge, adding to the challenge in explaining it. Studies of geography and environmental sciences discuss "geological time" – measured in time chunks of millions of years, separated in texts as eras, periods, and epochs. Description of distance in space is measured by *light years* due to its incredible constant velocity and capacity to cover vast spacetime distances.[40] Calendars, ancient and ubiquitous measuring tools, indicate time in years, months, and days – highly familiar concepts to most students. In contrast, time in engineering, medicine, and computer technology is measured by infinitely smaller time units from *microseconds*: one millionth (10^{-6}) of a second, to *femtoseconds*: one millionth of a nanosecond (10^{-15}) of a second, the measure used in laser technology[41] – concepts that are well beyond most students' conceptual or language repertoire. And yet, being time concept savvy is a central demand in the higher education *STEM* domains (Science Technology Engineering Math), and these include literally dozens of disciplines.[42] There is a lack of qualified graduates to fill the ever growing need for individuals educated and trained in STEM domains, and so instructing time concept with the appropriate related vocabulary is a societal duty if students are to be well prepared to enter these professions to meet the needs of modern life.

Temporal Competence in Children with Atypical Neurodevelopment: ASD and ADHD

Temporal Competence in ASD

The prevalence of children with ASD in the US, estimated at 1:44, is an alarming rise of 178% from 2000 to 2020, paralleled by a significant rise in costs.[43] The upward prevalence trajectory continues due to improved identification efforts such as supplying parents with digital applications facilitating inputs of their children's progress, report the *Centre for Disease Control* (CDC) and its autism monitoring and tracking arm (ADDM).[5,44] Children with ASD face considerable developmental and adaptive challenges due to their complex atypical neurobiology and its impact on their social-emotional and cognitive-linguistic development, among others, resulting in a noted heterogeneity of phenotypes. Although their core ASD symptoms are shared, they differ enormously in their intelligence and language acquisition – vital, but none core ASD traits.[7]

Challenges in temporal cognition are known in children with ASD, and some researchers posit they exhibit atypical temporal processing in all levels of time processing.[45] Others found their salient difficulty is in their "capacity to represent and understand changes that occur across time", or *diachronic thinking*.[46] Successful development of this capacity in typical development was shown to hinge on three slow maturating distinct components highly correlated with each other, but not with general intelligence: 1) *Diachronic Tendency* – the ability to evoke the past and future of a current situation, ie, think backwards and forwards in time (develops gradually between 7–12 years), 2) *Diachronic Transformation* – understand that some entities may transform physically over time but retain their identity, eg, tadpoles turn to frogs (noted at ages 9–12), and 3) *Temporal Synthesis* – A series of successive events can form a unitary entity, eg, athletic events occurring in a specified time and place form the *Olympics* (seen mostly by age 12). A two part study,[46] compressed considerably here, confirmed the presence of these components and their relative acquisition age, and revealed more.

The study's first part examined the presence of the three developments of diachronic thinking in an experimental group of children and adolescents with ASD (aged 7.5–16) with varied language and nonverbal IQ that included mild–moderate intellectual disability; the control group was closely matched by age (7.3–15.8), verbal, and nonverbal intelligence including those with mild–moderate intellectual disability, but no ASD or any other related syndrome. Both younger and older children with ASD were significantly less successful on all three components than their non-ASD ability and age-matched controls whose performance was comparable to typically developing 10–12 year olds, indicating a stronger diachronic thinking ability in the non-ASD control group. The second part included different participants but a somewhat older group (experimental group ages 12–18.4; control group: 12.6–17.3) but comparable to those in the first part. The tasks targeted diachronic thinking, as well as language, verbal reasoning, and *Theory of Mind* (ToM). Again, the non-ASD control group outperformed the ASD group on diachronic thinking. Moreover, their performance did not correlate with either verbal or nonverbal reasoning, language, or ToM, highlighting the *specificity* of diachronic thinking ability, and its independence from general cognitive capacity. The authors agree[46] that underlying weaknesses may operate in impaired diachronic thinking in ASD.

Individuals with ASD show varied strengths and weaknesses in knowledge of different time units. Although they may demonstrate relatively intact temporal estimation capacities for a short time (less than a minute),[47,48] they show consistent episodic memory weaknesses encompassing difficulties in reconstructing and monitoring a past experience or in *retrospective memory*.[49] The difficulty in retrieving and reliving the event's specific details including the spatial-temporal context, point to deficits in interaction and integration between neurocognitive systems rather than specific brain region or process-specific dysfunction, note the researchers. In investigating *Prospective memory* (PM) or remembering future-oriented planned action in children, researchers[50] constructed two types of tasks: 1) *Time-based tasks*, which depend greatly on EFs because they rely on self-initiation: acting on an intention at a particular time-point (eg, join an online meeting in 15 minutes) or *self-initiated recall*, and 2) *Event-based tasks*, which are less dependent on EF: acting on an intention at a specified event (eg, join a weekly online meeting) or *cued recall*; additionally, the researchers designed tasks to uncover PM cognitive correlates: flexibility, time estimation, and ToM – predicted to be implicated in PM failure. The study participants, all with intact intelligence, included an experimental group with ASD and a comparison neurotypical or non-ASD group matched by age, verbal, and nonverbal IQ. The ASD group showed impaired time-based PM but unimpaired event-based PM which matched the non-ASD performance – this group, however, performed comparatively well in both types of tasks. Lastly, while the ASD group did not exhibit impaired time estimation, cognitive flexibility was reduced on the mentalizing condition of the ToM animations task (eg, triangles coaxing) but not on the physical animation condition (triangles fighting). This dual performance on ToM task was an unexpected result. The authors[50] reason that those with ASD have difficulties mentalizing and recognizing their *own* present, past, or future intentions, an inefficiency that interferes with their ability to retrieve a "mental state" intention, and so contributing to an impaired PM.

In sum, the studies highlighted here demonstrate episodic memory weaknesses in both retrospective (going back in time) and prospective memory (going forward in time). The complexity of PM exposes selective weaknesses and a discontinuity of abilities depending on task demands, with poorer performance on the more cognitively demanding time-based tasks versus event based ones. Unlike diachronic thinking, an independent cognitive attribute, episodic memory retrospective and prospective retrieval is connected to higher order cognitive development. Nonetheless, all three, diachronic thinking, retrospective memory, and prospective memory, were found to have weaknesses in children with ASD regardless of intellectual capacities. Furthermore, a systematic research review[51] revealed individuals with ASD exhibit mostly temporally asynchronous behaviours when tasks demanded integration of modalities: audio-visual, audio-motor, visuo-tactile, visuo-motor, social motor, and conversational synchrony (diminished synchronisation in spontaneous and intentional interpersonal synchrony, and gesture performance). In effect, research confirmed[52] that auditory temporal processing for rapid signals associated with language processing are impaired in children with ASD. Moreover, recent research[53] found numbers of children with ASD have some degree of auditory difficulties in both peripheral and central systems, and vestibular dysfunction with underlying neural and structural abnormalities that implicate delays/disorders in language, cognitive, motoric, and social developments. Consequently, the identified sensory abnormalities affect temporal processing crucial for anchoring subjective time experience to physical time, and so predictive of difficulties in their successful integration. Moreover, the difficulties affect language and cognitive developments, the very components[35] needed in synchronization of cognitive and linguistic developments crucial for successful temporal development.

