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Time will tell

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Time will tell: sluggish cognitive tempo, attention and timing functioning in adults

Anna Katharina Toussaint

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«Mein Reich ist klein und unabsehbar weit.

Ich bin die Zeit.

Ich bin die Zeit, die schleicht und eilt,
die Wunden schlägt und Wunden heilt.

Hab weder Herz noch Augenlicht.

Ich trenn die Gut' und Bösen nicht.

Ich hasse keinen, keiner tut mir leid.

Ich bin die Zeit [...]

Klein wie ein Punkt ist der Planet.

Der sich samt euch im Weltall dreht.

Mikroben pflegen nicht zu schrei'n.

Und wollt ihr schon nicht weise sein,

Könnt ihr zumindest leise sein.

Schweigt vor dem Ticken der Unendlichkeit!

Hört auf die Zeit!»

Erich Kästner, Ich bin die Zeit.

Chapter 1

GENERAL INTRODUCTION

Chapter 1 GENERAL INTRODUCTION:

1.1. Cognitive Processing

“Cogito, ergo sum. I think, therefore I am.” (Descartes, 1637). This syllogism by Descartes does not only show the fundamental role he assigns to *the cogito*, as being the basis for “being”, but can be also understood as the philosophical origin for ensuing scientists to conceptualize, quantify and interpret the mental processes that are immanent to our human condition. The term cognitive functioning covers mental abilities such as: information processing, attention and memory. Cognitive functioning is a general term to describe mental processes involved in for example human perception, language, reasoning, decision-making and problem solving (Roy, 2013). The most commonly measured underlying, basic cognitive skills are: information processing (often measured as processing speed), sustained attention, selective attention, working memory, long-term memory, response inhibition and cognitive flexibility (Neisser, 2014). Cognitive functions cannot be measured directly but are inferred from observable behavior (e.g., reaction times (RT) and number of successful and/or unsuccessful executions of a task) or via non-invasive techniques, such as electroencephalogram (EEG) or functional magnetic resonance imaging (fMRI). For example, whereas ‘selective attention’ can be measured by the individual’s success in focusing on a single task while several distracting stimuli are presented, ‘long-term memory’ can be measured by asking the individual to recall the major points of last week’s meeting. More recently, computerized test batteries (Kane & Kay, 1992) measure cognitive functions.

Cognitive functions are different from sensations (e.g., smelling, hearing) and motor acts (e.g., moving your arm upwards). Cognitive functions are often called higher-level functions of the brain and they are involved in every aspect of human life (e.g., Neisser, 2014) starting from rather simple requirements such as being oriented toward date and place, to more complex tasks such as accomplishing and forming relationships. One of the core cognitive functions is attention. Without attention (to certain stimuli) no input would enter the brain for further processing. Attention has been shown to be important for higher-order processes such as memory, planning and executive functioning (e.g., Mirsky et al., 1992). Highly related to, but independent of attention is the perception and coding of time. The time with which we respond and work on incoming information has been shown to be one of the core requirements for further complex cognitive performances, such as reading ability (Denckla, 1972; Denckla & Rudel, 1974; Shanahan et al., 2006), motor movement and decision making (e.g., Buhusi &

Meck, 2005). This thesis will investigate attention- and timing processes in human cognition.

1.2. Timing, perception of time and processing speed

Perception of time has been a longstanding studied subject (i.e. Allan, 1979; Jones & Boltz, 1989; Pouthas & Perbal, 2004; Wittmann, 2011). The awareness of living in a world that is defined by time and the underlying process to perceive it (timing perception) are fundamental qualities of human life. So far, there seems to be no sensory organ that is responsible for the direct experience of time (e.g., Pouthas & Perbal, 2004). It was shown that perception of time is a construct that has strong associations with attention (Brown, 1985), memory (Block, 1985) and cognition in general (Jones & Boltz, 1989; Ornstein, 1969), which makes it rather difficult to isolate and measure it. Early discussions by Brecher (1932) showed that time is a crucial aspect of perception in general. Any stimulus that cannot be detected (by the senses) in a certain amount of time, cannot be perceived and therefore does not exist. It was shown that if the frequency of presentation of stimuli exceeds a specific time threshold, a single stimulus would not be perceived as a discrete entity but as a rhythm. Studies with a metronome showed that individuals will perceive one up to 5 beats per second as a rhythm, while 18 beats per second will be perceived as a single sound (e.g., Szelag, von Steinbüchel, Reiser, Langen, & Pöppel, 1996).

Several attempts have been made to scientifically conceptualize and measure the perception of time and its consequences. With regard to the scope of this thesis and with regard to Chapter 2 in which different timing functions will be analyzed in non-clinical adults, we will restrict ourselves in this thesis to the conceptualization of time perception as presented in Buhusi & Meck (2005). According to the authors, scientific research on the perception of time has often used a concept that divides time perception into three timing functions (Buhusi & Meck, 2005). These timing functions are differentiated by their time scales, which are (i) millisecond timing, (ii) sub- to supra-second timing and (iii) hours to years (Buhusi & Meck, 2005). *Millisecond timing* has been shown to be crucial in processing speech, music and processes associated with motor control (Buhusi & Meck, 2005). Millisecond timing is foremost measured with tasks targeting temporal event-structure coding. Hence, tasks concerning the perception of succession, simultaneity and temporal order (e.g., Poeppel, 1987; Schmidt et al., 2011). *Sub- (<1 s) to supra-second timing (>1 s)* has been shown to be involved in processes concerning the perception of duration (hence, perception, estimation, discrimination and reproduction of duration). The perception of duration has been shown to be crucial in conscious time estimation and decision-making (Buhusi & Meck, 2005). *Timescales*

that span hours to years have been shown to be associated with temporal foresight and are generally termed time perspective.

1.3. Difficulties with Timing.

Altered time perception has been found in psychopathological disorders, such as autism spectrum disorders (e.g., Bhatara, Babikian, Laugeson, Tachdjian, & Sininger, 2013; Falter et al., 2012; Wallace & Happé, 2008; Wimpory, Nicholas, & Nash, 2002), schizophrenia (e.g., Carrol et al., 2009; Franck et al., 2005; Martin, Giersch, Huron, & van Wassenhove, 2013; Ward et al., 2013) and ADHD (e.g., Luman, Oosterlaan, Sergeant, 2007; Noreika, Falter, & Rubia, 2013; Rubia et al., 2009). Individuals diagnosed with autism spectrum disorder often show an abnormal degree of schedule adherence, or more exact time estimations in objective testing (e.g., Wallace & Happé, 2008).

Individuals diagnosed with schizophrenia often show an „hyperbinding effect“, which is a phenomenon characterized by an accelerated time perception that results in the impression that events are actually linked to each other due to their consecutive order, even though there might be no factual association at all (e.g., Franck et al., 2005). This means that individuals suffering from schizophrenia often link external and internal events due to their consecutive order, but which are actually not related at all (Franck et al., 2005).

Individuals suffering from ADHD often present with high degrees of delay aversion (e.g., Luman, Oosterlaan, & Sergeant, 2005; Noreika, Falter, & Rubia, 2013) and often go for the riskier rewards in gambling paradigms (e.g., Noreika, Falter, & Rubia, 2013; Rubia et al., 2009), with the latter observation being indicative for a time perspective (psychological experience of time) that is focused on the immediate present and not so much on future consequences. Moreover, the strong urge to avoid delays by individuals with ADHD has been interpreted as representing a subjective insufferableness of waiting time (Noreika, Falter, & Rubia, 2013; Rubia et al., 2009). Previous research showed that individuals with ADHD showed impaired performances in free tapping, synchronization and rhythm reproduction tasks, which are all intended to measure time perception (e.g., Noreika, Falter, & Rubia, 2013). Moreover, individuals with ADHD had higher error rates in time reproduction tasks (e.g., Gooch, Snowling, & Hulme, 2011), and increased thresholds in time discrimination tasks (Rubia et al., 2003), when compared to the performance of non-clinical individuals. Similar differences were found for children with non-pathological traits of ADHD, when compared to children without traits of ADHD (Rubia, et al., 2003; Noreika et al., 2013). One of the ADHD traits that is often associated with altered timing functioning appears to be impulsivity (e.g.,

Arce & Santisteban, 2006; Bauman & Odum, 2012). Individuals scoring high on impulsivity have been shown to be easily bored, are faster in making decisions (often less elaborated decisions), presenting with premature motor skills and show less persistency in working on tasks (e.g., Buss & Plomin, 1975; Rubia et al., 2009). As a starting point in understanding the many clinical and non-clinical factors that might influence timing performance, we examined the impact of non-clinical impulsiveness on timing functions in Chapter 2 of this thesis. As was discussed above: ADHD was shown to be associated with deviant timing functioning (e.g., Gooch, Snowling, & Hulme, 2011; Noreika, Falter, & Rubia, 2013). ADHD's major cognitive feature is a deficit in attentional functioning. Attention as a cognitive function, is not only crucial in almost all other cognitive functions (e.g., Neisser, 2014) but seems to be strongly related to timing functioning as well (e.g., Brown, 1997).

1.4. Attention

One of the very frequently discussed cognitive functions in psychology and neuropsychology is the phenomenon of attention (e.g., Yantis, 1998; Mirsky et al. 1991, Posner & Boies, 1971; Posner & Petersen, 1990). Intuitively, the ability to be able to focus on one thing while ignoring the other is crucial in many daily activities. For example, students that suffer from attentional deficits may not be able to stay focused on their exams when the room in which the exam takes place is full of distracting elements (a cupboard full of books of which the student is able to read the covers), people (a coughing student somewhere else in the room) or other external factors. The concept of attention often implies the capacity to withdraw from less salient stimuli and refocus on higher priority stimuli in order to reply adequately in a given situation (e.g., Shallice, 1988; Zomerén & Brouwer, 1994). Attentional functioning is a multifaceted concept that is often subdivided into the following components: selective attention, focusing, sustained attention (also called vigilance), switching of attention and flexibility (e.g., Mirsky et al., 1991; Posner & Boies, 1971; Van Zomerén, Brouwer & Deelman, 1984; Zomerén & Brouwer, 1994). Attention as a cognitive function does not function in isolation but is involved in a broad range of cognitive processes such as memory, perception, planning, executive functioning and language (e.g., Mirsky et al., 1992). For example, attention is one of the fundamental components in successful memory encoding (e.g., Mirsky et al., 1991; Posner 1978). Similarly, attention is important in general information processing. Significant aspects of information processing are for example: focusing attention, sustaining attention (vigilance) and shifting of attention (e.g., Mirsky et al., 1992; Parasuraman & Davies, 1984). All of the components of attentional functioning are thought of as being related to each other but nevertheless can likely

be impaired individually (e.g., Sturm et al., 1997). There are numerous studies showing that specific attentional functions are affected selectively by specific focal brain damage. For example, lesions of the brainstem part of the reticular formation (e.g., Mesulam, 1985) and lesions of the right hemisphere (Toru, Atsushi, & Naoki, 1997; Sturm & Büssing, 1986) have led to impairments in phasic alertness and vigilance/sustained attention. A number of neuroimaging studies point to a right hemispheric dominance when it comes to vigilance/sustained attention (e.g., Pardo, Fox, & Raichle, 1991), whereas left hemispheric dominance is observed for selective attention (e.g., Bisiach, Mini, Sterzi, and Vallar, 1982; Dee & Van Allen, 1973; Sturm & Büssing, 1986).

Attention is further characterized by its selectivity and intensity (Posner & Boies, 1971; Van Zomeren, Brouwer & Deelman, 1984; Zomeren & Brouwer, 1994). Attention to a stimulus can be activated or increased voluntarily or automatically. This activation is often associated with the level of attraction of the external stimulus (e.g., Kahneman & Treisman, 1984). This means that attention is not solely voluntarily top-down regulated but also influenced by bottom-up processes. Hence, it is not only the attractiveness of an external stimulus (bottom-up) that affects the individual's attentional load but it could also be the individual's own effort/conscious decision to focus on the external stimulus (top-down) that shows its impact on the individual's attentional load (Zomeren & Spikman, 2007). This underlines that attentional functioning plays a crucial role in internal and external state (behavior-) regulation. Based on these observations, it can be concluded that attentional functioning is one of the most crucial systems in the human mind (e.g., Cowan, 1988; Norman, 1976; Posner & Peterson, 1990; Zomeren & Spikman, 2007).

Considering the expansive involvement of attention in many cognitive processes, it becomes obvious that impaired attention can have a huge impact on the individual's everyday functioning. It is known that attentional impairments are often seen in clinical- and neuropsychological disorders (e.g., ADHD: Barkley, 2006; Barkley et al., 2006; schizophrenia: Heinrichs & Zakzanis, 1998; Mirsky & Duncan, 1986; Nieuwenstein, Aleman, & de Haan, 2001; anxiety disorders: Eysenck et al., 2007; Pacheco-Unguetti et al., 2010; affective disorders: Gotlib et al., 2004; Hartlage et al., 1993; Mialet, Pope & Yurgelun-Todd, 1996).

1.5. Clinical forms of attentional deficits

Attentional deficits in clinical populations are common (e.g., in patients suffering from neurological disorders: Coulthard, Singh-Curry & Husain, 2006; patients suffering from schizophrenia: Carter et al., 2010; patients suffering from depression: Weiland-Fiedler et al.,

2004). However, the clinical disorder that is predominantly associated with attentional deficits is Attention-deficit-hyperactivity disorder (ADHD). ADHD is one of the most prevalent neurodevelopmental pediatric disorders, which is known to persist throughout adulthood (e.g., Biederman et al., 1998; Wender, Wolf & Wasserstein, 2001; Faraone et al., 2003). Core symptoms of ADHD can be divided into three behavioral features, i.e., symptoms of inattention, symptoms of hyperactivity and symptoms of impulsivity (American Psychiatric Association (APA), 2013). In contrast to other disorders such as generalized anxiety (e.g., Rowa & Antony, 2008; Wells, 2005) or major depressive disorder (e.g., Belmaker & Agam, 2008; Kessler et al., 2003) that can manifest themselves at any moment in life, ADHD in adulthood appears to require a retrospective diagnosis of ADHD in childhood (APA, 2013). Hence, it is a developmental disorder that is not bound to a concrete moment in time but that, most often, shows its impact on the individual's life throughout life span. It is noted that symptoms of ADHD can change with age (e.g., Goodman, 2009; Faraone, Biederman, & Mick, 2006). Accordingly, motor symptoms of hyperactivity are often less severe in adulthood or attenuated (e.g., Adler & Cohen, 2004; Biederman et al., 2000; 2001; Spencer, Biedermann, & Mick, 2007; Wasserstein, 2005). Symptoms of inattention, however, tend to become the most frequently reported impairments in adulthood (e.g., Barkley, 2006; Milstein et al., 1997).

According to the criteria of the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5), symptoms of inattention in ADHD are amongst others: (i) being easily distracted and missing details, (ii) having trouble to focus on the task at hand, (iii) being easily bored, (iiii) having difficulty in organizing and planning daily activities, (iiiii) having difficulties in following instructions (APA, 2013). Adult inattentive symptoms of ADHD often manifest themselves in severe difficulties in staying focused and attending to every-day tasks (such as not being able to complete tasks, getting lost while multitasking etc.).

The transition from the third to fourth edition of the DSM involved a removal of criteria that were intended to measure symptoms of inattention in ADHD (e.g., Frick et al., 1994; Schatz & Rostain, 2006). The criteria that were removed represented symptoms of sluggishness, extreme levels of confusion, and excessive daydreaming (e.g., Frick et al., 1994; Schatz & Rostain, 2006). Consequently, it was argued that the removal increased the reliability of measures but decreased the content validity of measuring ADHD, as ADHD is known to be a heterogeneous disorder (e.g., Barkley, DuPaul, McMurray, 1990; Hartman et al., 2004). Hence, this removal may have led to a higher rate of missing out on patients that otherwise would have met ADHD criteria (e.g., Jacobson et al., 2012; McBurnett, Pfiffner, & Frick, 2001). The realization that the elimination of the mentioned items might distort ADHD diagnoses led to an

increase in interest in individuals that actually suffer from symptoms related to sluggishness, daydreaming and being easily confused (e.g., Becker, 2013; Mueller et al., 2014). Investigations by some of the leading figures in ADHD research sparked the debate whether the inclusion of these items in the diagnostic process would actually lead to an identification of a “real attention disorder” (e.g., Barkley, 2006). This attentional disorder for now, became known and discussed under the term Sluggish Cognitive Tempo, or SCT.

1.6. Sluggish Cognitive Tempo, as a potential clinical example for deviant timing and attentional dysfunctioning?

The notion that there might be a “real attentional disorder” (SCT) that is associated with pure attentional deficits and slowed processing speed but of which there is not enough scientific evidence, yet, was a strong impetus to explore the concept of SCT with regard to its theoretical and psychometrical background.

SCT describes a set of symptoms that represent excessive “daydreaming”, excessive states of “being confused”, immoderate periods of “staring blankly”, an overall appearance of “being sluggish” and increased levels of “being unmotivated” (e.g., Lee et al., 2013; Penny et al., 2009). SCT is often measured by items such as “needing extra time to finish work”, “is slow in responding” etc. (e.g., Müller et al., 2014; Penny et al., 2009). Symptoms of SCT were identified in children and adults (e.g., Becker, 2013; Mueller et al., 2014) independent of (e.g., Garner et al., 2010; Graham et al., 2013; Reeves et al., 2007) and beyond ADHD symptoms of inattention (e.g., Bauermeister et al., 2012; McBurnett, Pfiffner, & Frick, 2001; Milich, Balentine, & Lynam, 2001).

Symptoms of SCT are often comorbid with the predominantly inattentive type of ADHD (ADHD/I: e.g., Frick et al., 1994; Jacobson et al., 2012; Langberg, Becker, & Dvorsky, 2013; Lee et al., 2013; Schatz & Rostain, 2006) and clinical levels of internalizing behavior, as seen in anxiety disorders and depression (e.g., Bauermeister et al., 2012; Becker & Langberg, 2013; Carlson & Mann, 2002; Garner et al., 2010; Lahey et al., 1987; Penny et al., 2009; Schatz & Rostain, 2006). Neurocognitive studies on SCT revealed deficits in attention that go beyond ADHD/I symptoms (e.g., Huang-Pollock, Nigg, & Carr, 2005; Skirbekk et al., 2011). So far, studies on SCT are rather sparse, which might partly result from the inconsistencies in measuring SCT (e.g., Becker, 2013; Mueller et al., 2014). SCT is not part of any formal diagnostic criteria, yet, and measurements of SCT are lacking consensus. This complicates the comparison of results across studies that more or less do report an impact of SCT symptoms on social-, occupational-, vocational- and overall psychological functioning. It is the aim of the

current thesis to psychometrically validate the construct of SCT and to explore the likely associations of the construct with self-rated attentional and timing functioning. By first exploring the psychometrical properties of SCT items that have been used in previous studies in a non-clinical population of adults we hope to set a baseline of which SCT items might be endorsed even more extreme in a clinical population of adults later on. The validated SCT scale for adults will then be used to test SCT's relation to cognitive functioning as measured by objective neurocognitive testing, both in clinical- and non-clinical adults (Chapter 5). We hope to provide objective evidence for the assumption that SCT impacts on a person's attentional and timing functioning by exploring the likely association of SCT and data from neurocognitive testing.

1.7. Outline of the thesis

This thesis investigated attention and timing processes in human cognition. In Chapter 2 we explored basic attentional and timing functions in non-clinical adults that are characterized by either low or high scores of impulsivity. Our aim to find a clinical phenomenon that might be related to objective attentional and timing deficits led us to focus on studies on SCT. Given the sparsity and inconclusiveness of studies presenting data on SCT we explored the construct (SCT) for its theoretical background in a systematic review of the recent literature and reported on that in Chapter 3. In Chapter 4 we investigated previously used SCT items for their psychometrical validity in non-clinical adults. The thereby obtained SCT scale and subscales were further tested for their likely associations with self-rated attentional and timing functioning, in order to provide some evidence for SCT's construct validity. In Chapter 5 we aimed at providing objective evidence for attentional and timing deficits that are likely to be associated with SCT by exploring the data of clinical- and non-clinical adults that on the one hand completed the newly validated SCT scale of Chapter 4 and that on the other hand performed a well validated computerized neurocognitive test battery. The general discussion in Chapter 6 of this thesis, represents a reflection on the results from the previous chapters.

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Chapter 2

SELECTIVE IMPAIRMENT OF TIMING FUNCTIONS IN NON-CLINICAL IMPULSIVENESS

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Chapter 2 SELECTIVE IMPAIRMENT OF TIMING FUNCTIONS IN NON-CLINICAL IMPULSIVENESS

2.1. Abstract

Time processing abnormalities in impulsive individuals have been reported by numerous studies, mostly using interval timing tasks. The aim of the current study was to investigate whether the relationship between time processing and impulsivity as a personality trait also holds for very short timescales as tested using a perceptual simultaneity task and for orientation towards longer temporal dimensions in terms of subjective time perspective. Thresholds of perceptual simultaneity were determined for forty-eight participants and their self-rated level of impulsivity and time perspective was assessed. Self-rated impulsivity and time perspective were found to be strongly related, but no relationship was found for impulsivity and perceptual simultaneity thresholds. These results suggest that perceptual simultaneity does not fall within the realm of timing functions related to personalities characterized by higher levels of impulsivity. The relationship between time processing and impulsivity seems to be selective to certain timing functions sparing very short timescales relevant for perceptual simultaneity.

2.2. Introduction

Impulsivity has been defined as an unplanned, immediacy-bound response style, without regard to possible future consequences (Rubia et al., 2009) and is often assessed with the Barratt Impulsiveness Scale (BIS-11; Patton, Stanford, & Barratt, 1995). Impulsivity as a personality trait is further characterized by decreased persistency, decreased decision time, heightened thresholds for boredom (Buss & Plomin, 1975), heightened resistance to delayed rewards (Logue, 1995), premature motor timing, impoverished temporal foresight, and increased temporal discounting (Rubia et al., 2009). Even though the underlying cognitive and affective processes of impulsivity are poorly understood (Wittmann & Paulus, 2008), a large body of research suggests that timing functions play a major role in non-clinical impulsivity (e.g., Baumann & Odum, 2012; Berlin & Rolls, 2004; Correa et al., 2010; Noreika, Falter, & Rubia, 2012; Ostaszewski, 1996; Wittmann et al., 2011).

Timing spans a large range of functions and timescales (Buhusi & Meck, 2005) and has been for instance subcategorized into motor timing, perceptual timing, and temporal foresight (see Noreika, Falter, & Rubia, 2012). Buhusi and Meck (2005) suggested that timing functions can be categorized according to their different timescales. They differentiated millisecond timing, which is important for speech, music, and motor control, interval timing, which is associated with foraging, decision-making and conscious time estimation, and circadian timing, which regulates appetite and sleep-wake rhythms (Buhusi & Meck, 2005).

Temporal event-structure coding concerns the temporal resolution of perception of the succession, simultaneity, and temporal order of events on a very short millisecond scale (e.g., Poeppel, 1978; Schmidt et al., 2011). Interval timing, the perception, estimation, discrimination, and (re)production of durations, is foremost measured on a sub- (<1 s) and supra-second (>1 s) range and is associated with decision making and conscious time estimation (Buhusi & Meck, 2005). Longer timescales, spanning hours to years (Buhusi & Meck, 2005), such as, e.g., temporal foresight, fall into the realm of time perspective. Time perspective is conceptualized as “the totality of the individual’s views of his psychological future and his psychological past existing at a given point in time” (Lewin, 1951, p. 75). Time perspective is further described as “the tendency to consider and value present versus future consequences of one’s own actions” (Hall & Fong, 2003; Strathman et al., 1994; Zimbardo & Boyd, 1999) and reflects the individual’s psychological orientation in time. Individuals that are characterized by a more present-oriented time perspective appreciate immediate rewards more than individuals foremost characterized by a future-oriented time perspective (e.g., Zimbardo & Boyd, 1999). Previous

studies on the relationship between impulsivity and timing functions are mainly based on mid-range interval timing tasks (e.g., Baumann & Odum, 2012; Berlin & Rolls, 2004; Correa et al., 2010; Ostaszewski, 1996). More impulsive individuals (as measured by the BIS-11; Patton, Stanford, & Barratt, 1995) tend to overestimate durations (Bauman & Odum, 2012) and underreproduce time intervals (Berlin & Rolls, 2004). An under-reproduction of durations is commonly associated with a faster internal sense of time (Rubia et al., 2009). Cognitive models of time perception suggest that a faster internal clock rate (also called pacemaker) increases the “accumulation of temporal units over time” (Wittmann & Paulus, 2008). This increased accumulation of temporal units over time supports a subjectively faster sense of time and has been further associated with levels of arousal in that highly aroused individuals show an overestimation of time (Wittmann & Paulus, 2008). Studies of clinical populations that show heightened levels of impulsivity have mainly focused on interval timing, and temporal foresight (e.g., Berlin & Rolls, 2004; Dougherty et al., 2003; Reynolds & Schiffbauer, 2004; Rubia et al., 2009; Wittmann et al., 2011). In these studies, impulsivity correlated with subjective experience of time (Berlin & Rolls, 2004; Dougherty et al., 2003; Reynolds & Schiffbauer, 2004; Wittmann et al., 2011). For example, under reproduction of time intervals has been observed in sleep-deprived individuals when compared to rested individuals (Reynolds & Schiffbauer, 2004), patients with borderline-personality disorder (Berlin & Rolls, 2004), patients with orbito-frontal cortex lesions (Wittmann et al., 2011), and in children with disruptive behavior disorder (Dougherty et al., 2003), all populations that are suggested to be temporarily (Reynolds & Schiffbauer, 2004) or due to their pathology (Berlin & Rolls, 2004; Wittmann et al., 2006) more impulsive.

The clinical model for impulsivity par excellence, however, has been shown to be attention-deficit/hyperactivity disorder (ADHD) (Noreika et al., 2012; Rubia et al., 2009). Therefore, most of the studies reporting altered timing functions in impulsive individuals focused on patients with ADHD. ADHD is a neuro-developmental disorder characterized by hyperactivity, inattention, and most notably, impulsive behavior as the main symptom (DSM-IV-TR: APA, 2000). Numerous studies have proposed that ADHD is characterized by an impaired sense of time (e.g., Barkley, 1997; Toplak, Dockstader, & Tannock, 2006; see Noreika, Falter, & Rubia, 2012 for a recent review). Individuals with ADHD have been shown to overestimate (e.g., Barkley et al., 1997; Hurks & Hendriksen, 2011) and underreproduce (e.g., Barkley, Murphy, & Bush, 2001; Kerns, McInerney, & Wilde, 2001) time intervals. This disturbance of timing functions in individuals with ADHD has been specifically ascribed to the symptom of impulsivity (Rubia et al., 2009) and was further interpreted to represent a faster

internal sense of time (Toplak et al., 2006). Furthermore, it has been consistently shown that children diagnosed with ADHD display deficits in interval discrimination in the milliseconds to seconds range (Rubia et al., 2003, 2007; Smith et al., 2002; Toplak et al., 2003). Most notably, interval discrimination deficits were the most homogeneous finding within a neuropsychological test battery of executive functioning by which individuals with ADHD could be identified (Rubia et al., 2007). Findings from clinical and neurotypical populations can therefore be summarized as supporting an association between impulsivity as a symptom as well as impulsivity as a personality trait and impaired performance on several timing functions, such as motor timing, temporal foresight, and interval timing.

Similar to timing in the midrange, very long timescales measured by subjective time perspective have been shown to correlate with impulsivity as a personality trait (e.g., Agarwal & Srivastava, 1981; Ferguson, 2007; Lennings & Burns, 1998; Neves, 2009; Wittmann et al., 2011). Studies on time perspective support the former assumption that a person's level of impulsivity is related to how the individual makes sense of its experience of time. Accordingly, an association between non-clinical levels of impulsivity and present as well as future time orientation has been reported on a variety of measures (e.g., Agarwal & Srivastava, 1981; Lennings & Burns, 1998).

Impulsivity has been further found to correlate negatively with future orientation and positively with present orientation on the Zimbardo Time Perspective Inventory (ZTPI; Zimbardo & Boyd, 1999; Ferguson, 2007; Neves, 2009; Wittmann et al., 2011), the Consideration of Future Consequences Scale (CFC; Ferguson, 2007) and the Future Time Perspective Scale (FTP; Ferguson, 2007) in neurotypical samples. The negative correlation of the trait impulsivity and future orientation can be interpreted as representing a diminished consideration of future consequences in relation to trait impulsiveness, which has been further linked to increased proneness to pathological gambling (MacKillop et al., 2006) and risk taking (Neves, 2009). Therefore, highly non-clinical impulsive individuals seem to show impaired temporal foresight indicated by their lack of thinking about the consequences of risky behavior, and their high awareness of present oriented goal pursuit. Impulsivity and present-boundness are also associated with individual differences in delay discounting, the extent to which people prefer a smaller immediate reward over a larger later reward (Stolarski, Bitner, & Zimbardo, 2011; Teuscher & Mitchell, 2011). Individuals that scored high on the present scale of the ZTPI and also demonstrated impulsive behavioral characteristics chose immediate over delayed rewards more frequently than non-impulsive and future-oriented individuals (Neves, 2009). These findings confirm the link between non-clinical impulsiveness and temporal foresight.

Cross-scale comparisons between time perspective profiles and performance on perceptual timing tasks are, nevertheless, sparse. Studies comparing time perspective with interval timing provided inconclusive results (e.g., Geiwitz, 1965; Lennings & Burns, 1998; Siegman, 1962; Wittmann et al., 2011), with some evidence for a positive relation between future orientation and time estimation (Siegman, 1962) and studies that failed to reveal such an association (e.g., Geiwitz, 1965; Lennings & Burns, 1998). Wittmann et al. (2011) showed that more present- oriented individuals as measured with the ZTPI showed higher levels of under-reproduction of temporal intervals (Wittmann et al., 2011). Lennings and Burns (1998), in contrast, found no association between the future time dimension of the Time Perspective Questionnaire (TPQ; Lennings, 1991) and time estimation but reported an association between future time perspective of the TPQ and estimations of very brief time periods when making use of a temporal extension measure (Lennings & Burns, 1998). Overall, these findings suggest that the relationship between perceptual timing tasks and time perspective might vary across different paradigms. Even though timing functions in the midrange (i.e., interval timing) seem to be altered in individuals characterized by high trait impulsivity and in some clinical populations described by high levels of impulsivity (e.g., Berlin & Rolls, 2004; Dougherty et al., 2003; Reynolds & Schiffbauer, 2004; Rubia et al., 2007; Wittmann et al., 2006) it remains open whether a relation exists between impulsivity and timing functions on very short and very long timescales. Given that interval timing is deviant in individuals characterized by high trait impulsivity (e.g., Baumann & Odum, 2012; Berlin & Rolls, 2004) and individuals diagnosed with ADHD (e.g., Barkley et al., 1997; Hurks & Hendriksen, 2011), it is suggested that temporal event-structure coding might be altered in individuals with high trait impulsivity as well.

The current study aims to investigate whether previous findings of associations between high non-clinical trait impulsivity and midrange timing functions can be extended to timing functions on very short and very long timescales, namely temporal event-structure coding and time perspective, respectively. Besides a few reports of impairments in auditory and linguistic simultaneity and temporal-order judgments of self-rated high-impulsive personalities (Breier et al., 2001, 2002), only one study focused on visual simultaneity judgments (Brown & Vickers, 2004). The study by Brown and Vickers (2004) made use of a clinical sample of individuals diagnosed with ADHD, however, and did not yield any significant group differences. Next to the fact that the sample size was very small (8 participants per group) and medication in some of the participants with ADHD might have influenced performance in this group, participants have not been tested individually for their actual scores on an impulsivity scale, such as the BIS-11. In the current study we tested the relationship between self-rated impulsivity as

assessed with the BIS-11 in a large non-clinical and unmedicated sample for temporal event-structure coding using a visual simultaneity task (e.g., Elliott, Shi, & Sürer, 2007; Falter, Elliott, & Bailey, 2012). The visual simultaneity task requires participants to judge whether two bars presented with variable stimulus onset asynchrony (SOA) appear either simultaneously or asynchronously. A threshold of perceptual simultaneity is determined as the smallest SOA at which participants still perceive the bars as simultaneous. According to previous interval timing studies, time is perceived to pass more slowly in more impulsive individuals (e.g., Barkley et al., 1997; Hurks & Hendriksen, 2011), which might be indicative for a hypersensitivity to the passage of time and the timing of events (Rubia et al., 2009). This assumed hypersensitivity to the timing of events by more impulsive individuals might be likely to be represented in participants' judgments of simultaneity as well. Thresholds of perceptual simultaneity would thus be lower for individuals with high trait impulsivity, representing an increased temporal resolution of the succession of events.

Furthermore, the association between impulsivity and time perspective remains, yet, unclear. Even though a relation between trait impulsivity and temporal foresight is often stated (e.g., Agarwal & Srivastava, 1981; Ferguson, 2007; Lennings & Burns, 1998; Neves, 2009; Wittmann et al., 2011), other orientations in time (time perspectives) yield much more inconclusive results (e.g., Lennings & Burns, 1998). The relationship found between trait impulsivity and time perspective (e.g., Ferguson, 2007; Neves, 2009; Wittmann et al., 2011) will be tested in the current study making use of the same sample of self-rated impulsive participants using time perspective scores of the ZTPI (measuring the extent to which people predominantly reminisce the past, value the present, or consider future consequences). More impulsive individuals were predicted to show a more present- and less future-oriented time perspective, as they have been shown to endorse immediate rewards and show poor temporal foresight (e.g., Rubia et al., 2009; Wittmann, 2011).

2.3. Methods

2.3.1. Participants

Forty-eight (14 male, 33 female, one participant did not indicate their sex) randomly selected students from the University of Groningen, aged between 19 and 37 years ($M = 22.73$, $SD = 3.08$), participated in the current study. Exclusion criteria were color blindness and a diagnosis of a psychiatric or neurologic disorder in the present or past. All participants had normal or corrected-to-normal vision. The students earned study credits for their participation and were blind to the study's purpose. The Ethical Committee of the Psychology

Department at the University of Groningen approved the study and written consent was obtained from participants prior to testing.

Stimuli and Design

2.3.2. Barratt Impulsiveness Scale

The Barratt Impulsiveness Scale (BIS-11) is a 30-item self-report questionnaire that is used to measure impulsive personality traits (Patton, Stanford, & Barratt, 1995). The BIS-11 consists further of three subscales: *Attentional* (e.g., "I have racing thoughts"), *Motor* (e.g., "I do things without thinking"), and *Non-planning* (e.g., "I plan tasks carefully") which are combined to a *Total* scale. Each item is rated on a four point scale from 1 (never) to 4 (always). Scores range from 30 to 120 and there is no established cut-off point. To identify individuals that score high or low on the trait impulsivity the use of the 25th and 75th percentile, respectively, is recommended (e.g., Baca-Garcia et al., 2004; Maloney et al., 2009). The clinical model for impulsivity has been shown to be attention-deficit/hyperactivity disorder (Noreika et al., 2012; Rubia et al., 2009). Adolescents (11–18 years of age) with ADHD have recently been shown to score on average 71 points on the Total scale of the BIS-11 (e.g., Nandagopal et al., 2011) and adults diagnosed with ADHD on average 77 points (e.g., Malloy-Diniz et al., 2007). We adopted the recommended 25th and 75th percentile categorization to identify individuals that score high or low on trait impulsivity.

2.3.3. Zimbardo Time Perspective Inventory

The Zimbardo Time Perspective Inventory (ZTPI) consists of 56 items and is used to measure the extent to which people reflect on the past, present and future (Zimbardo & Boyd, 1999). Each item is scored on a five point Likert- scale ranging from 1 (very untrue) to 5 (very true). The items are grouped into five subscales: *Past Negative* (e.g., "I think about the bad things that have happened to me in the past"), *Past Positive* (e.g., "It gives me pleasure to think about my past"), *Present Hedonistic* (e.g., "I take risks to put excitement in my life"), *Present Fatalistic* (e.g., "My life path is controlled by forces I cannot influence"), and *Future* (e.g., "Meeting tomorrow's deadline and doing other necessary work comes before tonight's play"). The scores on all items from each subscale are averaged and give a final score ranging from 1 to 5. A shortened version of the original ZTPI was used in the current study, with 5 items of each factor included. Three subscales (*Future*, *Present Hedonistic*, and *Present Fatalistic*) were used for the final analysis in accordance with previous studies (e.g., Wittmann et al., 2011).