Temporal Competence in ADHD

Significant numbers of children with ASD (37–85%) exhibit ADHD symptoms, while some children with ADHD also exhibit autistic-like behaviors and symptoms, making accurate diagnosis challenging.[7] Furthermore, both disorders exhibit the following: emotional dysregulation – A salient feature present from early childhood to adulthood,[54–56] compromised EF development,[57] and medical comorbidities.[58] However, the DSM 5 diagnostic criteria for each differs, as does the approach to detection. While very early detection and treatment is encouraged when ASD is suspected, an accurate diagnosis of ADHD is exceedingly difficult in children younger than age 7 given their major symptoms encompass inattention, hyperactivity, and impulsivity, ie, behavior dysregulation affecting test behavior.[7] Although the DSM 5 applies a dimensional approach to diagnosis,[59] here ADHD is used as the generic for the condition regardless of the dimension. The following section explores ADHD per se, a ubiquitous condition, impacting all aspects of individuals' lives during childhood and beyond, rendering affected individuals high-risk for learning disabilities, executive dysfunction, and concomitant difficulties in time competence development.[60]

The American Academy of Pediatrics 2011 guidelines changed very little,[59] while new guidelines and additions deal mainly with the comorbid condition of ADHD, and provide an updated care process to facilitate implementation of guidelines recommendation for preschool children, aged 4–6, and children and youth up to 18. The data from the 2016 national survey shows 9.4% prevalence of children aged 2–17 who have ever had an ADHD diagnosis, and 8.4% (translates to 5.4 million children) with a current (year of the survey) ADHD diagnosis, occurring more frequently in boys (2:1). The authors note a dearth in diagnosis and treatment of Latino and African-American children that needs to be addressed. Another grim reality is the overwhelming number of referred children and adolescents compared to the limited resources for addressing their needs. While the majority of the diagnosed children and adolescents received medication and half of these also received behavioral treatment, a notable minority received neither. The guidelines stress that the primary care professional to perform diagnosis and address their intervention are pediatricians, the first contact with families, however, diagnostic accuracy, warn the authors, is not obtained in children aged 4 or younger.

An accurate diagnosis requires application of the DSM 5 criteria, documentation of symptoms, and evidence of impairment in social, academic, or occupational settings accompanied by corroborating reports from parents or guardians, teachers, and other school-based clinicians. ADHD is a life-long condition and, although the hyperactive and impulsive symptoms diminish over time, persisting inattentive symptoms remain, with a frequency of debilitating learning and language distress comorbidity. In the face of this reality, their neglect, no matter the reasons, is indeed disheartening, and predictive of grim futures of the affected individuals. For example, ongoing from birth population-based German studies[61] found that children with ADHD are at significantly higher risk for reading, spelling, and math disorder compared to non-ADHD children. Viewed from a cautionary perspective, adult ADHD studies provide highly probable consequences of ADHD children's neglect by responsible societal institutions: researchers[62] showed 25% of adults with ADHD also exhibit comorbid psychiatric disorders such as mood, anxiety and substance use disorders among others. The authors cite studies indicating that early identification and treatment of ADHD and its comorbidities has the potential to prevent serious psychiatric morbidity later in life, with resulting improved overall function.

Studies demonstrated[35] temporal concept acquisition hinges on intact cognitive and linguistic developments and their effective integration to develop adequate temporal competence. These developments are often lagging in the presence of ADHD, making affected children vulnerable to deficits in temporal competence. For example, a meta-analysis of studies[63] reporting time perception impairment in children and adolescents with ADHD included 1,620 participants with ADHD and 1,249 in a non-ADHD comparison group. Those with ADHD exhibited significant timing impairments in accuracy, precision, and tendency to overestimate time compared to their non-ADHD peers. The time perception differences between the groups was not explained by the timing task type or the modality (visual or auditory) used. A study examining auditory time thresholds[64] revealed those with ADHD were severely impaired in the milliseconds range but not in seconds range, and they too tended to overestimate time in this range compared to non-ADHD peers, corroborating results from previous studies.[63] The abilities to represent time, space, and numeracy are the foundations for math and abstract time concept developments. Researchers note[65] studies confirming children with ADHD exhibit numeracy and temporal processing differences, and consequent deficits. Exacerbating their difficulties further is the National Health Institute finding that children with developmental disorders such as ADHD and ASD (including children with Intellectual Disabilities) suffer from chronic school absenteeism,[66] attesting to the serious interference of their condition in learning and school function. It seems that children with ADHD are "behind the eight ball", as their neuro-biological-physiological differences hinder essential adaptive developments needed for effective function in academic life and consequent occupational/vocational endeavours.[67]

EF Essential in Temporal Competence Growth in Children with ASD and ADHD

While the importance of time competence in our lives is well-established, it is often compromised in children with ASD and ADHD, both with high risk for academic distress and life-long difficulties. For example, a study[68] of parents' experience with their ASD children's knowledge of time and how it affects their daily lives and views of future plans was compared to parents of neurotypical children. It showed that, although time management, and especially punctuality was a common complaint from all parents, those of ASD children were considerably greater: punctuality was a persistent source of conflict and stress for both parent and child, with an impact on daily activities at home and school, routines, and social interactions. Some children exhibited these issues despite intact clock reading and time-related language, ie, they failed to actualize this knowledge to meet time-related obligations. Clock knowledge on its own, note the authors, is insufficient to address all the required aspects of time. An important ingredient seems to be the presence of intact executive organizational skills. Children with ADHD were found to have noted deficits in time-dependent organizational skills affecting their real world function.[69] In a study of executive dysfunction that included adolescents with ADHD, researchers[70] noted gaps between the affected individuals' time management and real world task demands needed in a complex task completion, attesting to their executive dysfunction, including time–space weaknesses. A review of EF in ASD[71] showed EF is highly related to language and social skills, and that deficits and improvements are reciprocal, suggesting a bidirectional relationship.

Although the importance of EF in control and regulation of behaviour, and metacognitive functions are accepted, there are debates on whether they constitute a set of unrelated components versus a unitary construct. Researchers' reviews of EF studies[72] showed an integrative framework to be the most appropriate when adopting a developmental perspective. They proposed that EF is both unitary and differentiated, and the degree of differentiations changes with development. They found, for example, that *Inhibition Development* starts early, with slower improvement and localization through childhood and adolescence. *Working memory* develops in a more linear fashion from preschool to adolescence, while the ability to *Shift* attention between tasks has a lengthy trajectory with middle adolescence ability to shift complex tasks improving and reaching adult level. The complexity and long developmental trajectory of EF predicts compromised EF competence in children and youth struggling with learning issues. For example, an examination of EF[73] with teacher ratings of a clinical sample of children with noted persistent academic distress, uncovered executive dysfunction underlying persistent reading disorders, thereby highlighting the utility in routinely braiding EF exams in evaluations of children and adolescents experiencing academic distress.

Clinical Examples Illustrating Time Competence in Children with ASD and ADHD

The Investigation Report

Investigation of time competence status and related functions in children diagnosed with ASD or ADHD is seen here as a clinical obligation as deficiencies impact effective function in the family, school, and social life. The following section describes the use of a set of tools in detecting time competence in two students diagnosed with ASD of different ages and symptom severity, and in a student diagnosed with ADHD with salient symptoms noted at home and school. The students were seen by this author at the parents' request, and the retrospective report of the results included here are for illustrative purpose of one approach to a clinical examination of students with high-risk for time competence weaknesses. The approach described here requires few instruments, and is time-efficient for the clinician, child, and parent. No manipulation or additional testing was performed with these children in connection with this three-person clinical report. The student and parent results, compiled and integrated for each participant, are presented in Tables 1–3, their clock drawings are depicted in Figures 1–3, clinical interpretations of results and summaries follow each table, and an integrated summary of all results are provided as well. The interpretation of results are based on this author's clinical judgment and experience with neuro-atypical individuals and use of the clinical tools described here.

Participants' Family Demographics and Participants' Characteristics

The three participants, all boys of varied ages, are from mid-Socio-Economic-Status families. Their parents are all well-educated: a college graduate with an additional certificate in social work, one with a master's degree, and another, a PhD candidate. In the three families, both parents are employed in either education or a related field. The younger student with ASD, aged 10.8, attends a multilingual private school with small classes with neurotypical peers. His parent reported a mild–moderate ASD severity. The older student with ASD, aged 13.6, is in a public high school in a specialized setting, and his parent reported a moderate–severe ASD diagnosis. The student with ADHD, aged 8.1, was non-medicated at the time of the exam, with a reported moderate ADHD severity. He attends a public school in a regular program with a bilingual curriculum. The three participants showed nonverbal reasoning in the average range, and varied strengths and weaknesses in language and academics (as per guarantee to the parents, quantitative results are not included here).