2.3.4. Perceptual Simultaneity Task

The perceptual simultaneity task (see detailed description in Falter, Elliott, & Bailey, 2012) was

presented on a desktop PC with an 18rr screen in a dimly lit testing room with a refresh rate of 120 Hz. Stimulus presentation and data collection were performed using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002). A white fixation cross was constantly present in the center of a black screen. In each trial, two vertical white bars appeared to the left and right of the fixation cross after 500 ms. Bar stimulus onset happened gradually with increasing luminance within 42 ms. The whole task consisted of 10 blocks of 26 trials each, resulting in 260 trials overall with breaks in between blocks. The two bar stimuli emerged either simultaneously or asynchronously, with randomized Stimulus Onset Asynchrony (SOA) that ranged between 0–91.7 ms, resulting in one synchronous (0 ms) and 11 asynchronous conditions (8.33 ms, 16.7 ms, 25 ms, 33.3 ms, 41.7 ms, 50 ms, 58.3 ms, 66.7 ms, 75 ms, 83.3 ms, and 91.7 ms), which varied randomly on a session-wise basis. The synchronous condition was presented on 40 occasions, whereas the asynchronous conditions were presented on 20 occasions each. The location of first bar presentation (left or right of fixation cross) was randomized. Participants had to judge whether the bars appeared simultaneously, or not, by pressing the left arrow key on a keyboard for asynchrony and the right arrow key for simultaneity. The bars remained on the screen until a response was given. No feedback on performance was given.

Analyses of the perceptual simultaneity task were based on individual percentages of ‘simultaneous’ responses for every level of SOA. A logistic curve on percentage data of ‘simultaneous’ responses was fitted (using the least-squares procedure of Cavallini, 1993; adapted for Matlab by Arnold, 2002) to obtain individual points of inflection of the fitted sigmoid function. Inflection points designated simultaneity thresholds for individual participants.

All participants received the same order of experimental tasks to control for any effects due to task presentation. First, participants completed the perceptual simultaneity task, which was followed by the BIS-11 and ZTPI and the experiment was closed by the demographic questionnaire.

2.4. Results

ZTPI and perceptual simultaneity thresholds were not normally distributed and non-parametric statistics will be reported throughout. Medians and quartile deviations of performance scores are reported in Table 1. A very high average goodness of fit was obtained in the curve-fitting procedure applied on perceptual simultaneity data (R^2 0.97 0.03). One participant was excluded based on a goodness of fit that was several SDs away from the group mean (R^2 0.82) and inspection of the respective logistic curve revealed that the data were not distributed as a sigmoid function. Thus, 47 participants were included in the final analysis.

Spearman's rank correlations (Bonferroni–Holm adjusted) were calculated to test the relationship between impulsivity scores (BIS-11) and perceptual simultaneity thresholds and between impulsivity and time perspective scores for the remaining participants. In addition, perceptual simultaneity thresholds and time perspective scores were correlated. Impulsivity scores and thresholds were not significantly correlated ($r_s(45) 0.05$, $p 0.74$) showing that visual temporal event-structure coding does not seem to be associated with impulsivity. The lack of relationship between impulsivity and perceptual simultaneity thresholds is further emphasized by the negligible effect size observed (Cohen, 1988).

Table 1. Medians (MD) and quartile (QD) deviations for impulsivity (Total BIS), thresholds of perceptual simultaneity, and time perspective scales (*Present Fatalistic*, *Present Hedonistic*, and *Future*)

	Total BIS	Threshold	Present Fatalistic	Present Hedonistic	Future	Total Z
MD	65.5	36.32	2.2	3.3	3.6	15.3
QD	6.75	6.19	0.4	0.5	0.6	1.38

Figure 1. Relationships between perceptual simultaneity thresholds, time perspective (*Future*,

Present Hedonistic, *Present Fatalistic* orientation) and impulsivity.

Significant correlations were found between impulsivity scores and time perspective scores corroborating the relationship between impulsivity and time perspective (see Wittmann et al., 2011). In particular, impulsivity scores were positively correlated with Present Fatalistic scores ($r_s(45) 0.40$, $p < 0.01$) and Present Hedonistic scores ($r(45) 0.44$, $p < 0.01$) and negatively correlated with Future scores ($r_s(45) 0.50$, $p < 0.01$), suggesting that more impulsive people are more concerned with the present moment and tend to have a reduced feeling of control over their life and future than less impulsive people (see Fig. 1). There were no significant

correlations between perceptual simultaneity thresholds and time perspective scores (largest $r=0.14$).

In order to test whether individuals with a high trait impulsivity of this sample had a decision bias that differs from less impulsive individuals an independent-sample t-test was calculated between high impulsive individuals (N 11, MTotalsBIS 60.25) (scoring in the 75th percentile of the BIS-11) and low impulsive individuals (N 11, MTotalsBIS 73) (scoring in the 25th percentile of the BIS-11) for the first condition (SOA 0 ms) of the perceptual simultaneity task revealing no significant difference between the low (M 93.18) and high (M 82.27) impulsive groups $t(20) 1.36, p > 0.05$. It seems therefore unlikely that the lack of a significant relationship between temporal event-structure coding and trait impulsivity is caused by a decision bias.

2.5. Discussion

The aim of the present study was to investigate whether the established relationship between timing functions and the trait impulsivity (e.g., Baumann & Odum, 2012; Berlin & Rolls, 2004; Correa et al., 2010; Noreika, Falter, & Rubia, 2012; Ostaszewski, 1996; Wittmann et al., 2011) also holds for very short time-scales in terms of temporal event-structure coding and for orientation towards longer temporal dimensions in terms of subjective time perspective. No association between impulsivity and perceptual simultaneity thresholds was found. Hence, the initial hypothesis that more impulsive individuals show reduced temporal resolution of event structure was not supported by the current results. Given the small effect size of the association between the trait impulsivity and temporal event-structure coding (<0.1) it seems likely that visual temporal resolution does not contribute to the cognitive and affective characteristics associated with trait impulsivity. Thus, in contrast to findings from studies showing a significant relationship between interval timing and impulsivity as a trait (Wittmann et al., 2011) the current study showed that this relationship does not hold for temporal event-structure coding and impulsivity. Whereas the relationship between interval timing and impulsivity might be explained by additional affective and attentional effects (Droit-Volet & Meck, 2007) the lack of findings for an association of temporal event-structure coding and impulsivity might be due to the observation that temporal event-structure coding takes place on a very short-timescale (millisecond timing) that can be assumed to be less affected by affective or attentional effects. According to Droit-Volet and Meck (2007), temporal distortions alternate in line with attentional resources, internal clock speed, and memory for timing of events. It has been shown in studies on interval timing that manipulation of attention to a temporal event leads the

participants to judge the event as shorter (Buhusi & Meck, 2006; Fortin, 2003). This shortening of perceived time for an event is also seen in stimuli with a high emotional valence (Noulhiane, et al., 2007) and has been shown to be maximal in durations of 2 s (hence, on a midrange timescale). More interestingly with regard to the current study, short timescales have been shown to be unaffected by emotional or attentional valence of a stimulus (Droit-Volet, et al., 2004). As already stated, individuals with a high trait impulsivity are characterized by a subjectively faster sense of time (e.g., Rubia et al., 2009). This subjectively faster sense of time has been further associated with heightened levels of arousal (Wittmann & Paulus, 2008). It is therefore proposed that the link between impulsivity and interval timing might be at least partly due to emotional or attentional effects as discussed by Droit-Volet et al. (2004). Temporal event-structure coding, however, seems to be less affected by an individual's personality level of affect and arousal.

In line with the current study's findings, previous research on temporal event-structure coding in individuals with ADHD, who are known to be highly impulsive, has shown that ADHD patients did not differ significantly from controls in their perception of simultaneity (Brown & Vickers, 2004). Although the reported study had a very small sample size (8 participants per group) and conclusions should be drawn with caution, the current results on non-clinical individuals with high trait impulsivity support the null findings in the clinical sample as reported by Brown and Vickers (2004). Likewise, no difference between ADHD patients and controls was found for an auditory temporal-order judgment task (Breier et al., 2002). Both ADHD patients and generally more individuals with a high trait impulsivity therefore seem not to exhibit abnormal temporal event-structure coding, in contrast to, for instance, individuals with autism (Falter, Elliott, & Bailey, 2012) or schizophrenia (Giersch et al., 2009).

Concerning the relationship between time perspective and trait impulsivity the current findings support previous findings, showing that more impulsive individuals tend to be more focused on their immediate present (Ferguson, 2007; Neves, 2009; Wittmann et al., 2011; Zimbardo & Boyd, 1999). Impulsivity and time perspective correlated positively with respect to present orientation indicating that more impulsive individuals can be best described as focusing foremost on their immediate reality and less on future consequences. The present study replicated nearly exactly the relationship between impulsivity and the subscales of the time perspective reported by Wittmann et al. (2011). Whereas more impulsive participants were found to have a more present and less pronounced future time perspective as shown by Wittmann et al. (2011), the association between impulsivity and a more present bound time

perspective was not only significant for the Present Fatalistic but also for the Present Hedonistic orientation in the current study. Previous findings that higher levels of trait impulsivity are linked to a psychological orientation in time that focusses more on the immediate experience of the individual's reality (e.g., Ferguson, 2007; Neves, 2009; Wittmann et al., 2011) are therefore supported. These findings have interesting implications concerning previous studies relating impulsivity to risk-taking behavior and substance abuse (e.g., Ryb et al., 2006; Stoltenberg et al., 2011). Instead of engaging in risky behavior for the gain of mere pleasure, more impulsive individuals might primarily be unable to gather enough self-control to inhibit harmful urges due to an altered sense of time.

The present study further showed that temporal event-structure coding and time perspective were unrelated corroborating the speculation of different brain mechanisms underlying different timing functions. Timing is involved over and across multiple timescales of human perception (Bradshaw & Szabadi, 1997; Meck, 2003; Pastor & Artieda, 1996) and distinct neural mechanisms for different timing functions have been proposed (e.g., Buhusi & Meck, 2005; Lewis & Miall, 2003). It has been suggested, that the cerebellum is strongly involved in millisecond timing such as temporal-event structure coding (Ivry et al., 2002; Mangels, Ivry, & Shimizu, 1998). The right prefrontal cortex, on the other hand, has been identified to be of particular importance in the perception and comparison of time intervals (Lewis & Miall, 2006). Frontal lobe deficiencies have been shown to be associated with a loss of self-regulating behavior in general (Harlow, 1848, 1868) and, specifically, with impulsivity (e.g., Bechara et al., 1994; Berlin & Rolls, 2004; Crews & Boettiger, 2009; Kim & Lee, 2011; Rolls et al., 1994). It can be speculated that timing functions, which are supported by frontal lobe integrity such as interval timing (Lewis & Miall, 2006), are altered in more impulsive individuals. On the other hand, timing functions, such as temporal event-structure coding, are more likely to be supported by deeper brain structures such as the cerebellum and basal ganglia (e.g., Lewis & Miall, 2003) and therefore are less likely to be altered in more impulsive individuals. Furthermore, the mechanisms responsible for millisecond timing are apparently independent from those that direct an individual's psychological orientation in time. Time perspective has been historically conceptualized to be more of social than biological origin (Lamm, Schmidt, & Trommsdorff, 1976; LeShan, 1952; Nurmi, 1987). Yet, anticipation of future events is associated with higher cognitive functions, most likely situated in the prefrontal cortex (Benoit, Gilber, & Burgess, 2011), which is again in contrast to the brain areas that are activated in temporal event-structure coding.

In conclusion, in contrast to interval timing and time perspective, temporal event-

structure coding was unrelated to trait impulsivity. This distinction suggests that processes underlying medium and long timescales on the one hand and very short timescales on the other hand are drawing upon different mechanisms with the former in contrast to the latter being stronger associated with reliance on frontal lobe functions, which are assumed to be compromised in more impulsive individuals.

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Chapter 3

SLUGGISH COGNITIVE TEMPO AND ITS NEUROCOGNITIVE-, SOCIAL- AND EMOTIVE CORRELATES: A SYSTEMATIC REVIEW OF THE CURRENT LITERATURE

Keywords: Sluggish cognitive tempo, ADHD, Genetics, Cognition, Social functioning, ADHD subtypes

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Chapter 3 SLUGGISH COGNITIVE TEMPO AND ITS NEUROCOGNITIVE-, SOCIAL- AND EMOTIVE CORRELATES: A SYSTEMATIC REVIEW OF THE CURRENT LITERATURE

3.1. Abstract

Since the elimination of items associated with Sluggish Cognitive Tempo (SCT) during the transition from DSM-III to DSM-IV from the diagnostic criteria of Attention-deficit Hyperactivity Disorder (ADHD), interest in SCT and its associated cognitive as well as emotional and social consequences is on the increase. The current review discusses recent findings on SCT in clinical as well as community-based ADHD populations. The focus will be further on clinical correlates of SCT in populations different from ADHD, SCT's genetic background, SCT's association with internalizing and other behavioral comorbidities, as well as SCT's association with social functioning and its treatment efficacy.

A systematic review of empirical studies on SCT in ADHD and other pathologies in PsycInfo, SocIndex, Web of Science and PubMed using the key terms "Sluggish Cognitive Tempo", "Cognitive Tempo", "Sluggish Tempo" was performed. Thirty-two out of 63 studies met inclusion criteria and were discussed in the current review.

From the current literature, it can be concluded that SCT is a psychometrically valid construct with additive value in the clinical field of ADHD, oppositional defiant disorder (ODD), internalizing disorders and neuro-rehabilitation. The taxonomy of SCT has been shown to be far from consistent across studies; however, the impact of SCT on individuals' functioning (e.g., academic achievement, social interactions) seems remarkable. SCT has been shown to share some of the genes with ADHD, however, related most strongly to non-shared environmental factors. Future research should focus on the identification of adequate SCT measurement to promote symptom tailored treatment and increase studies on SCT in populations different from ADHD.

3.2. Introduction

The current literature review gives an overview about the research performed on the concept of Sluggish Cognitive Tempo (SCT). SCT is a cognitive-emotional style that is commonly described by five typical characteristics, which are “daydreaming”, “being confused”, “staring blankly”, “being sluggish” and “being unmotivated” (Lee et al., 2013; Penny et al., 2009). SCT was originally introduced in the literature on ADHD but is nowadays recognized in disorders different from ADHD as well (e.g., Becker et al., 2013; Graham et al., 2013; Reeves et al., 2007). The Diagnostic and Statistical Manual of Mental Disorders (DSM- IV and DSM-5) distinguishes three different subtypes of ADHD, namely ADHD combined type (ADHD/C), ADHD predominantly inattentive (ADHD/I) or ADHD predominantly hyperactive/ impulsive (ADHD/HI) (e.g., Milich, Balentine & Lynam, 2001). The transition from the 3rd to the 4th edition of the Diagnostic and Statistical Manual of Mental Disorders 4th ed.; DSM-IV; (APA, 1994), however, led to the removal of items representing sluggishness, easy confusion, and daydreaming from the inattention dimension of ADHD (Schatz & Rostain, 2006) due to poor predictive validity (Frick et al., 1994). Regardless of the increasing interest in symptoms of sluggishness in ADHD during the last two decades (e.g., Bauermeister et al., 2012; Bauermeister et al., 2005; Garner et al., 2010; Langberg, Becker & Dvorsky 2013;) the current DSM-5 has not reintroduced the items representing a sluggish cognitive-emotive style. Based on recent psychometric findings, however, it is argued that the elimination of SCT symptoms during the transition from the DSM-III to the DSM-IV artificially increased ADHD’s homogeneity (e.g., Barkley, DuPaul & McMurray, 1990; Hartman et al., 2004). Consequently, it is hypothesized that some of the individuals who actually would have met diagnostic criteria of one of the ADHD subtypes are missed due to the elimination of SCT items. Especially, ADHD/I has been frequently linked to symptoms such as, daydreaming, staring, mental foginess, confusion, hypoactivity, sluggish or slow movement, lethargy, apathy and sleepiness (e.g., Barkley, DuPaul & McMurray, 1990; Barkley, 2012; Carlson & Mann, 2002; Diamond, 2005; McBurnett, Pfiffner & Frick, 2001; Milich, Balentine & Lynam, 2001). It is striking that the mentioned symptoms are very similar to items currently used in the measurement of SCT. In line with this, 30 to 50% of the children diagnosed with ADHD/I have been shown to present with increased levels of symptoms that emerged under the label SCT (Barkley, 2006). Based on the observation that approximately twice as many school-aged children are nowadays diagnosed with ADHD/I in contrast to ADHD/HI (e.g., Froehlich et al., 2007; Merikangas et al., 2010) and ADHD/I’s strong association with SCT, there is a need for a thorough definition

of SCT's cascading effects on individuals' functioning. This being said, the current literature on SCT is rather inconsistent in terms of the definition and measurement of SCT. No consensus has been met, yet, with regard to symptomatology or standardization in the assessment of SCT. Neurocognitive impairments that are seen in children with ADHD/I with comorbid SCT but not in children with pure ADHD/I further show that even though SCT is very similar to ADHD/I, SCT has its own neurocognitive characteristics (Carlson & Mann, 2002; Milich, Balentine & Lynam, 2001; Mikami et al., 2007; Wåhlstedt & Bohlin, 2010). A thorough look at the diagnostic validity of SCT and its impact on a variety of individuals' functional domains seems therefore to be warranted. Furthermore, given the heterogeneity in the measurement of SCT and its inconsistency in the definition of the concept SCT, treatment approaches of SCT are, so far, rather sparse. Yet, given the outlined neurocognitive characteristics that are typical for SCT but not ADHD (Carlson & Mann, 2002; Mikami et al., 2007; Milich, Balentine & Lynam, 2001; Wåhlstedt & Bohlin, 2010), treatment that is independent of a possible comorbidity of ADHD, seems to be important. The presence of SCT symptoms above and beyond ADHD symptoms might be one of the mediating factors in treatment efficacy in psychiatrically referred individuals.

During the process of the review, another review on the same topic was published (Becker, 2013). In contrast to Becker (Becker, 2013) the current review discusses findings on SCT in adults, genetic studies, gender differences, SCT in disorders different than ADHD (e.g., Becker et al., 2013; Graham et al., 2013; Reeves et al., 2007), specific treatment of SCT and stresses the current lack of standardization in the assessment of SCT. Each section of this review will be dedicated to one of the functional domains that have been shown to be affected in individuals with SCT. It was our aim to dissect the unique contribution of SCT to impairments, whenever the reviewed studies' designs allowed for such a conclusion.

3.3. Method

A systematic review of the English published literature of several databases (PsycInfo, SocIndex, Web of Science, PubMed) on the key terms "Sluggish Cognitive Tempo", "Cognitive Tempo", "Sluggish Tempo" revealed a total of 63 articles of which 32 (see Table A1 of the appendix. Studies and measures employed) were closely related to SCT and will be reviewed in here. Inclusion criteria were: SCT was measured by questionnaire or observation and its relation to neuropsychological, emotional or social functioning was tested. The remaining 31 studies were not included in this review since SCT was not systematically assessed or the focus was on age-related cognitive slowing or learning (e.g., reading ability) and its relation to

cognitive tempo. The majority (92%) of the studies focused on SCT comorbid to ADHD symptoms as a personality trait or clinical disorder.

3.4. Literature review

3.4.1. Lack of standards in the measurement of SCT

Current studies on SCT predominantly focused on SCT in children and/or adolescents with either traits (e.g., Bauermeister et al., 2012; Moruzzi, Rijdsdijk & Battaglia, 2013) or clinical diagnoses of ADHD (e.g., Harrington & Waldman, 2010; Langberg, Becker & Dvorsky, 2013). Only one study looked into SCT in adults with ADHD, examining hereby the association between self-rated SCT and executive functioning (Barkley, 2012). Initially, SCT was represented by four items (“difficulty following instructions”, “sluggishness”, “drowsiness”, “absent-minded, forgetful”: Lahey et al., 1987) that were then either reduced to two (“daydreams”, “is low of energy”: Bauermeister et al., 2005; Carlson & Mann, 2002; Skansgaard & Burns, 1998; Solanto et al., 2008; Todd et al., 2004) or expanded up to 17 items in more recent studies (McBurnett, Pfiffner & Frick, 2001; Pfiffner et al., 2007; Skirbekk et al., 2011).

Penny and colleagues (Penny et al., 2009) addressed the lack of agreement in standardized measures in SCT and came up with a unique SCT questionnaire based on items that have been shown to load highly on SCT in previous research (e.g., Hartman et al., 2004; McBurnett, Pfiffner & Frick, 2001). An extensive review of the literature on available items measuring SCT with subsequent reliability and factor structure analysis decreased the initial pool of 26 items to a 14-item SCT scale (see Table A1 of the appendix for individual items; (Penny et al., 2009)). In contrast to Penny’s 14 item scale, Skirbekk and colleagues (Skirbekk et al., 2011) compared the utility of Pfiffner and colleagues’ (Pfiffner et al., 2007) 17-item scale (SCT-17 see Table A1 of the appendix for individual items) to a 5-item scale (SCT-5 see Table A1 of the appendix for individual items) by Hartman and colleagues (Hartman et al., 2004) and showed that both scales capture the concept of SCT (e.g., Harrington & Waldman, 2010; Hinshaw, 2002; Mikami et al., 2007) but add to Penny and colleagues’ scale the dimensions of confusion (Hartman et al., 2004) or forgetfulness (SCT-15: Pfiffner et al., 2007). According to Penny and colleagues (Penny et al., 2009), the items measuring the concept of confusion (i.e., forgetfulness, disorganization and difficulty following instructions), were explicitly removed as they are part of the ADHD DSM-IV criteria and nowadays, DSM-5 criteria of inattention. Moreover, Hartman and colleagues (Hartman et al., 2004) showed that their five SCT items (SCT-5) loaded strongly on the same factor that was identified to represent cognitive and

physiological sluggishness by the more extensive Child Behavior Checklist (CBCL: Achenbach, 1991), contributing further evidence of adequate convergent validity of their 5-item SCT scale. The presented findings indicate that it appears not to be the number of items that matter in measuring SCT but the items' representativeness, with the short 5-SCT scale of Hartman and colleagues (Hartman et al., 2004) being a promising tool in diagnosing SCT in the pediatric setting. Whether the 5-SCT scale by Hartman and colleagues (Hartman et al., 2004) would outweigh the utility of Penny and colleagues' (Penny et al., 2009) 14-SCT scale is yet to be investigated. To conclude, even though various scales have been shown to effectively measure SCT (e.g., Barkley, 2012; Solanto et al., 2008; Jacobson et al., 2012), a standard of measurement across studies is not yet achieved. Moreover, some evidence points into the direction, that even though SCT items might identify individuals with SCT (e.g., Penny et al., 2009; Bauermeister et al., 2012; Hartman et al., 2004), their contribution in distinguishing subtypes of ADHD should be questioned (e.g., Garner et al., 2010; Pfiffner et al., 2007). Independent of the number of items that were used to represent SCT, "daydreaming", "sluggish/drowsy" and "underactive/apathetic" were items that consistently contributed to the identification of SCT in children (e.g., Bauermeister et al., 2012; Hartman et al., 2004; McBurnett, Pfiffner & Frick, 2001; Penny et al., 2009) and adults (Barkley, 2012). More in detail, the item "daydreaming" was represented in all studies reviewed e.g., (Harrington & Waldman, 2010; Hinshaw, 2002; Mikami et al., 2007; Skansgaard & Burns, 1998) followed by "sluggish/drowsy" (e.g., Barkley, 2012; Jacobson et al., 2012; Todd et al., 2004; Solanto et al., 2008;) and "underactive/apathetic" e.g., (Barkley, 2012; Bauermeister et al., 2012; Becker & Langberg, 2013; Mikami et al., 2007). Future research could use these three items as a baseline measurement for SCT without missing out to assess their individual link to behavioral and neurocognitive correlates.

A consequence of the lack of standardization in SCT measurement reinforced the discussion about whether SCT is a disorder itself above and beyond ADHD (e.g., Milich, Balentine & Lynam, 2001; Bauermeister et al., 2012; Barkley, 2012; McBurnett, Pfiffner & Frick, 2001) or whether SCT is comorbid to, or a subtype of ADHD (e.g., Garner et al., 2010; Carlson & Mann, 2002; Desman, Petermann & Hampel, 2008; Jacobson et al., 2012). The following section is dedicated to this issue and will give more insight into the comorbidities of SCT.

3.4.2. SCT and its link to ADHD subtypes

To start with, not only SCT is questioned for its diagnostic value in and above ADHD but so is

ADHD itself. One of the current debates concerning ADHD focuses on the question whether ADHD should be handled as a continuum or as a clear-cut category of behavioral, cognitive and emotional deficits (e.g., Lee et al., 2013; Todd et al., 2004). Supporters of the former thesis welcomed the increase in studies focusing on SCT in ADHD and tested the contribution of SCT in diagnosing ADHD (e.g., Lee et al., 2013; Todd et al., 2004). Evidence was found that SCT not only enhances the reliability of diagnosing ADHD (e.g., Jacobson et al., 2012; McBurnett, Pfiffner & Frick, 2001; Todd et al., 2004) but also contributes to the identification of a new subtype of ADHD (e.g., Penny et al., 2009) or a disorder itself (e.g., Barkley 2012; Bauermeister et al., 2012; Milich, Balentine & Lynam, 2001; McBurnett, Pfiffner & Frick, 2001). It is currently hypothesized that the SCT construct captures attentional deficits that are not represented by the nine symptoms measuring inattention according to the DSM-IV (as well as DSM-5) guidelines for ADHD/I (e.g., McBurnett, Pfiffner & Frick, 2001; Skirbekk et al., 2011). The endorsement of *sleepy/sluggish* and *slow/daydreamy* symptoms were shown to be more likely to be associated with ADHD/I than with ADHD/C or ADHD/HI (Carlson & Mann, 2002; Desman, Petermann & Hampel, 2008; Garner et al., 2010; Langberg, Becker & Dvorsky, 2013; Lee et al., 2013; Mikami et al., 2007; Skansgaard & Burns, 1998), supporting the idea, that the inclusion of the SCT items in diagnosing ADHD might enhance the reliability of ADHD/I diagnoses (e.g., Jacobson et al., 2012; McBurnett, Pfiffner & Frick, 2001). In line with this, SCT subscales have been shown to present with both, good discriminant validity with symptoms of hyperactivity and strong convergent validity with symptoms of inattention (Penny et al., 2009). McBurnett and colleagues (McBurnett, Pfiffner & Frick, 2001) showed that when SCT symptoms were tested in ADHD/I, (e.g., Jacobson et al., 2012; Langberg, Becker & Dvorsky, 2013; Lee et al., 2013) the SCT items did not show the extremely poor loading that ultimately led to the exclusion of SCT items from the DSM-IV (e.g., Frick et al., 1994; Schatz & Rostain, 2006). It can be concluded, that the inclusion of SCT items in the identification of individuals with ADHD/I seems therefore valuable. At the same time, it can be reasoned that when SCT contributes to a more defined subtyping of ADHD/I it also (indirectly) enhances the number of ADHD diagnoses. This is in line with the former proposed argument that excluding SCT from ADHD criteria might lead to missing out on individuals that would otherwise be diagnosed with ADHD/I (e.g., Jacobson et al., 2012; McBurnett, Pfiffner & Frick, 2001).

In contrast to accumulating evidence that SCT item inclusion enhances the number of ADHD/I diagnoses (e.g., Carlson & Mann, 2002; Desman, Petermann & Hampel, 2008; Garner et al., 2010), no difference in SCT were found in children with ADHD/I and ADHD/C (e.g., Garner et al., 2010; Harrington & Waldman, 2010; Skirbekk et al., 2011) or in class room

observations of children with behavior of ADHD (e.g., Hinshaw, 2002; Todd et al., 2004). Expanding the association of SCT with ADHD or ADHD/I to ADHD common comorbidities, Skirbekk and colleagues (Skirbekk et al., 2011) found that children with anxiety comorbid to ADHD exhibited the highest levels of SCT, followed by children with exclusively ADHD and finally children with clinical levels of anxiety compared to children with neither anxiety nor ADHD (Skirbekk et al., 2011). Unfortunately, children were not further subtyped into ADHD/I, ADHD/C or ADHD/HI, complicating thereby the comparison of findings across studies. Nevertheless, the presence of the highest SCT symptoms in children with anxiety and ADHD support the idea that not merely ADHD is affected by SCT but SCT might be present in ADHD comorbidities in general and emotional disorders in particular. Further evidence that SCT can be found in disorders different from ADHD is given in the following section.

3.4.3. *SCT is not ADHD but a disorder distinct from ADHD*

SCT has been shown to not only be present in children with ADHD (e.g., Penny et al., 2009; Skirbekk et al., 2011) but also in children who do not meet ADHD criteria (e.g., Barkley, 2012). Findings that SCT and ADHD/I relate differently to symptoms of inattention (Bauermeister et al., 2012; McBurnett, Pfiffner & Frick, 2001; Milich, Balentine & Lynam, 2001), underline the idea, that SCT is a disorder itself and not merely comorbid to ADHD/I. Moreover, SCT emerged as a separate psychometric valid construct during data analysis in children that did not reach ADHD thresholds of DSM-IV criteria but presented with clinical symptoms of behavioral/emotional and/or learning difficulties (Garner et al., 2010). The idea that SCT might relate to attentional impairments in clinical groups in general led Reeves and colleagues (Reeves et al., 2007) to assess the presence and relationship of SCT to later cognitive outcomes of pediatric survivors of acute lymphoblastic leukemia. Lymphoblastic leukemia survivors were successfully identified from their healthy siblings by SCT. Moreover, SCT related to the survivors' intellectual and achievement deficits (Reeves et al., 2007). Similarly, SCT was found in children diagnosed with Fetal Alcohol Syndrome (FAS) with and without comorbid ADHD and in children with clinically behavioral deviance (Graham et al., 2013). SCT was found to be statistically linked but distinct from ADHD in a large sample of clinically distressed children (Becker et al., 2013). The items "being confused", "daydreaming", and "stares blankly into space" related to internalizing and social deficits, as well as behavioral problems independently of ADHD or other psychopathologies in psychiatrically hospitalized children (Becker et al., 2013). It can be concluded that SCT is not only a valuable factor in the clinical assessment of children or adolescents with ADHD but might be a valuable factor to look at in pathologies

different from ADHD (e.g., Garner et al., 2010; Graham et al., 2013; Reeves et al., 2007).

3.4.4. SCT etiology: environment vs. genetics

Based on the observation that SCT was typically associated with ADHD, and ADHD has been shown to be highly heritable (additive and dominant genetic effects of around 75% for ADHD: Faraone et al., 2005), researchers became interested in SCT's genetic background. A recent twin study showed that the association between SCT and ADHD/I was almost twice as strong as the association between SCT and ADHD/HI (Moruzzi, Rijdsdijk & Battaglia, 2013). While genetic factors were shown to be of particular significance in hyperactive-impulsive behavior in general, the non-shared environmental factors were the major factor likely to explain individual differences in SCT (Moruzzi, Rijdsdijk & Battaglia, 2013). Accordingly, the association of SCT with ADHD/I was found to be partly due to genetic ($r = 0.29$) and partly due to non-shared environmental factors ($r = 0.21$), whereas the association of SCT with ADHD/HI was almost purely attributable to genetic factors (Moruzzi, Rijdsdijk & Battaglia, 2013). These findings indicate that SCT, even though it is genetically related to ADHD, is the least heritable subtype among ADHD (Moruzzi, Rijdsdijk & Battaglia, 2013). SCT's special association with environmental factors, led the authors to suggest that SCT might develop due to the environment created by facing ADHD symptoms (Moruzzi, Rijdsdijk & Battaglia, 2013). Moruzzi and colleagues' pioneering work should be carried on in a population in which SCT symptoms are the main reason for being referred to a clinician. If similar neurocognitive and or behavioral SCT symptoms exist between individuals who are seen for their SCT symptoms only and those with other comorbid conditions (such as ADHD or other pathologies), symptoms should be further tested for their genetic vs. (psychopathological-) environmental background. SCT's cognitive and neuropsychological correlates

3.4.5. Processing speed

SCT's association to various cognitive and neuropsychological correlates has been one of the major interests in the last decade of research in the field of ADHD. Whereas earlier studies suggested that children with SCT present with slow motor and processing speed (e.g., Barkley, DuPaul & McMurray, 1990; Carlson & Mann, 2002; Desman, Petermann & Hampel, 2008; Lahey et al., 1987; Milich, Balentine & Lynam, 2001) more recent studies could not replicate a link between SCT and processing speed (Bauermeister et al., 2012). The studies which reported such a link (e.g., Barkley, DuPaul & McMurray, 1990; Carlson & Mann, 2002; Desman, Petermann & Hampel, 2008; Lahey et al., 1987) are based on the assessment of individuals with ADHD/I that are characterized by high levels of SCT, whereas Bauermeister

and colleagues (Bauermeister et al., 2012) focused on individuals with pure SCT and its impact on information processing. Furthermore, the majority of studies reporting an association between SCT and slowed information processing (e.g., Barkley, DuPaul & McMurray, 1990; Carlson & Mann, 2002; Lahey et al., 1987) did not make use of neuropsychological/behavioural assessments of cognitive tempo, but refer to teacher and parent observations only (e.g., the child seems to be “lost in a fog”, “daydreaming or getting lost in thought,” and “apathetic or unmotivated”). It has to be questioned whether behavior observations reliably reflect slow processing speed or whether reductions of processing speed are better depicted by actual assessments using psychometrically valid information processing tasks, such as reaction time measures, visual search- and pattern recognition tasks, or perceptual timing tasks. Experimental data indeed confirmed that children with ADHD/I and SCT presented with a slower task accomplishment during the Tower of London Task (ToL) and higher mean reaction times in the Continuous Performance Test (CPT: Solanto et al., 2008; Conners, 1994). The authors concluded that children with ADHD/I and SCT do not present with inaccurate performance but do perform neurocognitive tasks in a conspicuous slow tempo (Solanto et al., 2008). It has therefore been hypothesized that SCT does not affect the underlying cognitive function per se (e.g., EF, inhibitory control) but compromises the overall task performance by slowing down task related processes (Solanto et al., 2008).

3.4.6. Attention

Solanto and colleagues (Solanto et al., 2008), however, did not control in their study for the children’s attentional functioning. Especially deficits in sustained attention have been found to be related to SCT (e.g., Harrington & Waldman, 2010; Skirbekk et al., 2011; Wåhlstedt & Bohlin, 2010). The reason why some studies failed to confirm attentional deficits in children with SCT (Carlson & Mann, 2002; Huang-Pollock, Nigg & Carr, 2005) might again be that subjective teacher ratings based on class-room observations are not sufficiently sensitive and valid and by this miss relevant aspects of the children’s attentional problems. While studies applying neuropsychological tasks, such as classic vigilance, divided attention and selective attention tasks, revealed no differences in attention between ADHD subtypes (Huang-Pollock, Nigg & Carr, 2005; Tucha et al., 2006; Tucha et al., 2008), a unique association was found between SCT and early selection deficits in a perceptual load paradigm (Huang-Pollock, Nigg & Carr, 2005). For an overview of the exact neuropsychological tests applied, please view Table 1. Children with ADHD and comorbid SCT showed more interference on early selection tasks than children with ADHD but without SCT (Huang-Pollock, Nigg & Carr, 2005). Deficits in

sustained attention of individuals with SCT were further explained by an increased variability in spatial memory performance (Skirbekk et al., 2011). It seems likely that other functions, such as EF or inhibitory control as reported above (see discussion of Lahey, Neeper & Frick, 1990), might also be deviant due to sustained attention deficits rather than processing speed.

3.4.7. Executive functioning

Barkley (Barkley, 2012) recently showed that SCT symptoms explained unique variance of self-rated executive functioning (EF) independent of the impairments associated with ADHD/I or ADHD/HI. These results, however, could not be replicated in a younger sample of children scoring high on ADHD and SCT (Bauermeister et al., 2012). Furthermore, behavioral ratings of EF in adolescents were also found to be unrelated to SCT but associated with ADHD/HI symptomatology (Becker et al., 2013). These inconsistencies in findings might result from different assessment strategies applied (self-rated vs. observer-rated) and different age groups assessed (children vs. adolescents vs. adults) in the mentioned studies (Barkley, 2012; Bauermeister et al., 2012; Becker et al., 2013). With regard to the differences in age between the samples, it has to be considered that EF is known for its developmental trajectory (Anderson, 2002). More in detail, EF was shown to be relatively mature at the age of 12 but knows a transitional period of development at the beginning of adolescence (Anderson, 2002). It therefore can be speculated that the adult sample of Barkley (Barkley, 2012) was much more aware of their EF deficits and, hence, more likely to report them than the observer-rated younger participants of Bauermeister and colleagues (Bauermeister et al., 2012) and Becker and colleagues (Becker et al., 2013). Furthermore, previous research has shown that EF self-ratings are more sensitive to particular EF related symptoms than neuropsychological tests (Barkley & Fischer, 2011). However, as Barkley (Barkley, 2012) did not control for the impact of comorbid ADHD subtypes it remains open whether the association between SCT and EF was unaffected by the underlying ADHD symptomatology.

3.4.8. Summary Executive Functioning

Studies that controlled for ADHD/I symptomatology in order to show the unique impact of SCT on attentional functioning support the idea that SCT is associated with more severe attention deficits than ADHD/I (Harrington & Waldman, 2010). Moreover, SCT related to sustained attention deficits that were not seen in ADHD/I (Wåhlstedt & Bohlin, 2010). The established link between SCT and attention deficits (e.g., Huang-Pollock, Nigg & Carr, 2005; Wåhlstedt & Bohlin, 2010) might lead to the suggestion that individuals with SCT are in general more prone than individuals with ADHD to perform worse on neurocognitive tasks and experience more

deficits in everyday functioning. This knowledge appears relevant for the treatment of SCT because attentional functioning has been shown to be one of the core factors predicting rehabilitation outcome (Brooks et al., 1987; van Zomeren & van den Burg, 1985), including treatment efficacy and socio-cognitive functioning in general (Brooks et al., 1987; van Zomeren & van den Burg, 1985). Research confirming a link between SCT and poor cognitive outcome (Garner et al., 2010; Reeves et al., 2007) further underlines the need for research on SCT in neuro- rehabilitation populations. To support this, SCT has been proposed to be the behavioral manifestation of slow processing speed (Reeves et al., 2007), with slow processing speed being one of the rather common cognitive late effects after acquired or developmental neurocognitive pathologies in general (Schatz & Rostain, 2006). Research on SCT in neuro-rehabilitation populations seems therefore warranted.

3.4.9. SCT and internalizing symptoms: SCT's relation to depression and anxiety

Lahey (Lahey et al., 1987) was one of the first who reported differences in comorbidities according to ADHD subtypes. Whereas ADHD/C is more likely to be associated with externalizing behavior, ADHD/I appears more often to be linked to internalizing symptoms, with both types of ADHD also being related to conduct disorder (CD) (Lahey et al., 1987). After removing children with CD from their analysis, cognitive tempo was the most distinguishing factor between ADHD/C and ADHD/I (Lahey et al., 1987). Lahey (Lahey et al., 1987) therefore concluded that except for the cognitive tempo factor, other symptom differences in ADHD might be due to other comorbidities than SCT, such as externalizing and internalizing. Given that SCT is foremost believed to be associated with ADHD/I, SCT's proneness to internalizing behavior seems to be comprehensible.

Consequently, recent research confirms the link between SCT and internalizing symptoms such as anxiety and depression (e.g., Bauermeister et al., 2012; Becker & Langberg, 2013; Carlson & Mann, 2002; Garner et al., 2010; Penny et al., 2009; Schatz & Rostain, 2006), with some authors claiming that SCT is stronger related to depression than to anxiety (Becker et al., 2013; Jacobson et al., 2012) even though correlations of SCT with depression were rather modest (Jacobson et al., 2012). Comorbidity of internalizing disorders was based on validated rating scales such as the DISC-IV (e.g., Becker et al., 2013; Becker & Langberg, 2013), the Emory Combined Rating Scale (ECRS) (e.g., Harrington & Waldman, 2010) or the Impairment Rating Scale (IRS) (e.g., Jacobson et al., 2012). Moreover, clinically referred children with severe SCT presented with increased symptoms of depression, a greater risk for generalized anxiety, social phobia and obsessions than children with low SCT (Harrington & Waldman,

2010). The authors concluded that SCT is more likely to go along with internalizing disorders, such as depressive disorders and generalized anxiety disorders, than ADHD (Harrington & Waldman, 2010). However, SCT has been shown not to be merely a measure of depression but to be statistically distinct from depression (Becker et al., 2013; Jacobson et al., 2012). Furthermore, internalizing problems correlated with SCT independently of ADHD inattention problems (Bauermeister et al., 2012), leading to the assumption that SCT knows its own internalizing dimension that is not linked to ADHD symptomatology (Bauermeister et al., 2012; Penny et al., 2009).

With regard to anxiety, it has been shown that the association between SCT and symptoms of anxiety is mediated by symptoms of inattention (Skirbekk et al., 2011). The authors hypothesized that anxiety disorder comorbid to ADHD decreases individuals' attentional capacities even further (Skirbekk et al., 2011). The decrease in attentional capacities by anxiety is further believed to make individuals more vulnerable to leave the impression of being sluggish and slow (Skirbekk et al., 2011). However, it seems likewise probable that ADHD with comorbid SCT makes individuals more prone to develop a depressive or anxiety disorder (Skirbekk et al., 2011; Harrington & Waldman, 2010). For example, a similar association between SCT and internalizing behavior was observed in clinical populations suffering from ADHD and SCT (e.g., Skirbekk et al., 2011) as well as in populations with SCT and a clinical condition different from ADHD (FAS: Graham et al., 2013). Furthermore, anxiety and depressive symptoms of clinically-distressed children correlated with levels of SCT, even beyond the ADHD/ODD symptomatology (Becker et al., 2013). Notably, SCT levels were found to be stronger related to depression than to anxiety symptoms when parent-ratings were controlled for the parents' own anxiety and depressive symptoms (Becker et al., 2013). Becker and colleagues' findings indicate that the raters own mental constitution should be taken into consideration when interpreting results from ratings that are not directly derived from the target population (e.g., no self-rating measures).

In contrast, the findings of studies focusing on SCT's impact on externalizing, disruptive behavior, which is often seen in ODD, are rather promising (Wåhlstedt & Bohlin, 2010). For example, Wåhlstedt and colleagues (Wåhlstedt & Bohlin, 2010) showed that behavioral symptoms of SCT were not associated with internalizing problems but showed an interaction with inattention and ODD in a community sample of children. In more detail, more severe SCT decreased the likelihood of ODD symptoms in children with very distinct symptoms of ADHD symptoms (Wåhlstedt & Bohlin, 2010; Harrington & Waldman, 2010). Furthermore, high levels of SCT were shown to be related with low levels of disruptive behavior (Penny et al.,

2009), making SCT a protective factor against ODD symptomatology in children with ADHD (Barkley, 2006; Carlson & Mann, 2002; Mikami et al., 2007).

3.4.10. Summary SCT and Internalizing Symptoms

It can be concluded that even though SCT seems to be related with internalizing, emotive disorders, its unique interaction with other comorbidities should be disentangled first. Moreover, whereas SCT can be interpreted as a risk factor per se, making individuals more prone to depression, SCT has also been shown to lower individuals' risks of severe disruptive behavior.

3.4.11. SCT and other characteristics: SCT's link to academic functioning, gender, age-of-onset

SCT has been demonstrated to be further associated with academic outcomes in general (Langberg, Becker & Dvorsky, 2013), math (Bauermeister et al., 2012), linguistic processing deficits (Schaughency et al., 1992) and initiative taking as well as motivation in particular (Jacobson et al., 2012; Langberg, Becker & Dvorsky, 2013). It has been shown that especially low levels of initiation and persistence in clinically referred children with ADHD and SCT contribute to the impairments seen in academic achievements (Jacobson et al., 2012). Furthermore, math scores did not only negatively relate to ADHD symptoms of inattention but also to SCT (Bauermeister et al., 2012). It was shown that SCT beyond symptoms of inattention and hyperactive-impulsive symptoms relate to academic achievements (Bauermeister et al., 2012; McConaughy et al., 2009). However, when relying on parent ratings of SCT, a link between SCT and academic achievements as was seen in teacher ratings (Bauermeister et al., 2012; McConaughy et al., 2009) could not be confirmed (Marshall et al., 2013). The observation that teacher and parent ratings of SCT yield different results with respect to SCT's impact on academic functioning calls for thorough investigation of to what extent findings on SCT and its correlates are affected by within- (SCT levels and correlates assessed by same rater-population) versus between-context ratings (SCT levels assessed based on ratings of observer population A but correlates of SCT rated by observer population B).

With regard to other socio-demographic variables, it has been observed that gender ratios differed according to ADHD subtype and SCT diagnosis (Todd et al., 2004). Todd and colleagues (Todd et al., 2004) showed that SCT item loadings were different for males and females. Accordingly, two SCT items ("day dreams", "low energy") were identified to form a separate factor in boys (explaining 6.6 % of the total variance) but not in girls. In girls, the two SCT items ("day dreams", "low energy") loaded on the inattentive factor of ADHD/I. The

authors concluded that boys with ADHD and SCT are best described by an inattentive and a hyperactive-impulsive factor, whereas girls' subtyping was not facilitated by the inclusion of SCT symptoms (Todd et al., 2004). However, Garner and colleagues (Garner et al., 2010) showed that SCT symptoms were generally increased in boys prone to behavioral deviance and/or individuals with an ADHD/I diagnosis. Various research on ADHD shows that ADHD is more closely linked with being male than female. Male-to-female ratios of ADHD diagnosed individuals have been shown to range from 9:1 to 6:1 (APA, 2000), with community-based samples presenting with a ratio of approximately 3:1 (APA, 2000). Research on gender differences in ADHD is however, highly needed (Gaub & Carlson, 1997). Not only should attention be drawn on methodological limitations such as gender-biased diagnostic tools, but also on the possibility of confounding effects due to referral biases (Gaub & Carlson, 1997). For example, girls from community-based samples of ADHD presented on average with lower levels of inattention, internalizing behavior and peer aggression than boys with ADHD, whereas clinical samples of ADHD did not show any differences on these variables for gender (Gaub & Carlson, 1997). It should be questioned whether differences in gender on SCT and ADHD are a mere effect of referral-bias or whether future research should handle different standards in evaluating SCT and ADHD in line with the individual's gender.

With regard to mean age of symptom-onset of SCT, no differences were found between ADHD samples with low SCT and high SCT (Harrington & Waldman, 2010). Bauermeister and colleagues (Bauermeister et al., 2005), however, found a later onset of inattention and SCT symptoms in their group of individuals with inattention. However, it remains unclear whether these differences in mean onset age of symptoms are indeed due to differences in samples or simply due to a distortion associated with retrospective assessments of ADHD/SCT symptoms. Moreover, Bauermeister and colleagues' sample (Bauermeister et al., 2005) was characterized by a low impairment in adaptive functioning and the assessed mothers reported only little to no child-related family stress. The results of Harrington and Waldman (Harrington & Waldman, 2010), in contrast, stem from clinically referred children who were seen due to their suspiciousness for attentional and behavioral deviances. It can be speculated that the onset time of symptoms is either better remembered for those who are suspicious of severe behavioral deviance (Harrington & Waldman, 2010) compared to those who are rather adapted (Bauermeister et al., 2005) or that the onset of symptoms indeed differs due to differences in symptom severity.

3.4.12. SCT and social functioning

Within the last decade, the interest in ADHD diagnosed individual's social and emotional functioning is on the increase (e.g., Bagwell et al., 2001; Greene et al., 1997; Greene et al., 2001; Nijmeijer et al., 2008). It was already mentioned above that individuals with SCT are more prone to internalizing behaviors (e.g., Bauermeister et al., 2012; Becker et al., 2013; Becker & Langberg, 2013; Carlson & Mann, 2002; Garner et al., 2010; Marshall et al., 2013; Penny et al., 2009; Schatz & Rostain, 2006), such as turning inward, not expressing certain needs, and appearing rather shy. Internalizing behaviors have been further shown to increase the proneness of being less socially interactive. It can be assumed that a decreased opportunity for social interactions might affect social functioning in general and vice versa. In line with this, it was shown that children with ADHD/I with SCT tended to take less initiative in social situations and were rated to be less assertive and more self-controlled during home and school based observations (Bauermeister et al., 2005). This finding was not replicated in a later study in which inappropriate on- task behavior was found to be unrelated to SCT but associated with symptoms of inattention (Bauermeister et al., 2012). While both studies (Bauermeister et al., 2005; Bauermeister et al., 2012) used information obtained from behavioral observations during task performance (Bauermeister et al., 2005) or class-room performance (Bauermeister et al., 2012) to measure social functioning, the authors failed to implement a standardized measure of social functioning.

Mikami and colleagues (Mikami et al., 2007) in contrast, applied computer simulated peer interaction in order to measure social skills of children with ADHD and SCT compared to different ADHD subtypes. In line with the observation that children with ADHD/I and SCT have more social problems, are more likely to be socially withdrawn (e.g., Carlson & Mann, 2002; Marshall et al., 2013), less happy and more anxious in social interactions (Carlson & Mann, 2002), Mikami and colleagues (Mikami et al., 2007) found fewer responses, a weaker memory and a reduced ability to attend to subtle social cues in children with ADHD/I and SCT compared to children with ADHD/I without SCT. Moreover, a relation between SCT and children's hostility was observed (Mikami et al., 2007) with children suffering from ADHD/I and SCT showing less symptoms of hostility than the group of children with ADHD/I but without SCT (Mikami et al., 2007). A reduced hostility of children with SCT was further confirmed by Becker and colleagues (Becker et al., 2013), supporting the formerly proposed positive impact of SCT on severe disruptive behavior (e.g., Barkley, 2006; Carlson & Mann, 2002; Mikami et al., 2007). Again, it can be speculated that even though SCT seems to impact negatively on the individuals social functioning, by making individuals more socially reluctant

and less attentive to social cues (Mikami et al., 2007), SCT also functions as a protective factor, making the individual more resilient to deviant behavior such as hostility (Becker et al., 2013; Mikami et al., 2007).

Another consequence of impaired social functioning associated with SCT might be seen in increased levels of peer-rejection. For example, teachers' ratings of children on the item "cannot pay attention and looks sleepy" were related to greater peer rejections in pupils independent of internalizing, anxious or depressed features of the assessed child (Schaughency et al., 1992). The authors concluded that SCT was the only predictive factor with regard to peer rejection (Schaughency et al., 1992).

So far, no study focused on social perceptual functioning in children with SCT. Future studies should therefore implement the measurement of social cognitive as well as social perceptual performances of children with SCT in order to bridge the gap between SCT and social-perception as well as social-cognition. The observation that social deficits might arise due to slower responses or inattention to meaningful social cues might further plead for research assessing the timing sensitivity of children with SCT in social situations. In particular, considering that (Becker, 2013) children with ADHD have a poorer perception of time (e.g., Barkley, 2006; Barkley et al., 1997) and timing functions have been shown to be crucial in social interactions (e.g., Reed & McGoldrick, 2007; Trevarthen & Aitken, 2001), the examination of a relationship between abnormal timing functions and impaired social functioning in children with SCT could enhance the understanding of social shortcomings seen in SCT.

3.4.13. SCT treatment efficacy

Clinical observations suggested that treating children with ADHD/I and ADHD/C together might be detrimental for children with ADHD/I (e.g., Antshel & Remer, 2003), underlining hereby the need for individualized treatments according to patients' unique psychopathology. Similar, children with ADHD/I and SCT have been shown to benefit the most from treatment that addresses the processing deficits and social impairments associated with ADHD/I (Pfiffner et al., 2007). For example, SCT symptoms were shown to be as responsive as ADHD/I symptoms to the Child Life and Attention Skill (CLAS) program devised by Pfiffner and colleagues (Pfiffner et al., 2007). Furthermore, the positive effects remained stable at follow-up (Pfiffner et al., 2007). The CLAS program was adapted from a program for the treatment of mild closed head injury in children and is characterized by prompts, routinization and task complexity reduction. Unfortunately, no control group was examined in this study so that it

remains unclear to what amount the observed improvements of children were caused by nonspecific effects of treatment, such as the positive influence of the teacher or parent training. Ludwig and colleagues (Ludwig et al., 2009) showed that individuals with ADHD/I and SCT do not differ in their response to stimulant drug treatment using methylphenidate from individuals with ADHD/I without SCT. The CLAS program (Pfiffner et al., 2007) might, therefore, be a promising approach to address symptoms seen in children with ADHD/I and SCT.

3.5. Conclusion

The current review's aim was to provide a comprehensive overview of the psychometric as well as empirical validity of SCT, its etiology, its unique contribution to individuals' neuro-cognitive profiles, its impact on individuals' social and emotional well-being, as well as its treatment. Even though there seems to be no consensus yet whether SCT could account as a disorder itself (e.g., Bauermeister et al., 2012; Barkley, 2012), recent studies confirm the link between ADHD/I and SCT (e.g., Desman, Petermann & Hampel, 2008; Garner et al., 2010; Jacobson et al., 2012; Lee et al., 2013; Langberg, Becker & Dvorsky, 2013; Mikami et al., 2007; Skansgaard & Burns, 1998).

The removal of SCT symptoms from the DSM-IV criteria of ADHD resulted in a loss of relevant information about cognitive impairments associated with ADHD/I (Huang-Pollock, Nigg & Carr, 2005) and might even lead to overdiagnosing of ADHD/C, in particular of those cases that would rather fit the category of ADHD/I and SCT or pure SCT (Huang-Pollock, Nigg & Carr, 2005). The fact that the items assessing SCT were not reintroduced into the current DSM-5 might increase ADHD's homogeneity artificially (e.g., Hartman et al., 2004; Moruzzi, Rijdsdijk & Battaglia, 2013), leading thereby to a distorted diagnosis and treatment of individuals with ADHD. Furthermore, SCT was present in or comorbid to a variety of clinical or physical disorders different from ADHD (e.g., clinical-referred children: Garner et al., 2010; FAS: Graham et al., 2013; leukemia survivors: Reeves et al., 2007), increasing the need for future research on SCT in a variety of clinical populations. The current review points out that it is warranted to assess for SCT symptoms in patients suffering from attention deficits within the context of neuro-cognitive treatment and rehabilitation.

However, before SCT can be used in research or clinical settings, its construct and empirical validity needs to be substantiated. Based on the research studies performed in the field of SCT, the current review concludes that SCT measures vary widely across studies and lack standardization. Three components of SCT (i.e., "slow", "sleepy", "daydreamer": Penny

et al., 2009) however, seem promising for being implemented in future studies on SCT. By applying these unique SCT items, SCT emerged as a psychometrically valid factor, which is even distinct from ADHD/I (e.g., Hartman et al., 2004; Penny et al., 2009). Moreover, each of these three components was found to be independently related with different comorbidities (Penny et al., 2009). Accordingly, whereas the “slow” component was foremost related to ADHD/I, ADHD in general, and ODD, the other two components “sleepy/daydreamer” were more likely to be related to a more pure form of SCT (Penny et al., 2009). Even though, some of the studies tried to integrate the individual impact of each of these three components of SCT (e.g., Bauermeister et al., 2012; Garner et al., 2010; Wåhlstedt & Bohlin, 2010), none of the studies explicitly assessed the items’ unique associations with ADHD subtypes or other comorbidities. The aim of future research could be to take the mentioned components as a starting point for further analysis of SCT and its behavioral as well as cognitive markers.

The majority of the reviewed studies were based on teacher and parent ratings. Self-measurements and objective measures of SCT (e.g., computerized cognitive tasks) are lacking so far, however, it was proposed that the nature of SCT symptoms requires longer behavioral as well as cognitive observations. Simple observations of ten minutes of on-task behavior were, for example, considered to be insufficient to reasonably capture SCT (Skansgaard & Burns, 1998).

Whereas a link between sustained attention deficits and SCT was consistently found (e.g., Wåhlstedt & Bohlin, 2010), the hypothesized association of SCT with both cognitive and behavioral speed (e.g., Barkley et al., 1997; McBurnett, Pfiffner & Frick, 2001) or slowed information processing in general (e.g., Bauermeister et al., 2005; Carlson & Mann, 2002; Hartman et al., 2004) was rather inconsistent and needs further investigation. It has been hypothesized that a decreased processing speed might lead to a general distortion in individuals’ perception of time (e.g., Barkley et al., 1997) and impacts on several timing functions such as motor- and perceptual timing, as well as temporal foresight (Noreika, Falter & Rubia, 2012). These timing functions, however, are important for motor control, decision making and the individual’s psychological orientation in time (Buhusi & Meck, 2005). Several studies so far showed that patients with ADHD present with a different sense of time (e.g., Barkley et al., 1997; Toplak, Dockstader & Tannock, 2006; Toplak et al., 2003), see (Noreika, Falter & Rubia, 2012) for a recent review. Given SCT’s strong link to ADHD and its proposed association with slowed processing speed, it would be interesting to examine the impact of SCT on timing functions in general and perceptual timing in particular.

The findings concerning the impact of SCT on classroom behavior and children’s

academic achievement remain inconsistent (e.g., Langberg, Becker & Dvorsky, 2013; Jacobson et al., 2012), however, SCT's impact on children's social- as well as emotional well-being has been shown to be concerning (Becker et al., 2013; Becker & Langberg, 2013; Marshall et al., 2013), with SCT showing a clear link to internalizing disorders such as anxiety and depression (e.g., Bauermeister et al., 2012; Becker & Langberg, 2013; Garner et al., 2010; Penny et al., 2009; Schatz & Rostain, 2006;).

While the majority of studies focused on adolescents or children, only one study examined SCT in adulthood (Barkley, 2012). Because of the clear association between ADHD and SCT and the fact that ADHD persists from childhood throughout adulthood (e.g., Simon et al., 2009), thorough examinations of SCT in longitudinal studies would be desirable. These studies could, for instance, provide information about the presence and consequences of SCT in community-based as well as clinical populations and add valuable insights into the developmental trajectory of SCT.

The only genetic study available in this field indicates that SCT seems to share some of the genes with ADHD but is most strongly associated with environmental factors (Moruzzi, Rijdsdijk & Battaglia, 2013). The idea, that SCT is a by-product of ADHD related environmental factors (Moruzzi, Rijdsdijk & Battaglia, 2013) seems worth to be further studied in future research. Based on Barkley's (Barkley, 2012) classification of SCT symptoms, it can be assumed that if a threshold of 5 or more out of 9 SCT symptoms will be applied as a standard for diagnosing SCT, 5.1% of the general population would be diagnosed with SCT, which is comparable to the number of ADHD diagnoses in children (APA, 2000). Barkley's estimate therefore gives an impression of the number of patients, which can be expected if SCT establishes as a disorder itself.

Based on the discussed literature, it can be concluded that SCT in ADHD but also SCT in other populations and pathologies is understudied. Whereas first attempts for valid and consistent measurements have been made (Penny et al., 2009), recent studies on SCT lack coherence and standardization of measurement. To allow the diagnosis of SCT, a consensus about which dimensions actually represent SCT has to be reached first. Two factors, represented by the condition "sleepy/daydreamer" seem promising for a future taxonomy of SCT e.g., (Penny et al., 2009). Neurocognitive tests focusing on timing functions and attention (in particular sustained attention) should be combined with behavioral observations that target sleepy/daydreaming behavior and absent-mindedness, without missing the importance of assessing SCT's link to internalizing and other mood disorders. Especially, patients with depressive disorders or acquired brain lesions (e.g. during the phase of neuro-rehabilitation)

might benefit from a thorough assessment of comorbid SCT. SCT symptoms have been shown to improve by means of non-pharmacological treatment (Pfiffner et al., 2007). As these results are rather preliminary, additional psycho-educative, therapeutic, and behavioral interventions should be tested for their efficacy in populations with clinical levels of SCT. Studies on the genetic background of SCT should be encouraged, testing hereby the assumption whether SCT is a by-product elicited by the environmental constraints put forward by the disorder to which SCT is comorbid to (e.g., ADHD).

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Chapter 4

SLUGGISH COGNITIVE TEMPO IN ADULTS: A VALIDATION STUDY OF THE
SLUGGISH COGNITIVE TEMPO QUESTIONNAIRE FOR ADULTS (SCT-QA)

Keywords: Sluggish Cognitive Tempo, Adults, Validation Study, Measurement, Attentional functioning, Timing behavior

Chapter 4 SLUGGISH COGNITIVE TEMPO IN ADULTS: A VALIDATION STUDY OF THE SLUGGISH COGNITIVE TEMPO QUESTIONNAIRE FOR ADULTS (SCT-QA).

4.1. Abstract

The current study focussed on a highly discussed cluster of symptoms that have been summarized as Sluggish Cognitive Tempo (SCT). SCT measurement so far lacks scientific and clinical consensus. 26 SCT items were identified that were used in previous studies. A scale of these 26 items was created and analyzed based on 577 adult participants' responses, making use of an exploratory factor analysis. The exploratory factor-analysis successfully reduced the former 26 SCT-items to a 16-item scale with high internal consistency (Cronbach's $\alpha=.84$). Three subscales with acceptable to high rates of reliability were identified (subscale 1: *sluggish- & sleepiness*, Cronbach's $\alpha=.78$; subscale 2: *lacking persistency & motivation*, Cronbach's $\alpha=.75$; and subscale 3: *mind wandering & lacking concentration*, Cronbach's $\alpha=.59$). The current results suggest that SCT is a multidimensional construct with at least two subscales (*sluggish- & sleepiness* and *lacking persistency & motivation*) that are supported by a high rate of reliability. Cronbach's α of the third subscale is questionable. Future studies could focus on finding more evidence against or for the third subscale, maybe by adding more items in line with behavior that is typical for mind wandering and the lack of concentration. In a second step, the SCT scale total and the derived sumscores on the subscales were correlated with scales that measure attentional functioning and timing behavior, in order to explore the convergent validity of SCT. Effect sizes of the bivariate associations between overall SCT scores and attentional and timing behavior scales were high. The same can be said for the bivariate associations between the SCT subscales and attentional and timing behavior. Evidence was found that SCT and attentional complaints are related, thereby supporting the convergent validity of the present SCT scale. Moreover, an interesting link between SCT and timing behavior was found. The findings can be used to encourage future studies to measure timing functioning in adults suffering from SCT more objectively by applying cognitive testing.

4.2. Introduction

One of the topics in pediatric research that has recently received increased attention concerns a cluster of symptoms also known as Sluggish Cognitive Tempo (SCT). SCT is described as a cognitive-emotional style that is commonly characterized by symptoms of “daydreaming”, “being confused”, “staring blankly”, “being sluggish” and “being unmotivated” (e.g. Lee et al. 2013; Penny et al. 2009). SCT was originally introduced in the literature on attention-deficit/hyperactivity disorder (ADHD) (e.g. Bauermeister et al., 2012; Langberg, Becker & Dvorsky, 2013; Mueller et al., 2014; Penny et al., 2009), but is nowadays recognized in other patient populations as well (children with Fetal Alcohol Syndrome: Graham et al., 2013; survivors of lymphoblastic leukemia: Reeves et al., 2007; clinically distressed children: Becker et al. 2013). SCT has been shown to impact on many facets of the individual’s life, such as academic- (Langberg, Becker & Dvorsky, 2013) and social functioning (e.g. Bauermeister et al., 2005; Becker et al., 2013; Penny et al., 2009), as well as on general mental well-being (e.g. Becker et al., 2013; Jacobson et al., 2012). It has further been shown that SCT, beyond symptoms of inattention and hyperactive-impulsive symptoms of individuals with ADHD, relates to academic achievements (e.g., mathematics: Bauermeister et al. 2012; linguistic processing: McConaughy et al., 2009) and general initiative taking in classroom situations (Jacobson et al., 2012; Langberg, Becker & Dvorsky, 2013). With regard to the social functioning of individuals with SCT, it was observed that children with the inattentive type of ADHD (ADHD/I) and symptoms of SCT are more likely to be socially withdrawn (e.g. Carlson & Mann, 2002; Marshall et al., 2013) and are more anxious in social interactions (Carlson & Mann, 2002), than children with the inattentive type of ADHD (ADHD/I) without additional SCT symptoms. It was found that SCT correlated highly with symptoms of depression and anxiety (e.g., Bauermeister et al., 2012; Becker et al., 2013; Carlson & Mann, 2002; Garner et al., 2010; Penny et al., 2009; Schatz & Rostain, 2006). So far, it is known that symptoms of SCT can be associated with certain cognitive impairments but not with others. For example, it has repeatedly been shown that SCT is associated with an impairment of sustained attention (e.g., Harrington et al., 2010; Skirbekk et al., 2011; Wåhlstedt & Bohlin, 2010). However, findings supporting a relationship between SCT and processing speed (e.g., Bauermeister et al., 2012; Barkley, DuPaul & McMurray, 1990; Carlson & Mann, 2002) and cognitive- or behavioral speed (e.g., Solanto et al., 2008) remain inconsistent. The current study is going to assess a possible relationship between SCT and subjectively reported everyday-timing functioning in adults in order to address the lack of data on processing speed and SCT in adults.

Moreover, another measure will be applied that also gives insight into the timing of motor movements and SCT. All of the to be tested relationships will be based on self-report only, as it has been shown that associations can be identified the best if the same measurement tool has been applied (e.g., data from self-report questionnaire 1 and its association to data from questionnaire 2 and not data from questionnaire 1 and its association with data obtained by objective cognitive testing: Barkley & Fischer, 2011).

Studies measuring SCT, however, face one major limitation, which may also partly contribute to inconsistent findings in previous studies. This limitation refers to the fact that there is as of yet no agreement on how to measure SCT (e.g., Becker et al., 2018; Mueller et al., 2014). So far, a variety of SCT scales have been introduced (e.g., Barkley, 2012; Becker et al., 2018; Penny et al., 2009) but no consensus on which items are indicative for SCT or which classification criteria (e.g. cut-offs) should be applied in order to determine if someone is presenting with SCT. So far, only a limited amount of authors presented cut-off criteria (Table 1. Overview of classification criteria across studies).

Similar limited as the attempts to provide classification criteria, has been the attempt to estimate how many individuals present with SCT, if diagnostic criteria were available. One attempt has been made by Barkley (2012), who proposed a cut-off score of 5 out of 9 SCT symptoms for a diagnosis of SCT. Such a cut-off score would result in 5.1% individuals of the general population meeting diagnostic criteria for SCT. However, the suggested scale and cut-off criteria by Barkley (2012) has not been used in clinical research, yet. Furthermore, its utility has not been examined in comparison with other scales' sensitivity and specificity in measuring SCT.

Table 1. Overview of classification criteria across studies

Authors	SCT items used	Classification criteria to detect SCT
Becker et al. 2014	8 out of the 14 items of Penny et al. 2009 Mean score of these 8 items was used as indicative for SCT: 1. Appears to be sluggish; 2. Seems drowsy; 3. Daydreamy; 4. Appears tired, lethargic; 5. Seems to be in a world of his or her own; 6. Has a yawning, stretching or sleepy-eyed appearance; 7. Is underactive, slow moving, or lacks energy; 8. Gets lost in his or her own thoughts;	SCT is considered as high if participants score larger than one standard deviation above the group mean.
Capdevila-Brophy et al. 2014	SCT items of CBCL/6-18 (Achenbach 2001) 1. Confused or seems to be in a fog 2. Daydreams or gets lost in his/her thoughts 3. Stares blankly 4. Underactive, slow moving, or lacks energy	SCT is considered as high if participants score 0.5 standard deviations above the group mean.
Barkley 2013	12 items of the 14 item SCT scale by Penny et al. 2009 1. Appears to be sluggish 2. Is apathetic; shows little interest in things or activities 3. Appears tired; lethargic 4. Seems to be in a world of his or her own 5. Seems drowsy 6. Daydreams 7. Gets lost in his or her own thoughts 8. Is unmotivated 9. Underactive, slow moving, or lacks energy 10. Needs extra time for assignments 11. Effort fades quickly 12. Yawning, stretching, sleepy-eyed Appearance	SCT is considered as high if participants rated 3 or more symptoms of SCT as <i>often</i> or <i>very often</i> .
Willcutt et al. 2014	Nine potential SCT items were developed based on theoretical models of SCT and items used in previous studies of ADHD and SCT (e.g. Carlson & Mann 2002; McBurnett et al. 2001; Penny et al. 2009). No further information is given	SCT is considered as high if participants score larger than one standard deviation above the group mean.
Watabe et al. 2013	1. Daydreams 2. Forgetful 3. Sluggish/drowsy	SCT is considered as high if participants endorsed 2 out of 3 SCT items as <i>pretty much</i> or <i>very much</i> .
Huang-Pollock, Nigg & Carr 2005	1. Stares into space/ daydreams 2. Low in energy, sluggish or drowsy 3. Apathetic or unmotivated to engage in goal-directed activities	SCT is considered as high if participants score larger than one standard deviation above the group mean.
Harrington & Waldman 2009	1. Forgetful, forgets what he or she is doing during daily activities,	The high-SCT ADHD/IT group has higher mean levels of SCT than the low-SCT ADHD/IT group.

	2. Daydreams, stares into space and daydreams 3. Sluggish or drowsy, seems to be tired, sleepy, or have no energy	Hence, categorization was based on the group mean.
Garner et al. 2010	1. Confused, seems lost in a fog 2. Daydreams or gets lost in his or her thoughts 3. Apathetic or unmotivated 4. Stares blankly 5. Underactive, slow moving or lacks energy	The high-SCT group has higher SCT levels than the low-SCT group. Hence, categorization was based on median split.
Carlson & Mann 2002	SCT scale based on Teacher Rater Form of Achenbach 1991 1. Confused, seems lost in a fog 2. Daydreams or gets lost in his or her thoughts 3. Apathetic or unmotivated 4. Stares blankly 5. Underactive, slow moving or lacks energy	SCT is considered as being high if participants endorsed 2 items with <i>very much</i> .
Barkley 2011	1. Prone to daydreaming 2. Trouble staying alert 3. Easily confused 4. Easily bored 5. Spacey or in a fog 6. Lethargic, more tired than others 7. Underactive, having less energy than others 8. Slow moving 9. Don't seem to process information as quickly or as accurately as others.	SCT is considered as being present if participants endorse 5 or more out of the 9 items.
Ludwig 2009	1. Being confused or lost 2. Daydreaming 3. Stares 4. Drowsiness	SCT is considered as being present if participants endorse 1 or more out of the 4 items.

The items that have been used across studies to measure SCT do not only differ in number but also in content. For example, while SCT was initially measured by four items (“difficulty following instructions”, “sluggishness”, “drowsiness”, “absent-minded, forgetful” (Lahey et al. 1987) its measurement was later reduced to two (“daydreams”, “is low of energy”: Bauermeister et al., 2005; Burns et al., 1997; Carlson & Mann, 2002; Solanto et al., 2008; Todd et al., 2004) or expanded to up to 17 items (e.g., McBurnett et al., 2001; Pfflner et al., 2007; Skirbekk et al., 2011). Moreover, while a majority of studies incorporated items such as “feeling sluggish” (e.g., Becker & Langberg, 2013; Becker et al., 2013; Combs et al. 2014; Graham et al. 2013) or “daydreaming” (e.g., Barkley, 2012; Bauermeister et al., 2012; Capdevila-Brophy et al., 2014; Carlson & Mann, 2002), a minority of studies included more rare items such as “effort fades quickly” (e.g., Langberg, Becker & Dvorsky, 2013; Penny et al., 2009) or “needs extra time in accomplishing tasks, being delayed” (e.g., Jacobson et al., 2012; Penny et al., 2009). Despite this variability in the measurement of SCT, three items or categories of items

(“daydreaming”, “sluggish/drowsy”, “underactive/apathetic”) have consistently been found to contribute to the identification of SCT in children (e.g., Bauermeister et al., 2012; Hartman et al., 2004; Penny et al., 2009; McBurnett et al., 2001) and adults (Barkley, 2012). More recently, a meta-analysis of all items that have been previously used (150 items in total) showed that the high amount of items could be broken down to 18 core features of SCT (Becker et al., 2016). Further support for either 16, 11 or 13 items that are measuring SCT were given by Becker and colleagues (e.g., Becker, Leopold et al., 2016; Becker et al., 2018; Becker & Willcutt, 2019).

However, none of the included study by the meta-analysis made use of all of the 18 items (Becker et al., 2016). The current study took these 18 core features into account but expanded its scale by taking items into consideration that are measuring working behavior as suggested by Penny and colleagues (2009). This was decided on as the focus of the current study was on possible effects of SCT on adult functioning in everyday life (including tasks put forward by a working environment). Please see Table 2 for an overview of the 26 items that were identified to be commonly used in previous studies and which were therefore used in the current study.