Parental Consent

The three participants were identified by their parents who consented to have their children's results on Time Competence tasks examined by this author included in the present article. The article aims were elaborated in the consent form and clarified difficulties children with neurodevelopmental disorders exhibit in time perception development, and the need to promote detection of their time concept competence, an important adaptive skill, using clinically useful tools. The inclusion of their results is a valuable contribution "to the body of knowledge about time concept development", and for promotion of intervention for time-related difficulties in children diagnosed with ASD and ADHD. The consent form stated the usual guarantees of no foreseeable risks involved

Table 1 ASD-Y's Results on TKQ, Parent Open-Ended Questions, and BRIEF Questionnaire Ratings

ASD-Y **Age 10.8**	**Time Knowledge Questionnaire (TKQ)**	
	Conventional Time	**Estimative Time**
	Orientation: No difficulty with day, time, month, year, season; *Time Sequences*: problem saying what comes after a named month, but named all months, and seasons in accurate order; *Time Units*: no problem. *Telling time on a clock*: no problem with requested absolute and relative times that are depicted, but error on question probe of relative time that requires calculating by 5 minutes intervals.	*Diachronic Thinking*: No problem; Birthdays: No problem with how many months passed since his birthday, and how long to next birthday, and saying his age now, last year, and next year. *Estimating interview duration*: No problem, within acceptable range (said 10 minute interview was 15 minutes).
ASD-Y **Parent** **Questions**	**BRIEF Questionnaire** **Behavior Regulation BRI**: 3/3=clinically significant dysfunction in Inhibit, Shift, and Emotional Control; **Metacognitive function**: 4/5**=**Clinically Significant Dysfunction in all except Organization of materials with a slightly less severe, behavioral-clinical dysfunction.	
	Parent Open-Ended Questions 1. Getting to school on time is challenging for my child even though he really wants to be punctual. 2. I help him make a list of all things he needs to do the night before to have everything ready for school. I have to prompt him to do the things on the list. I encourage him to use a timer to remind him when he needs to do important things. 3. During the day he loses track of time and he insists that he just started playing. He also loses track of time when he has to leave home even for an event that he is looking forward to. 4. He does not know when he has time for another game/activity. He once forgot to go to a party and sometimes misses extracurricular activities. He is often late for school. 5. 5.He has difficulty with story retell in the proper sequence.	

Table 2 ASD-J's Results on TKQ, Parent Open-Ended Questions, BRIEF Questionnaire Ratings

ASD-J **Age 13.6**	**TKQ**	
	Conventional Time	**Estimative Time**
	Orientation: Knew present day, month, year, and season, but not time of day. *Time sequences*: Knew month in isolation, and months of the year in order, but not order of seasons; *Time Units*: Knew length of units, but not hours per day. *Telling time on a clock*: Knew depicted requested absolute and relative times, but not question probe of relative time that needs 5 minute intervals calculation.	*Diachronic Thinking*: Problem with all ages; *Birthdays*: Problem with own age, could not say his exact age, 13.6, even with prompts; did not know his age last year, or next year (said 2010 his birth year – did not understand the question); gave his birthday month and day but omitted the year. *Estimating interview duration*: Lasted 9 minutes, said 2 hours, a significant overestimate.
ASD-J **Parent** **Questions**	**BRIEF Questionnaire** **Behavior Regulation BRI**: 2/3=Behavioral-Clinically significant dysfunction in Shift, and Emotional Control, while Inhibit is in the adequate range; **Metacognitive function**: 2/5=Behavioral-significant dysfunction in Initiate, Working Memory is in the Clinically significant dysfunction range; Plan/Organize, Organization of Materials, and Monitor ratings are in adequate ranges.	
	Parent Open-Ended Questions 1. J does not like to be late to school. If he arrives late, he needs to get a late slip, which he does not like to do. 2. We need to remind him several times that he needs to get ready so that he will arrive on time to school, for example. 3. He is aware of and has difficulty with the changing of the seasons, especially from summer to fall and fall to winter. For the last few months, J has been going to bed at exactly 9:15 pm every night and no matter what he is doing, he is aware of the time in the evening and goes to bed by himself, without needing reminding. He also wakes up by himself and starts his day at 5 am every morning. 4. The changing of the seasons in not easy for J. This weekend we had our first snowfall and J was not in a very good mood because he saw the snow and wanted it to stop. He kept asking us if it was winter yet and seemed somewhat satisfied when we said it only officially starts on December 21st. 5. I would say he does remember sometimes, as he often likes to know what the order of events will be on a particular day. I think it helps him prepare for the day and "deal" with or get ready for potential events he does not like much. He has written lists and checks off items as we go along …	

Table 3 ADHD-L's Results on TKQ, Parent Open-Ended Questions, BRIEF Questionnaire

ADHD-L Age 8.1	**TKQ**	
	Conventional Time	**Estimative Time**
	Orientation: No difficulty with day, month, year, but problem with present time, and season (asked: what is season?); ***Time sequences***: Problem with remembering months in sequence, naming seasons in sequence; knew *time units;* ***Telling time on a clock***: Showed absolute time and relative time; error on reading relative time in question form.	***Diachronic Thinking***: All correct. ***Birthdays***: Cannot say his birthday in entirety; correct with present, past, and future age; estimated how many months passed since last birthday, and how many to next. ***Estimating interview duration***: Underestimated – said 1 minute – The duration was 12 minutes.
ADHD-L Parent Questions	**BRIEF Questionnaire** **Behavior Regulation BRI**: 1/3=Behavioral significant dysfunction in Inhibit while Shift, and Emotional Control is in the adequate range; **Metacognitive function: 2/5=**Clinical significant dysfunction in Working Memory and Organization of Materials, while Initiate, Plan/Organize, and Monitor are in the adequate ranges.	
	Open-Ended Questions 1.L does not like to be late to school. This makes him disorganized as he misses instructions causing him to be lost. He does not like it when the students look at him coming in – he feels all eyes are on him. 2.L uses a time timer which mom sets. He gets 10–15 minutes per "to do" item – eating breakfast, getting dressed, etc. 3.L does not notice time pass. No concept of time. He over-exaggerates the length or understates. 4.His executive functioning skills – ability to organize himself is difficult and he is dependent on external tools to ensure he gets everything done in the expected amount of time. 5.L has difficulty with retelling a story due to sequencing. He does not always have a beginning, middle, and end. He also leaves out some details so his story becomes difficult to understand or follow.	

in including the child's diagnosis severity, age, and test results in the article, and only very sparse and basic details about the parents' education and family socioeconomic status. The guarantees included complete anonymity/confidentiality and exclusion of identifying information. The parents' consent form explained the tasks included in their examination were similar to the ones experienced at school, and their role in completing two questionnaires, and they were then asked to sign the *Informed Consent* once they had read and understood the information.

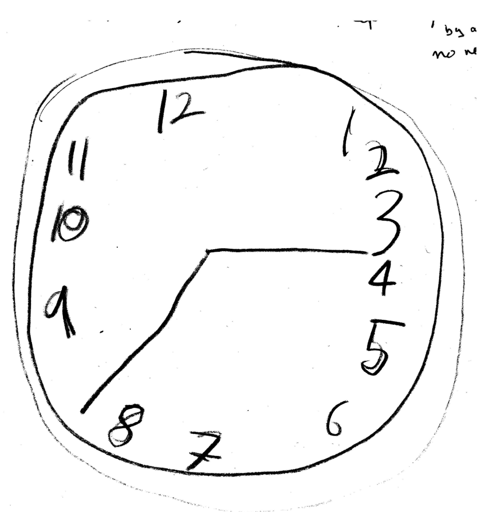

Figure 1 ASD-Y DAC drawing with qualitative errors: Size: Macrographic (larger than 12.7 cm). Graphomotor: wobbly circle, duplicated lines and, numbers (a repetitive behaviour), some tilted, and an oversized minute hand. Spatial planning: all numbers present but crowded to right; uneven spaces with noted gaps bottom center and left. Conceptualization: all numbers present in correct sequence but 12–6 and 9–3 not opposed shows lacks understanding these as traditional orienting points on a clock to facilitate time reading.