Table 2. Overview of SCT item content and corresponding authors

Content of Items	Corresponding authors (please see footnote below for the listed numbers and their corresponding study)
1. feeling sluggish (sluggish)	10-18, 20, 21, 25-29, 30, 31, 34, 36, -41, 44-46, 48,
2. being apathetic; lacking interest (apathetic/unmotivated)	8-18, 24, 25, 28, - 31, 34, 35, 38- 41
3. feeling tired; lethargic (tired/lethargic)	1-7, 10-18, 25, 26, 29- 31, 39- 41, 43
4. leaving the impression of being in your own world (lost in thoughts)	10, 13, 18, 29-31
5. being sleepy, drowsy (sleepy/drowsy)	10-18, 20-23, 35, 26-34, 38, 39, 44, 45-48
6. daydreaming (daydreams)	1-34, 36-48,
7. losing track in your own thoughts (loses train of thought/loses cognitive set)	22,23, 32-34, 39,40, 45
8. being unmotivated	8-19, 24, 28-31, 38- 40,
9. moving slowly, lacking energy (underactive/slow moving)	1-19, 22-25, 29, 30-33, 36, 37, 39-42-45,
10. needing extra time to accomplish tasks (slow work/task completion)	29-31, 39, 40, 45
11. lacking initiative to finish work (low initiative and persistence)	1-18, 30-32, 39, 40, 45
12. efforts fade quickly (low initiative and persistence)	10-18, 30, 31, 39, 40
13. stretching, yawning, looking sleepy (in a fog)	10-18, 29-31 39, 40
14. slow in accomplishing tasks, delaying tasks (slow work/task completion)	10-18, 30, 31, 39, 40, 45
15. staring blankly (stares blankly)	10-19, 24-26, 28, 34, 39, 41-45, 47, 48
16. being easily distracted, confused (easily confused)	1-23, 26, 27, 30- 32,39, 43, 45, 48
17. losing track while listening (loses train of thought/loses cognitive set)	6, 22, 23, 39, 45,
18. needs to be remembered to be alert (spacey/alertness changes from moment to moment); (absentmindedness)	32, 39,
19. work varies qualitatively and/or quantitatively	1-18,38, 39, 45
20. work is messy	39*
21. work is incomplete	39*,45
22. sleeping during work	39*
23. excessive sleeping during the day	39*
24. losing track during daily activities or conversations (loses train of thought/loses cognitive set)	26, 36, 37, 41,
25. preferring random changes in daily activities	39*
26. needs to be remembered to start working	39*

*was deleted during the factor analysis by Penny et al. 2009, but suggested in their initial collection of items that might represent SCT; items written in (..) are the items as suggested by Becker et al. 2016

¹Barkley et al., 1997; ²Barkley, DuPaul & McMurray, 1991; ³Barkley, 2006; ⁴Barkley, 2012; ⁵Barkley & Fischer, 2011; ⁶Barkley, 2013; ⁷Bauermeister et al., 2012; ⁸Bauermeister et al., 2005; ⁹Becker & Langberg, 2013; ¹⁰Becker et al., 2013a; ¹¹Becker et al., 2013b; ¹²Becker, 2014; ¹³Becker & Langberg, 2014; ¹⁴Becker et al., 2014a; ¹⁵Becker, Luebbe & Langberg, 2014; ¹⁶Becker et al., 2014b; ¹⁷Becker, Luebbe & Joyce, 2015; ¹⁸Berlin & Rolls, 2004; ¹⁹Carlson & Mann, 2002; ²⁰Combs et al., 2015; ²¹Comrey & Lee, 2013; ²²Del Mar Bernad et al., 2014; ²³Desman, Petermann, & Hampel, 2008; ²⁴Graham et al., 2013; ²⁵Harrington & Waldman, 2010; ²⁶Hartman et al., 2004; ²⁷Hinshaw et al., 2007; ²⁸Jacobson et al., 2012; ²⁹Jiménez et al., 2013; ³⁰Langberg, Becker & Dvorsky., 2014; ³¹Lee et al., 2013; ³²Leopold et al., 2015; ³³Ludwig et al., 2009; ³⁴Maloney et al., 2009; ³⁵McBurnett, Pfiffner & Frick, 2001; ³⁶McBurnett et al., 2014; ³⁷McConaughy et al., 2009; ³⁸Milev, Arndt & Andreasen, 2005; ³⁹Penny et al., 2009; ⁴⁰Pfiffner et al., 2007; ⁴¹Raiker et al., 2014; ⁴²Reeves et al., 2007; ⁴³Schatz & Rostain, 2006; ⁴⁴Skirbekk et al., 2011; ⁴⁵Solanto et al., 2008; ⁴⁶Spencer, Biederman & Mick, 2007; ⁴⁷Wahlstedt & Bohlin, 2010; ⁴⁸Watabe et al., 2013

Please note, the items *absentmindedness*, *easily bored* and *poor listening/difficulty with directions*, which were used by Becker and colleagues (2016) were not included in our questionnaire. However, as results by Becker and colleagues (2016) shows, the mentioned items did not load on any SCT factor. It can be concluded that, there is little evidence so far indicating which selection of items actually captures SCT adequately.

Moreover, the psychometric properties of the majority of scales used to date have not yet been examined sufficiently. For example, analyses of the convergent or divergent validity of SCT are often lacking. Only one study so far provided insight into the convergent validity (5-item SCT scale by Hartman et al., 2004). The authors showed that SCT correlated strongly with one of the factors of the Child Behavior Checklist (CBCL; Achenbach, 1991) that is assumed to represent physical and cognitive sluggishness (Hartman et al., 2004). Even though previous research demonstrated that SCT is highly associated with ADHD (e.g. Barkley, 2013; Müller et al., 2014) and deficits in sustained attention (e.g., Harrington et al., 2010; Skirbekk et al., 2011; Wåhlstedt & Bohlin, 2010), only a minority of studies actually assessed the association between SCT and attentional functioning (e.g., Carlson & Mann, 2002; Harrington & Waldmann, 2010; Skirbekk et al., 2011), which would provide further evidence for the construct validity of SCT. Wåhlstedt and Bohlin (2010) for example showed that symptoms of SCT were associated with children's performance on a Go/No-go paradigm that measured sustained attention independently of comorbid symptoms of ADHD. Hence, even though there might be an overlap between symptoms of SCT and ADHD (e.g., Penny et al., 2009; Wåhlstedt & Bohlin, 2010), cognitive impairments that can only be linked to SCT were found. It was further shown that some of the SCT subscales presented with good discriminant validity with hyperactivity symptoms as seen in ADHD (Penny et al., 2009). This finding was recently supported by an extensive meta-analysis by Becker and colleagues (2016) that showed that almost all (but two) previous studies assume that items can be identified that load on a SCT factor that is distinct from ADHD symptoms of inattention (ADHD/I) and hyperactivity-impulsivity (ADHD/HI). Based on these findings, it can be concluded that SCT can be distinguished from ADHD and even present with distinct neurocognitive characteristics.

It should be pointed out that only a minority of studies (12 out of 73 studies as reviewed by Becker et al., 2016) assessed SCT in adults. Three out of these 12 studies showed that SCT symptoms can be differentiated from ADHD/I symptoms in adulthood (Barkley, 2012; Becker et al., 2014; Leopold et al., 2015). The current study assesses the responses of adults only. We therefore hope to provide further data on SCT in adulthood.

Finally, the majority of studies on SCT that examined psychometric parameters of SCT

provided data of non-clinical respondents (e.g. Becker et al., 2016; 2017; Carlson & Mann, 2002; Skansgaard et al., 1998; Schaughency et al., 1992; Todd et al., 2004). If some degree of psychometric evidence is indeed found based on non-clinical samples, a subsequent step should include the assessment of clinical populations in order to explore the validity of SCT in a clinical setting.

It can be concluded that, although a variety of SCT scales are available (Becker et al., 2016; 2017; Mueller et al., 2014), no clinical or scientific consensus on how to measure SCT has been reached (Becker et al., 2016; Mueller et al., 2014). Furthermore, only a minority of previously used scales have been compared to other questionnaires measuring (cognitive-) impairments. Such comparison would provide a great insight into the construct validity of SCT. The current study aims to address this gap and examines the psychometric and construct validity of previously used SCT items in adults. The current study therefore addressed some of the limitations of previous research by challenging the contents of previously used SCT items (N=26) the content of which is in line with most recently tested SCT items (Becker et al. 2016) that have been shown to present with adequate divergent and convergent construct validity. As the current study made use of an adult sample we reasoned that it would be interesting to add items of previous SCT studies that were related to work parameters (e.g., “work varies qualitatively and or quantitatively” (e.g., Becker, Luebbe & Langberg, 2014; Becker, Luebbe & Joyce, 2015; Berlin & Rolls, 2004), “work is messy” (Penny et al., 2009), “work is incomplete” (Penny et al., 2009; Solanto et al., 2008), in order to see whether these items load on a SCT factor in adults. These items were administered to a large non-clinical adult sample (N=577). By means of an exploratory factor-analysis, the items were psychometrically tested in the non-clinical sample. The resulting set of items and the emerging subscales were then tested for a possible association with attentional functioning (construct validity) as well as with everyday-functioning in timing parameters, as SCT has been associated with slowed processing speed (construct validity).

4.3. Method

4.3.1. Participants

A total of 588 adult participants completed demographic questions on their general background information, and the set of questionnaires on Sluggish Cognitive Tempo, everyday timing behavior and attentional functioning. Data inspection based on boxplots of the individuals' SCT sum scores (the total score of SCT symptoms) showed that 11 participants should be excluded from further analysis due to their extreme responses (SCT sum score > 3 SD from the mean of

SCT). The extreme responses were most likely due to a lack of interest in sincerely filling out the questionnaires. The 11 participants did not only fill out the questionnaires in a suspicious fast time (< than 3 SD of the mean time required to fill out the questionnaire) but also presented with large omissions of questions. The exclusion of these participants reduced the original dataset of N=588 to N=577. The 577 respondents were first-year undergraduate psychology students of the University of Groningen, The Netherlands. The respondents' age ranged from 17 to 43 with a mean age of 19.85 years (SD=2.01). The sample consisted of 178 males (30.85%) and 399 females (69.15%). None of the participants reported a former or current diagnosis of any psychiatric disorder, and/or the current use of psychopharmacological medication. We were surprised by the fact that none of the students reported any current or former psychiatric disorder. However, from other studies conducted at our department it seems to be quite common, that students at the beginning of their academic career report similar numbers of absence of psychiatric disorders. However, as students are not yet that familiar with replying to questionnaires that are handed to them by the university in their first year might cause at least some bias due to social desirability. Even though the questionnaires were filled in anonymously students might be afraid to fully disclose, as they are not yet aware what their data might be used for.

4.4. Measures

4.4.1. Demographic questionnaire

8 demographic questions (i.e. on age, gender and nationality) were asked in order to obtain general background information of participants. Participants were also asked to indicate former or current psychiatric diagnosis and, if applicable, current use of medication.

4.4.2. Items of Sluggish Cognitive Tempo (SCT)

Based on an extensive literature review on SCT and its measurements, 26 items were identified that were used in previous studies on SCT until the end of 2016. These items are highly in line with a more recently published study that suggested 18 main features that are measuring SCT (Becker et al., 2016). Please see Table 2 for an overview of the SCT item content and the corresponding authors who either initially suggested the relevant SCT items or used them in their studies. Next, the items were randomly ordered and transformed into statements to which the respondents were asked to indicate how often they experience the described situation/symptoms. The questionnaire utilises a 6-point-Likert-scale (0= never, 1= seldom, 2=sometimes, 3=often, 4=very often, 5= always), with higher scores being indicative for a more

frequent, hence, stronger experience of SCT symptoms. The SCT questionnaire used in this study was designed as a self-administered scale that takes less than five minutes to complete. The items were phrased as neutral as possible with respect to the respondents' age (e.g. "I finish tasks slowly [...]"), or "The result of my work varies qualitatively or quantitatively").

4.4.3. The Barratt Impulsivity Scale (BIS-II)

The BIS-II (Patton, Stanford & Barratt 1995) consists of 30 questions that measure different aspects of impulsivity, of which attentional functioning is one. The BIS-II is a well-validated scale (e.g., Patton, Stanford & Barratt, 1995) that comprises three subscales; attention, motor and non-planning. The attention scale measures the ability to focus on one specific task and to handle intruding thoughts. The motor scale measures speed of acting and stability in the accomplishment of daily activities. The non-planning scale measures the ability and willingness to act independently as well as the appreciation of mental challenges (Reise, Moore, Sabb, Brown & London, 2013). The current study focused particularly on the subscales Attention and Non-planning as these functions have been shown to be crucial in attentional disorders (e.g., Barkley, 2012). The BIS-II makes use of a 4-point-Likert scale. The participants had to indicate how often they display a certain behavior (1="Never" to 4="Always"). Total sum scores of the BIS-II range from 30 to 120 and there is no established cut-off score. To identify individuals that score high or low on the trait impulsivity, the use of the 25th and 75th percentile, respectively, is recommended (e.g., Baca-Garcia et al., 2004; Maloney et al., 2009).

4.4.4. The 'It's all about time' questionnaire (IAT)

The IAT (Barkley, Koplowitz, Anderson & McMurray, 1997) contains 25 items and assesses the following aspects: (1) ability to judge the passage of time, (2) awareness of the passage of time, (3) how often participants are prepared for deadlines concerning work assignments, (4) how far in advance participants begin preparing for assignments having deadlines, (5) how often participants used retrospection or the recall of past events before responding in situations, (6) how often participants use prospection or the anticipation of future events before responding, (7) how frequently participants speak about time with others, and (8) the extent to which distractions interfered with participants' ability to accurately assess the passage of time (Barkley, Koplowitz, Anderson & McMurray, 1997). Respondents' answers (with the exception of answers to item 15 and 25) were scored on a 4-point-Likert-scale ranging from 1= rarely to 4= almost always. Respondents were asked to indicate how often they experience the aspects mentioned above (1-8). Item 15 asks respondents to indicate how fast they start working on a project if the deadline of the project is within a week. Item 25 asks respondents to evaluate

the quality of their time perception in comparison to their peers. Both items are not included in the scoring of the IAT. In the present study, the sum score of the IAT (*IAT total*) is understood as being indicative of the individual's functioning on tasks of everyday timing behavior.

4.5. Procedure

All participants were invited to take part in the study on a voluntary basis. Non-clinical participants were credited towards a study requirement. The time to complete the questionnaires was estimated to take around 40 minutes. Participants were informed about the aim of the study and it was emphasized that all data would be analyzed anonymously.

4.6. Ethics statement

The study concerning the non-clinical sample was approved by the Ethical Committee Psychology (ECP) affiliated to the University of Groningen, the Netherlands. Before taking part in the study, participants were required to read and acknowledge an information sheet prior to completion of the questionnaire. Formal written consent was not sought for the non-clinical participants; submission of completed questionnaires was taken as implied consent.

4.7. Data Analysis

All analyses were performed using Statistical Package for the Social Sciences (SPSS) Version 23 for Windows (IBM Corp., 2014).

4.7.1. Previously used scales for measuring SCT.

The existing literature on SCT was scanned in order to identify a set of items that was used in research up to the time the analysis of the literature took place (2016) (please see Table 3 for an overview of SCT item content and the corresponding authors who made use of the particular items).

4.7.2. Development of a new scale for measuring SCT (SCT-QA)

Exploratory factor analysis (EFA) was performed on the data of the non-clinical student sample in order to assess the psychometric structure of the initial set of SCT items. For EFA, a principal axis factoring (PAF) was applied using oblique rotation (PROMAX in SPSS). The sample consisted of 577 participants. According to Comrey and Lee's (2013) classification, a sample of $n \geq 500$ represents a "very good" sample size. PAF gives information about the ratio of an item's unique variance to its shared variance, which is called communality (Samuels, 2016). EFAs aspire to identify items with shared variance. Any items that presented with

communalities lower than 0.2 therefore should be removed (Child, 2006 in Samuels, 2016). The oblique rotation often improves the intercorrelation between the items within the different factors (Samuels, 2016). According to advices by Samuel (2016) factors with eigenvalues bigger than 1 were retained. As a next step, item loadings of each factor were examined. Items with loadings $<.3$ on any factor were removed and the analysis re-run. The next step was, to remove items with loadings $<.4$ on any factor one at a time. This was done for items one at a time in reverse order of highest factor loading (Samuel, 2016). The factors that will finally be selected should consist of at least 3 items with loadings $>.4$. Moreover, as a rule of thumb, the retained factors should explain at least 50% of the total variance (Streiner, 1994 in Samuel, 2016).

4.7.3. Internal consistency

Cronbach's alpha (Cronbach's α) was calculated for the total scale and the subscales of the SCT-QA as a measure of internal consistency.

4.7.4. Associations with other scales of cognitive functioning (construct validity)

Pearson's rank correlations (Bonferroni-Holm adjusted) were performed to analyze the associations between the sum score of the SCT-QA (*SCT-QA total*) and BIS-II subscales and *SCT-QA total* and *IAT total*. The subscales of the SCT-QA were correlated with the BIS-II subscales and with the IAT total, as well. Furthermore, the variables age and IQ were correlated with the above-mentioned variables as well.

4.7.5. Effect sizes.

Effect sizes are reported for bivariate associations according to Cohen (1988).

4.8. Results

4.8.1. Development of a new scale for measuring SCT (SCT-QA)

Psychometric properties were quantified by making use of a PAF with oblique rotation. A Kaiser-Meyer-Olkin value of .89 indicated *meritorious* sampling adequacy according to Kaiser (1974). Bartlett's test of sphericity indicated that correlations between items were sufficiently large for PCA ($\chi^2(120)=2323.83, p<.001$). Following the procedure as described in the section on data analysis, the extraction of three psychological meaningful factors that consisted of a total of 16 items was justified. The eigenvalues of these 3 factors were > 1.12 . The 3 factors were interpreted as representing the following psychological constructs (questionnaire subscales): *sluggish- & sleepiness* (items: 3, 9, 5, 1, 2, 13), *lacking persistency & motivation* (items: 11, 12, 26, 8, 19, 14), and *mind wandering & lacking concentration* (items: 17, 24, 16,

10). By following the method of Samuels (2017) it was aspired to reduce cross loadings of items between scales, however, the item “being unmotivated” loaded on both subscales: sluggishness- & sleepiness and lacking persistency & motivation. We decided to assign this item to the scale that corresponds to its content. Hence, the item “being unmotivated” became part of the subscale lacking persistency & motivation. Table 3 shows the factor loadings of the PAF.

Table 3. Summary of results of the PAF

Items	Factor loadings on each factor		
	1	2	3
3. Feeling tired, lethargic	.76		
9. Moving slowly, lacking energy	.72		
5. Being sleepy, drowsy	.56		
1. Feeling sluggish	.56		
2. Being apathetic, lacking interest	.51		
13. Stretching, yawning, looking sleepy	.44		
11. Lacking initiative to finish work		.82	
12. Efforts fade quickly		.62	
26. Needs to be remembered to start working		.47	.32
8. Being unmotivated	.41	.45	
19. Work varies qualitatively and or quantitatively		.34	
14. Slow in accomplishing tasks, delaying tasks		.33	
17. Loosing track while listening			.59
24. Loosing track during daily activities or conversations			.43
16. Being easily distracted, confused			.41
10. Needing extra time to accomplish tasks			.36
Eigenvalue	4.98	1.63	1.12
% explained variance	31.14	10.18	6.97

N=577, Cronbach's α Scale total = .84,

4.8.2. Internal Consistency

The overall scale reliability (internal consistency) of the 16 items was high (Cronbach's α = .84). The scale reliabilities of the three subscales (Cronbach's α) were .78 (*sluggish & sleepiness*), .75 (*lacking persistency & motivation*), and .59 (*mind wandering & lack of concentration*), respectively.

4.8.3. Associations with other scales of cognitive functioning (construct/divergent validity)

SCT-QA total, IAT total and the subscales of the BIS-II were largely normally distributed. Therefore, bivariate correlations using Pearson's rank correlations (Bonferroni-Holm adjusted) were calculated (Table 5). The SCT-QA total correlated negatively with the IAT total ($r(576) = -.30, p < 0.01$), indicating that the higher participants responded on SCT items, the less competent the respondents are in daily-life with respect to timing behavior. Furthermore, the SCT-QA total showed positive associations with all subscales of the BIS-II, showing that the higher participants responded on SCT items, the more difficulties in attentional functioning (BIS_ATTENTION), premature motor behavior (BIS_MOTOR) and failure in planning or the willingness to act independently (BIS_NONPLANNING) can be observed. All SCT-QA

subscales were significantly correlated with the subscales of the BIS-II. Hence, traits associated with *sluggish- & sleepiness* as well as traits associated with *lacking persistency & motivation* as well as traits that are typical for *mind wandering & lacking concentration* were found to be related to deficits in attentional, motor and planning behavior as measured by the BIS-II. Especially the association between all subscales and the premotor behavior further support the assumption that SCT is related to timing of motor behavior. Same holds true for the positive associations between all subscales and attentional functioning. Both findings clearly support the idea that SCT and attentional as well as timing processes are related. Furthermore, all subscales were negatively associated with the *IAT total*. This finding shows that the more SCT traits as measured by the individual subscales are present, the more deficits in everyday timing behavior can be expected. The variables Age and IQ did not correlate significantly with the subscales of the SCT-QA, the SCT-QA total or with subscales of the BIS-II. Age correlated negatively with the *IAT total*. However, when exploring the possible effects of age and IAT total on the SCT total or the SCT subscales by means of linear regression the effects were not significant. Hence, we can assume that the correlation between Age and IAT total does not affect the results of the subsequent analyses. Please see Table 4 for all bivariate associations of the variables under investigation.

Table 4. Pearson's rank correlations (Bonferroni-Holm adjusted) between *SCT-QA total*, SCT-QA subscales and the *IAT total* and between the *SCT-QA total*, SCT-QA subscales and the subscales of the BIS-II

SCT-QA Subscales	BIS ATTENTION	BIS MOT OR	BIS NONPLAN NING	<i>IAT</i> <i>total</i>	<i>SCT-QA total</i>	Age	IQ
<i>sluggish- & sleepiness</i>	.33**	.10*	.18**	-.16**	.81**	-.001	-.03
<i>lacking persistency & motivation</i>	.42**	.25**	.41**	-.34**	.87**	.05	.06
<i>mind wandering & lack of concentration</i>	.51**	.20**	.24**	-.23**	.76**	.03	.05
<i>SCT-QA total</i>	.50**	.22**	.35**	-.30**	--	.03	.03
Age	.03	.06	.05	-.12**	.03	--	--
IQ	.01	-.004	-.01	.02	.03	--	--

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed)

All significant correlations between the *SCT-QA total*, the *IAT total* and the BIS-II subscales presented with small to medium effect sizes (Cohen 1988). The associations between the subscales of the SCT-QA with the *SCT-QA total* present large effect sizes (Cohen 1988). The

effect sizes of the correlations of the SCT-QA subscale *sluggish- & sleepiness* with the subscales of the BIS-II were small. The significant association between the SCT-QA subscale *lacking persistency & motivation* and the subscales of the BIS-II presented with small effect sizes. The associations between the SCT-QA subscale *mind wandering & lack of concentration* and BIS MOTOR and BIS NONPLANNING presented with small effect sizes, too. The association between the SCT-QA subscale *mind wandering & lack of concentration* and BIS ATTENTION presented with a medium effect size.

4.9. Discussion

The study's aim was to broaden the insights on SCT's convergent validity in adulthood. For this reason a questionnaire was composed that encompassed previously used SCT items. This questionnaire was tested for its psychometric properties and convergent validity of SCT in non-clinical adults.

4.9.1. Factor-structure of the SCT-QA scale

The PAF resulted in a reduction of the previously 26 items to a 16-item questionnaire. It was shown that three psychologically meaningful subscales can be derived from the responses to the questionnaire. The subscales were labelled as followed: *sluggish- & sleepiness*, *lacking persistency & motivation*, and *mind wandering & lack of concentration*. Most recently, Becker and colleagues (2016) theoretically approached the lack of consensus in measuring SCT in form of a critical review and meta-analysis. In their review, the authors compared 26 studies, which analysed their data using factor analytic approaches. Based on this review, Becker and colleagues (2016) concluded that a set of 13 items would measure SCT adequately. These 13 items were consistently associated with an SCT factor, which was found to be independent from inattention or hyperactivity-impulsivity symptoms in 24 of the 26 reviewed studies (Becker et al., 2016). Hence, this review provided further support for the assumption that SCT is distinct from ADHD. The retained items by Becker and colleagues (2016) were highly in line with the items that were retained by the current PAF. However, the current study did find evidence for retaining the item easily confused, which is in contrast with studies that explicitly excluded this item (e.g., Penny et al., 2009) or did not retain it (Becker et al., 2016). The current study therefore provides empirical data in line with the proposed items from Becker and colleagues' (2016) critical review.

Becker and colleagues (2016) further showed that SCT scales of seven or more items present with an optimal reliability, whereas scales with three or less SCT items showed weaker

reliabilities. This observation is in agreement with the high reliability of 0.84 (Cronbach's α) as found in the present study's 16-item scale.

The current study's factor structure corresponds to earlier conceptions of SCT (e.g., Penny et al., 2009). Two of three frequently identified items in previous research to assess SCT ("daydreaming", "sluggish/drowsy", "underactive/apathetic"; e.g., Barkley, 2012; Bauermeister et al., 2012; Hartman et al., 2004; Penny et al., 2009; McBurnett et al., 2001) were also retained by the current PAF, with the items measuring sluggishness and being apathetic being part of the same factor in the current study.

Previous findings on whether to include the concepts of confusion (e.g. Hartmann et al., 2004) and/or forgetfulness (e.g., Piffner et al., 2007) in measuring SCT are still in contrast (e.g., Penny et al., 2009). Some of the studies on SCT (e.g., Penny et al., 2009) explicitly excluded these items, as they are part of the diagnostic criteria for ADHD/I (e.g., DSM-5, American Psychiatric Association, 2013). In the current study, the items measuring confusion ("loosing track while listening"; "loosing track during daily activities"; "being easily distracted", "confused"; "needing extra time to accomplish tasks") were initially considered in the item development phase and retained in the current factor structure. The content of the factor that also contains the item measuring confusion ("being easily distracted", "confused") was interpreted as measuring mind wandering activities or the lack of concentration. This lack of concentration is indeed typical for patients suffering from ADHD/I. However, the subscale nevertheless seems reasonable in the light of the suggestion by Barkley (2014) saying that SCT seems to be a purer form of concentration deficits. Future studies on patient populations have to show whether this assumption can be clinically validated.

A highlight of the current study was the detection of the subscale *lacking persistency & motivation*. No previous study explicitly elaborated on the concept of lacking persistency or lacking motivation in the context of SCT before. The lack of persistency is closely related to sustained attention deficits (as defined by a more pronounced decrease in task performance over time; e.g., Barkley, 1997; Sarter, Givens & Bruno, 2001), as well as to EF deficits (e.g., Anderson, 2002). The detection of this subscale could be on the one hand explained by the already established strong association between SCT and difficulties in sustained attention (e.g. Harrington & Waldman, 2010; Skirbekk et al., 2010; Wåhlstedt & Bohlin, 2010) or, on the other hand by an association between SCT and executive dysfunctioning (ED; Barkley, 2012). Alternatively, one may explain this association by the presence of both, difficulties in sustained attention and ED.

4.9.2. Associations of SCT and other cognitive functions

The convergent validity of SCT was further supported by the observed significant associations between overall SCT symptom severity and difficulties in attentional functioning, premature motor behavior, planning failures and difficulties in everyday timing behavior as derived from the responses of the non-clinical adults. These results give support to previous findings on the association between SCT and attentional dysfunctioning (e.g., Harrington & Waldman, 2010; Skirbekk et al., 2010; Wåhlstedt & Bohlin, 2010). Moreover, this is the first study showing associations between SCT and (self-reported) timing behavior. Given the finding of the current study that SCT is associated with subjectively reported difficulties in timing behavior, it can be hypothesized that the underlying (e.g., perceptual-, cognitive-, motor-) timing mechanisms are altered in clinical populations with SCT, which should be tested more objectively in the future by means of reaction time tasks. In the next chapter we will report on a study that focuses on SCT and its association with cognitive functioning and timing behavior (e.g., reaction times in a variety of cognitive tasks).

The pronounced associations of various cognitive functions (e.g. attention, planning) and motor behavior with the subscales of the SCT-QA could be interpreted as SCT being a multifaceted- rather than a homogeneous (uniform) concept. Especially the dimension of *mind wandering & lack of concentration* was strongly associated with difficulties in attentional functioning. This finding is in line with findings of previous research, which already demonstrated a link between mind wandering activities and attentional dysfunctioning (e.g., Bigelsen et al., 2009). Bigelsen and colleagues (2016) showed that excessive daydreaming was associated with significant attention deficits, symptoms of dissociation and obsessive-compulsive symptoms. Even though no study so far focused on the question whether SCT is associated with obsessive-compulsive symptoms, the current study provided evidence that SCT is associated with attentional deficits. Moreover, when having a close look at the retained items, some of the items could be indeed typical for signs of dissociative tendencies (e.g., “being apathetic” or “loosing track while listening/during daily activities”). All subscales of the SCT-QA correlated significantly with the subscales of the BIS-II. Even though the effect sizes were small to moderate according to Cohen (1988), this finding strengthens the already illustrated link between SCT and attentional functioning in general and a specific deficit in sustained attention (lack of persistency) as discussed above. It further shows that SCT also associates with premature motor behavior. Apparently, SCT does not only relate to pure cognitive functions (attention, including sustained attention) but also to motor behavior, which is the behavioral execution of a cognitive process. On the basis of correlations as discussed above, it

can be concluded that high responses on the SCT-QA are linked to cognitive- and motor-dysfunctioning in non-clinical adults.

Becker and colleagues (2016) discussed whether the concept of SCT fulfills criteria for adequate diagnostic validity as outlined by Cantwell and colleagues (1995). They concluded that the findings of previous studies on SCT generally provide support for these eight domains. However, they also noted that (a) there is a lack of longitudinal research (showing whether SCT has transdiagnostic utility), (b) there is a lack of research focusing on SCT in populations different from ADHD, (c) there is a lack of studies focusing on biological or genetic markers for SCT. And finally, (d) there is insufficient evidence for whether SCT should be treated as a uni- or multidimensional construct and whether individuals that fulfill certain symptom criteria of SCT can be distinguished from individuals suffering from ADHD, depression, anxiety or sleep disorders (Becker et al., 2016). The current study clearly gives more support for the idea that SCT is a multidimensional construct.

4.9.3. Limitations

The construct validity of SCT would be supported by showing convergent and discriminant validity. Even though evidence on the convergent validity is provided (by associations between SCT and attentional functioning), the present study failed to implement a measure that targets the discriminant validity. Future studies exploring the validity of SCT should therefore not only include measures that are assumed to be associated with SCT, but should also consider to include measures that are assumed to primarily load on different aspects of functioning (e.g., memory functioning), in order to define the construct of SCT more specifically.

Interpretations of convergent and divergent validity with regard to SCT become more complicated in the light of previous findings showing that SCT affects overall task performance by slowing down cognitive processes that are needed in performing the task, while not affecting the underlying cognitive function (Solanto et al., 2008). For example, it could be hypothesized that cognitive tasks that do not require a certain speed with which a reaction to the task is given would identify individuals with SCT less likely than tasks that indeed require a certain tempo in reacting to the task. Hence, memory tasks that not only require the participant to memorize and react to the memorized stimulus in a rather quick way (as the stimulus that needs to be remembered is presented only for a short amount of time and a quick reaction is needed) could result in a bad result for individuals suffering from SCT not because individuals with SCT are bad in remembering information but because they were too slow to react.

The assumption that SCT is slowing down cognitive processes in general, while sparing

the underlying cognitive function (Solanto et al., 2008) could motivate future studies to focus on time related processes within the assessment of various cognitive functions. If evidence can be revealed that the slowing down of task performance is indeed the major difficulty for individuals suffering from SCT across a variety of cognitive tasks, the initial assumption of a slowed processing speed (e.g., Barkley, 2012; Lahey et al., 1987) in SCT would be supported. Hence, if data shows that SCT does not relate to deficits in a specific cognitive domain but affects several cognitive domains rather indirectly because of the speed component that might be inherent to the accomplishment of the cognitive tasks, the slowed processing speed hypothesis would be supported. This issue cannot be explored on the basis of the present data as the current study did not include neuropsychological testing but based its results on self-report measures. Future research should study timing related parameters (e.g. reaction time) in objective neuropsychological test performances of individuals suffering from SCT and relate them to overall task performance.

Furthermore, it has previously been shown that SCT correlates highly with measures of depression and anxiety (e.g., Becker & Langberg, 2013; Penny et al., 2009; Schatz & Rostain, 2006). The current study did not assess current symptoms of depression or anxiety but merely asked participants to indicate whether they are suffering from or have suffered of any psychopathological disorder. In line with this, sleep deprivation and sleep disorders have been hypothesized to be associated with SCT symptoms (e.g., Becker et al., 2014; Langberg et al., 2014; Becker, Garner & Byars, 2016). It was pointed out that a high number of items that are used to describe SCT are also used in assessing daytime sleepiness (e.g., Cortese et al., 2009; Willoughby et al., 2008). Becker, Garner and Byars (2016) showed that the presence of SCT in children with clinical significant sleep disorders was associated with additional functional impairments independent of other psychopathological symptoms, such as depression, anxiety or hyperactive symptoms of ADHD. It can be assumed that the failure to control for symptoms of depression, anxiety, or abnormal sleep did not distort the present analysis considerably, given that statistics are based on a healthy group of individuals. However, further studies are needed in the clinical field in order to explore the associations between SCT and pathological levels of depression, anxiety, and abnormal sleep. Furthermore, it must be noted that clinical studies on SCT are difficult to perform as no established criteria exist, yet, of how to diagnose SCT in the clinical context. This being said, it should be pointed out that the origin of the SCT items varied considerably across previous studies. Whereas some studies made use of items that are believed to resemble SCT the most but which are originally created to measure ADHD according to the DSM (in its current form at that specific time) (e.g., McBurnett, Pfiffner & Frick, 2001; Mikami

et al., 2007), others, for example, made use of items of the Child Behavior Checklist (CBCL: Achenbach, 1991; Ludwig, 2009; Reeves et al., 2007), which again did not arise due to suspicious clinical observations that there might be a disorder that foremost relates to sluggishness. This leads to the assumption that SCT was originally considered as a set of comorbid symptoms of other pediatric disorders, such as ADHD (e.g., Barkley, 2013) and not as a disorder on its own. If SCT would have been arisen as a disorder on its own the spectrum of items for its assessment might have been broader in the first instance. Hence, it can be questioned whether the currently available set of SCT items does not miss out on items that might be very specific for measuring SCT. Only thorough clinical observations in the future will reveal whether other or new items are better suited for the measurement of SCT. Even though the current study provided a set of items that supports findings by previous studies, actual long-term observations of individuals that are likely to suffer from SCT should tell whether the concept of SCT holds up to clinical criteria

Finally, in the context of whether the SCT-QA could be applied and compared to other scales in a future clinical setting, it must be noted that it has been previously shown that various aspects of a Likert-scale can influence the respondents' answers to the item (e.g., Hitzenko, 2013) independent of the type of population you are assessing (e.g., clinical vs. non-clinical). For example, it was shown that the wording of the choices of the scale (e.g., Friedman, Herskovitz & Pollack, 1994; Schuman & Presser, 1996; Schwarz et al., 1991) and the number of options of responding (Dawes, 2008) impact on the respondents' answer to the items. More in detail, Dawes (2008) showed that 5- and 7-point scales can be rescaled from one to the other without distorting the data structure. However, a 10-point scale produced mean scores that were slightly but, nevertheless, significantly lower than those obtained with a 5- or 7-point scale; when all scales were re-scaled to a common metric (Dawes, 2008). A possible future comparison of diagnostic accuracies of various scales and classification criteria should be interpreted with caution given the fact that the present study employed a different scale (6-point) as compared to the majority of the previous studies on SCT (mostly 4-point) (e.g., Combs et al., 2014; Becker et al., 2018; Becker et al., 2016; Becker, Luebke & Langberg, 2014; Penny et al., 2009). Even though the criterion of 'item endorsement' was similar in the 6-point scale applied in the present study as compared to the 4-point scale of most previous research, we cannot exclude the possibility that the present sample responded differently to the 6-point Likert scale than they would have responded to a 4-point Likert scale. It can be speculated that responses as yielded from 6-point and 4-point scales are comparable given the findings of previous research showing comparable responses of 5-point and 7-point scales (Dawes, 2008).

However, future studies should bear in mind that the comparison of results of studies that used different types of Likert-scales is not without risks.

4.10. Overall conclusion

The findings of the current study provide support for the convergent validity of SCT. It was shown that SCT is not only associated with attentional functioning but also with timing behavior. Evidence was given that SCT is a rather multidimensional construct. Findings should be interpreted with caution as they are based on a non-clinical sample of adults. However, the finding that SCT relates to everyday timing behavior in adults should encourage future studies to measure timing functions in populations that are presenting with signs of SCT more objectively.

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Chapter 5

SLUGGISH COGNITIVE TEMPO: ITS MANIFESTATION IN COGNITIVE
FUNCTIONING AND ITS ASSOCIATION WITH TIMING BEHAVIOR

Keywords: Sluggish Cognitive Tempo, Adults, Neuropsychology, Cognition, Processing
Speed

Chapter 5 SLUGGISH COGNITIVE TEMPO: ITS MANIFESTATION IN COGNITIVE FUNCTIONING AND ITS ASSOCIATION WITH TIMING BEHAVIOR.

5.1. Abstract

Previous studies on Sluggish Cognitive Tempo (SCT) have suggested that SCT is associated with a substantial decrease in the speed of cognitive processing. However, most of the studies that reported decreased processing speed in SCT did not make use of objective cognitive tests but based their results on self-ratings of behavior or subjective observations. The current study explored performance on objectively measured, timing-related variables in cognitive functioning (e.g., reaction times and errors in various cognitive domains) in a clinical and a non-clinical sample of adults. The cognitive performance of the clinical and non-clinical adults was explored for its association with SCT. We found a marginally significant effect of SCT on cognitive task performance, which disappeared when Clinical Group was entered as a factor in the analysis. Furthermore, no evidence was found for an association between SCT and slowed processing speed, when measured objectively. We concluded that, if there is a relation between SCT and objective cognitive performance in adults, including processing speed, it is very weak. Future studies should expand their research on SCT to diverse clinical groups.

5.2. Introduction

5.2.1. Sluggish Cognitive Tempo (SCT)

Sluggish Cognitive Tempo (SCT) is a cognitive-emotive condition that became a major topic of interest in pediatric research during the last two decades (e.g., Becker, 2013; Becker et al., 2018; Mueller et al., 2014). SCT is characterized by symptoms such as “daydreaming”, “being confused”, “staring blankly”, “being sluggish” and “being unmotivated” (e.g., Lee et al., 2013; Mueller et al., 2014; Penny et al., 2009). The interpretation of studies on SCT is often difficult due to two major challenges. First, SCT has been originally and foremost tested in a very specific clinical population, namely children suffering from attention-deficit/hyperactivity disorder (ADHD) (e.g., Bauermeister et al., 2012; Langberg, Becker, Dvorsky, 2013; Mueller et al., 2014; Penny et al., 2009). Even more specifically, the majority of studies on SCT present findings of individuals diagnosed with the predominantly inattentive type of attention-deficit/hyperactivity disorder (ADHD/I) and high levels of SCT (e.g., Huang-Pollock et al., 2005; Weiler et al., 2002).

Secondly, many different instruments for measuring SCT have been used (e.g., Becker

et al., 2018; Becker, Leopold et. al., 2016; Mueller et al., 2014). Hence, an important challenge in research on SCT is the lack of agreement on how to measure SCT and there is no diagnostic consensus, that is, no agreement on cut-off scores (clinical versus non-clinical) of the various instruments. Various scales have been developed and tested for their psychometrical utility in measuring SCT (e.g., Barkley, 2012; Becker et al., 2018; Penny et al., 2009). Unfortunately, the majority of studies that developed an instrument that is supposed to measure SCT do not provide information about the convergent or divergent validity of their measurement. There was one study that showed that SCT correlated strongly with one of the factors of the Child Behavior Checklist (CBCL: Achenbach, 1991) which is assumed to represent physical and cognitive sluggishness in a community sample of twins (8-18 years old) that was over-selected for ADHD and learning disabilities (Hartman et al., 2004). The study showed that SCT emerged as a factor independent of DSM-IV inattention and hyperactivity-impulsivity symptoms as seen in clinical ADHD. Nevertheless, SCT correlated strongly with inattentive and combined symptoms of ADHD, making it hard to distinguish whether the SCT items measure symptoms of sluggishness/slowness that are different from those seen in ADHD. The authors concluded that SCT is an internally consistent construct that presents with significant associations with symptoms of inattention (Hartman et al., 2004).

More robust results were found when looking at SCTs discriminant validity (Penny et al., 2009). SCT had a significant negative association with ADHD/H and ODD even when controlling for ADHD/I symptoms, which was shown to be strongly related to SCT (Penny et al., 2009). Finally, symptoms of SCT were correlated with children's performance in a sustained attention task independent of their comorbid ADHD symptoms (Wåhlsted & Bohlin, 2010). This leads to the conclusion that even though there might be an overlap between symptoms of SCT and ADHD (e.g., Penny et al., 2009; Wåhlsted & Bohlin, 2010), impairments can be found that are independent of ADHD. These impairments were interpreted to be associated with SCT.

With regard to the clinical utility of the available SCT measures, studies focusing on patient populations are still missing (e.g., Becker et al., 2016; Mueller et al., 2014). In the rare cases in which SCT was assessed in a patient sample, it was done in children (with ADHD: Penny et al., 2009; children who survived leukemia: Reeves et al., 2007; and children with Fetal Alcohol Syndrome: Graham et al., 2013). A thorough meta-analysis by Becker and colleagues (2016) showed that only 12 out of 61 studies were done in adults. Three of these studies in adults found that SCT can be differentiated from ADHD/I symptoms (Barkley, 2012; Becker et al., 2014; Leopold et al., 2015), the remaining studies did not control for ADHD/I symptoms.

Notably, all of the mentioned studies were done in non-clinical samples and not in a clinical population. Studies in clinical populations, especially adult clinical populations, are missing.

5.2.2. *SCT and cognitive functioning.*

Previous studies suggested that SCT relates to decreased cognitive- and motor tempo (e.g., Solanto et al., 2008) and slowed information processing (e.g., Bauermeister et al., 2012; Barkley et al., 1990; Carlson et al., 2002). This previously proposed link between SCT and being cognitively and behaviorally slow is only rarely backed up by objective neuropsychological testing. Instead, the majority of studies based their results on self-rated or external-rated measures (teacher and parent ratings: e.g., Huang-Pollock et al., 2005; Solanto et al., 2008; Wählstedt et al., 2010). Studies that actually implemented objective neurocognitive testing to assess the impact of SCT on cognition (e.g., Desman et al., 2008; Hinshaw et al., 2007; Solanto et al., 2008) are few. Only 9 out of 32 studies on SCT present experimental data of objective neurocognitive testing (Please see Table 1. Previous studies and cognitive measures applied). Hence, much more objective experimental testing of patients' cognitive functioning who are likely to suffer from SCT is needed.

Table 1. Previous studies and cognitive measures applied

Author(s)	Sample(s)	SCT measure(s) ^a	Cognitive measure(s)
Weiler et al., 2002	Evaluated population: 230 children with ADHD Age range: 7.6-11.1 yrs. (111 males; 119 females) (a) ADHD (n=24) (b) Reading disability (RD) (n= 42) (c) Comorbid ADHD and RD (n=9) (d) Controls (n=149)	Class-room observations (Weiler et al., 2002)	Kaufman Brief Intelligence Test (K-BIT: Kaufman & Kaufman, 1990): IQ Visual Filtering Task (Weiler et al., 2002): Parallel search, Serial search, Decision and Motor response Rapid Auditory Processing Task (Waber et al., 2000): Auditory Processing, Decision and Motor response
Bauermeister et al., 2005	Evaluated population: 98 children, Age range: 6 - 11 yrs. (58 males; 40 females) (a) Inattentive and hyperactive group (n=47) (b) Inattentive only (n=44) (c) Control (n=29)	5-item SCT scale (SCT-5): "Confused or seems to be in a fog", "Daydreams or gets lost in his/her thoughts", "Stares blankly", "Underactive, slow moving or lacks energy", and "Apathetic or unmotivated"	Bender-Gestalt Test (BGT: Koppitz, 1975): Visual-motor integration Conners' Continuous Performance Test (CPT: Conners, 1995): Vigilance, impulsiveness
Huang-Pollock et al., 2005	Evaluated population: 79 children Age range: 8–12 yrs. (a) ADHD/I (n=16) (b) ADHD/C (n=28) (c) Control (n=35)	3-item SCT scale [Carlson & Mann, 2002; McBurnett et al., 2001]: "Stares into space/daydreams", "Low in energy, sluggish, or	Selective attention paradigm [Wechsler, 1991]: Selective attention

		drowsy”, “Apathetic or unmotivated to engage in goal-directed activities”	
Hinshaw et al., 2007	Evaluated population: 228 girls Age range: 6-12 yrs. (a) Psychiatrically-referred girls (n=140) (b) Controls (n=88)	Group of ADHD with SCT was formed based on: (a) presence of very few HI symptoms, (b) high levels of parent- and teacher- rated sluggish cognitive tempo	Taylor Complex Figure Test (TCFT: Taylor, 1969): Planning, perceptual organization, graphomotor abilities Conners’ CPT (Conners, 1995): Visual attention, set shifting Rapid Automatized Naming Test (RAN: Denckla & Rudel, 1974): Orienting, semantic processing and retrieval Underlining Test (Rourke & Gates, 1980; Rourke & Orr, 1977): Word recognition, controlled processing
Solanto et al., 2008	Evaluated population: 80 children Age range: 7-11 yrs. (43 males; 37 females) (a) ADHD/I (n=26) (b) ADHD/C (n=34) (c) No ADHD but other psychiatric condition (n=20)	2 Items of SNAP-IV Teacher and Parent Rating Scale (Swanson et al., 1983): “Stares into space and reports daydreaming”, “Appears to be low in energy levels, sluggish or drowsy”	Delay Aversion Test (DAT: Sonuga-Barke et al., 1992): Delay aversion Buschke Selective Reminding Test (Buschek & Fuld, 1974): Verbal learning and memory Visual Learning Test of the WRAML (VLT: Sheslow & Adams, 1990): Spatial memory Sternberg visual memory search task (Sternberg, 1969): Information-processing Stroop Color-Word Test (Golden, 1978): Cognitive flexibility, resistance to interference Conners’ Continuous Performance Test (CPT: Conners, 1994): Inhibitory control Posner Test (Posner & Petersen, 1990): Covert visuospatial orienting task Tower of London (TOL: Culbertson & Zilmer, 1998): Planning Stimulus–Response Processing Task (SRPT: Solanto et al., 2008): Target detection Wisconsin Card Sorting Test (WCST: Berg, 1948): Cognitive set shifting, inhibition Warned Simple Reaction Time Test (WSRT: Solanto et al., 2008): Reaction time

Desman et al., 2008	Evaluated population: 38 boys Age range: 8–12 yrs. (a) ADHD/I (n=19) (b) Controls (n=19)	Children with ADHD/I that responded slower on Go/No-Go paradigm in line with SCT symptomatology	The Go/No-Go paradigm of the Test Battery for Attentional Performance (TAP: [Zimmermann & Fimm, 1993, Zimmermann & Fimm, 1994]): Inhibitory control, interference Stroop-like day-night test (Gerstadt, Hong, Diamond, 1994; McInerney, Hrabok, Kerns, 2005): Inhibitory control Children’s Size-Ordering Task (Nigg, 2006): Working memory Pig House: Spatial working memory task Go-/No-go [van der Meere & Sergeant, 1988; Wilding, 2005]: Sustained attention, state regulation
Wählstedt et al., 2010	Evaluated Population: 209 children Age range: 8-9 yrs. (111 males; 98 females)	5 SCT items from Child Behavior Checklist (CBCL: Achenbach, 1991): “Confused or seems to be in a fog”, “Daydreams or gets lost in his/her thoughts”, “Stares blankly”, “Underactive, slow moving or lacks energy”, “Apathetic or unmotivated”	
Skirbekk et al., 2011	Evaluated population: 141 children Age range: 7-13 yrs. (90 males; 51 females) (a) ADHD and Anxiety disorder (n=25) (b) ADHD (n=39) (c) Anxiety disorder (n=41) (d) Controls (n=36)	17-item SCT scale (SCT-17: Pfiffner et al., 2007): “Daydreams”, “Stares into space”, “In a fog”, “Unresponsive”, “Easily confused”, “Mind wanders”, “Absentminded”, “Easily disoriented”, “Loses cognitive set”, “Gets tongue tied”, “Poor memory consolidation”, “Drowsy”, “Moves slowly”, “Works slowly and takes a long time to complete tasks”, “Gets tired easily”, “Low initiative”, “Poor time appreciation”. 5-item SCT scale from the Child Behavior Checklist [CBCL: Becekr & Langberg, 2013; Diamond, 2005]: “Sluggish/slow to respond”, “Seems to be in a fog”, “Drowsy or sleepy”, “Easily confused”, “Daydreams/stares into space”	Wechsler Abbreviated Scale of Intelligence (WASI: Wechsler, 1999): IQ Attention Network Test (ANT; Rueda et al., 2004): Reaction time Digit Span subtest of the WISC-III (Wechsler, 1991): Verbal memory span, working memory Adaptation of the Finger Windows subtest from the Wide Range Assessment of Memory and Learning (WRAML: Sheslow & Adams, 1990): Spatial memory
Bauermeister et al., 2012	Evaluated population: 140 children Age range 6-11 yrs. (87 males; 53 females)	4 Sluggish items from Child Behavior Checklist (CBCL: Achenbach, 1991): “Confused or seems to be in a fog”, “Daydreams or gets lost in his/her	Observed Behavior- Continuous Performance Test (CPT: Conners, 1995): Vigilance, impulsiveness Hand Movements Scale (HMS: Kaufman & Kaufman, 1983): Skilled

thoughts”, “Stares blankly” and “Underactive, slow moving, or lacks energy”	hand movement, nonverbal working memory, motor sequencing Simon Task (ST: Barkley et al., 2001): Nonverbal working memory Stroop Color-Word Test (SCWT: Golden, 1978): Interference control Wisconsin Selective Reminding Test (WSRT: Barkley, DuPaul, & McMurray, 1991): Verbal learning and memory test adapted from Buschke’s Selective Reminding Test (Newby, 1989) WISC-R PR Backward Digit Span Test (Herrans & Rodríguez, 1992) Verbal working memory Rapid Automatized Naming (RAN: Denckla & Rudel, 1974): Digit-, color-, object-naming
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Some studies that implemented objective cognitive testing in children pointed out that processing speed is suspiciously low in individuals that present with signs of SCT (e.g., Bauermeister et al., 2012; Barkley et al., 1990; Carlson et al., 2002). For example, children with ADHD/I and symptoms of SCT were shown to present with slower task performance and increased reaction times during objective, cognitive testing (Solanto et al., 2008; Huang-Pollock et al., 2005; Table 1). Solanto and colleagues (2008) highlighted that even though the children with ADHD/I and SCT symptoms performed in a conspicuously slow tempo, the underlying cognitive functions that are needed to accomplish the tasks were not affected. In line with this observation, a relationship between symptoms of SCT and deficits in sustained attention was found that was merely due to an increased variability in processing speed during task performance (Harrington et al., 2010; Skirbekk et al., 2011; Wåhlstedt et al., 2010). More in detail, the performance of children with signs of SCT on tasks that required a quick response was not as stable as the performance of children that did not present with signs of SCT. Moreover, those tasks that required a quick response were performed worse by children with signs of SCT than tasks that did not require a quick response. It seems that the task’s underlying speed factor, impacts on the performance of individuals with signs of SCT (Harrington et al., 2010; Skirbekk et al., 2011; Wåhlstedt et al., 2010).

The current study looked into diverse cognitive functions and their association with SCT. It was not only aspired to provide objective evidence for possible cognitive alterations in SCT but to also explore whether SCT shows associations with cognitive functions other than

those generally seen in ADHD. Moreover, special attention was dedicated to the just mentioned link of SCT and processing speed. We therefore looked into the tasks' subparameters, such as reaction time, in order to see whether SCT is indeed associated with a slowed information processing speed. It should be pointed out that the current study's nature was very much explorative. Due to the previously proposed link between SCT and attentional deficits (e.g., Harrington et al., 2010; Skirbekk et al., 2011; Wåhlstedt et al., 2010), we hypothesized that it would be more likely to find participants that actually present with high levels of SCT, when we over-select for participants that suffer from attentional complaints. Moreover, we did not restrict ourselves to cognitive tasks that exclusively measure attentional deficits but also aimed at looking into tasks that measure diverse cognitive functions. One of the study's highlights is that we made use of an adult sample that was clinically seen due to attentional complaints. While exploring SCT and its association to objective cognitive functioning we also explored ADHD adult symptoms and its link to cognitive functioning.

5.3. Method

5.3.1. Participants

The clinical sample consisted of 63 psychiatrically referred adults. This clinical sample (females= 33; males= 30; mean age= 33.76, SD=9.69) consisted of outpatients that were recruited and assessed at the Department of Psychiatry and Psychotherapy, SRH Group, in Karlsbad-Langensteinbach, Germany. All outpatients were screened with the ADHS-LE (Schmidt, 2009). The ADHS-LE consists of 64 items that screen for *attentional control, restlessness and hyperactivity, impulsivity and disinhibition, emotion and affect, intolerance to stress, extraversion, and retrospective information*. We used the ADHS-LE to over-select our sample for signs of daily attentional adversities. Clinical participants were invited to take part in the study when the cut-off score of a percentile <5 was met for *attentional control*. This means, all patients met a clinical relevant degree of attentional difficulties. Patients were not included if they i) had clinically significant chronic medical conditions, ii) reported a history suggestive of 'psychosis' (indicating schizophrenia, delusional disorder, depressive disorder with psychotic features or manic episode), iii) had a history of neurological disorder including head injury, ii) had a history of substance abuse during the previous two months, and/or iii) if the clinical psychiatric interview was indicative for a current major depressive episode (MDE).

The non-clinical population consisted of 44 individuals (females: 22, males: 21, no info: 1) that were recruited and assessed by the Psychology Department of the University of

Regensburg, Germany. None of the non-clinical individuals took any medication known to affect the central nervous system or reported a history or current diagnosis of neurological or psychiatric diseases. Intellectual functioning of the clinical and non-clinical population was measured by making use of the Multiple Choice Vocabulary Test (e.g., Lehr, Triebing & Fischer, 1995). The clinical- and non-clinical individuals participated voluntarily in the study and gave written informed consent prior to the assessment. The clinical- and non-clinical participants were debriefed about the study's aims after participation.

5.4. Measures

5.4.1. Clinical interview/ diagnostic process.

As described above all participants (clinical and non-clinical participants) were clinically interviewed according to DSM-5 criteria for ADHD symptoms (Barkley & Murphey, 1998). Furthermore, all participants were asked to complete two standardized self-report scales that measure current and retrospective ADHD symptoms (Rössler et al., 2008). Childhood ADHD symptoms were self-rated on a five-point Likert scale with the short version of the Wender Utah Rating Scale (WURS-K, 25 items; Ward, 1993). Adulthood ADHD (ADHD_adult) symptoms were self-rated on a four-point Likert scale with the ADHD self-report scale that is in line with the diagnostic criteria of DSM-IV (APA, 1994; Rösler et al., 2008). The adult ADHD symptom self-report measure will be used in this study as a parameter for ADHD adult symptoms in our sample.

5.4.2. Personal inventory

8 questions were asked to obtain demographic and general background information such as age, education, nationality and gender.

5.4.3. SCT measure

The recently developed and psychometrical tested SCT Questionnaire for Adults (SCT-QA) (please see Chapter 4 of this thesis) was used. The SCT-QA contains 16 items that represent 3 domains of SCT; subscale 1: *sluggish & sleepiness* (items: 1-6), subscale 2: *lacking persistency & motivation* (items: 7-12), and *mind wandering & lacking concentration* (items: 13-16) (Table 2. Item number, item content and subscale of the SCT-QA).

Table 2. Item number, item content and subscale of the SCT-QA

Item number	Item content	Subscale
1	Feeling tired, lethargic	sluggish & sleepiness
2	Moving slowly, lacking energy	sluggish & sleepiness
3	Being sleepy, drowsy	sluggish & sleepiness
4	Feeling sluggish	sluggish & sleepiness
5	Being apathetic, lacking interest	sluggish & sleepiness
6	Stretching, yawning, looking sleepy	sluggish & sleepiness
7	Lacking initiative to finish work	lacking persistency & motivation
8	Efforts fade quickly	lacking persistency & motivation
9	Needs to be remembered to start working	lacking persistency & motivation
10	Being unmotivated	lacking persistency & motivation
11	Work varies qualitatively and or quantitatively	lacking persistency & motivation
12	Slow in accomplishing tasks, delaying tasks	lacking persistency & motivation
13	Loosing track while listening	mind wandering & lacking concentration
14	Loosing track during daily activities or conversations	mind wandering & lacking concentration
15	Being easily distracted, confused	mind wandering & lacking concentration
16	Needing extra time to accomplish tasks	mind wandering & lacking concentration

The overall scale reliability (internal consistency) of the SCT-QA was shown to be high (Cronbach's $\alpha = .84$). The scale reliabilities of the 3 subscales were .78 (*sluggish & sleepiness*), .76 (*lacking persistency & motivation*), and .59 (*mind wandering & lacking concentration*), respectively. The SCT-QA is scored on a 6-point-Likert-scale with higher scores being indicative for how often individuals experience symptoms of SCT (0= never, 1= seldom, 2=sometimes, 3=often, 4=very often, 5= always). Table 3 gives an overview about relevant participant' descriptive and significant differences between the clinical- and non-clinical sample on these variables.

Table 3. Overview mean age, IQ and SCT scores of non-clinical and clinical participants

Variable	Non-clinical group (N=44)	Clinical group (N=63)
	Mean (SD)	Mean (SD)
Age	32.81 (12.65)	33.67 (9.69)
IQ	116.73* (14.11)	104.78* (12.89)
SCT-QA	21.00* (8.19)	34.25* (13.56)
ADHD_adult	11.59* (7.46)	22.12* (10.07)

*indicates a significant difference between the clinical- and non-clinical sample at $p < .05$

The groups differed significantly on the variable intelligent functioning ($t(103) = 4.52, p < .001$), but not on the variable *Age* ($t(105) = -.44, p = .66$). Hence, the participants' age was

comparable across groups. However, the non-clinical sample presented with higher scores on the intellectual functioning measure than the clinical sample. Nevertheless, both groups score in a normal IQ range, with the non-clinical group scoring slightly higher than the average population. It was previously shown, that IQ increases with the amount of schooling a person has attained (e.g., Ceci 1991, 1992). The participants' level of education was rated as follows: 1= no formal educational degree was obtained, 2= secondary educational degree after 9 years of school, 3= secondary educational degree after 9 years of school and on the job training, 4= secondary educational degree after 10 years of school, 5=secondary educational degree after 13 years of school, 6= higher education entrance qualification, 7= higher education entrance qualification and a Bachelor or Master degree or a qualified on the job training. The non-clinical sample in the current study was more likely to have accomplished a higher school education than the non-clinical sample ($t(105) = 3.71, p < .001$, with the clinical sample $M=4.79$ and the non-clinical sample $M=5.93$, which is equivalent to having at least accomplished a degree in secondary school for the clinical sample and with having accomplished a university entrance qualification in the non-clinical sample). The non-clinical and clinical sample differed significantly on the variables *SCT-QA* ($t(104) = 5.73, p < .001$) and *ADHD_adult* ($t(98) = 5.79, p < .001$). The clinical sample presented with higher scores (more signs of ADHD and signs of SCT) than the clinical sample.

5.4.4. Cognitive Measures

5.4.4.1. Trail-making-test (TMT A, B, Reitan & Wolfson, 1985)

Information processing and cognitive flexibility was measured with the TMT. The TMT consists of two parts. Part A and Part B, respectively. Part A asks participants to draw a line between numbers in ascending order as fast as possible. Part B, adds letters to the numbers and asks participants to alternate between numbers and letters in ascending order. Letters have to be ordered according to the alphabet and the line has to be drawn from number to letter to number to letter and so on. Again, this task had to be performed as fast as possible. Whereas part A of the TMT (TMT-A) measures information processing, and, especially speed of information processing, part B of the TMT (TMT-B) measures cognitive flexibility as attention has to be switched between two concepts (numbers vs. letters).

5.4.4.2. Vienna test system- selective attention (VTSSA, Schuhfried, 1992).

Selective attention was measured with the selective attention task. The selective attention task requires participants to respond to relevant target stimuli and disregard irrelevant distractor stimuli. A response is given by pushing a reaction time button on the testing console. There

were in total three alternating stimuli. Squares, circles and triangles. The participants had to push the reaction time button whenever the squares and circles appeared and their color intensified. Target stimuli were therefore squares and circles with intensifying color. If a triangle was presented or the squares and circles did not identify in color, no action was required.

5.4.4.3. Vienna test system- vigilance (VTSV, Schuhfried, 1992)

Sustained attention/ vigilance was measured by the vigilance task. The vigilance task asked participants to observe a reoccurring square in the middle of the computer screen, which randomly changes color from grey to black. A response is required when the square changes into black. The change of color, which requires a response, only occurs in 5% of the times that a stimulus is produced during the 30 minutes. A response was given by pushing a reaction time button on the testing console.

5.4.4.4. Vienna test system- inhibition (VTSI, Schuhfried, 1992)

Inhibition of premature responses was measured with a go/no-go paradigm, the inhibition task. The inhibition task required participants to decide whether they have to respond or they do not have to respond. The stimuli are made up of triangles and squares. The participants are asked to give a response to squares only by pushing a button on the testing console. By means of eliciting a homogeneous response pattern (thereby repeatedly prompting the participant to give a certain response) of the participants (frequently pushing the button to indicate that a triangle was present) participants are manipulated in a certain direction, which increases the chance of an incorrect response.

5.4.4.5. Vienna test system- cognitive switching (VTSCF, Schuhfried, 1992)

Cognitive switching was measured with the switching task. The switching task requires the participant to apply two rules. Rule (i) participants have to respond differently in line with different shapes (square vs. circle); and (ii), participants have to react to a certain brightness (dark vs. bright). Both rules are alternated in a way that participants have to respond two times in a row to (i) shape, which is followed by switching to rule (ii) responding two times in a row to the brightness of the stimuli. Please see Table 4. for an overview of cognitive domains tested, its related measures and task parameters that will be examined in the following.

Table 4. Cognitive domains, measures and underlying performance parameters.

Cognitive domain	Abbreviation of the cognitive domain	Measure	Underlying performance parameters
Information processing	IP	TMT-A	Reaction time

Information processing and cognitive Flexibility	IPCF	TMT-B	Reaction time
Selective attention	SA	VTSSA	Reaction time Omission errors Commission errors Automatic attention Controlled attention Sensitivity (standard deviation of task performance)
Sustained attention/vigilance	SAV	VTSV	Reaction time Omission errors Commission errors Sensitivity (standard deviation of task performance)
Inhibition of premature responses	IN	VTSI	Reaction time Omission errors Commission errors Sensitivity (standard deviation of task performance)
Cognitive switching, flexibility	CSF	VTSCF	Reaction time Accuracy Congruency of time for reaction time Congruency of time for accuracy

Abbreviations: Trail-Making-Test A (TMT-A), Trail-Making-Test B (TMT-B), Vienna test system- selective attention (VTSSA), Vienna test system- vigilance (VTSV), Vienna test system- inhibition (VTSI), Vienna test system- cognitive switching (VTSCF)

5.5. Procedure

All participants were asked to complete the SCT-QA, the demographic inventory, the IQ measure and the ADHD scales (adult and retrospective child symptoms of ADHD) prior to cognitive testing. The cognitive tasks were always administered in the following order: TMT-A, TMT-B, VTSSA, VTSV, VTSI, and finally, VTSCF.

5.6. Ethics Statement

The study of the clinical sample was conducted in line with the Helsinki Declaration. Ethical approval was granted by the ethics committee of the medical faculty of the University of Heidelberg, Germany. Formal written consent was given by the clinical participants prior to the assessment and the assessment was ended by a thorough debriefing of all participants. The study of the non-clinical population was approved by the Ethical Committee of the Psychology Department of the University of Regensburg in Germany. All clinical- and non-clinical participants gave written-informed consent.

5.7. Data Analysis

Two multiple regression analysis were performed. First, (i) a multiple regression analysis was performed using general linear model (GLM) for multivariate effects. The dependent variables

were the results on the above introduced cognitive tests. Before analysis, measures were trimmed, taking 3SD as the criterion for identifying outliers. The variables sum score on the newly developed *SCT-QA*, *Age*, *Gender*, *IQ* and the sum score of the ADHD scale for adults (*ADHD_adult*) were entered into the model as covariates. And second, (ii) the same analysis was done, but now with an additional factor *Group* (representing the participant's affiliation to either the clinical- or the non-clinical sample)

5.8. Results

5.8.1. Results of the multivariate tests

Analysis (i) revealed a significant multivariate effect for the covariate *Age*, Wilks' $\lambda = .50$, $F(20, 76) = 3.73$, $p < .001$, partial eta squared = .49. The power of the observed effect was 1. Hence, the hypothesis that *Age* impacts on the performance on the various cognitive tests was confirmed.

Another significant multivariate effect was found for the covariate *IQ*, Wilks' $\lambda = .64$, $F(22, 76) = 2.18$, $p = .008$, partial eta squared = .36. The power of the observed effect was .98. Hence, the hypothesis that *IQ* does impact as a covariate on the performance on the cognitive tests was confirmed.

The variable *ADHD_adult* yielded a multivariate effect as well. With Wilks' $\lambda = .67$, $F(22, 76) = 1.88$, $p = .03$, partial eta squared = .33. The power of the observed effect was .95. Hence, the hypothesis that *ADHD_adult* does impact as a covariate on the performance on the cognitive tests was confirmed.

The variable *SCT-QA* showed a multivariate effect with a trend to significance. With Wilks' $\lambda = .69$, $F(22, 76) = 1.65$, $p = .06$, partial eta squared = .30. The power of the observed effect was .92. Hence, the hypothesis that *SCT-QA* does impact as a covariate on the performance on the cognitive tests was confirmed, if a less strict alpha-level of .10 is handled.

Gender did not yield any significant multivariate effect. With Wilks' $\lambda = .81$, $F(22, 76) = .87$, $p = .62$, partial eta squared = .19. The power of the observed effect was .59. Hence, the hypothesis that *Gender* does impact as a covariate on the performance on the cognitive tests was not confirmed. Based on this analysis it is unlikely that the participants' gender is associated with cognitive performance.

Since four (*Age*, *IQ*, *SCT-QA*, *ADHD_adult*) of five covariates presented with (marginally) significant multivariate effects and their between-subject effects on the cognitive tasks these will be explored in more detail in the following.

5.8.2. Results of the between-subjects effects: Analysis (i) without Group as a covariate.

As can be seen in Table 5 and Table 6, intellectual functioning was associated with four speed measures out of in total 9 significant subparameters.

The participants' age was associated with two speed measures out of in total four significant subparameters.

ADHD adult symptoms were associated with no speed measure at all but with 4 subparameters of two domains of attention (selective and sustained attention).

Finally, the variable *SCT-QA* that would be significant if we handle a less strict alpha-level of .10 was only significant for the association with a subparameter measuring information speed.

Table 5. Summary of significant associations between covariates and subparameters (differentiated in speed- and non-speed subparameters)

Covariate	Significant speed subparameter	Significant non-speed subparameter
IQ	Information processing speed and cognitive flexibility: -reaction time Selective attention: -automatic attention Sustained attention: -reaction time Cognitive switch/flexibility: -reaction time of the error response	Selective attention: -omission errors, -commission errors Sustained attention: -omission errors, -commission errors Inhibition: -commission errors
Age	Information processing speed: -reaction time Information processing speed and cognitive flexibility: -reaction time	Inhibition: -commission errors Cognitive switch/flexibility: -congruency of the reaction time of correct responses
ADHD_adult		Selective attention: -controlled attention Sustained attention: -omission error -commission error -variance of the reaction time
SCT-QA	Cognitive switch/flexibility paradigm: -reaction time	

Please see Table 6 for all significant and non-significant associations between the covariates and cognitive subparameters.

Table 6. Results GLM multivariate between-subject effects for the covariates: *Gender*, *IQ*, *Age*, *ADHD_adult* and *SCT-QA*, with *Gender* and *Age* being the only significant multivariate effects.

Cognitive test subparameter	Gender		IQ ^a		Age ^a		ADHD_adult ^a		SCT-QA ^b	
	B (SE)	Partial eta squared	B (SE)	Partial eta squared	B	Partial eta squared	B	Partial eta squared	B	Partial eta squared
Information processing (IP)	.006 (.642)	.000	-.035 (.022)	.025	.185* * (.029)	.297	-.021 (.035)	.004	.045 (.028)	.026
IP and information processing & cognitive flexibility (IPCF)	1.752 (2.008)	.008	-.195* (.069)	.077	.340* * (.091)	.127	-.094 (.109)	.008	.066 (.088)	.006
Selective attention (SA) reaction time	1.644 (15.491)	.000	-.775 (.535)	.022	-.170 (.705)	.001	1.268 (.841)	.023	.538 (.683)	.006
SA standard deviation	3.239 (9.773)	.001	-.621 (.338)	.034	-.106 (.445)	.001	1.687 * (.531)	.096	-.277 (.431)	.004
SA omission errors	-.052 (.232)	.001	-.021* (.008)	.065	-.016 (.011)	.022	.006 (.013)	.003	-.010 (.010)	.009
SA commission errors	-.407 (.637)	.004	-.055* (.022)	.062	-.009 (.029)	.001	.022 (.035)	.004	.017 (.028)	.004
SA automatic attention	-6.057 (15.499)	.002	-1.205* (.536)	.051	1.005 (.705)	.021	1.126 (.841)	.019	.672 (.683)	.010
SA controlled attention	11.667 (16.393)	.005	-1.091 (.567)	.038	.670 (.746)	.008	2.228 * (.890)	.062	.979 (.722)	.019
Sustained attention/vigilance (SAV) omission errors	-1.277 (1.278)	.010	-.096* (.044)	.047	-.068 (.058)	.014	.244* * (.069)	.116	.025 (.056)	.002
SAV commission errors	-.825 (1.134)	.006	-.111* (.039)	.077	-.060 (.052)	.014	.149* (.062)	.058	.012 (.050)	.001
SAV reaction time	-11.703 (38.331)	.001	-4.391* * (1.325)	.104	3.084 (1.745)	.032	6.445 * (2.081)	.092	2.790 (1.689)	.028
Inhibition (IN) commission errors	.381 (1.346)	.001	-.107* (.047)	.053	- .128* (.061)	.044	.050 (.073)	.005	.078 (.059)	.018

IN omission errors	1.199 (1.439)	.007	-.082 (.050)	.028	-.106 (.066)	.027	.072 (.078)	.009	-.064 (.063)	.011
IN sensitivity/ standard deviation	-.249 (.294)	.007	-.012 (.010)	.013	-.006 (.013)	.002	.010 (.016)	.004	-.007 (.013)	.003
IN reaction time	-.076 (.221)	.001	.013 (.008)	.031	.013 (.010)	.018	-.021 (.012)	.031	-.011 (.010)	.013
IN standard deviation of the reaction time	.002 (.023)	.000	.000 (.001)	.002	.001 (.001)	.003	-.001 (.001)	.007	-.001 (.001)	.015
Cognitive switching, flexibility (CSF) reaction time	.042 (.034)	.016	-.001 (.001)	.003	-.001 (.002)	.002	.002 (.002)	.012	.001 (.002)	.004
CSF accuracy	-1.605 (.763)	2.103	.037 (.026)	.020	-.017 (.035)	.003	.066 (.041)	.026	.044 (.034)	.017
CSF congruency of reaction time of correct response	-.043 (.136)	.001	.002 (.005)	.002	.014* (.006)	.051	-.006 (.007)	.008	-.007 (.006)	.013
CSF reaction time of error response	-3.076 (2.196)	.020	-.226* (.076)	.085	-.003 (.100)	.000	.099 (.119)	.007	.353* (.097)	.123

*a multivariate effect of this variable was significant at $p < .05$.; *b multivariate effect of this variable was significant at $p < .10$.; please note. the p-values of the between-subject effects that correspond to the significant multivariate effects are written in bold; between-subject effect of this variable was significant at $p < .05$;

According to Cohen (1988) values of partial eta squared of $\leq .01$ are interpreted as small; values $> .01$ and $\leq .06$ as medium; and values of $> .06$ and $\leq .14$ are called large effect sizes. It can be concluded that all covariates but gender contributed with medium to large effect-sizes to the explanation of variance of the corresponding subparameter.