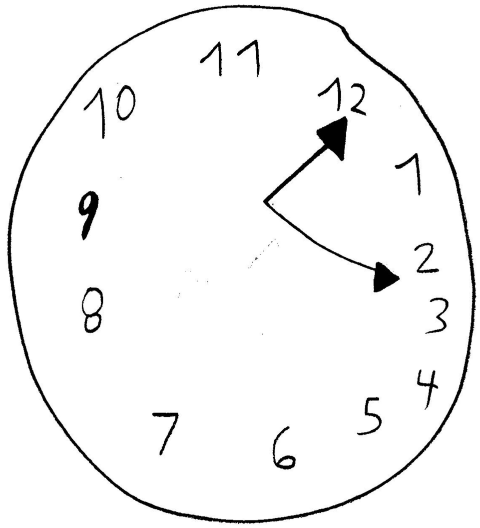

Figure 2 ASD-J DAC with qualitative errors: Size: Acceptable; Graphomotor: slightly wobbly circle, 9 darkened as are the hands (a repetitive behavior). Numbers well-formed, legible; Spatial planning: numbers crowded to right; hands off-center; uneven spaces at lower and left quadrant; Conceptualization: all numbers present in correct sequence but incorrectly placed: 11–6 and 9–1 opposed instead of 12–6 and 9–3; Note: while darkening the hands (the hour hand is 4 mms long, the minute hand is 6 mms), he was asked the time he wanted to show, he said, 2:00 o'clock but here 12:10 is set– shows weak knowledge of clock time setting, and features.

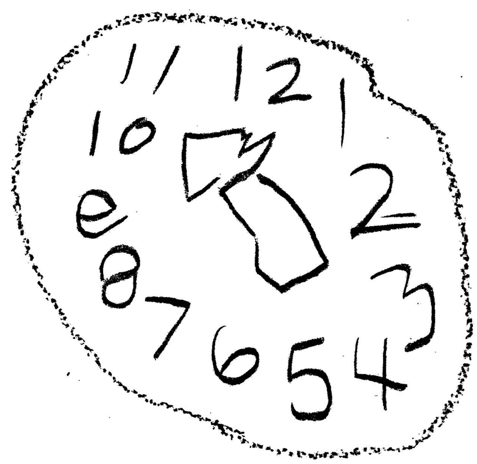

Figure 3 ADHD-L DAC drawing with qualitative Errors: Size: Macrographic error (15 cm). Graphomotor: oval instead of circular shape, line wobbly, 9 is reversed; some numbers tilted. Spatial Planning: numbers are well spaced, equal size, 12–6 opposed at an angle, 9- opposed to 2 instead of 3. Conceptualization: hand missing.

Clinical Tools, Tasks, and Procedures Employed in the Examinations

The three students were examined individually on separate dates. The order of completion of the three student tasks was replicated for each, as appears in the order in *Student Instruments and Tasks* paragraph. Parents were given open-ended questions and a behavior rating questionnaire in advance of the exam date, and the completed forms were collected on the exam date.

Student Instruments and Tasks

Time Knowledge Questionnaire for Children (TKQ):[74] the authors operationally define time knowledge as *the correct representation and use of the various time units*. The questionnaire was validated and norms obtained for typically developing children aged 6–11 years, and some norms were based on adult responses. It includes 25 questions broken down into seven categories examining: a) *conventional time knowledge*: orientation; sequence; time units; telling time on a clock, and b) *estimative time knowledge*: diachronic thinking or Lifespan; birthdays; interview duration. Although quantitative data can be obtained, a qualitative approach was taken here: the actual errors and successes were noted for each student on all questions including student's birthdates and ages (noted in the protocol as not meant to be included in the quantitative calculations) to obtain a clearer view of their time competence landscape. The authors state that a clinical application of the tool was *shown to be of interest for children with disorders or disabilities*, accordingly, it is used here and includes a participant somewhat older than the norming group age limit. The tool's accompanying graphics were applied as suggested by the authors. The clock task is of interest as it included five items: One absolute time probe asking the child to "show me" a named time on the clocks graphic, and three asking for relative time; the fifth, embedded in a question form, is also a relative time probe, "How many minutes to X" requires calculating by 5-minute intervals to reach the named time.

Draw-A-Clock (DAC): The clock-drawing test is a screening measure of visuospatial skills, graphomotor abilities, the conceptualization of time, and knowledge of the features of a clock.[75] In typical 6–12 year olds, the skill shows a developmental progression with errors diminishing over time. In atypical populations, for example children with ADHD, DAC errors stem from executive dysfunction,[76] and those with Dyslexia tend to show left visuospatial neglect.[77] In the present study, the DAC task was accompanied with verbal instructions and a colourful visual model of an analog clock which was then removed; participants were asked to draw a clock of their own (not asked to specify a time), and no other instructions were given during their execution of the task. DAC qualitative error scheme was adapted from adult studies of individuals with mild neurological disorders[78] that included functional magnetic resonance imaging (fMRI) activating areas corresponding to clock hand placement errors revealing underlying neuroanatomical areas. However, verification of neuroanatomical correlates described in the study was beyond the scope of this article, and their descriptions were omitted as well since they encompass and tax readers' knowledge of complex human neuroanatomy. The participants were not asked to indicate a specific time, so that the associated error was omitted, and only these were examined: *size errors*: micrographic or macrographic (poor visuospatial planning); *graphical difficulties* (poor coordination of fine motor control and planning); *conceptual errors* (incomplete or poor knowledge of a clock and its attributes pointing to deficit in semantic memory that stores knowledge about the world and concepts); *spatial planning* (number layout crowded or neglected areas); *perseveration*: numbers repeated (suggests EF impairment). The qualitative error scheme was found to be effective in a study with ASD children and adolescents as it highlighted difficulties with time comprehension, and showed low frequency errors such as *Perseveration* seen in only 2/21 participants, and Macrographic Size error appeared in only 4/21 participants.[79]

Parent Instruments and Tasks

Behaviour Rating Inventory of Executive Function (BRIEF; Parent form):[80] This instrument examined the three participants' real-world ecologically valid EFs based on parental perspective (rather than a performance-based investigation) as it best reflected intimate knowledge of the child's function. The BRIEF was chosen since it reflects the view that Ecological Validity "refers to the extent to which an assessment produces logically sound data representing individuals" *interactions with their surroundings*',[81] and the fact it was found effective in uncovering EF difficulties in a clinical sample of school aged children.[73] All three parent questionnaires were examined for elevated negativity and inconsistency ratings, and none showed these were an issue. The BRIEF is organized around two indexes, each with scales: The Behavioral Regulation Index (BRI) includes: Inhibit, Shift, and Emotional Control; the Metacognitive Index (MCI) contains: Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor. The instrument's mean T-score is 50 and 10 the standard deviation. For clinical purposes the scores were interpreted as follows: ≤59=Adequate Function; 60–65=Behaviorally Significant Dysfunction; ≥66=Clinically Significant Dysfunction. The two indexes general function was interpreted according to the number of scales with a ≥60 score: in BRI (3 scales) 0=Adequate Function; 1–2=Behaviorally Significant Dysfunction; 3=Clinically Significant Dysfunction. In MCI (5 scales) 0–1=Adequate Function; 2–3=Behaviorally Significant Dysfunction; 4–5=Clinically Significant Dysfunction.

Parent written open-ended questions: these questions, related to their child's time issues, were adapted from a study noted here.[68] They were instructed to respond to all five questions and add any other relevant comments they may have: 1) Please explain whether punctuality affects your child and give examples. 2) How does your child prepare so they can go to school, on time? Do they (or you) use specific strategies to help them get ready? 3) The extent to which we are aware of the passage of time can change depending on what we are doing, does your child ever appear more, or less, aware of the passage of time and in what activities have you noticed this? 4) To what extent do any differences in the understanding and experience of time affect your child's life? 5) Please comment on your child's ability to retell events or stories heard or read in terms of understanding and experience of time: is the sequence logical, clearly understood, do you have an example? Parents completed all questions, but only one offered additional comments (orally).