In order to see whether the participants' affiliation to one or the other group (clinical vs. non-clinical) does impact on the performance of the cognitive tests, we added *Group* as a fixed factor and conducted a second GLM on the cognitive test performances (that as equal to analysis (i) functioned as the dependent variables again). The GLM yielded the following results.

5.8.3. Results of the multivariate tests. Analysis (ii) with Group as a covariate

Analysis (ii) revealed a significant multivariate effect for the covariate *Age*, Wilks' $\lambda = .52$, $F(20, 75) = 3.4$, $p < .001$, partial eta squared = .48. The power of the observed effect was 1. Another significant multivariate effect was found for the factor *Group*, Wilks' $\lambda = .11$, $F(22, 75) = 31.12$, $p < .001$, partial eta squared = .89. The power of the observed effect was 1.

The remaining covariates (*IQ*, *Gender*, *SCT-QA*, and *ADHD_adult*) did not reach significance in the multivariate testing. Please see Table 7 for the non-significant multivariate effects of the remaining covariates.

Table 7. Non-significant multivariate effects for *IQ*, *Gender*, *SCT-QA* and *ADHD_adult* of analysis (ii) with Group as a covariate

Variable	Wilks'Lambda	F	p-value	Partial eta squared	Observed power
IQ	.76	1.19	.29	.24	.80
Gender	.73	1.42	.14	.27	.85
SCT-QA	.76	1.17	.30	.24	.76
ADHD adult	.75	1.27	.23	.25	.80

5.8.4. Results of the between-subjects effects Analysis (ii).

As can be seen in Table 8 and Table 9, similar to the results of analysis (i) the participants' age was associated with three subparameters measuring information processing speed out of in total five significant subparameters.

Group was associated with three information processing speed measures out of in total eight significant subparameters.

Again, all significant between-subject effects by *Age* or *Group* yielded medium to large effect sizes (Cohen, 1988).

Table 8 Summary of significant associations between covariates and subparameters (differentiated in speed- and non-speed subparameters)

Covariate	Significant speed measure	Significant non-speed measure
Age	Information processing speed: -reaction time Information processing speed and cognitive flexibility: -reaction time Inhibition: -reaction time	Inhibition: -commission errors Cognitive flexibility: - congruency of the reaction time of a correct response
Group	Sustained attention: -reaction time Inhibition: -reaction time Cognitive flexibility: -reaction time of the error response	Selective attention: -standard deviation Sustained attention: -omission error -commission error -variance of the reaction time Inhibition: -commission errors

Please see Table 9 for more details concerning the results of analysis (ii).

Table 9 Results GLM multivariate between-subject effects for the variables *ADHD_adult*, *SCT-QA*, *Group*, *Gender*, *IQ* and *Age*

Cognitive test subparameter	ADHD_adult		SCT-QA		Group ^a		Gender		IQ		Age	
	B (SE)	Partial eta squared	B (SE)	Partial eta squared	B (SE)	Partial eta squared	B (SE)	Partial eta squared	B (SE)	Partial eta squared	B (SE)	Partial eta squared
Information processing (IP)	-.052 (.036)	.022	.020 .029	.005	-2.244 .827	.073	.099 (.622)	.000	-.009 (.024)	.002	-.170** (.029)	.270
IP and information processing & cognitive flexibility (IPCF)	-.160 (.114)	.021	.013 .092	.000	-4.714 2.641	.033	1.948 (1.988)	.010	-.141 (.075)	.036	-.308* (.092)	.106
Selective attention (SA) reaction time	1.294 (.894)	.022	.559 .725	.006	1.860 20.722	.000	1.567 (15.597)	.000	(-.796) (.589)	.019	-.157 (.723)	.001
SA standard deviation	1.087 (.530)	.043	-.763 .431	.032	-42.910** 12.301	.115	5.017 (9.259)	.003	-.124 (.350)	.001	-.399 (.429)	.009
SA omission errors	.000 (.013)	.000	-.014 .011	.019	-.433 .307	.021	-.034 (.231)	.000	-.016 (.009)	.033	-.019 (.011)	.031
SA commission errors	.012 (.037)	.001	.009 .030	.001	-.765 .848	.009	-.014 (.030)	.004	-.046 (.024)	.037	-.014 (.030)	.002
SA automatic attention	.796 (.888)	.008	.405 .721	.003	-23.619 20.589	.014	-5.079 (15.497)	.001	-.932 (.585)	.026	.843 (.718)	.014
SA controlled attention	1.798 (.936)	.038	.631 .760	.007	-30.692 21.698	.021	12.939 (16.332)	.007	-.736 (.617)	.015	.460 (.757)	.004
Sustained attention/vigilance (SAV) omission errors	.182* (.071)	.065	-.026 .058	.002	-4.473* 1.646	.073	-1.092 (1.239)	.008	-.044 (.047)	.009	-.099 (.057)	.031
SAV commission errors	.102 (.064)	.027	-.026 .052	.003	-3.336* 1.477	.051	-.687 (1.112)	.004	-.072 (.042)	.030	-.082 (.052)	.026
SAV reaction time	2.533 (1.828)	.020	-.378 1.483	.001	- 279.811** 42.380	.317	-.110 (31.898)	.000	-1.156 (1.205)	.010	1.173 (1.478)	.007
Inhibition (IN) commission errors	-.028 (.074)	.002	.015 .060	.001	-5.571* 1.707	.102	.612 (1.285)	.002	-.043 (.049)	.008	- .167* (.060)	.077

IN omission errors	.039 (.082)	.002	-.091 .067	.019	-2.330 1.910	.016	1.296 (1.438)	.009	-.056 (.054)	.011	-.122 (.067)	.034
IN sensitivity/standard deviation	.010 (.017)	.004	-.007 .014	.003	-.015 .394	.000	-.248 .296	.007	-.011 (.011)	.011	-.006 (.014)	.002
IN reaction time	-.005 (.012)	.002	.002	.000	1.104** .273	.148 *	-.122 (.206)	.004	.001 (.008)	.000	.021* (.010)	.049
IN standard deviation of the reaction time	.000 (.001)	.001	-.001 .001	.004	.046 .031	.024	.000 (.023)	.000	-.001 (.001)	.010	.001 (.001)	.006
Cognitive switching. flexibility (CSF) reaction time	.001 (.002)	.006	.001 .002	.001	-.037 .045	.007	.043 (.034)	.017	.000 (.001)	.000	-.001 (.002)	.003
CSF accuracy	.055 (.044)	.016	.034 .036	.010	-.827 1.017	.007	- 1.570* (.766)	.043	.046 (.029)	.027	-.023 (.035)	.004
CSF congruency of reaction time of correct response	-.003 (.008)	.002	-.004 .006	.005	.221 .180	.016	-.052 (.135)	.002	.000 (.005)	.000	.015* (.006)	.060
CSF reaction time of error response	.008 (.123)	.000	.279* .100	.076	-6.540* 2.859	.053	-2.806 (2.152)	.018	-.150 (.081)	.035	-.048 (.100)	.002

**a multivariate effect of this variable was significant at $p < .05$; *the between-subject effect of this variable was significant at $p < .05$; ** the between-subject effect of this variable was significant at $p = .001$

For further insights into our significant between subject effects of analysis (ii) we looked at the mean scores on the subparameter of the cognitive tests of the two groups, which are summarized in Table 10.

Table 10. Mean scores of the performances on the cognitive tasks (subparameters) by the non-clinical and clinical group

Variable	Non-clinical (N= 43)		Clinical (N= 48)		Total (N= 91)	
	Mean	SD	Mean	SD	Mean	SD
Information processing (IP) TMT-A	16.93^{ab}	3.34	19.16^{ab}	3.75	18.19	3.73
IP and information processing & cognitive flexibility (IPCF) TMT-B	25.83^{ab}	10.21	31.09^{ab}	10.67	28.79	10.75
Selective attention (SA) reaction time	356.05	64.64	384.24	86.22	371.96	78.47
SA standard deviation	1.21	.07	46.31	61.43	26.66	51.17
SA omission errors	.22	.91	.65	1.34	.46	1.19
SA commission errors	1.95	1.99	3.52	3.83	2.84	3.25
SA automatic attention	350.36	71.29	399.84	80.36	378.23	80.06
SA controlled attention	361.93	61.45	428.27	94.91	399.37	88.09
Sustained attention/vigilance (SAV) omission errors	.82^a	1.37	7.28^a	8.39	4.47	7.12
SAV commission errors	1.11^a	.69	5.99^a	7.48	3.86	6.12
SAV reaction time	207.61^a	192.28	523.74^a	122.09	386.02	221.49
Inhibition (IN) commission errors	7.46^{ab}	6.56	13.29^{ab}	6.54	10.75	7.12
IN omission errors	4.41	5.04	6.51	8.48	5.59	7.23
IN sensitivity/standard deviation	2.55	1.97	2.72	.87	2.64	1.45
IN reaction time	1.40^{ab}	1.55	.28^{ab}	.09	.77	1.16
IN standard deviation of the reaction time	.15	.11	.11	.11	.13	.11
Cognitive switching. Flexibility (CSF) reaction time	.16	.11	.22	.19	.19	.17
CSF accuracy	1.42	2.69	2.68	4.64	2.13	3.95
CSF congruency of reaction time of correct response	.38^{ab}	1.02	.09^{ab}	.15	.22	.69
CSF reaction time of error response	5.24^a	6.39	17.37^a	13.81	12.08	12.69

^a between-subject effect of this variable was significant at $p < .05$ for the variable *Group*; ^{ab} between-subject effect of this variable was significant at $p < .05$ for the variable *Age*; ^{ab} between-subject effect of this variable was significant at $p < .05$ for both variables *Group* and *Age*

The comparison of the mean scores of the previously significant different subparameters of the cognitive domains revealed that the clinical group performed throughout worse than the non-clinical group except for the reaction time measure of the inhibition task. The clinical group was significantly faster than the non-clinical group in the inhibition task. However, they also performed significantly more commission errors. They responded more often when they should not have responded than the non-clinical group. Hence, the increase in errors could be the trade-

off for reacting much faster than the non-clinical group.

The previously (marginally) significant multivariate effects for *IQ*, *SCT-QA* and *ADHD_adult* were no longer significant when Group was added as a factor. This is most likely the case because the participants' affiliation (whether they belong to the clinical- or non-clinical group) functions as a proxy for these other variables. In other words, the effect produced by Group replaces the formerly significant effects of the participants' intellectual functioning and their scores on the *SCT-QA* and *ADHD_adult* symptom scale.

In order to support our interpretation that Group functions as a proxy for the covariates *IQ*, *SCT-QA* and *ADHD_adult*, we performed a binary logistic regression with Group as the dependent variable, and *Gender*, *IQ*, *Age*, *ADHD_adult* score and *SCT-QA* score as predictor variables. Binary logistic regression tests the relationship between a dichotomous dependent variable and one or numerous independent variables that can be measured on ordinal, nominal, ratio or interval-level. As we proposed that the participants' affiliation (being either part of the clinical- or non-clinical group) has major effect on our covariates, we tested with effect accordingly. Please see Table 11a and b for the results

Table 11a. Results of the binary logistic regression with Group as the dependent variable and *Gender*, *IQ*, *Age*, *ADHD_adult* and *SCT-QA* as the predictor variables: predictive success in terms of classification

Observed			Predicted		Percentage correct
			Group		
			Non-clinical	Clinical	
Step	Group	Nonclinical	34	10	77.3
1		Clinical	10	47	82.5
Overall Percentage					80.2

The cut value is .500

Table 11b. Results of the binary logistic regression with Group as the dependent variable and *Gender*, *IQ*, *Age*, *ADHD_adult* and *SCT-QA* as the predictor variables

Predictor Variable	B	SE	OR	WALD	df	p-value
Gender	-.417	.586	.659	.507	1	.476
IQ	-.090	.023	.914	14.783	1	.000
Age	.068	.028	1.070	5.874	1	.015
ADHD_adult	.127	.041	1.135	9.652	1	.002
SCT-QA	.099	.031	1.104	9.883	1	.002

The outcome of the logistic regression confirmed the above-mentioned hypothesis. Group membership could be predicted rather well from the set of predictors: classification based on the predictors was successful on average 80.2% of the time, whereas in the null model this was only 56.4 per cent. In Table 11, we can see that the factors *IQ*, *Age*, *SCT-QA* and *ADHD_adult* were responsible for that outcome, as they were all significantly associated with the factor

Group, with the exception of *Gender*, which was not significantly associated with *Group*. So as group membership can be predicted well from this set of covariates, it is of no surprise that the efficacy of these covariates as predictors of cognitive processing parameters is strongly diminished when *Group* is added as an extra predictive variable.

We did wonder whether a reduction of cognitive subparameters would yield different effects by our covariates (*Gender*, *IQ*, *Age*, *ADHD_adult*, *SCT-QA* and *Group*). This led us to perform a Principal Component Analysis on the cognitive subparameters with a follow-up regression analysis of the extracted factors with our covariates. Please see Appendix C for further information. The results of this exploratory analysis did not offer any new evidence for the involvement of the SCT-QA scale in predicting neurocognitive functioning.

5.9. Discussion

The current study aimed at assessing neurocognitive functioning in an adult population of clinical- and non-clinical participants and relate the results on the cognitive tests to their responses to a newly validated SCT scale for adults. The underlying subparameters, especially reaction times of the individual cognitive tasks were explored, in order to shed light on the question whether objective evidence can be found for the previously proposed association between SCT and slowed processing speed.

5.9.1. Findings concerning SCT

Despite our oversampling strategy, we only found very weak evidence for the expected association between SCT and cognitive performance. In our first regression analysis, covariates *Age*, *IQ*, and *ADHD_adult* (but not *Gender*) explained more variance than SCT, which only had a marginally significant contribution to the results. The between-subject results showed that SCT was significantly related with only one of the 20 task parameters. Even though this single significant association was with a speed subparameter (reaction time of the cognitive switch/flexibility task), the information we get from this finding is still weak. In our second analysis, where we did the same regression but included the factor *Group* (clinical vs. non-clinical), the effect of SCT was even further reduced. SCT did not predict task performance over and above group membership. Given this weak association of SCT and the results on the objective cognitive tests, we ask ourselves whether the observation by Barkley (2012) that self-rate measures do not associate well with objective cognitive testing but do show strong associations with self-rate measures of cognitive functioning, holds true for our results as well. The mentioned observation could encourage future studies to explore the question to what

extent self-rated functioning is comparable to actual objective performance, especially when it comes to cognitive functioning. Studies on self-rated cognitive functioning are generally sparse. Moreover, it should be taken into account that factors that contribute to the perception that we have about ourselves and our abilities are manifold and complex, intertwined with our past and present experiences. To be more precise, participants might rate their cognitive ability as much worse than it actually is, due to for example a lack of self-worth, detrimental past experiences (with authorities telling them they do not have the capacity to succeed in this subject), and/ or the experience of failing at certain tasks. Furthermore, it should be kept in mind that the cognitive tasks we are using are often broken down to track one specific domain of cognitive functioning. However, in order to succeed in real life tasks, a combination of cognitive functions is needed. When we fail in real life at a certain task it could be due to its' complexity. A complexity that can be hardly replicated in a psychological laboratory, especially if the research question targets one specific cognitive domain and not the combination of many.

5.9.2. Findings concerning the factor ADHD adult

Based on analysis (i) there was stronger evidence that ADHD adult symptoms contribute to differences in cognitive performance as compared to SCT. Interestingly, ADHD adult symptoms were solely significantly associated with non-speed subparameters and not with speed subparameters. These results nevertheless must be called instable, as we could not replicate those findings in analysis (ii), with *Group* as a covariate.

5.9.3. Findings concerning participants' age

When the factor *Group* was added, the effects of *Age* on the cognitive domains remained significant. Moreover, the effects of *Age* were even extended by one more significant subparameter measuring information processing speed. The results of analysis (ii) showed that the participants' age was associated with five of the in total 20 assessed subparameters of the cognitive tasks. Three of these five significant subparameters were reaction time measures (TMT-A & B and reaction time of the inhibition task). The observed association between age and performances on the trail making test are well-validated (Salthouse & Fristoe, 1995). TMT performance was shown to depend on attentional abilities (e.g., Jarvis & Barth, 1994; Lyness, Eaton & Schneider, 1994), visual search, visuospatial or scanning abilities (e.g., Lyness et al., 1994; Stuss et al., 1987), motor skills (e.g., Kennedy, 1981), cognitive flexibility (e.g., Greenlief et al., 1985; LaRue, 1992) and psychomotor speed (e.g., Greenlief et al., 1985; Jarvis & Barth, 1994). Even though the test seems simple, it is a very sensitive test to brain damage and age (e.g., Salthouse & Fristoe, 1995). Salthouse and Fristoe (1995) investigated its sensitivity to

various age groups (18-29 years, 30-39 years, 40-49 years, 50-59 years, 60-69 years, 70-88 years), and showed that it is really the speed with which the task is performed that is slower due to age and not the influence of age on the cognitive-motor ability to connect dots. They further provide evidence that the time with which targets are processed and the time to switch directions is associated with age. Hence, the older the participant, the slower the processes (information processing, switching of directions between targets) are performed. They conclude that there is a general slowing of processing and a specific slowing of target processing and slowing of redirecting your movements with age (Salthouse & Fristoe, 1995). Based on their results, differences in speed while performing the TMT can even be seen between the age group 20-29 years and 30-39 years. Our groups did not differ significantly in mean age. Moreover, both groups had a similar age range (clinical group minimum age: 19 years, maximum age: 63 years; non-clinical group minimum age: 20 years, maximum age: 62 years). We therefore conclude that it is likely that we replicated an already well-known phenomenon, that age impacts on information processing speed and the speed with which you redirect your response.

Furthermore, the significant association of age with the congruency of the reaction time with which the cognitive flexibility task was performed could support previous findings that showed that redirecting one's movements or redirecting one's thoughts (letting go of one rule of performance and applying a different, secondary learned rule) decreases with age (e.g., Greenlief et al., 1985; LaRue, 1992; Salthouse & Fristoe, 1995). The cognitive flexibility task puts a higher cognitive load on the participant. The participants need to alter between rules in order to perform well, and they have to be quick in this alternation. In the current cognitive flexibility task, the speed in general, with which the task was performed, was not associated with age. Hence, we could conclude, that it is rather the increase in cognitive load that contributes to the difficulties in performance associated with age.

Finally, a significant association between age and an increase in commission errors in the inhibition task was found. Inhibition of a response involves either the ability to withhold a premature motor response or the ability to abort a response that has been already initiated. Commission errors are errors in which a wrong response is given. Hence, the participant either did not withhold or cancel his/her response. A large meta-analysis showed that withholding ones' response is a higher order cognitive control process that is future oriented (Miller & Cohen, 2001) and if poorly regulated can lead to tremendous impairment in the individual. Poor response inhibition has been associated with several psychiatric disorders (e.g., ADHD, bipolar disorder, substance abuse, personality disorders, e.g., Barkley, Murphy & Kwasnik, 1996; Goldstein et al., 2001) and impulsivity in general (e.g., Mueller et al., 2013). Most recently, the

whole debate whether inhibition declines with age was questioned in a large meta-analysis (e.g., Rey-Mermet & Gade, 2018; Rey-Mermet, Gade, Oberauer, 2018) as it was shown that older participants do not perform worse in inhibition tasks in general but only on some specific tasks. According to the authors, older participants show impaired inhibition on go/no-go tasks and stop signal tasks but not on the color Stroop, flanker or n-2 repetition tasks (Rey-Mermet & Gade, 2018). Hence, age dependent effects on inhibition seem to be very much task related. The current inhibition task was a go/no-go paradigm. We therefore, conclude that it is likely that our age dependent effects on the go/no-go paradigm adds to the observation as outlined in the discussed meta-analysis (Rey-Mermet & Gade, 2018).

5.9.4. Findings concerning the factor Group

It was already pointed out that adding the factor *Group* removed all previous significant effects of *IQ*, *SCT-QA* and *ADHD_adult* symptoms. *Group* was significantly associated with the standard deviation of the selective attention paradigm. The clinical group performed the selective attention task less stable over time than the non-clinical group. There is not much known about which factors influence response variability. Some studies suggest that physical fitness support a more steady performance during cognitive testing (Wu et al., 2011). Others showed that performance variability can be a valid predictor for Alzheimer Disease (Gorus et al., 2008). Given the fact that our clinical sample is rather heterogeneous and the only hard inclusion criteria was that they are clinically seen due to their own perceived attentional difficulties, it is impossible to relate any specific characteristic of our clinical group to the observed increased variability in performance. Data on other clinical scales, such as depression, anxiety etc. or even simple personality trait scales could have given more insights into which specific aspects of our clinical group relate to increased performance variability.

The most pronounced effect of the factor *Group* had was on the sustained attention task. All subparameters of the sustained attention task were associated with *Group*. Based on the mean scores it can be concluded that the clinical group performed significantly worse than the non-clinical group on all subparameters of the sustained attention task. Sustained attention is one of the crucial cognitive functions for performing well in everyday life. Sustained attention is the ability to stay focused on a task independent of external and internal distractions. Sustained attention has been shown to be crucial in daily life activities (e.g., Robertson et al., 1997), driving ability (e.g., Schmidt et al., 2009), and academic performance (e.g., Steinmayr, Ziegler & Träuble, 2010). It is known that sustained attention performance can be adversely influenced by factors such as childhood trauma and general stress (e.g., Banz et al., 2016; Kim

et al., 2013). On the other hand, physical and mental exercise in general, have been shown to support the development of a well-matured sustained attentional control system (e.g., Diamond & Lee, 2011; Kerns, Eso & Thomson, 1999). Differences in sustained attention for clinical and non-clinical samples are rather common, especially in studies on ADHD (e.g., Mick, Faraone, & Biederman, 2004; Marchetta et al., 2008). Sustained attention deficits are even part of the DSM-5 criteria for ADHD in adulthood (APA, 2000). However, our study did not show any links between ADHD adult symptoms and sustained attention deficits. Similar, SCT was not associated with performances on the sustained attention task. As was pointed out in the introduction, children with ADHD/I and SCT symptoms performed a sustained attention task in a noticeable slow tempo (Salanto et al., 2008). Similar, Wåhlstedt and Bohlin (2010) showed that symptoms of SCT were uniquely associated with sustained attention deficits in a community sample of children, whereas symptoms of ADHD inattention related stronger to deficits in executive functioning. None of these findings was replicated in our adult sample. Nevertheless, our clinical group did perform generally worse than the non-clinical group. We conclude that even though we could not relate SCT or ADHD symptoms to difficulties in sustained attention, sustained attention nevertheless does seem to be a sensitive measure to detect cognitive deficits in a clinical population.

Furthermore, the factor *Group* was also associated with the amount of commission errors and reaction time with which the inhibition task was performed. The clinical group made more commission errors and responded significantly faster than the non-clinical group. From this finding, we can interfere that the increase in commission errors is a trade-off for the faster responses in the clinical group. Certain psychological disorders seem to be advanced in inhibition tasks, which is ascribed to their general overactive behavioral inhibition system (e.g., Epstein et al., 2001; Quay, 1997). It was previously shown that individuals with anxiety disorders are often better in response inhibition (e.g., Epstein et al., 2001; Quay, 1997), whereas individuals with less impulse control, as it is suggested to be the case in ADHD, are worse in response inhibition (e.g., Epstein, et al., 2001). Again, it depended on the task used, whether deficits in response inhibition for patients with ADHD were found, with the go/no-go paradigm being a fairly sensitive measure (Epstein et al., 2001).

Finally, the factor *Group* was significantly associated with the reaction time with which errors were made during the cognitive flexibility/switching task. The clinical group was significantly slower when performing errors than the non-clinical group. Previous studies agreed on the observation that cognitive switching is a function associated with executive functioning (EF) (e.g., Anderson, 2002). EF is an umbrella term that summarizes functions such

as cognitive control, inhibition, switching, planning and execution of cognitive and motor movements (e.g., Anderson, 2002). Studies in ADHD populations on EF are numerous (e.g., Sergeant, Geurts, & Oosterlaan, 2002) and indeed support ADHD related deficits in many to almost all of the EF domains (e.g., Boonstra et al., 2005; Sergeant, Geurts, & Oosterlaan, 2002). However, as multifaceted as the construct EF is, as manifold are the methods to measure it (e.g., Boonstra et al., 2005). Moreover, the only study so far that assessed EF in SCT is the study by Barkley (2012), who examined self-report measures of EF in a community sample of adults with SCT. Barkley (2012) indeed showed an association between reports of SCT and EF, independent of symptoms of ADHD. As described above the cognitive switching paradigm of the current study required the participants to alternate between two rules. Hence, a certain amount of cognitive load and switching in the execution of certain rules was needed. Again, nor were ADHD adult symptoms nor were SCT symptoms associated with the performance on the cognitive switching task.

We would like to end with a comment on the factor *Group*. It is possible (and maybe likely) that *Group* is a potent predictor of task performance also because of other factors contained in group membership. The clinical group consisted of people with many different backgrounds in terms of emotional and/or cognitive complaints, each of which may have contributed negatively to processing speed and other aspects of neurocognitive performance

5.9.5. Limitations

The current study is an explorative study and should be interpreted as such. We chose a broad and diverse participant group, which could be criticized for its' heterogeneity. The whole sample was over-selected for attentional complaints which was intended to function as a 'magnifying glass' on likely and much less likely relations between SCT and attentional functioning. We welcome new studies with large and perhaps more representative samples of both the clinical and the nonclinical population. In addition, we rely on future studies to provide valid criteria for adequate cut-offs for clinical vs. non-clinical levels of SCT. In order to reach that goal we need much more consensus on how SCT presents itself in clinical populations. The clinical group scored on average 13 points ($M=34.25$, $SD=13.56$) higher on the SCT-QA scale than the non-clinical group ($M=21.00$, $SD=8.19$). It could be questioned whether a score of about 34 points out of a total possible score of 80 is extreme enough in order to find associations with cognitive performances. Research on SCT is still facing the dilemma that it is not part of any diagnostic manual yet, nor, that there are any clinically valid cut-off criteria for SCT. Future research should keep working on finding valid clinical criteria for SCT.

It can be further speculated, that the patients included in this study were relatively well adjusted and not severely impaired. None of the assessed clinical individuals was hospitalized and all of them lived independently. If more extreme forms of SCT need to be included, populations that are more severely impaired in their everyday functioning should be tested in future studies. Symptoms associated with sluggishness are frequently seen in patients with neuro-psychological impairments (e.g., Silver et al., 2010). Future studies could focus on or at least include a large subset of patients recovering from traumatic brain injury and alike in order to see if more severe forms of SCT could be identified. Similarly, not all individuals in the clinical-population have been medication-free at the day of testing. So far, there are no studies available that assessed the impact of medication on SCT symptoms. From some psychopharmaceutic medication it is known that side effects, such as increased tiredness or slowing of responses is common (e.g., Gaertner, Fischer, & Hoss, 1989; Silva et al., 1992). However, none of the medicated patients in the current study reported negative side effects that would be suspicious for increasing the likelihood of reporting symptoms that are in line with SCT. SCT is not part of the current DSM-5 criteria of any psychiatric disorder, yet (e.g., Becker, 2013; Mueller et al., 2014), nor have there been any attempts to test psychopharmaceutic medication in SCT. Future studies should nevertheless aim at controlling for possible effects of medication, by testing whether patients who are using medication that is known for increasing tiredness and/or slowing down of responses are overrepresented in samples identified as suffering from SCT.

5.10. Overall conclusion

The current study found only very weak evidence that SCT relates to cognitive functioning, when it is tested objectively. Moreover, no evidence was found that SCT relates to slowed processing speed in an adult sample. We should acknowledge the fact that our research methods can be questioned for their explanatory power in reflecting the individual's perceived reality, as observations were made by others (Barkley, 2012) that self-rated measures do not associate well with objective cognitive measures. We would like to conclude with a comment on the whole debate on whether SCT is a disorder independent of ADHD or not. From our clinical point of view, the idea that a pure form of SCT can ever be identified should be questioned anyway. It is debatable whether any psychological disorder can be isolated from other comorbidities at all. It is also unclear if we would not do the individual greater harm if we reduce his or her symptoms to one disorder and not the other. From our clinical experience, we can say that therapeutic sessions (independent of the patient's diagnosis) are most fruitful if the

individual is not reduced to some of their behaviors and all facets of their existence are considered. Future studies should align with the current development put forward by the committee of experts working on the revision of the DSM. These experts acknowledge the fact that an individual cannot ‘put into boxes’ but should be seen for what they are; a multifaceted person with strengths and weaknesses and with deficits or pathological traits that are as complex as the person him- or herself.

5.7. References

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Chapter 6

FINAL DISCUSSION AND FUTURE DIRECTIONS

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6.1. Summary

In the present thesis, we investigated attentional and timing processes in human perception. The focus was on studying these processes in neurotypical and in clinically referred adults. Moreover, attentional and timing related processes were explored from the perspective of a relatively new concept called Sluggish Cognitive Tempo (SCT). I will address the following research questions: (i) whether there is a relationship between time processing as measured on various time scales and a personality trait (impulsivity) that is known for its immediacy bound style of responding (**Chapter 2: *Selective Impairment of Timing Functions in Non-Clinical Impulsiveness***). (ii) how SCT can be defined based on previous literature (**Chapter 3: *Sluggish cognitive tempo and its neurocognitive-, social- and emotive correlates: a systematic review of the current literature***). (iii) how to create a comprehensive instrument to measure SCT on the basis of previously used SCT items and to what extent this newly constructed SCT questionnaire for adults (SCT-QA) correlates with self-rated attentional and timing functions (**Chapter 4: *Sluggish Cognitive Tempo in Adults: A Validation Study of the Sluggish Cognitive Tempo Questionnaire for Adults.***). Finally, we aimed at answering the question (iiii) whether SCT can be related to specific cognitive impairments in clinical- and non-clinical adults (**Chapter 5: *Sluggish Cognitive Tempo: its manifestation in objective cognitive functioning and timing behavior***).

In summary, as can be read in **Chapter 2**, the previous literature showed that impulsivity is associated with attention and timing problems, such as for example premature motor timing and poor temporal foresight. The results of **Chapter 2** showed that impulsivity was solely associated with the individual's representation of his or her mental future and past and not with more basic, perceptual timing processes. In order to shed light on the mechanisms underlying attention and timing processes (real-life timing behavior but also timing within cognitive processes) we turned to investigating SCT as a crucial clinical phenomenon in which attention and timing were believed to be strongly interlinked. The review of the literature on SCT in **Chapter 3** showed that SCT affects many facets of an individual's life (such as the individual's academic-, cognitive-, and socio-emotional functioning). The literature review further showed a need for more SCT studies in adults and for more studies that explore SCT's relation to objective cognitive testing. Finally, the literature review suggested a special link between SCT and slowed processing speed but also highlighted the fact that there is no consensus in

measuring SCT, yet. **Chapter 4** shows how the SCT-QA, a self-report measure for adults, was created, and how it turned out to be significantly associated with self-report measures on everyday timing functioning and attentional functioning. We hoped to find objective evidence for the previously found association between SCT and self-rated attentional and timing functioning. **Chapter 5**, however, showed that there was only weak evidence for the hypothesis that self-rated SCT relates to objectively measured cognitive functioning in general and to processing speed in particular. An overall emerging theme, when discussing the findings of this thesis became the observation that results based on self-report measures often correlate with other self-report measures but not with objective performance (e.g., during neurocognitive testing). We will discuss this observation further in the section *Comparison of self-rated performance vs. objective neurocognitive performance* in the current general discussion. We will start our discussion on the findings on the main subject of this thesis: SCT.

6.2. Discussion

Sluggish Cognitive Tempo: what do we (not) know? The field of SCT faces major challenges. Even though it is a phenomenon known since the 1980s (Lahey et al., 1984) there is still an (i) apparent lack of consensus on what SCT is, and (ii) a corresponding lack of standardization in measuring SCT (Mueller et al., 2014). In addition, clinical studies in measuring SCT, especially in adults are sorely missing. To understand SCT we need to understand its scientific and clinical origin.

When reviewing the studies on SCT it became clear that the scientific interest in SCT was quite probably a consequence of the distinction of ADHD into two subtypes (ADD with (+H) and without (–H) hyperactivity (we called this the predominantly inattentive type (ADHD/I) throughout the thesis) made in the DSM-III in the 1980s (American Psychiatric Association, 1980). Soon after that, a rise in studies was noticed that examined the differences between the two ADHD subtypes (e.g., Carlson, 1986; Lahey et al., 1984; Maurer & Stewart, 1980; Milich, Ballentine, & Lynam, 2001). However, the differentiation in ADHD subtypes never proved convincing in the clinical field, as results across studies that were focusing on subtyping ADHD remained mixed (Barkley, 2018; Willcutt, 2012). In contrast to the inconsistent results associated with the subtyping of ADHD, studies focusing on individuals, characterized by high levels of what we would characterize, as being typical for SCT, seemed to yield much more promising results (Barkley, 2018). SCT was identified as a set of symptoms that - just as ADHD is characterized by attentional deficits but without ADHD's heterogeneity in symptom presentation (Barkley, 2018). SCT, then, could in principle, describe individuals

who are constantly underaroused, slow in information processing and motor behavior, and who suffer from inattention considerably (e.g., Mueller et al., 2014). Recently, SCT was even labeled to be “the real attention deficit disorder” (Barkley, 2018). We will return to this statement later on.

6.2.1. Measurement of SCT

Lahey and colleagues (1984) are often cited as being the first who investigated a group of children that were later labelled as qualifying for SCT symptoms. They examined 20 children with ADD/-H (predominantly inattentive type of ADHD). These children were observed to show high levels of drowsiness, behavioral and mental sluggishness and increased daydreaming (e.g., Barkley, 2018). The assessed children were further rated as being socially withdrawn, shy, anxious, poor in sports and other academic achievements and rather unpopular within their peer group (Lahey et al., 1984).

The reviewed studies (Chapter 3) agree on the observation that three components are mainly characteristic for SCT: individuals identified by SCT score high on being “slow”, being “sleepy” and engaging in (excessive) “daydreaming”. The items that were identified in our validation study (Chapter 4) are highly in line with those described in earlier work that aimed at identifying psychometrically and clinically valid SCT items (Barkley (2014); Becker et al., 2016, Penny et al., 2009). The recurring items that are believed to measure SCT are: (1) daydreaming, (2) trouble staying awake/alert, (3) feeling mentally foggy/easily confused, (4) staring a lot, (5) looks/feel spacey, mind is elsewhere, (6) is lethargic, (7) is underactive, (8) is slow-moving/sluggish, (9) doesn’t process questions or explanations accurately, (10) appears drowsy/sleepy, (11) appears apathetic/withdrawn, (12) is lost in thoughts. Whereas the “slow” component of SCT is often associated with ADHD/I, ADHD in general, and oppositional defiant disorder, the “sleepy” and “daydreamer” components seem to relate foremost to a more pure form of SCT (e.g., Mueller et al., 2014). From this, it could be speculated that the “slow” component is not as specific for SCT as the “sleepy” and “daydreamer” components. Our validation study (Chapter 4) showed that the highest reliability was found for the subscale measuring “sluggish- & sleepiness” (items 1-6 of Table 1). We did not find evidence that would justify positing an isolated “slow” or “sluggish” factor. Hence, our results do not allow for further testing of the hypothesis that the “sleepy” and “daydreamer” components are much more specific for SCT than the “slow” component.

Nevertheless, we did find that the subscale “sluggish-& sleepiness” was significantly associated with self-rated attention & cognitive instability in our non-clinical adult sample

(Chapter 4). We should keep in mind that these psychometrical valid effects are based on reports of non-clinical adults and it remains open how the factor structure would have looked like if the validation study was done in a clinical population. However, the fact that the “sluggish & sleepiness” scale already associated with “attention & cognitive instability” seemed promising for us to find even more extreme associations of SCT with cognitive processes in a clinical population. The validation study further opens up the possibility to expose the previously used SCT items to a diverse patient pool in the future, in order to see what factor structure, subscales and overall information we can gain from SCT’s representation in the clinical field.