Student TKQ and DAC Results, Brief Questionnaire, and Parent Open-Ended Questions Responses

The student and parent results are integrated and compiled for each student separately in tables: Table 1 includes the 10.8 year old student with ASD, designated ASD-Y, and contains the TKQ, Brief questionnaire results, and the Parent Open-Ended Questions. His DAC drawing with qualitative errors is included in Figure 1. Table 2 includes the 13.6 year old student, designated ASD-J, and includes the TKQ, Brief questionnaire results, and the Parent Open-Ended Questions results. His DAC drawing with qualitative errors is included in Figure 2. Table 3 centers on the 8.1 year old student with ADHD, designated ADHD-L. It contains the TKQ, Brief questionnaire, and the Parent Open-Ended Questions results. His DAC with qualitative errors are included in Figure 3.

Results Interpretation and Discussion

ASD-Y results interpretation: TKQ *Conventional Time* Orientation: Y had no difficulty saying the present time, or naming the month, year, and season. Sequences: He struggled with saying what comes after a named month, but named and ordered accurately all the months, indicating a rigidity in that he remembers the 12 months as a chunk but unable to identify one out of sequence. He named the seasons in order. Time units: This was a strength for Y where he understands the duration of second, week, month, and year when compared, and knew a day has 24 hours. Telling time on a clock: he is able to read requested absolute and relative times that are depicted, but struggled with the question form in which relative time was embedded and where he needed to calculate 5 minute intervals to arrive at the requested time. It points to language weaknesses in syntax and vocabulary, and calculating time. *Estimative Time* Diachronic Thinking: his estimations were within the acceptable ranges showing intact lifespan transitions knowledge. Birthdays: he knew his age last year, but overestimated his age for the following year. In his present age, he omitted the day – this is seen here as an "attention error". He was able to say accurately how long ago since his last birthday, and how long to the next one. Interview duration: intact time estimation competence was shown here. Y's DAC is depicted in Figure 1. Task Result: Y's clock drawing showed 4/5 errors. Clock size: Macrographic- A rare error in a cohort of children with ASD.[79] The error is attributed to underlying EF weaknesses;[78] Graphical errors showed fine motor coordination and control problems as he attempted forming a circle twice resulting in a "squarish" wobbly clock. Handwriting too was implicated, with numbers tilted, indicating he needed to reposition the paper to form the numbers, which may be due to poor visual recall of the clock face depicting forward facing numbers. His clock hands were too long for the space and the minute hand encroached on the numbers space. Spatial Planning: all numbers were present but crowded to the right, with the rest unevenly spaced and noted gaps from the bottom center to the left. Conceptualization: the numbers were sequenced accurately but 12–6 and 9–3 were not opposed, showing poor observational skills and lack of understanding these are traditional orienting points to facilitate time reading. Perseveration: no perseveration error was present.

Parent Brief Questionniare: Consistent clinically significant dysfunction in Y's EF Behaviour Regulation index was noted, implying a strong possibility of ADHD presence according to the BRIEF authors. The Metacognitive index too consisted of clinically significant dysfunction, and only slightly less severe in Organization of Material scale. Working Memory in this index is also attributed to the presence of ADHD. The possibility of an ADHD comorbidity in Y's ASD is high. Open-Ended Questions: Y's weaknesses in time cognition and competence are all pervasive as they permeate all time related procedures and tasks at home, school, and leisure or "fun" activities, including retelling events or stories in proper sequence. Punctuality and time estimation are the major culprits in the difficulties both Y and his parent face in their daily lives.

Summary: Y shows a strength with few errors in comprehension of conventional and estimative time. Comprehension of question embedded relative time was problematic as he was unable to "solve the problem" and recognize that he needs to calculate 5-minute units to arrive at the answer, while other errors were due to omission. His error on naming a month in isolation indicates he learned the order as "a chunk" and has difficulty separating them, confirming a working memory weakness, and pointing to a rigidity in problem-solving. The DAC confirms difficulties in four of the aspects of a clock, errors due to graphomotor weaknesses, planning – An EF based skill, and incomplete understanding of the function of the various details of the clock face. They also show low need for accuracy and attention to details. His parent results show he has difficulty applying his temporal knowledge in his daily life as all activities, both social and school based, are adversely affected. In this case, functional synchronization of subjective time with objective time is not yet achieved. He requires strategies in how to apply his temporal knowledge to all his life activities, a level conceptualized in Bloom's Taxonomy of Learning[82] that moves a learner forward from remembering and knowing to the more cognitively demanding applying level.

ASD-J results interpretation: TKQ *Conventional Time* Orientation: J had difficulty saying the present time or estimating it, but succeeded in naming the present day, year and season. Sequences: He was able to name a requested month in isolation, and name all months of the year in correct sequence, but could not name the seasons in order. Time units: he shows understanding of the duration of second, week, month, and year when compared, except the number of hours in a day. Telling time on a clock: he is able to read requested absolute and relative times that are depicted, but unsuccessful on the question form in which relative time was embedded and where he needed to calculate by 5 minute increments to arrive at the requested time. It points to language comprehension weaknesses in syntax and vocabulary, and problems calculating relative time. In *Estimative Time*, Diachronic Thinking: he was unable to provide numeric estimates of life span transitions for any age, instead offering age-related words, *young, old, older* in response to each depicted figure on the graphic, showing he understands an aging process is depicted. Birthdays: he said his global age but when asked if he may be a bit older he said no, obviously unaware that the months since his birthday count as well. He had no answer for how old he was last year, or his age in the following year – he provided his birth year instead. For his birthdate, he offered the month and day but omitted the year. He was unable to say how long ago his birthday was or how long to the next one, indicating he has problems calculating months, it could indicate he learned the sequence as a chunk but did not associate these with a number. Interview duration: he grossly overestimated the duration with his response of 2 hours – The actual interview lasted 9 minutes.

Parent Brief Questionnaire: J's dysfunction in Behaviour Regulation EFs indicate an adequate range in Inhibit, an ADHD presence marker, but elevated dysfunction in Shift, and highly significant clinical dysfunction in Emotional Control. In the Metacognitive index, while Initiate is in the behaviorally significant dysfunction range, Working Memory, also an ADHD presence marker, is in the Behavioral-Clinically significant dysfunction range, and so more severe. Plan/organize, Organization of Materials, and Monitor are in the adequate ranges. His compromised Working Memory may indicate attentional problems due to the presence of ADHD. Perseveration error was absent. Open-Ended Questions: J's weaknesses in time cognition and competence affect punctuality, and require adult supervision. However, the fact that he recently overcame problems with bed-time, and is now independent in waking up on time indicates improvement in appreciation of importance of time in carrying out routines. He still has a difficulty understanding the change of seasons – climate dependent events whose occurrence is marked with calendars, implicating weakness in comprehension of calendar function. He sometimes remembers the routine order of events in a defensive manner to be able to face specific activities he dislikes. School punctuality remains an issue of sorts as he is anxious about it because he dislikes the consequences.

Summary: J's time-related difficulties are in transition with some improvement in clock time related function, but noted gaps in calendar-related time. He has weaknesses in EF related to ADHD, and requires adult support and repeated explanations in his struggles to understand events he finds unwelcome. He recently began to use lists of daily activities which he checks off when completed, an external aid to help him remember and manage his day, another sign for improvement in his adaptive strategies for self-management in coping with the challenges of time obligations. J would benefit from expansion of his background knowledge with ample examples of calendar related events interlaced with climate changes, as well as strengthening his math skills for the purpose of calculations of time, and especially estimative time.

ADHD-L results interpretation: TKQ *Conventional Time* Orientation: L had difficulty saying the present time or estimating it, and naming the season, as apparently the word is either not yet in his vocabulary or he is unable to retrieve it from his mental lexicon. He asked several times "what is season?" Although this is a frequently practiced concept since preschool, the word meaning remains opaque for him. Sequences: He struggled with remembering sequences of months, and had no strategies for retrieving their names although it was practiced repeatedly, reported his parent. Similarly, he was unable to name the seasons, and again claimed he did not understand the word "season". Time units: this was a strength for him as he understands the duration of second, week, month, and year when compared. Telling time on a clock: he is able to read requested absolute and relative times that are depicted. However, he struggled with the question form in which relative time was embedded and where he needed to calculate by 5-minute increments to arrive at the requested time. It points to language weaknesses in vocabulary and syntax, and problems with calculating time. *Estimative Time* Diachronic Thinking: he overestimated the transition from young man to old man, but estimated correctly baby to child, and child to young man transitions. Birthdays: he knew his age last year, present year, and the following year, however he provided the month and day of his birthday but omitted the year. He could not say how long ago his birthday was, but knew how long to the next one. Interview duration: he underestimated the duration saying 1 minute while the interview lasted 12 minutes. DAC Task Result: L's drawing showed 4/5 errors. Clock size: Macrographic error was rare in a cohort of children with ASD; Graphic errors: a reversed 9 was present – indicating lack of attention to direction – An immaturity, while the other errors indicated coordination and control issues and are related to poor handwriting as well (reported by his parent as a problem), and the clock was lopsided; Spatial Planning: his number placement showed some planning skill as they were not crowded in any quadrant, and they were rather equal in size, however, his positioning of guiding points for clock reading was half right. Conceptual error: he only opposed the 12–6, but not the 9–3 mostly due to the planning of the numbers position, but also indicative of a limited understanding of the function of the time guiding points, and the need for their specific arrangement for accurate time reading. In addition, he drew only one hand on the face. The omission of an hour hand on the clock indicates an immaturity reported by researchers[38] as an error frequently seen in grade 1 and 2 children with mathematics disorder and typical children. They classified the error as "selective attention" since it shows they paid attention to only one clock hand, either the minute hand or the hour hand. Supposedly, the error diminishes considerably from about age 8, but obviously L is not yet at that stage. In addition, it indicated poor monitoring of his own product, a symptom of executive dysfunction although his parent rated his monitoring skill as in the adequate range. Perseveration: The error was absent.

Parent Brief Questionnaire: L has inconsistent dysfunction in EF, at times he is able to use EF effectively, indicated by behaviourally significant rather than clinically significant dysfunction. His noted problems in BRI is inhibit, and Metacognitive index showed Working Memory as compromised. These are signature dysfunctions in children with ADHD. His difficulty with Organization of Materials shows he is adult-dependent as he often would misplace or lose his materials and tools needed for completing work and tasks at home and school. Open-Ended Questions: L's weaknesses in time cognition and competence are all pervasive as they permeate all time-related procedures and tasks. Punctuality is a great issue for him as it occurs often and he is embarrassed by lateness. His parent noted that his estimation of time is the culprit in his difficulties.

Summary: L shows a strength in comprehension of time units but gaps and weaknesses in all other examined time categories. The DAC confirms difficulties with time concept, and his inattention to detail resulted in omission of a hand and number reversal. His parent results show that his immaturities may be due to EFs, the control mechanism with a long developmental trajectory. His obvious lags in time knowledge are affecting his life adversely. He is unable to retell events and stories sequentially as he leaves off important details, making his retell incomprehensible to the listener. It seems that at the present function, the synchronization of his internal clocks with actual time is a work in progress, but not yet fully realized. He could obviously benefit from instruction to improve his current time knowledge, and practice to achieve competence in use of time in all activities at home, school, and recreation.

Integrated Comparative Summary of Results for the Three Examples

The set of tools and tasks used in detecting time competence in these students effectively exposed strengths and detected weaknesses in the various time elements investigated here, and demonstrated ecological validity. The information gleaned from the parents' responses indicated struggles with time awareness and knowledge affecting punctuality, and memory for perspective and prospective events in their daily lives at home and school, and resentment in their children when these are revealed. Time knowledge appeared most depleted in ASD-J, where the parent did not respond directly to the question on event sequencing retells, seemingly a rarely requested task for him. There was a decided difference between the knowledge of time between ASD-Y with mainly intact knowledge and ADHD-L with noted gaps in knowledge. However, there was a marked similarity in their clock drawing as in both EFs in planning, conceptualization, and sensory-motor weaknesses were exposed, while ASD-J too showed conceptualization and planning weaknesses, he exhibited a strength in sensory-motor control. Interestingly, the Macrographic clock size error implicating EF and visuospatial impaired functioning, was found to be relatively rare in the ASD study,[79] occurred in the drawings of both ASD-Y and ADHD-L. The similarly rare Perseveration error was absent in all three participants. The BRIEF results for ASD-Y and ADHD-L showed both students with dysfunction in the Inhibit scale and Working Memory, while in ASD-J, only Working Memory was an issue. ASD-Y exhibited clinically significant dysfunction in almost all scales. His parent informed the examiner that he required a year with intensive stimulation to have him remember the months of the year in order, and any time-related concept required a great deal of effort to help him comprehend and remember. In all, the set of tools used here were able to detect time competence strengths and weaknesses, and EF weaknesses and immaturities that exacerbate the temporal issues in the students with ASD that are mirrored in the child with ADHD.

Discussion

The aims of this review with three illustrated examples were met as delineated earlier. The article described the unfolding of episodic memory and short time measuring structures with reference to tested models and explanations that shed light on the development of subjective time. It expounded on the exceedingly complex concept of time and its interchangeability with space to form spacetime, the fourth dimension in our understanding of the universe. Amazingly, the time and space neurological detectors are housed in very close proximity in our brain structures and are stimulated simultaneously in formation of our episodic memories so that we are able to retrieve not only the what and when and accompanying emotions, but also the where of remembered events. The article clarified that anchoring subjective time to physical time requires intact underlying neurobiological systems and connections to achieve optimal synchronous temporal processing so that the presence of atypical or compromised neurobiological systems and connections in individuals is predictive of challenges in achieving this crucial neurobiological goal. Additionally, it explained that the formation of temporal cognition, the bank of knowledge essential for developing temporal abilities, relies on the reciprocal interaction between the neurobiological systems and the higher cognitive functions via language, and so requires successful integration of temporal abilities with cognitive-linguistic capacities. This finding is highly informative for clinical and educational practice as it highlights the importance of integration of language development with cognitive development. The article emphasized that, although time concepts are expected to be taught in elementary and secondary school, educators at all levels find it is a difficult concept to teach. Next, the review expounded on the challenges individuals with ASD and ADHD face in development of temporal cognition. Finally, as outlined in the review aims, a set of clinical tools used in the varied illustrated cases, successfully detected their temporal competence gaps and ecological executive dysfunction, and demonstrated ASD results were mirrored in the child with ADHD. The results for each child were then integrated and demonstrated in Tables 1–3, interpretive summaries for each case were included, as was an integrated comparative summary.

The Added Value of This Review

The finding that language is a major player in temporal competence development is highly informative for clinical practice as it highlights the need to determine the child's language capacity and weaknesses, includes more integrative cognitive-linguistic tasks in investigations, anticipates struggles in developing temporal competence in individuals with delays or disorders in cognitive and linguistic domains, and encourages inclusion of a greater number of integrative cognitive-linguistic tasks with temporal content in their interventions. In short, it can inform direction of assessments and intervention for ASD and ADHD, the temporally challenged individuals, as well as enhance temporal knowledge in typical children by adopting such tasks in the classroom, in fact, using complex tasks to foster the desired skills. For example, a complex task replete with cognitive-linguistic demands (based on a real cooking task exam), was used in a study with adolescents with dysfunctional EF.[70] It provided evidence of their inefficient time usage, and disorganized procedure to accomplish the timed task. These abilities are needed for independent function and protracted projects, note the authors, so that the gaps between their abilities and environmental demands may negatively impact their participation and success in life events. The BRIEF used in the reported study confirmed the presence of ADHD in the participants. The study incorporated earlier research[69] in which an organizational scale was developed to measure specific deficits in performance of youth with ADHD and salient disorganized skills on complex tasks. The scale demonstrated ADHD individuals are riddled with disorganization due to EF deficits that contributes to task completion failure and ineffective use of time. Besides its intrinsic value, the noted research results showed that complex tasks were instrumental in uncovering ADHD and EF deficits in disorganized individuals, and so are applicable to those with ASD. Moreover, adaptation of complex tasks for intervention with ASD students and those with ADHD would be invaluable for promoting more effective EF development, and subsequent organized thinking and performance based on gains in temporal knowledge and management, the crucial life-permeating functions.