6.2.2. *SCT and its overlap with other disorders*

The previous literature showed that SCT is more likely to be associated with ADHD/I than with the predominantly hyperactive- and impulsive type of ADHD (e.g., Mueller et al., 2014). Our validation study showed that self-rated SCT was indeed associated with self-rated attentional functioning. Those who scored higher on SCT symptoms also agreed more often on “having racing thoughts” or “not paying attention” items of the “attention & cognitive instability” subscale of the Barrat-Impulsiveness scale than those who scored lower on the SCT-QA (Chapter 4). The main signs of ADHD/I symptoms in adults are: “having a short attention span and being easily distracted”, “making careless mistakes”, “appearing forgetful or losing things“, and “being unable to stick to tasks that are tedious or time-consuming” (APA,2015). When comparing the content of these items to the SCT subscales that were found in Chapter 4, we can conclude that SCT does have some overlap contentwise with ADHD/I (e.g. with regard to the items “being easily distracted”) but does come with items that go beyond ADHD/I items (e.g., “feeling sluggish”, “lacking initiative to finish work”, “loosing track while listening”). Please see Table A2 of Appendix A for a comparison of ADHD/I items and the SCT-QA items that were extracted in the factor analysis of Chapter 4.

Furthermore, it was often proposed that SCT shares some overlap with affective disorders such as depression, too (e.g., Mueller et al., 2014; Penny et al., 2009). When exploring the content of items measuring major depression and SCT, it, however, becomes clear that the psychometrically valid SCT items do not track feelings of self-worth, lack of meaning and despair, which are much more typical for depression (Please see again Table A2 of the appendix for a comparison of ADHD/I Adult items, Beck’s depression inventory items and SCT-QA items).

It was argued that removing SCT symptoms from the DSM-IV criteria of ADHD might lead to overdiagnosing individuals with the combined type of ADHD (ADHD/C), while some

of the patients would rather fit a possible diagnosis of SCT or ADHD/I (Mueller et al., 2014.). This thesis did not aim to answer the question whether there is a risk for overdiagnosing ADHD, when removing SCT items from the DSM. However, from the discussion above it is clear that SCT items go beyond ADHD items. Moreover, the results of our cognitive performance study (Chapter 5) suggest that SCT relates to different cognitive functions than ADHD adult symptoms. For example, whereas SCT solely correlated with the reaction time of a cognitive flexibility task, ADHD adult symptoms were significantly associated with controlled attention of the selective attention paradigm, with omission- and commission errors and also with the stability of the reaction time with which the sustained attention task was performed. Please keep in mind that the trends that are discussed in the previous paragraph disappear when controlling for the effect of group affiliation (clinical vs. non-clinical). It could be that our clinical sample did not score extreme enough on the SCT scale to produce clear and significant effects. However, we assessed a clinical group that was oversampled for attentional complaints, hence, if SCT is indeed a pure form of a attention disorder, we would have expected to find at least some objective evidence for attentional deficits based on the cognitive testing. In a future study we would aim at gathering more information about our clinical sample. For example, information about the clinical participants' personality structure (likely presence or absence of personality disorders) or the participants' current mood and affect. It was shown that personality disorders (axis II disorders) are often seen in adult patients diagnosed with ADHD (e.g., Matthies & Philipsen, 2016; Reimherr et al., 2010) and even though it was shown that depressive symptoms and SCT load on different factors in children (Burns et al., 2013), depressive symptoms in adulthood and their likely confounding effects on SCT were not yet assessed. We therefore encourage future studies to explore comorbidity in SCT of axis II disorders in general and likely effects of depression in adulthood in particular.

6.2.3. SCT and Timing Behavior

The current SCT validation study was interesting with respect to its insights that were found for SCT and timing behavior. None of the reviewed previous studies on SCT looked into the relation between SCT and either subjective (everyday timing functioning) or objective timing functioning (processing speed). Chapter 4 showed that SCT was related to subjectively reported difficulties in timing behavior (timing of everyday tasks). Forgetting about deadlines, being late for appointments and similar can have major effects on the person's private and professional life. Barkley (2018) proposes that SCT has a major impact on the individuals' social functioning. He cites previous research and shows that social interactions of individuals who

score high on SCT are often problematic (e.g., Becker & Langberg, 2013; Becker et al., 2014; Burns et al., 2013; Capdevila-Brophy et al., 2012; Camprodon-Rosanas et al., 2017; Garner et al., 2010; Marshall et al., 2013; Willcutt et al., 2013) and characterized by social withdrawal and less responses in social interactions as well as a lower perception for subtle social cues (Mikami et al., 2007). The processing of social cues has been shown to happen quickly and in early information processing stages (e.g., Mueller et al., 2013). For example, human faces are consistently detected earlier than objects (Ro, Russel & Lavie, 2001), words (Halgren et al., 1994) or distorted, scrambled faces (Pegna et al., 2004). It is known that certain disorders, especially those characterized by social impairments (i.e. Autism Spectrum Disorder, ASD) do not show the perceptual prioritizing and speeding of responses to social cues as seen in neurotypicals (e.g., Green & Zaidel, 2010). Unfortunately, we did not look into the speed with which individuals scoring high on SCT respond to social cues. Future studies should test whether SCT shows slowed responses to social cues similar to those as reported in ASD or similar disorders. This could be done by simple reaction time measures to social stimuli versus non-social stimuli. Furthermore, it could also be insightful if these tasks were linked to event-related potential measures, in order to see whether very early perceptual processes are altered in individuals with SCT (e.g., Mueller, Falter-Wagner & Tucha, 2013). In addition, it may be worthwhile to try and find out whether SCT shows any associations with ASD. Hence, the current results underline a need for research in SCT that focusses on objective measures for the hypothesis of a slowed processing speed in general and to social cues in particular.

6.2.4. Comparison of self-rated performance vs. objective neurocognitive performance.

Our study on objective cognitive functioning and its relation to SCT found only weak evidence for objective cognitive- and timing related deficits that can be associated with SCT. The fact that we did not find any associations of SCT with cognitive processes and/or timing functioning when making use of objective neurocognitive testing raised at least three questions on how to interpret these findings. First it could be assumed that (i) SCT does not exist as a distinct, clinical phenomenon. Or secondly, (ii) SCT does exist but our SCT-QA scale does not adequately measure it. Or finally, (iii) SCT does exist and our SCT scale is sufficient but the relationship between SCT and objective cognitive functioning cannot be revealed due to other methodological issues.

With regard to assumption one, *SCT does not exist*: Proving the clinical significance of a certain set of symptoms could be the most difficult and most challenging part of research in the clinical field. The DSM-5, which is the most commonly used clinical tool to diagnose

disorders of many kinds, seeks to incorporate information that ranges from basic neuroscience and genetics to self-reports in order to present empirically valid and reliable sets of symptoms for each disorder. If standards for a certain diagnosis are too strict, some who actually would profit from treatment would be missed out. However, if standards are too loose, some will receive redundant, expensive and in some cases maybe even harmful treatment. Moreover, whether a certain diagnosis becomes established (for example in the DSM) has major consequences for insurance coverage, qualification for specific services (reserved for certain disabilities), legal and workforce related status and an overall chance for recognition and reduction of prejudices. However, it is also known that a diagnosis with a mental disorder can work the other way round. Hence, it can increase the risk for stigmatization. As can be read in a review on stigma in patients suffering from ADHD (Mueller et al., 2012), being diagnosed with a mental disorder increases the individual's risk for being stigmatized. Disorders that are known for their heterogeneity in symptom severity and symptom presentation (e.g., variation in hyperactive, impulsive and inattentive symptoms) across temporal and contextual situations are at higher risk for being stigmatized than more stable disorders (Mueller et al., 2012). These factors (heterogeneity in symptom severity and presentation) go hand in hand with questioning the existence of the disorder itself. In addition, disorders whose symptoms are believed to be under the individual's control (e.g., "people with ADHD just have to focus/concentrate a little better", "they just need to pull themselves together") are very prone to public stigmatization (e.g., Goffman, 1963). Stigmatization itself is acknowledged as being detrimental to the individual's life satisfaction and mental well-being (e.g., Rüsch et al., 2005; van Zelst, 2009). It was shown that stigmatization can even initiate a devastating cascade of formerly light symptom presentation to an aggravation in symptom severity that would allow for a clinical significant diagnosis (e.g., van Zelst, 2009).

Barkley (2018) recently proposed a new label for SCT. He suggested SCT to be called Concentration Deficit Disorder (CDD). He argued that CDD keeps the focus on attention (concentration) as being the major deficit of individuals suffering from it, yet, being likely to reduce the prejudices or stigmatizations that are associated with ADHD. He further argues that CDD sounds less offensive and less derogatory than SCT (Barkley, 2018). However, the term CDD has not been used scientifically or clinically, yet. It remains questionable whether it is reasonable to confront a field of research that is already mixed in its results with regard to whether SCT should be recognized as a disorder itself, with a new name at this stage. As long as there is no consensus on this question and on the issue on how to measure SCT, the introduction of a new label could lead to even more confusion within the research community,

clinicians and those who suffer from symptoms of SCT.

Against assumption one that states that SCT does not exist as a distinct clinical phenomenon, one should point out that all studies reviewed (including a thorough meta-analysis of those studies that provided psychometrical data on SCT: Becker et al., 2016) consistently showed that there is a set of symptoms that seems to occur together. Moreover, this cluster of symptoms is obtained by different scales used (e.g., Mueller, 2013). Based on these observations, we assume that there must be a mutual mechanism that causes this cluster of symptoms to co-occur, which would then lead to the assumption that SCT does exist.

Furthermore, it was shown that this set of symptoms correlates differently with attention deficits than ADHD/I in children (e.g., Bauermeister et al., 2012; McBurnett, Pfiffner & Frick, 2001). Moreover, SCT emerged as a psychometric valid factor in children that did not meet ADHD criteria (Garner et al., 2010) and in children that suffer from other clinical conditions (pediatric survivors of acute lymphoblastic leukemia: Reeves et al., 2007; children diagnosed with Fetal Alcohol Syndrome: Graham et al., 2013). These observations provide at least some information about SCT's independence of ADHD. It is often stated that SCT is simple ADHD. Against this assumption would be the observation that 24 out of 26 factor-analytical studies provided evidence that a cluster of SCT symptoms can be found that is independent of inattention and hyperactive-impulsive symptoms (Becker et al., 2016) and that SCT symptoms were associated with attentional problems that go beyond ADHD symptoms (e.g., Harrington & Waldman, 2010; Wählstedt & Bohlin, 2010). Furthermore, the SCT items "being confused", "daydreaming", and "starring blankly into space" related to internalizing and social deficits that were shown to be independent of ADHD or other psychopathologies in psychiatrically hospitalized children (Becker et al., 2013).

With regard to assumption (ii) that SCT does exist but our SCT scale is not sufficient to measure SCT: we need to admit that there is still a lack of consensus on how to measure SCT in general. However, our 16 item SCT scale (Chapter 4) is highly in line with the 13 item SCT scale that was the result of a critical review and meta-analysis of 26 studies that provided data of factor-analytical approaches (Becker et al., 2016). It was further shown by this review that SCT can be reliably measured with scales that provide seven or more items (Becker et al., 2016). Our 16 item scale therefore should be sufficient with regard to this argument. Our obtained subscales (*sluggish- & sleepiness*, *lacking persistency & motivation*, and *mind wandering & lack of concentration*) are comparable to those by previous studies (e.g., Becker et al., 2016) except for the subscale *lacking persistency & motivation*. None of the previous studies examined the impact of motivation or persistency in SCT, nor did any study report

finding a similar subscale. Even though this subscale seems to be unique for our study, we would not assume that our SCT-QA in total deviates significantly from those scales that were found reliable in measuring SCT by previous studies. Although there is some debate which exact items should be included or excluded when measuring SCT (Becker et al., 2016, Penny et al., 2009), all studies that focused on finding a reliable SCT scale, including our own study (Chapter 4), share the observation that the items “daydreaming” and being “sluggish/drowsy” need to be included (e.g., Barkley, 2012; Becker et al., 2016; Bauermeister et al., 2012).

With regard to more basic prerequisites when testing a construct psychometrically, our participant pool for the validation study was shown to be more than sufficient. However, we did use a non-clinical sample only for the validation study. Future studies should try to set up a validation study of all previously used SCT items by making use of answers of a large clinical sample. As already pointed out, in case a validation study would be performed in a large clinical sample it is of high relevance to test this sample for possible comorbid disorders (such as for example, depression, ADHD, sleeping disorder etc.).

For us, the biggest limitation in the quest on finding an adequate SCT scale is the observation that most of the SCT items were originally used in research on ADHD. We assume that the spectrum of items that in the end would cluster and represent the condition SCT would be much more specific for SCT if we would make use of thorough qualitative research in cases that stand out because of their for example excessive daydreaming or extreme cognitive or behavioral sluggishness and use their symptoms as a starting point to investigate the construct SCT all over again.

Finally, the last assumption (iii) that SCT does exist, we did measure it well but we cannot find any objective cognitive evidence for its existence leads us to an aspect put forward by Barkley (2012). Barkley (2012) pointed out that results of self-rated measures (e.g., questionnaires) and results of objective measures (neurocognitive tests) correlate less strongly than measures of the same kind (hence, self-rated measure with self-rated measure and objective measure with objective measure). We try to explore the factors that might contribute to this observation in the following. First, it seems likely that there might be statistical factors such as differences in distributions (skewness, kurtosis) based on the different measurement modalities that are used, that might contribute to the weakening of the aspired associations. Correlation analysis and regression are quite robust to non-normality of the distributions; however, the variables under investigation should be more or less symmetrically distributed. We could further ask ourselves whether cognition measured by self-rated questionnaires is comparable to the cognition that we measure with objective neurocognitive tests. It seems very likely that

factors that might contribute to the subjectively perceived and reported lack of attention and timing functioning, which was shown to be associated with SCT are different than processes of attention and timing when measured with cognitive tasks. We used the “It’s about time“-scale (IAT) by Barkley (1998) as a measure of subjectively perceived difficulties with everyday timing. The IAT interrogates the participants on their awareness of temporal information in everyday life situations. This awareness or the lack thereof is very likely to be different from the type of temporal information that we measure with objective neurocognitive tests, in which the reaction time is the representative of the participants’ timing abilities. Similarly, the BIS-II was used to measure subjective deficits with attention. Items of the Attention scale of the BIS-II such as “I don’t pay attention” or “I concentrate easily” are again very likely to measure different aspects of attention than computerized attention tasks, such as a Go/No’-Go paradigm in which the participants’ ability to selectively respond to or ignore certain stimuli is tested.

We could also ask on which level SCT shows its actual effects. The current literature review (Chapter 3) and the validation study (Chapter 4) with the associations of the self-report data did provide evidence that SCT does associate with factors that would underline SCT’s construct validity. It could be that SCT is a phenomenon that is much more bound to the mental state/affective state of the individual than to basic aspects of cognitive processing. For example, it is known that factors such as intrinsic motivation, self-control (the capability to control one’s attention and emotions in the presence of temptation) and perseverance are important determinants in everyday-life (e.g., Duckworth & Gross, 2014; Locke & Latham, 2013), yet, these factors are not reflected by data from neurocognitive laboratory test.

It could also be that there is a discrepancy between our own awareness of our cognitive abilities and our actual cognitive performance. Being (self-) aware of our own limitations and capabilities is of no question critical in everyday life. Self-awareness is also a critical component of normal cognition (Williamson et al., 2010). Individuals’ self-ratings have been shown to be influenced by (i) individual differences in self-reflection and self-observation, (ii) the individual’s current affective mood (it is very well known, that if you are currently in a rather depressed mood, you will not rate your own capacities as superior or “good” e.g., Kavanagh & Bower, 1985; Sedikides, 1992), (iii) characteristics associated with the individual’s self-esteem and (iv) the individual’s understanding of cognitive concepts such as attention, concentration etc. Lack of insight into one’s own neurocognitive functioning has been linked to specific psychiatric disorders (e.g., schizophrenia: Medalia, Thysen & Freilich, 2008; Moritz et al., 2004, Keefe et al., 2006, Harvey et al., 2001) and physical/neurological disorders, such as chronic fatigue syndrome (Lakein et al., 1997; Metzger & Denney, 2002), epilepsy

(Sawrie et al., 1999), lymphoma (Cull et al., 1996), HIV (van Gorp et al., 1991), and coronary bypass surgery (Khatri et al., 1999; Newman et al., 1989). Usually patients suffering from physical disorders overestimate their cognitive deficits (e.g., Middleton et al., 2006) rather than reporting less cognitive deficits. This effect is reversed by patients suffering from psychiatric disorders, such as schizophrenia (e.g., Medalia & Lim, 2004) or dementia (Williamson et al., 2010), in which an underestimation of cognitive deficits is more common.

As can be seen in Chapter 4 of this thesis, our SCT scale did correlate with self-rated everyday timing functioning and with self-rated attention, motor performance etc. In this case, SCT as well as the cognitive functions (e.g., attention, timing) were assessed by questions that are likely to start a reflective process within the individual. We assume that this reflective process is equally influenced by the above mentioned factors (i.e., the individual's understanding of the concepts, level of self-reflection, current mood/ mental state, and self-esteem), for the two domains under investigation (hence, SCT and attention or timing). In conclusion, it is likely the case that, whereas data assessed with questionnaires represent the outcome of this more holistic reflective process; data by computerized cognitive testing is much less reflective in nature. Following this reasoning, SCT might not affect basic cognitive processes but solely shows its effects on higher order functioning as we see it in every-day tasks: making decisions, responding to present or future demands, finishing projects in time, taking initiative to start working on something that's essential for the person or its environment is much more complex than responding to a well-defined computerized task. Cognitive tasks tapping into the concept of executive functioning (EF) promise to produce results that are much more associated with the individual's every-day success/functioning in life, as they tap into a combination of cognitive and perceptual processes, and create a less artificial situation as seen in lab situations. None of the existing studies on SCT has measured the relation between SCT ratings and objective EF in adults. Future studies could aim at testing whether there is an association of SCT ratings and more realistic, less restricted EF tests that tap much more into functions necessary to respond adequately to an adult's life-requirements.

Apart from this, it should be pointed out that whereas the validation study (Chapter 4) was based on data of students, the study using objective cognitive testing (Chapter 5) was based on data of non-clinical and clinical adults with diverse professional backgrounds. Hence, we cannot be sure whether we would have obtained different associations between SCT and cognitive functioning if we had validated our SCT scale based on reports by the clinical sample. Future studies should therefore on the one hand make use of the same participant pool, when validating a scale and test this scale's association with cognitive functioning and on the other

hand keep in mind that effects across measurement modalities (self-report vs. objective cognitive testing) might be harder to detect than effects obtained by the same modality. Our results are somewhat in favor of the assumption that SCT does show its' effect on higher order functioning, hence functioning that is characterized by reflective, complex processes but does not affect cognitive functioning. Future studies could explore this aspect more in detail.

6.2.5. Time perception

The impact of subjectivity (time perspective) and objectivity (time perception, as measured on a ms and ms-sec scale) was also explored in Chapter 2. Chapter 2 presents a study on the temporal nature of cognitive and perceptual phenomena in individuals with either high or low levels of impulsivity. Perception of time and altered timing functions have been previously associated with attentional processes in general (e.g., Brown, 1985; Zakay, 1992) and with specific personality traits (e.g., Rammsayer, 1997; Wittman & Paulus, 2008) or psychological disorders (e.g., Bonnot et al., 2011; Meck, 2005) in particular. It seems of no question that the human condition is a condition defined by time. Previous research showed that a certain time period might dominate the individual's thoughts (Cottel, 1967). Moreover, it is known that the maturity of one's cognitive capacities also relates to the understanding of time (Piaget, 1955). It is further known that one's orientation in time has major effects on how we make decisions (e.g., Wittman & Paulus, 2008). Even as simple decisions of whether we take the stairs or wait for the elevator is determined by how we experience time and the duration of its' passage (Wittman & Paulus, 2008). Time is not a quantity itself, nor is there a sensory organ (such as the eyes or ears) that is dedicated to sensing the passage of time. Nevertheless, when we think about time, we foremost make use of descriptions that are characterized by motion or locations and space (Evans et al., 2004). For instance, we say "time passed quickly", "that party last night lasted long". Lakoff and Johnsen (2003) point out that time has become a valuable resource in Western culture. Time, is clearly a construct that emerged in line with modern industrialized societies and that is strongly tied to our understanding that time can be spent, wasted, owned, invested more or less wisely and that it is often associated with a certain reward (e.g., money: we get paid by hour, month or per year, Lakoff & Johnson, 2003). Hence, even though we do not consciously think about the construct of time constantly, it does affect our daily life at almost every awake moment.

6.2.6. Basic, early perceptual timing processes

The assessment of individuals with high levels of impulsivity (Chapter 2) showed that trait impulsivity is indeed associated with the individual's psychological evaluation of time but not

so much with very basic, early perceptual processes of time processing (as measured on a millisecond scale) that were measured objectively. From these findings, it could be concluded that early processes associated with basic time perception are less affected by the impact of affective or attentional factors. Moreover, it seems that more basic, early time perception processes are independent of those mechanisms that determine an individual's psychological orientation in time. Even though previous research showed that impulsivity is consistently associated with a subjectively faster sense of time (e.g., Rubia et al., 2009) and an increased arousal level (Wittmann & Paulus, 2008), our findings showed that very basic timing functions (as measured on a millisecond scale) are robust to effects of affect (impulsivity) or arousal (attention). Whereas timing functions that are measured on a much longer timing scale (months, years) and that represent the extent to which the individual thinks about its' past, present and future showed that affect (impulsivity) indeed associated with a tendency to endorse the present much more than the past or the future (future consequences). Hence, whereas basic timing functions were not affected by affect or arousal, more cognitively elaborate timing functions (time perspective) that are more stable across the individual's life, associated with the individual's level of impulsivity. This finding reminded us very much of our interpretation of our findings of the SCT studies. We proposed that SCT seems to be much more related to a higher order, reflective cognitive process, and that SCT might show its effect on this mental level but not on basic cognitive processes. Hence, impulsivity as a trait, and SCT as a proposed clinical phenomena do show effects on higher order (reflective processes) but not on basic perceptual (with regard to impulsivity and timing) or basic cognitive (with regard to SCT and objective cognitive functioning) processes. It remains open for future exploration whether the individual's orientation in time is a more flexible psychological function that varies in line with major life events or aging or whether it is rather consistent throughout life.

6.3. Future directions

This paragraph will briefly summarize our suggestions for future studies on SCT. When discussing the literature on SCT it became clear that SCT with all its possible facets is yet understudied. There is a lack of qualitative case studies that aim at exploring SCT, in detail. Only if we broaden our knowledge by making use of qualitative case studies on SCT we can actually test the emerging items. These items should then be tested in a variety of non-clinical and clinical samples.

We assume that we would find much more extreme scores of SCT, when SCT is tested in populations suffering from tremendous attentional dysfunctioning, such as patients with

neurological damage or diseases affecting the brain. Moreover, SCT should be assessed in diverse clinical populations that suffer from different psychological or psychiatric disorders, in order to see whether SCT contributes to the understanding of these disorders. Insights of SCT's association with diverse clinical populations could also provide the missing information whether SCT is different from ADHD. If SCT symptoms for example associate with different clinical disorders than ADHD, evidence would be given that enhances SCT's divergent validity. Moreover, SCT's link to individuals' personality structure (attenuated personality or personality disorders) could provide insights into SCT that have not been revealed so far. As was shown in Chapter 2, impulsivity as a personality trait does associate with higher order reflective timing functioning. It could be interesting to see whether there are some personality traits that correlate stronger with SCT than others. Behavioral sluggishness is often associated with ratings of shyness, passivity, fearfulness and little verbal communication in children (e.g., Caspi & Silva, 1995). We therefore assume that SCT might correlate with traits such as introversion. The association of personality and psychological vulnerability has a long history of scientific research. If we want to understand the full scope of SCT and its effects on the individual we need to broaden our investigations and take personality into consideration.

There are few studies, yet, that investigated possible differences in the likelihood to suffer from SCT and gender. From ADHD it is known, that males are more likely to be diagnosed with ADHD (e.g., Ramtekkar et al., 2010). One study showed that including information of SCT symptoms in the subtyping of children with ADHD was only beneficial for finding a proper diagnosis for the boys (e.g., Todd et al., 2004). Our study did not explore whether SCT items were endorsed differently due to gender. However, future studies should take this possibility into consideration

Furthermore, longitudinal research on SCT is lacking. We need more insights into a possible developmental aspect of SCT. It was pointed out that for example ADHD symptoms change from child- to adulthood. From ADHD we know that there is a peak of symptom presentation when children start attending primary education (e.g., Barkley et al., 1991). This observation is believed to be at least partly due to the higher cognitive load associated with class-room situations (such as many possible distracting stimuli (noise, objects, other pupils etc.), an increase in rules, which the students have to follow, multiple tasks that need to be prioritized etc.). It would be interesting whether there is a moment in life at which SCT symptoms might be more severe or more detrimental to the individual's life. The apparent lack of studies on SCT in adults in general has been mentioned several times throughout the thesis. As life becomes more complex with time and SCT has been shown to be more likely to associate

with complex adult every-day tasks (taking initiative, finishing tasks in time etc.) we promote future studies to assess SCT in adults. A special focus on SCT in adults could be on its relation to objective obtained data from executive functioning tests. We assume that SCT's effects will be much more obvious the more complex the task at hand gets.

In line with this, future studies should investigate whether there are signs of SCT symptom compensating behavior. A similar question would be whether different compensating behavior can be observed due to different phases of life. For example, are adults with signs of SCT better in compensating for being behaviorally slow than children with SCT.

There is a pronounced lack of studies on possible treatment options for SCT. Pfiffner and colleagues showed that children with SCT benefited from a special program that targets processing and social information deficits (Pfiffner et al., 2007). It would be interesting to see whether an adapted program would improve signs of SCT in adults as well. Moreover, pharmaceutical treatment studies are lacking. Children with ADHD/I and signs of SCT did not differ from children with ADHD/I without signs of SCT in their responses to methylphenidate (Ludwig et al., 2009). It therefore seems rather questionable whether signs of SCT can or should actually be treated pharmaceutically. It is known that psychopharmaceutics change or balance the amount of neurotransmitter in the brain. These neurotransmitters are involved in perception and emotions. With regard to methylphenidate it was shown that methylphenidate increases levels of dopamine in the brain. Dopamine is involved in experiencing pleasure but is also strongly associated with motivational processes (e.g., Gottlib, 2001). It thereby improves attentional processes and levels of distractibility in individuals suffering from ADHD (Gottlib, 2001). We did not find evidence for objective attentional or processing speed deficits associated with SCT. And thereby question the use of psychopharmaceutics for those who are likely to suffer from SCT.

6.4. Conclusion

This dissertation aimed at investigating attentional processes and information processing (especially timing functioning) through different approaches. The different studies showed that (i) very basic timing functions that are related to crucial human behavior, such as perception of speech, music and motor control are unaffected by psychological traits that are associated with attentional dysfunctioning, (ii) SCT, a highly discussed phenomenon in the scientific field, seems to be related to attentional deficits and time perception when measured with the same method (self-rated questionnaires) but was not associated with objective neurocognitive testing, (iii) the idea of making SCT a disorder on its own should be handled with caution as findings

remain mixed. The fact that (iv) SCT symptoms related to attentional deficits and troubles with everyday timing behavior when all parameters (SCT, attention, everyday timing behavior) were assessed subjectively (self-ratings), but not when some of the parameters were assessed objectively, led us to the assumption that SCT might show its effects on higher order (reflective) processes and not so much on basic cognitive processes. Whether this assumption can be backed up by results of future studies remains open. Wherever our scientific inquiries lead us, it is the scientist's responsibility to acknowledge that each person lives and strives for context and purpose. In order to understand clinical phenomena we need to broaden our view, question our methods and acknowledge the fact that some phenomena might not be able to be put in numbers.

“Idris: Are all people like this?
The Doctor: Like what?
Idris: So much bigger on the inside.”
— Neil Gaiman

6.5. References

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APPENDICES

Appendix A Studies, samples and measures applied

Author (s)	Sample (s) ^a	SCT measure (s) ^b	Other measure(s)
Carlson et al. 2002 Community-based population No medication	<u>Evaluated population:</u> 346 children Age range: 4–11 yrs. (180 males; 166 females) (a) ADHD/C (n = 50) (b) ADHD/I high SCT (n = 34) (c) ADHD/I low SCT (n = 89) (d) Controls (n = 123) <u>Raters:</u> Teachers	5 item SCT Scale: Five items from the Child Behavior Checklist-Teacher Rating Form (CBCL-TRF: (Hartman et al., 2004; Achenbach, 1991): “Sluggish/slow to respond”, “Seems to be in a fog”, “Drowsy or sleepy”, “Easily confused”, and “Daydreams/stares into space”	DSM 4 checklist for ADHD, ODD (Gaub & Carlson, 1997) 3 Item Social functioning scale (Dishion, 1990) CBCL TRF (Achenbach, 1991): Childhood behavior
Weiler et al. 2002 Clinical population Off Medication	<u>Evaluated population:</u> 230 children with ADHD Age range: 7.6–11.1 yrs. (111 males; 119 females) (a) ADHD (n = 24) (b) Reading disability (RD) (n = 42) (c) Comorbid ADHD and RD (n = 9) (d) Controls (n = 149) <u>Raters:</u> Teachers	Classroom observation (Weiler et al., 2002)	Kaufman Brief Intelligence Test (K-BIT: Kauman & Kaufman, 1990): IQ Visual Filtering Task (Weiler et al., 2002) Parallel search, Serial search, Decision and Motor response Rapid Auditory Processing Task (Waber et al., 2000): Auditory processing Decision and Motor response
Hartman et al. 2004 Clinical population Medication withhold at least 24 hr. prior to testing	<u>Evaluated Population:</u> 296 twins with ADHD and learning disabilities Age range: 8–18 yrs. (141 males; 145 females) <u>Raters:</u> Teacher, Parents	5 SCT items based on e.g., (Achenbach, 1991; Frick et al., 1994): “Sluggish/slow to respond”, “Seems to be in a fog”, “Drowsy or sleepy”, “Easily confused”, and “Daydreams/stares into space”	Disruptive Behavior Rating Scale (DBRS: Barkley & Murphey, 1998): ADHD DSM-III-R parent-report version of the Diagnostic Interview for Children and Adolescents (DICA-P: Reich & Wellner, 1988): ODD, conduct disorder (CD), generalized anxiety disorder (GAD), and major depressive disorder Child Behavior Checklist (CBCL: Achenbach, 1991): Internalizing/Externalizing behavior Wechsler Intelligence Scale for Children (WISC-R: Wechsler, 1974): IQ

		Wechsler Adult Intelligence Scale (WAIS: Wechsler, 1981): IQ Peabody Individual Achievement Test (PIAT: Dunn & Markwardt, 1970): Academic achievement	
Todd et al. 2004 Community-based population No medication	Evaluated Population: 229 twins Age range: 8–14 yrs. (109 males; 120 females) (a) No ADHD (n = 163) (b) ADHD/I (n = 30) (c) ADHD/C (n = 29) (d) ADHD/HI (n = 7) Raters: Parents	2 SCT items: “Stares into space and daydreams”, “Appears to be low in energy, sluggish, or drowsy”	DSM IV: ADHD and questions about major depression (MDD), generalized anxiety disorder (GAD), social phobia, and other disorder
Bauermeister et al. 2005 Community-based population No medication	Evaluated population: 98 children, Age range: 6–11 yrs. (58 males; 40 females) (a) Inattentive and hyperactive group (n = 47) (b) Inattentive only (n = 44) (c) Control (n = 29) Raters: Teachers, Mothers	5 item SCT scale (SCT-5): “Confused or seems to be in a fog”, “Daydreams or gets lost in his/her thoughts”, “Stares blankly”, “Underactive, slow moving or lacks energy” and “Apathetic or unmotivated”	School Behavior Inventory (SBI: Bauermeister, 1994): Distraction-Motivation (DM) and Activity-Impulsivity (AI) scales Disruptive Behavior Rating Scale (DBRS:Barkley et al., 1997): Behavior functioning Child Behavior Checklist (CBCL;Achenbach, 1991): Behavioral functioning Developmental and Diagnostic Interview DISC IV (Shaffer et al., 2000): DSM-IV psychopathology Children’s Global Assessment Scale-Spanish (CGAS:Bird et al., 1987): Adaptive functioning Home and School Situations Questionnaires (HSQ & SSQ: Barkley et al., 1997): Behavior functioning It’s About Time Questionnaire (IATQ: Barkley et al., 1997): Sense of time Spanish Social Skills Questionnaire (SSSQ:Gresham & Elliot, 1990): Social functioning Wechsler Intelligence Scale for Children–Revised for Puerto Rico (WISC-R PR: Herrans & Rodriguez, 1992): IQ Spanish Spelling-Test of Reading and Written Language: TRWL: Hammil et al., 1982): IQ Bender Gestalt Test (BGT: Koppitz, 1975): Visual-motor integration Conners’ Continuous Performance Test (CPT: Conners, 1995): Vigilance, impulsiveness Restricted Academic Situation Behavior Coding Syste (Barkley,

			<p>DuPaul, McMurray, 2004): Behavioral functioning</p> <p>Solid State Actigraph (Ambulatory Monitoring Inc., 1995): Number of movements a child makes per unit of time</p> <p>Beck Depression Inventory Spanish (BDI: Bernal, Bonilla & Santiago, 1995): Mother self-report measure</p> <p>Family APGAR Spanish (Goodman et al., 1998): Parent's satisfaction with family relationships</p> <p>ADHD Symptoms Scale Self Report Form (ADHD SS-SRF: Barkley et al., 1997): ADHD</p> <p>Family Experiences Inventory (FEI: Bauermeister, Matos & Reina, 1999): Family stress</p> <p>Parent Practices Inventory (PPI: Salas-Serrano, 2001): Parental monitoring and supervision, parental involvement, parental discipline</p>
<p>Huang-Pollock et al. 2005</p> <p>Clinical population</p> <p>Medication withhold at least 24 hr. prior to testing</p>	<p>Evaluated population: 79 children Age range: 8–12 yrs. (a) ADHD/I (n = 16) (b) ADHD/C (n = 28) (c) Control (n = 35)</p> <p>Raters: Teachers, Parents</p>	<p>3 item SCT scale (Carlson & Mann, 2002; McBurnett, Pfiffner & Frick, 2001): “Stares into space/ daydreams”, “Low in energy, sluggish, or drowsy”, “Apathetic or unmotivated to engage in goal-directed activities”</p>	<p>Behavior Assessment Scale for Children (BASC: Reynolds & Kamphaus, 1992): Attention, hyperactive, or conduct problem scale</p> <p>ADHD rating scal (DuPaul et al., 1998): ADHD</p> <p>Conners' Rating Scales Revised (Conners, 1997): ADHD</p> <p>Developmental and Diagnostic Interview DISC IV (Shaffer et al., 2000): DSM-IV psychopathology</p> <p>Selective attention paradigm (Huang-Pollock, Carr & Nigg, 2002; Maylor & Lavie, 1998): Selective attention</p>
<p>Hinshaw, 2002</p> <p>Clinical population</p> <p>Medication withhold at least 24 hr. prior to</p>	<p>Evaluated population: 228 girls Age range: 6–12 yrs. (a) Psychiatrically-referred girls (n = 140) (b) Controls (n = 88)</p> <p>Raters: Researchers</p>	<p>Group of ADHD with SCT was formed based on: (a) presence of very few HI symptoms, (b) high levels of parent- and teacher- rated sluggish cognitive tempo</p>	<p>Wechsler Intelligence Scale for Children (WISC-III: Wechsler, 1991): IQ</p> <p>Taylor Complex Figure Test (TCFT: Taylor, 1969): Planning, perceptual organization, graphomotor abilities</p> <p>Conners' CPT (Conners, 1995): Visual attention, set shifting</p> <p>Rapid Automatized Naming Test (RAN: Jellinek, 1988): Orienting, semantic processing and retrieval</p> <p>Underlining Test (Rourke & Gates, 1980, Rourke & Orr, 1977): Word recognition, controlled processing</p>
<p>Mikami et al. 2007</p> <p>Clinical population</p> <p>Medication withhold at least 24 hr.</p>	<p>Evaluated population: 116 children Age range: 7–12 yrs. (81 males; 35 females) (a) ADHD-C (n = 33) (b) ADHD-I (n = 45) (c) Control (n =</p>	<p>SCT items from DSM IV scale: “Often daydreams” , “Sluggish or drowsy”, “Apathetic and unmotivated”</p>	<p>Cooperation subscale of the Social Skills Rating Syste (SSRS: Gresham & Elliot, 1990): Social functioning</p> <p>Peer Relations Scal Pfiffner LJ: Peer Relations Scale. 2002</p> <p>Unpublished manuscript, U.C.S.F.]: Peer-ratings: subscales of “positive nominations” (measuring whether the child is sought out and liked by peers),</p>

prior to	38)		and “negative nominations” (measuring whether the child is actively disliked by peers) Typing ability: Time to accomplish 3 standard sentences Wechsle Intelligence Scale for Childre , 4th ed (WISC-IV: Wechsler, 2003) or Wechsler Abbreviated Scale of Intelligence (WASI: Wechsler, 1999): IQ Word Reading and Reading Comprehension subtests on the Wechsler Individualized Achievement Test, 2nd ed (WIAT-II: Wechsler, 2001): Reading ability Computerized Chat Room Peer Interaction: Social functioning
Pfiffner et al. 2007 Clinical population Off medication	Evaluated population: 69 children with ADHD/I Symptoms Age range: 7-11 yrs. (46 males; 23 females) Raters: Teachers, Parents	15 item SCT Scale (SCT-15: (McBurnett & Pfiffner, 2012)	DSM IV Inattention Symptoms (Gadow & Sprafkin, 1994): Inattention Social Skills Rating System (SSRS: Gresham & Elliot, 1990): Social functioning Children’s Organizational Scale (COSS: Abikoff & Gallagher, 2003): Organizational functioning Test of Life Skill Knowledge (Pfiffner & Mikami, 2005): Social and organizational functioning Clinical Global Impressions Improvement (NIMH, 1985): Psychopathology
Reeves et al. 2007 Clinical population Off medication	Evaluated population: 99 children and adolescents Age range: 6–19 yrs. (53 males; 46 females) (a) Survivors of acute lymphoblastic leukemia (n = 80) (b) Controls (n = 19) Raters: Researchers	SCT scale (SCT 5) of Child Behavior Checklist (CBCL: Achenbach, 1991): “Confused or in a fog”, “Daydreams or gets lost in his or her thoughts”, “Overtired”, “Stares blankly”, “Underactive, slow moving, or lacks energy”	Wechsler Intelligence Scale for Children , third edition (WISC-III: Wechsler, 2003): IQ Wechsler Adult Intelligence Scal (The Psychological Corporation, 1992): IQ Wechsler Individual Achievement Test (WIAT: The Psychological Corporation, 1992): Academic functioning
Solanto et al. 2008 Community-based population No medication	Evaluated population: 80 children Age range: 7–11 yrs. (43 males; 37 females) (a) ADHD/I (n = 26) (b) ADHD/C (n = 34) (c) No ADHD but other psychiatric condition (n = 20) Raters: Teachers,	2 Items of SNAP IV Teacher and Parent Rating Scale (Swanson et al., 1983): “Stares into space and reports daydreaming”, “Appears to be low in energy levels, sluggish or drowsy”	Delay Aversion Test (DAT: Sonuga-Barke et al., 1992): Delay aversion Buschke Selective Reminding Test (Buschke & Fuld, 1974): Verbal learning and memory Visual Learning Test of the WRAML (VLT: Sheslow, 1990): Spatial memory Sternberg visual memory search task (Sternberg, 1969): Information-processing Stroop Colo Word Test (Golden, 1978): Cognitive flexibility, resistance to interference.