In addition, the use of Open-Ended parent Questions modeled on a previous study,[68] provided ecological validity to the TKQ[74] results used here with atypical children. It successfully exposed temporal weaknesses that were accompanied by real-life daily struggles as reported by their parents, so that, in effect, it provides support for use of the TKQ with atypical children with high risk for temporal challenges including adolescents, absent in the instrument's typically-developing control group. Additional studies are needed to confirm effectiveness of the TKQ with wider age ranges in both typical and atypical groups, and the adjustments it would require to make items challenging enough for higher age individuals. In addition, the use of clock drawing errors showed that, aside from temporal knowledge struggles, it was effective in uncovering other aspects that habitually plague these children: sensory motor issues, handwriting, and task planning – An EF based skill.

In retrospect, the modified Open-Ended Parent Questions would have enhanced the temporal information with more questions regarding children's references to past, present, and future events as noted by the authors of the questionnaire, and thus would have offered a better view into their understanding of retrospective and prospective time. Information regarding the child's estimation of duration of task completion (eg, parent asking, *how long do you need to complete the puzzle before bedtime?*) compared to the actual duration till completion, would be invaluable in detecting how well the child's subjective time is synchronized with physical time and the child's feeling for the flow of time. When lagging, temporal estimation could then be added to the child's intervention goals. Moreover, asking parents for detailed accounts of their children's sleeping habits would provide a vista into their circadian timing efficacy. Insomnia and difficulties with sleep–wake circadian cycle dysregulation are highly prevalent in ASD (50–80%),[83] and their disturbed sleep–wake cycle, frequently associated with gastrointestinal and seizure co-morbidities,[84] is central to conflict and distress in the child and family. Sleep disorders prevalence in ADHD is high as well (25–50%),[85] and is associated with sleep-disordered breathing, restless leg syndrome, circadian sleep–wake cycle disturbance, insomnia, narcolepsy, and daytime dysfunction because of excessive tiredness. Details on the affected children's time management can include information on excessive focus and time spent on their special interests at the cost of neglecting physical, social, and literacy based activities to enhance their well-being and progress in school.

Finally, the review confirmed that indeed temporal knowledge is compromised in children with ASD and ADHD and, although these disorders are often comorbid, their temporal competence is rarely (if ever) seen in clinically invested professional evaluations or treatment plans for these children and adolescents; even where measured, intervention plans are recommended for individuals with traumatic brain injury mainly, with rare inclusion for those with atypical brain development. Researchers[45] confirm that time competence, one of the most difficult sets of skills to develop, seems to be a neglected aspect of ASD and, consequently, there are limited tools to measure time processing and management in children. Although each of the tools described in this review is known and used in isolation, albeit in slightly varied form and measures, their integrated use here as a "clinical set" is a novelty, as is the primarily qualitative information focus to detect essential facets of temporal knowledge and adaptive use as reported by parents. It contributes an additional effective tool to the meagre armoire of tools to investigate temporal competence in children with ASD, as well as ADHD, as shown here. The advantages in using this set of tools (proven to be effective in several studies) include the ease and economy of time and cost in their administration, and their potential to uncover essential information to guide the direction of individualized temporal intervention.

Directions in Evaluation and Treatment of Compromised Temporal Competence

Why Persist with Instruction of Analog Clocks Reading

Educators agree that teaching time concept is difficult at all levels, and especially in making time comprehensible using analog clocks. They question whether analog clock reading is essential for students as they find them difficult to read, and reason that because digital clocks are easy to read and ubiquitous they should replace the analog clocks that are soon to become an anachronism.[86] Digital clocks great disadvantage is that, although they do differentiate and mark Ante Meridian from Post Meridian time, a difficult concept in itself, their lack of hands does not permit children to "see" time moving to facilitate anchoring physical time to subjective time, consequently, when reading digital clocks, time remains invisible. However, Common Core State Standards (CCCs)[87] in the United States for example, include clock reading skills in both analog and digital formats in their *Measurement & Data* section starting in Kindergarten, and throughout the grades, with progressively more advanced skills.

Students with disabilities too are expected to be supported in acquiring clock reading skills.[88] Interestingly, the application guidelines for these students were formulated in 2010 while the CCCs were updated in 2022, a gap that may be due to insufficient research of effective novel strategies to support these students. In fact, children with mathematics disabilities, associated with other multiple problems, include clock reading struggles.[38] Mathematics challenges can be predictive of problems in clock reading note the researchers, as there are similarities between them. Clock reading hinges on acquiring mathematical facts which must be remembered and applied in time calculations for reading absolute or relative time couched in complex language; some clocks allow 24 hour reading where there is no need for marking meridians while others are based on 12 hours where meridians must be marked. They are different from math as clocks do not apply a base-10 structure, and all details on a clock face have a time significance with a base of 60. In another study[89] 3rd graders with and without dyscalculia risk experienced difficulties in clock reading. At an early age, these difficulties can act as an early red flag to identify dyscalculia risk in children, conclude the authors.

Underlying mathematics disability (and thereby clock reading problems), is deficient number fact knowledge, indicating poverty of mathematics background knowledge, posit researchers.[90] Analogously to importance of background knowledge in reading, so in mathematics, background knowledge is essential in acquiring mathematical proficiency. It represents skills such as oral counting, objects counting, counting knowledge, number identification, quantity discrimination, comparative quantitative vocabulary, sequential vocabulary, etc. The benefit in clock reading instruction is its capacity for early identification of mathematic disability, while mathematics background knowledge instruction can remediate both simultaneously. It is therefore wise for primary educators to instruct these simultaneously in early grades and so ensure the forming of a strong foundation for mathematic competence in parallel with analog clock reading to gift students with a vital adaptive skill essential throughout life.

While teachers may complain that analog clock reading is too difficult and children would be better served with the less cognitively demanding digital clocks, they are essentially depriving them from developing and enhancing the cognitive processes including EFs needed in all learning. The benefits of analog clock reading are impressive, and are used as a staple in examinations and rehabilitation of individuals with various brain function altering diseases and traumas. For example, a noted rehabilitation center,[91] dedicated to providing self-help skills in patients, use digital therapeutics to train individuals to read, and do math to calculate times on analog clocks. They state that these adaptive skills are needed throughout our lifespan for keeping us on track, and regulating our days. Clock reading enhances brain function by targeting cognitive processes including sustained attention and memory, visuospatial and mathematical skills, cognitive-linguistic skills, and executive functioning. Some specialized schools for students with serious learning disabilities due to neurological damage or difference, center their program on reading clocks with progressive addition of multiple hands to increase the cognitive load and successfully affect the needed changes in their neurology while increasing their cognitive capacity.[92,93] Clock reading intensive training was found to remediate deficits in focused sustained attention for extended periods of time, a skill believed to be causally related to deficits in EFs.[94]

How can teaching time concept be facilitated in secondary schools? Science instructors are encouraged to begin by acknowledging to students that it is a difficult concept, and that scientists continue to discuss time.[39] Furthermore, notes the author, since preconceived ideas and sensory perception often interfere with comprehension and learning, it is important to find out the student's opinion or notion so discussion can take place and misconceptions addressed. To facilitate learning, concepts need to be taught explicitly, and their terminology explained without assuming they are clear to all. In fact, the New South Wales Online University[95] provides a study guide with several proven effective strategies for teaching complex concepts. It can facilitate writing a lesson plan, and can be adapted for instructing students with typical and atypical neurological development who may struggle in acquiring these complex concepts.[95] Other researchers advise enhancing learning with the use of demonstrations such as time-lapse photography (videos), and clocks, the appropriate metaphors for time.[35] Lastly, explaining the role of various time measurements facilitates understanding of time, while having students manipulate them etches it into their neurology. Naturally, the general approach, and the sequencing of concepts meant for secondary level students in environmental and natural science studies,[39] would require noted adaptations when addressing those with known learning challenges and younger students. Application of the Vygotskian dynamic framework[96] in lesson planning would facilitate teaching and learning as the needed degree of scaffolding (support), and time spent on each concept can be adjusted to accommodate the target students' learning rate and flow.

However, the preparation for learning complex concepts such as time must begin at least upon kindergarten entry or even sooner, when children can be transformed into reflective learners with an approach such as "tools of the mind", a pedagogical framework gifted us by Vygotsky's dynamic approach of mediated learning.[97] This framework, based on scaffolding children's learning journey, was used to develop a curriculum focused on planning play scenarios, literacy, math, science, etc, with all activities and tasks designed to foster prosocial attitudes and skills, and effective EFs or "learning how to learn" competently. The EFs needed to be successful in modern life, posit researchers are creativity, flexibility, self-control, and discipline to persist with a task to completion.[98,99] This approach, with a complementary curriculum, facilitates learning cognitively demanding concepts such as time and clock reading which must continue to be instructed throughout the grades with demonstration of real life applications to prepare them better for secondary education.

The Role of Home in Children's Temporal Development

The home too has an important role to play in their children's development of time concepts that require planting into their consciousness from early on. Research[35] highlights the dependence of temporal development on understanding and talking about time, grasping the differences between past, present, and future, and the ability to reason about sequence of events. Families with ASD and ADHD children, known for their time competence issues, are encouraged to change this trajectory by incorporating time, space, and number vocabulary and discussion into their daily lives in all interactions with their children. Targeted stimulation with time words, displayed analog clocks, and frequent references to time-space and numbers is imperative. Talking about and explaining the calendar ties to cyclical events and climate affects comprehension and learning salient time words, skills that are highly desired in kindergarten and beyond. Calendars are effective in helping recall of retrospective events and planning prospective activities. Engaging children in cooking activities are useful in developing time, space, procedural knowledge, and growing their EFs as they represent complex activities.[70] All appliances and gadgets at home are potential "time teaching tools" with their measurement function, and association with time-space that requires demonstration and age-appropriate explanations. Timers and Visual Schedules help children "hear, see, and feel" time in the past, present, and future, while toy analog clocks are effective in teaching them to manipulate "time" and impress upon them the idea that "hands talk": they tell us the time. Parents are advised to incorporate strategies to increase the effectiveness of their efforts: encourage their children to observe closely, attend to details, have them participate actively in planning and executing the time-space promoting activities and, finally, stimulate recall of the activity sequence, and retell it to other members of the family.

Furthermore, the idea that time and space are interchangeable is neither foreign nor novel in our existence but rarely explained to children. While vehicles register distance (either in miles or kilometres), we tend to use travel time rather than distance to refer to travel on land and in the air. The interchangeability of time and space in our existence should be made familiar to children from early on in real time travel, demonstrated with distance and time measure instruments we use, with explanations of the measurement units. These need to be highlighted in school curriculums from very early on so to complement the knowledge acquired at home, thereby increasing children's awareness of physical time and distance, demonstrated by actual use in their daily life. Understanding temporal markers in language, reiterate researchers,[35] rests on maturation of cognitive skills to be able to differentiate time terms, and map them to linguistic expression, however, given the reciprocal interaction of these, enrichment of their children's time awareness, vocabulary, and concepts is certain to expedite cognitive maturation.

Call for Changes in Assessment and Intervention with ASD and ADHD Children and Families

To date, autism research continues to focus on biological aspects, observe researchers,[100] and, although indisputably valuable, it fails to address the urgent needs of individuals with autism and their families. What is needed, state the authors, is prioritizing clinical research to find solutions to problems that will result in "immediate improvements in the lives of people with autism and their families". Some proposed evaluation and intervention approaches delineated here may potentially provide solutions to the temporal problems that children with ASD and their families face on a daily basis, as do those with ADHD.

A recent study[101] used a socioecological approach to investigate the impact of the serious challenges families face in trying to address their children's Autism, a multifaceted disorder with many needs and behavior issues affecting their daily function at home, school, and recreation. A statistically significant relationship occurred between autism impact measures and level of dissatisfaction with family life as both children and parents were negatively impacted by their stressful experiences. Although time issues were not specified directly, it must have included daily struggles with punctuality, the center of time-based difficulties in many families. These conflicts succeed in adding fuel to the boiling cauldron of resentment and dissatisfaction these families experience. Family and child needs have to be considered in clinical intervention for allocating service resources, note the researchers. Other researchers[102] advocate measuring intervention effects using a *Dynamic Lens* to consider individual variability in matching effectively the best intervention with a given child's profile. They state that the within-person changes are lost in group treatment outcomes and, since behavior symptoms in ASD are dynamic, it stands to reason that a dynamic treatment approach which takes into consideration chronogeneity (changes over time) of symptoms and capacities, would better predict individuals' response to intervention.

The studies[69,70] using complex task performance of children with weaknesses in their EF, noted in the presence of ADHD, successfully identified deficits in their temporal management. By extension, complex task performance evaluation would be equally effective in uncovering specific temporal and EF deficits in those with ASD, a syndrome marked by disorganized function. Moreover, the use of complex tasks in treatment would be invaluable in developing the cognitive tools needed for temporal and procedural knowledge acquisition, while promoting more effective EF development. These uses of complex tasks for ASD are contingent on clinical research dedicated to developing appropriate executable complex tasks with accompanying tools to measure their effectiveness with varied populations, and outcome guidelines in determining whether and when adaptations are needed. While research evidence for this approach in practice may be lacking or inefficient, clinicians are encouraged to adopt a reason-based approach.[103] This venue is legitimate as it is theoretically linked to existing research, and applied using the scientific approach, ie, hypothesize, implement a strategy, evaluate its effectiveness, observe and record outcomes, and determine if modifications are needed in considering the individual profiles of children with ASD and, by extension, those with ADHD.

Conclusion

The importance in detecting time concept in ASD is highlighted in this thematic review. Researchers[45] posit that temporal processing aspects in ASD may be regarded as central factors in their symptoms. This requires determining their temporal perception needs in "global functional assessments", and addressing them in early intervention to alter their symptom trajectory. This view is echoed here: promoting temporal competence is crucial given the extensive disheartening consequences of temporal incompetence as discussed in this review. It is therefore obvious that temporal competence integrity investigations must become an integral component of these high risk children's clinical assessments to inform timely appropriate interventions.

In sum, this review's take-home message includes the following:

- Examining thoroughly ASD and ADHD children's syntactic and semantic development to determine the presence of concept words of numbers and counting, direction-position, quantity, time, sequence, etc, and probing their cognitive-linguistic integration – The important ingredients in development of temporal cognition.
- Detecting their time competence using the ecologically valid clinical set of tools used here that incorporates parent input, and demonstrated potential to uncover gaps and weaknesses to guide the direction of individualized temporal intervention.
- Including complex tasks to examine their real-world time-space competence, and to treat deficits to effectively close the gaps between their abilities and environmental demands.
- Instructing analog clock reading from early on as it promotes extended sustained attention, effective EF, and cognitive development crucial for successful life and school performance.
- Promoting clinical research using a dynamic approach that considers individual variability and change overtime so as to match the best intervention with a child's profile, and develop executable complex tasks and measures of their effectiveness.
- Adopting a socioecological approach to determine families' stresses and dissatisfaction in addressing their children's complex needs, with a view to facilitate resource accessibility to ameliorate these families' lives.

Statement of Ethics

No external approval was sought for the following reasons: All procedures performed were in accordance with the ethical practice standards of clinical practice as delineated by the Order of Speech Language Clinicians licensed in the province of Quebec, Canada, and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Furthermore, informed parental consent was obtained for each participant explaining the tasks the student will be asked to complete and that they have no known adverse effects and are no different from those they perform daily in their classrooms. Students too were told that the exam consists of familiar tasks and it is completed in a short time. Parents were informed that they will be asked to contribute two tasks. The informed consent was accompanied by a statement of intention to publish results in a peer-reviewed ethical journal with a strong guarantee of confidentiality and complete anonymity. The benefit to their children was highlighted as all results were to be shared with the parents and individualized treatment suggestions will be provided. They then signed the informed consent and agreed to complete the two tasks prior to the examination of the children.

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Disclosure

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