	Parents		Conners' Continuous Performance Test (CPT: Conners, 1994): Inhibitory control. Posner Test (Posner & Petersen, 1990): Covert visuospatial orienting task Tower of London (TOL: Culbertson & Zillmer, 1998): Planning
Desman et al. 2008 Clinical population On medication	<u>Evaluated population:</u> 38 boys Age range: 8–12 yrs. (a) ADHD/I (n = 19) (b) Controls (n = 19) <u>Raters:</u> Researchers	Children with ADHD/I that responded slower on Go/No-Go paradigm in line with SCT symptomatology	DSM IV (American Psychiatric Association, 1994): ADHD Conner's Parent Rating Scale (CPRS 10-item index: Conners, 1973): Psychopathology Strength and Difficulties Questionnaire (SDQ-G: Klasen et al., 2000): Hyperactivity The Go/No-Go paradigm of the Test Battery for Attentional Performance (TAP: Zimmermann & Fimm, 1993; Zimmermann & Fimm, 1994): Inhibitory control, interference
Ludwig et al. 2009 Clinical population On medication	<u>Evaluated population:</u> 88 ADHD/I children and adolescents Age range: 8–15 yrs. (63 males; 25 females) (a) ADHD/I and SCT (n = 18) (b) ADHD/I no SCT (n = 70) <u>Raters:</u> Researchers	SCT scale from Child Behavior Checklist (CBCL: Achenbach, 1991): "Being confused or lost", "Daydreaming", "Stares", "Drowsiness"	Kiddie Schedule for Affective Disorders and Schizophrenia–Epidemiological version (K-SADS-E: Polanczyk et al., 2003; Rohde et al., 2005): Psychopathology Swanson, Nolan, and Pelham Questionnaire scale–version IV (SNAP-IV: Swanson et al., 2004): ADHD Wechsler Intelligence Scale Third edition (WISC-III: Wechsler, 1991): IQ
McConaughy et al. 2009 Clinical population Off medication	<u>Evaluated population:</u> 136 children Age range: 6–11 yrs. (116les; 47 females) (a) ADHD/C (n = 64) (b) ADHD/I (n = 22) (c) Psychiatrically-referred children without ADHD (n = 51) (d) Controls (n = 26) <u>Raters:</u> Teachers, Parents	SCT scale of Direct Observation Form (DOF: McConaughy et al., 2009; Skansgaard & Burns, 1998)	ADHDRS IV (DuPaul et al., 1998): ADHS NIMH DISC 4 (Shaffer et al., 2000): Psychopathology DOF (McConaughy et al., 2009): Standardized form for rating observations of children's behavior in classrooms, at recess, and in other group settings.
Penny et al. 2009 Community-based population No medication	<u>Evaluated population:</u> 335 children Age range: 4–13 yrs. <u>Raters:</u> Teachers, Parents	14 Item SCT scale (Penny et al., 2009): "Appears to be sluggish", "Is apathetic: shows little interest in things or activities",	Disruptive Behavior Disorder rating scale (DBD: Pelham et al., 1992): ADHD, oppositional defiant disorder (ODD), conduct disorder (CD) Internalizing subscale of the Pediatric Symptom Checklist (PSC: Jellinek, 1988): Internalizing

		<p>“Appears tired, lethargic”, “Seems to be in a world of his or her own”, “Seems drowsy”, “Daydreams”, “Gets lost in his or her own thoughts”, “Is unmotivated”, “Underactive, slow moving, or lacks energy”, “Needs extra time for assignments”, “Lacks initiative to complete work”, “Effort fades quickly”, “Yawning, stretching, sleepy-eyed appearance”</p> <p>“Slow or delayed tasks”</p>	
<p>Garner et al. 2010</p> <p>Clinical population</p> <p>Medication status unknown/not stated by the authors</p>	<p><u>Evaluated population:</u> 322 Psychiatrically-referred children and adolescents</p> <p>Age range: 5–17 yrs</p> <p>(a) ADHD-I (n = 40)</p> <p>(b) ADHD-C/H (n = 90)</p> <p>(c) Learning Disability or Language Disorder (n = 32)</p> <p>(d) Controls (n = 44)</p> <p><u>Raters:</u> Teachers, Parents</p>	<p>5 item SCT scale (SCT 5) from the Child Behavior Checklist (CBCL: Achenbach, 1991): “Sluggish/slow to respond, “Seems to be in a fog,” “Drowsy or sleepy”, “Easily confused”, and “Daydreams/stares into space”</p>	<p>DSM-III-R parent-report version of the Diagnostic Interview for Children and Adolescents (DICA-P: Reich & Welner, 1988): symptoms of oppositional defiant disorder (ODD), conduct disorder (CD), generalized anxiety disorder (GAD), and major depressive disorder.</p> <p>Child Behavior Checklist (CBCL: Achenbach, 1991): Behavioral functioning</p> <p>Wechsler Intelligence Scale for Children (WISC-R: Wechsler, 1974): IQ</p> <p>Wechsler Adult Intelligence Scale (WAIS: Wechsler, 1981): IQ</p> <p>Peabody Individual Achievement Test (PIAT: Dunn & Markwardt, 1970): Reading and mathematics</p>
<p>Wählstedt et al. 2010</p> <p>Community-based population</p> <p>No medication</p>	<p><u>Evaluated Population:</u> 209 children</p> <p>Age range: 8–9 yrs. (111 males; 98 females)</p> <p><u>Raters:</u> Teachers, Parents</p>	<p>5 SCT items from Child Behavior Checklist (CBCL: Achenbach, 1991)</p> <p>“Confused or seems to be in a fog”, “Daydreams or gets lost in his/her thoughts”, “Stares blankly”, “Underactive, slow moving or lacks energy”, “Apathetic or unmotivated”</p>	<p>Stroop like day night test (Berlin & Bohlin, 2002; Gerstadt, Hong & Diamond, 1994): Inhibitory control</p> <p>Children’s Size Ordering Task (McInerney, Hrabok & Kerns, 2005): Working memory</p> <p>Pig House: Spatial working memory task</p> <p>Go /No go (Nigg, 2006; Van der Meere & Sergeant, 1988; Wilding, 2005): Sustained attention, state regulation</p> <p>Wechsler Intelligence Scale for Children third edition (WISC-III: Wechsler, 1991): IQ</p> <p>DSM IV (American Psychiatric Association, 1994): ADHD, ODD</p> <p>Strengths and Difficulties Questionnaire (SDQ: Malmberg, Rydell</p>

			& Smedje, 2003): Internalizing symptoms Academic achievement: Swedish, mathematics, and social sciences
Skirbekk et al. 2009	Evaluated population: 141 children Age range: 7–13 yrs. (90 males; 51 females)	17 item SCT scale (SCT-17: Pffiffer et al., 2007): “Daydreams”, “Stares into space”, “In a fog”, “Unresponsive”, “Easily confused”, “Mind wanders”, “Absentminded”, “Easily disoriented”, “Loses cognitive set”, “Gets tongue tied”, “Poor memory consolidation”, “Drowsy”, “Moves slowly”, “Works slowly and takes a long time to complete tasks”, “Gets tired easily”, “Low initiative”, “Poor time appreciation”. 5 item SCT scale from the Child Behavior Checklist CBCL: (Achenbach 1991, Hartman et al., 2004): “Sluggish/slow to respond”, “Seems to be in a fog”, “Drowsy or sleepy”, “Easily confused”, “Daydreams/stares into space”	Children’s Global Assessment Scale (CGAS: Shaffer et al., 1983): Child’s overall severity of disturbance Disruptive Behavior Rating Scale (DBRS: Barkley & Murphey, 1998): ADHD Wechsler Abbreviated Scale of Intelligence (WASI: Wechsler, 2007): IQ Attention Network Test (ANT; Rueda et al., 2004): Reaction time Digit Span subtest of the WISC III (Wechsler, 2003): Verbal memory span, working memory Adaptation of the Finger Windows subtest from the Wide Range Assessment of Memory and Learning (WRAML: Sheslow, 1990): Spatial memory
Clinical population	(a) ADHD and Anxiety disorder (n=25) (b) ADHD (n = 39) (c) Anxiety disorder (n = 41) (d) Controls (n = 36)		
Off medication	Raters: Researchers, Mothers		
Barkley, 2011a	Evaluated population: 1.249 adults Age range: 18–96 yrs.	Adult SCT rating (Barkley, 2011): 9 items: “Prone to daydreaming when I should be concentrating”, “Have trouble staying alert or awake in boring situations”, “Easily confused”, “Easily bored”, “Spacey or in a fog”, “Lethargic, more tired than others”,	Adult ADHD Rating Scale IV (Barkley, 2011a): ADHD Functional Impairment Rating Scale (Barkley, 2011b): Impairment in 15 major life domains The Deficits in Executive Functioning Scale (Barkley, 2011c): Executive functioning
Community-based population	(a) No ADHD but SCT (n = 33) (b) ADHD but no SCT (n = 46)		
No medication	(c) ADHD and SCT (n = 39) (d) Controls (n = 1131) Raters: Adults themselves		

		“Underactive or have less energy than others”, “Slow moving”, “I don’t seem to process information as functioning quickly or as accurately as others”	
Bauermeister et al. 2012	<u>Evaluated population:</u> 140 children Age range 6–11 yrs (87 males; 53 females) <u>Raters:</u> Teachers, Researchers	4 Sluggish items from Child Behavior Checklist (CBCL: Achenbach, 1991): “Confused or seems to be in a fog”, “Daydreams or gets lost in his/her thoughts”, “Stares blankly” and “Underactive, slow moving, or lacks energy”	ADHD Scales of the Disruptive Behavior Rating Scale (Barkley et al., 1997): ADHD Observed Behavior Continuous Performance Test (CPT: Conners, 1995): Vigilance, impulsiveness Hand Movements Scale (HMS: Kaufman & Kaufman, 1983): Skilled hand movement, nonverbal working memory, motor sequencing Simon Task (ST: Barkley et al., 2001): Nonverbal working memory Stroop Color Word Test (SCWT: Golden, 1978): Interference control Wisconsin Selective Reminding Test (WSRT: Barkley, DuPaul & McMurray, 1991): Verbal learning and memory test adapted from Buschke’s Selective Reminding Test (Newby, 1989) WISC R PR Backward Digit Span Test (Herrans & Rodriguez, 1992): Verbal working memory Rapid Automatized Naming (RAN: Denckla & Rudel, 1974): Digit-, color-, object- naming Woodcock Psychoeducational Battery Spanish (WPB-S: Woodcock, 1982): Academic functioning Child Behavior Checklist (CBCL) and CBCL-Teacher Report Form (TRF) (Achenbach, 1991): Internalizing, externalizing, social problems, thought problems, and attention problems Social Skills Questionnaire (Gresham & Elliot, 1990): Cooperation, assertion, self- control scales, parent responsibility scale
Harrington & Waldman, 2010	<u>Evaluated population:</u> 291 children Age range: 5–18 yrs (206males; 85 females) (a) ADHD/C (n = 124) (b) ADHD/H (n = 23) (c) ADHD/I (n = 81) (d) Controls (n = 63) <u>Raters:</u> Mothers	SCT items from Emory Combined Rating Scale (ECRS: Waldman et al., 1998): “Forgetful”, “Daydreams”, “Sluggish/drowsy”	The Emory Combined Rating Scale (ECRS: Waldman et al., 1998): Psychopathology

Jacobson et al. 2012	<u>Evaluated population:</u> 143 children (no formal diagnosis of ADHD but high on symptoms of ADHD) Age range: 3–18 yrs.	SCT 14 item scale (Penny et al., 2002)	ADHD Rating Scale IV (DuPaul et al., 1998): ADHD Vanderbilt Assessment Scales (Wolraich et al., 1998): Internalizing Impairment Rating Scale (Fabiano et al., 2006): Behavioral functioning
Clinical population			
On medication	(96 males; 47 females) (a) Low ADHD symptoms (n = 85) (b) High ADHD/I (n = 37) (c) High ADHD/HI (n = 8) (d) High ADHD/C (n = 13)		
	<u>Raters:</u> Teachers		
Becker et al. 2013	<u>Evaluated population:</u> 680 children Age range: 6-12yrs (497 males; 183 females) (a) ADHD only (n = 102) (b) ODD only (n = 61) (c) CD only (n = 41) (d) Anxiety disorder only (n = 54) (e) Mood disorder only (n = 41) (f) ADHD + ODD (n = 190) (g) ADHD + CD (n = 34) (h) ADHD + anxiety disorder (n = 82) (i) ADHD + mood disorder (n = 75)	5 SCT items from CBCL 6 18 (SCT-5: Achenbach & Rescorla, 2001): “Sluggish/slow to respond”, “Seems to be in a fog”, “Drowsy or sleepy”, “Easily confused”, and “Daydreams/stares into space”	CBCL (Wolraich et al., 1998): Mental health, social functioning, ADHD, SCT, anxiety, depression, ODD Observed Behavioral Dysregulation: Assessment form of behavior modification program Hopkins Symptom Checklist (HSCL: Derogatis, 1974): Parent anxiety and parent depression symptoms
Clinical population			
Medication status unknown/not stated by the authors			
	<u>Raters:</u> Parents		
Becker & Langberg, 2013	<u>Evaluated population:</u> 52 adolescents Age range: 12–16 yrs. (37 males; 15 females) (a) ADHD/I (n = 27) (b) ADHD/C (n = 25)	SCT 14 item scale (Penny et al., 2009)	Wechsler Intelligence Scale for Children 4th Edition (WISC-IV: Wechsler, 2003): IQ Wechsler Individual Achievement Test, 3rd Edition (WIAT-II: Wechsler 2003): Academic achievement Vanderbilt ADHD Diagnostic Rating Scale (VADRS: Wolraich et al., 1998): ADHD
Clinical population			
Medication status unknown/not	<u>Raters:</u> Teachers, Parents		

stated by the authors		Behavior Rating Inventory of Executive Function (BRIEF: Gioia et al., 2000): Behavioral functioning	
Graham et al. 2013	<u>Evaluated population:</u> 272 clinically referred children Age range: 8–16 yrs. (162les; 110 females) (a) alcohol-exposed children with ADHD (n = 75) (b) alcohol-exposed children without ADHD (n = 35) (c) nonexposed children with ADHD (n = 60) (d) Controls (n = 102) <u>Raters:</u> Parents	SCT Scale (SCT-S: Pffiffer et al., 2007; McBurnett & Pffiffer, 2012)	Child Behavior Checklist (CBCL: Achenbach, 1991): Behavioral functioning Computerized Diagnostic Interview Schedule for Children— Fourth Edition (C-DISC-4.0: Shaffer et al., 2000): ADHD Dysmorphology examination (for details, see Jones et al., 2006; Matson et al., 2010)
Langberg et al. 2013	<u>Evaluated population:</u> 52 adolescents with ADHD Age range: 12–16 yrs. (37 males; 15 females) <u>Raters:</u> Teachers, Parents	SCT 14 item scale (Penny et al., 2009)	Diagnostic Interview Schedule for Children IV (DISC-IV: Shaffer et al., 2000): ADHD, psychopathology Vanderbilt ADHD Diagnostic Teacher Rating Scale (Wolraich et al., 1998): ADHD Wechsler Intelligence Scale for Children 4th Edition (Wechsler, 2003): IQ Homework Problems Checklist (HPC: Anesco et al., 1987): Academic functioning Children’s Organizational Skills Scal (COSS: Abikoff & Gallagher, 2003): Organization, planning, and time-management skills Impairment Rating Scale (IRS: Fabiano et al., 2006): Behavioral functioning School Grades End of year grade point average (GPA): Academic functioning
Lee et al. 2013	<u>Evaluated population:</u> 366 children Age range: 5–13 yrs (164 males; 202 females) <u>Raters:</u> Teachers, Parents	10 item SCT Scale of Kiddie-Sluggish Cognitive Tempo Diagnostic Interview Module for Children and Adolescents (McBurnett, Pffiffer & Frick, 2001): “Easily distracted”, “Avoids mental effort”, “Does not	Child and Adolescent Disruptive Behavior Inventory (CADBI: Burns & Lee, 2010): Anxiety, depression, ADHD, ODD, academic functioning, social functioning Teacher version of the Child and Adolescent Disruptive Behavior Inventory (CADBI: Burns & Lee, 2010): Behavioral functioning Parent version Child and Adolescent Disruptive Behavior Inventory (CADBI: Burns & Lee, 2010):

		seem to listen”, “Does not follow instructions”, “Difficulty sustaining attention”, “Difficulty organizing tasks/activities”, “Loses things”, “Forgetful”, “Daydreams”, “Sluggish”.	Behavioral functioning, anxiety, depression
Moruzzi et al. 2013 Community- based population No medication	<u>Evaluated population:</u> 398 twin pairs Age range: 8–17 yrs. (374 males; 422 females) <u>Raters:</u> Mothers	SCT items of CBCL 6 18 (Achenbach et al., 2008): “Confused or seems to be in a fog”, “Daydreams or gets lost in his/her thoughts”, “Stares blankly” and “Underactive, slow moving, or lacks energy”	CBCL (Achenbach, 1991): Behavioral functioning

Appendix B Comparison of ADHD/I Adult items, Beck's depression inventory items and SCT-QA items

ADHD/I Adult items (APA, 2015)	Depression Beck's depression inventory (Beck, Steer & Brown, 1996)., (always the most extreme statement)	SCT-QA items
1. Makes careless mistakes/lacks attention to detail	1. I am so sad and unhappy that I can't stand it.	1. Feeling tired, lethargic
2. Difficulty sustaining attention	I feel the future is hopeless and that things cannot improve.	2. Moving slowly, lacking energy
3. Does not seem to listen when spoken to directl	I feel I am a complete failure as a person.	3. Being sleepy, drowsy
4. Fails to follow through on tasks and instructions	I am dissatisfied or bored with everything.	4. Feeling sluggish
5. Exhibits poor organization	I feel guilty all of the time.	5. Being apathetic, lacking interest
6. Avoids/dislikes tasks requiring sustained mental effort	I feel I am being punished.	6. Stretching, yawning, looking sleepy
7. Loses things necessary for tasks/activities	I hate myself.	7. Lacking initiative to finish work
8. Easily distracted (including unrelated thoughts)	I blame myself for everything bad that happens.	8. Efforts fade quickly
9. Is forgetful in daily activities	I would kill myself if I had the chance	9. Needs to be remembered to start working
	I used to be able to cry, but now I can't cry even though I want to.	10. Being unmotivated
	I feel irritated all the time	11. Work varies qualitatively and or quantitatively
	I have lost all of my interest in other people.	12. Slow in accomplishing tasks, delaying tasks
	I can't make decisions at all anymore.	13. Loosing track while listening
	I believe that I look ugly.	14. Loosing track during daily activities or conversations
	I can't do any work at all	15. Being easily distracted, confused
	I wake up several hours earlier than I used to and cannot get back to sleep.	16. Needing extra time to accomplish tasks
	I am too tired to do anything.	
	I have no appetite at all anymore.	

I have lost more than fifteen pounds.

I am so worried about my physical problems that I cannot think of anything else.

I have lost interest in sex completely.

Appendix C Principal component analysis with the cognitive subparameters as dependent variables and Age, IQ, Gender, ADHD_adult, SCT-QA and Group as covariates.

We wanted to explore whether a reduction of cognitive subparameters would yield different effects by our covariates (*Gender, IQ, Age, ADHD_adult, SCT-QA* and *Group*). To that end we conducted a principal component analysis (PCA) on the 20 variables that represent the subparameters of the cognitive tests by using an oblique rotation (direct oblimin). The Kaiser-Melkin-Olkin measure for the sampling adequacy (KMO= .598, mediocre according to Kaiser) is just above the accepted limit of .5 (e.g., Hill, 2011; Field, 2013). Bartlett’s test of sphericity $\chi^2(190) = 1449.764, p < .001$, showed that the obtained correlations were sufficient for further PCA. The initial PCA produced 8 components with eigenvalues over Kaiser’s criterion of 1. These 8 components explained 82.015 % of the total variance. Scree plot inspection would support the retention of either 1, 3 or 5 factors (figure C1 Scree plot of the retained factors of the PCA).

Figure C1 Scree plot of the retained factors of the PCA

The convergence of the scree plot inspection and Kaiser’s criterion resulted in the conclusion to use five factors for the final analysis. We did not include items with a factor loading $< .4$ (Field, 2009). The retained five factors explained a 71.83% of the total variance. Table C1 shows the factor loadings after rotation. The overall scale reliability of these five factors was poor, with a Cronbach’s α of .58. Factor 1 represents the cognitive function of *Vigilance* and presented with a Cronbach’s $\alpha = .82$. Factor 2 represents the cognitive function *Inhibition* and

presented with a Cronbach's $\alpha = .29$. The loading on the subparameter congruency of reaction time of a correct response of the cognitive switch paradigm of factor 2 can be explained by the observation that the performance on the cognitive switch paradigm is partly dependent on the individual's ability to inhibit premature responses. Factor 3 represents the cognitive function *Selective attention* and presented with a Cronbach's $\alpha = .95$. Factor 4 clearly represents *Information processing* as measured by the two subtests of the Trail-Making-Test (TMT-A and B). Factor 4 presented with a Cronbach's $\alpha = .98$ Factor 5, again, is a merging of *Inhibition* and *Cognitive flexibility*. But this time, and in contrast to factor 2, it is rather a representation of inattention (omission errors) and a lack of congruency in task performance. Factor 5 presented with a Cronbach's $\alpha = .41$. Based on the subscales' reliability analysis factor 1, 3 and 4 showed very good reliabilities. Factor 2 and 5 did not produce acceptable reliabilities (Field, 2013).

Table C1. Factor loadings of the retained cognitive components

Items	Factor loadings on each factor				
	1	2	3	4	5
Vigilance reaction time	.85				
Vigilance omission errors	.84				
Selective attention standard deviation	.38	-.37			
Inhibition reaction time		.82			
SWITCH Congruency of reaction time of correct response		.70			
Inhibition comission errors		-.66			
Inhibition standard deviation of the reaction time		.58			-.53
Selective attention reaction time			.99		
Selective attention controlled attention			.92		
Selective attention automatic attention			.91		
Trail Making Test B				.99	
Trail Making Test A Rohwert (raw data)				.99	
SWITCH Accuracy					.83

Inhibition omission errors		-.62
SWITCH Flexibility reaction time		
SWITCH Reaction time of error response	-.34	.32
Inhibition sensitivity/standard deviation		
Selective attention commission errors		
Vigilance commission errors	.48	
Selective attention omission errors	.37	-.35

Factor loadings written in gray were not taken into consideration for further analysis

Results of the multivariate tests using General Linear Model (GLM):

A significant multivariate effect was found for the covariate *Age*, Wilks' $\lambda=.76$, $F(5,82) = 5.19$, $p < .001$, partial eta squared = .24. The power of the observed effect was .98. Hence, the hypothesis that *Age* impacts on the five cognitive factors was confirmed.

The variable *ADHD_adult* did not yield a multivariate effect: Wilks' $\lambda=.89$, $F(5, 82) = 2.09$, $p=.08$, partial eta squared=.11. The power of the observed effect was .67. Hence, the hypothesis that *ADHD_adult* does impact as a covariate on the five cognitive factors was not confirmed.

The variable *IQ* showed a significant multivariate effect with Wilks' $\lambda=.87$, $F(5, 82) = 2.49$, $p=.04$, partial eta squared=.13. The power of the observed effect was .76. Hence, the hypothesis that *IQ* does impact as a covariate on the five cognitive factors was confirmed.

Gender did not yield any significant multivariate effect. With Wilks' $\lambda=.94$, $F(5, 82) = 1.13$, $p=.35$, partial eta squared=.06. The power of the observed effect was .38. Hence, the hypothesis that *Gender* would act as a covariate on the five cognitive factors was not confirmed. Based on this, it is unlikely that the participants' gender is associated with cognitive performance.

The variable *SCT-QA* did not yield any significant multivariate effect. With Wilks' $\lambda=.91$, $F(5, 82) = 1.64$, $p=.16$, partial eta squared =.09. The power of the observed effect was .54. Based on this, it is unlikely that the participants' level of sluggish cognitive tempo is associated with cognitive performance.

The variable *Group* did show a significant multivariate effect, with Wilks' $\lambda=.86$, $F(5, 82) = 2.62$, $p=.03$, partial eta squared=.14. The power of the observed effect was .78.

Since three (*Age*, *IQ* and *Group*) of five covariates presented with significant multivariate effects their between-subject effects on the five cognitive factors were explored in more detail.

Results of the between-subject effects:

As can be seen in Table C2 and C3 *Age* was significantly associated with the cognitive functions of: *Information processing*. *IQ* was significantly associated with the cognitive function of *Information processing*. Finally, the variable *Group* was significantly associated with the cognitive functions *Inhibition* and the factor measuring a merging of *Inhibition and Cognitive flexibility*.

Table C2 Summary of significant associations between covariates and factors extracted from the PCA

Covariate	Significant factors
Age	Factor 2 representing: <i>Inhibition</i> Factor 4 representing: <i>Information processing</i>
IQ	Factor 4, representing: <i>Information processing</i>
Group	Factor 2 representing: <i>Inhibition</i> Factor 5 representing: <i>Inhibition and Cognitive flexibility</i>

Please see Table C3 for all significant and non-significant associations between the covariates and cognitive subparameters.

Table C3 Results GLM multivariate between-subject effects for the covariates: *Gender*, *IQ*, *Age*, *ADHD_adult*, *SCT-QA* and *Group*, with *IQ* and *Age* being the only significant multivariate effects.

Factor	Gender		IQ ^a		Age ^a		ADHD_adult		SCT-QA		Group ^a	
	B (SE)	Partial eta squared	B (SE)	Partial eta squared	B (SE)	Partial eta squared	B (SE)	Partial eta squared	B (SE)	Partial eta squared	B (SE)	Partial eta squared
1	14.07 (11.49)	.02	- .89 (.46)	.04	.66 (.58)	.02	1.50 (.73)	.05	.92 (.78)	.02	49.94 (18.54)	.08
2	1.09 (1.19)	.01	-.04 (.05)	.00	-.17 (.06)	.09	.04 (.08)	.00	.02 (.08)	.00	.78 (.64)	.02
3	3.19 (13.27)	.00	-1.01 (.54)	.04	.08 (.67)	.02	1.03 (.85)	.02	1.74 (.91)	.04	-6.80 (21.42)	.00
4	1.21 (1.08)	.01	-.09 (.04)	.05	.25 (.05)	.19	-.09 (.07)	.02	.08 (.07)	.01	-6.80 (21.42)	.00
5	1.95 (1.20)	.03	-.07 (.05)	.02	-.03 (.06)	.00	-.07 (.08)	.01	-.11 (.08)	.02	-.33 (.65)	.00

^a variables with significant multivariate effects, significant between-subject effects written in bold

Conclusion:

Based on the results of the PCA and GLM it can be concluded, that it is possible to reduce the 20 cognitive subparameters to five factors, although the KMO statistic showed that our sample might not have been sufficient for doing a PCA on the cognitive subparameters. Three of the five factors showed good internal consistency. The results of the GLM showed that the

covariates Age, IQ and Group were significantly associated with the extracted cognitive factors. The between-subject effects showed that the significant multivariate effects of Age, IQ and Group are likely caused by their associations with either factor 4 (IQ), factor 2 and 4 (Age) or factor 2 and 5 (Group). As can be seen in Table C4 the covariate *Group* did not replace/erase the effects of the other covariates as observed in analysis (ii) of chapter 5.

Table C4 Comparison of significant multivariate effects of analysis (i) and (ii) of chapter 5 and the analysis of Appendix C

Analysis (i)	Analysis (ii)	Analysis (Appendix)
Age	Age	Age
IQ	Group	IQ
ADHD_adult		Group

Please see a comparison of significant between-subject effects of analysis (i) and (ii) of Chapter 5 with the significant between-subject effects of the analysis of the Appendix C in Table C5.

Table C5 Comparison of between-subject effects of analysis (i) and (ii) of chapter 5 and the analysis of Appendix C

Analysis (i)	Analysis (ii)	Analysis Appendix C
<u>IQ: Information processing speed and cognitive flexibility:</u> -reaction time <u>Selective attention:</u> -automatic attention <u>Sustained attention:</u> -reaction time <u>Cognitive switch/flexibility:</u> -reaction time of the error response <u>Selective attention:</u> -omission errors, -commission errors <u>Sustained attention:</u> -omission errors, -commission errors <u>Inhibition:</u> -commission errors <u>Age: Information processing speed:</u> -reaction time Information processing speed and cognitive flexibility: -reaction time <u>Inhibition:</u> -commission errors <u>Cognitive switch/flexibility:</u> -congruency of the reaction time of correct responses <u>ADHD adult: Selective attention:</u>	<u>Age: Information processing speed:</u> -reaction time <u>Information processing speed and cognitive flexibility:</u> -reaction time <u>Inhibition:</u> -reaction time <u>Inhibition:</u> -commission errors <u>Cognitive flexibility:</u> - congruency of the reaction time of a correct response <u>Group: Sustained attention:</u> -reaction time <u>Inhibition:</u> -reaction time <u>Cognitive flexibility:</u> -reaction time of the error response	<u>Age: Information processing, Inhibition</u> <u>IQ: Information processing</u> <u>Group: Inhibition, Inhibition and Cognitive flexibility</u>

-controlled attention
Sustained attention:
-omission error
-commission error
-variance of the reaction time
SCT-QA: Cognitive
switch/flexibility paradigm:
-reaction time

In sum, as in analysis (ii) of Chapter 5, our exploration did not support the hypothesis that our SCT-QA scale would be predictive of neurocognitive processing.

Appendix C References:

- Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *psychometrika*, 16(3), 297-334.
- Hill, B. D. (2011). Sequential kaiser-meyer-olkin procedure as an alternative for determining the number of factors in common-factor analysis: A monte carlo simulation (Doctoral dissertation, Oklahoma State University).
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DUTCH SUMMARY

Hoofdstuk 1 Inleiding:

“Cogito, ergo sum. Ik denk dus ik ben.” (Descartes, 1637 in Garber, 1988). Dit syllogisme van Descartes laat niet alleen het fundamentele belang zien van het denken voor de menselijke conditie an sich, maar kan ook begrepen worden als de filosofische oorsprong voor de wetenschap die zich gericht heeft op de samenhang tussen cognitie en het menselijke functioneren.

Cognitief functioneren is een algemene term om mentale processen te beschrijven die een rol spelen bij bijvoorbeeld menselijke perceptie, taal, redeneren, besluitvorming en probleemoplossing (Roy, 2013). De fundamentele cognitieve vaardigheden die het meest gemeten worden zijn: informatieverwerking (vaak gemeten als verwerkingssnelheid), aandacht (waaronder vigilantie en selectieve aandacht), werkgeheugen, langetermijngeheugen, responsremming en cognitieve flexibiliteit (Neisser, 2014). Cognitieve functies kunnen niet rechtstreeks worden gemeten, maar worden afgeleid uit waarneembaar gedrag (bijvoorbeeld reactietijden (RT) en succesvolle en/of niet-succesvolle reacties op een van tevoren vastgelegde taak) of gemeten via niet-invasieve technieken, zoals elektro-encefalogram (EEG) of functionele magnetische resonantie beeldvorming (fMRI).

Cognitieve functies zijn anders dan perceptuele functies (zien, ruiken, horen, of voelen) en motorische handelingen (zoals een arm omhoog bewegen). Cognitieve functies worden vaak hersenfuncties op een hoger niveau genoemd en zijn betrokken bij elk aspect van het menselijk leven (bijv. Neisser, 2014)

Een van de belangrijkste cognitieve functies is aandacht. Zonder aandacht (voor bepaalde prikkels) zou er geen input de hersenen binnenkomen, laat staan verwerkt kunnen worden. Aandacht is belangrijk gebleken voor processen van hogere orde, zoals geheugen, planning en uitvoerend functioneren (‘executive functioning’, zie bijv. Mirsky et al., 1992). Sterk gerelateerd aan, maar onafhankelijk van aandacht, is de perceptie en codering van tijd. De tijd die nodig is om te reageren en binnenkomende informatie te verwerken blijkt een bepalende factor te zijn voor verdere complexe cognitieve prestaties, zoals leesvaardigheid (Denckla, 1972; Denckla & Rudel, 1974; Shanahan et al., 2006), motoriek en besluitvorming (bijv. Buhusi & Meck, 2005). Dit proefschrift onderzoekt aandachts- en timingprocessen in menselijke cognitie. Hierbij richten wij ons op een nog niet klinisch bevestigd fenomeen dat bekend staat onder de term Sluggish Cognitive Tempo (SCT), oftewel vertraagd cognitief tempo. De recente literatuur beweert dat SCT in vergelijking met de aandachtstekortstoornis

met hyperactiviteit (ADHD) de 'echte aandachtsstoornis' (Barkley, 2014) genoemd zou kunnen worden. De tot nu toe onduidelijke bevindingen in wetenschappelijke onderzoek over SCT waren de aanleiding om het concept SCT nog eens theoretisch, psychometrisch en klinisch te onderzoeken.

In Hoofdstuk 2 hebben we eerst basale aandachts- en timingfuncties bij niet-klinische volwassenen die laag of juist hoog op impulsiviteit scoren onderzocht. Impulsiviteit staat bekend om zijn verband met ADHD. Ons doel om een klinisch fenomeen te vinden dat mogelijk verband houdt met objectieve aandachts- en timingsstoornissen, bracht ons ertoe om ons te richten op studies over SCT. Gezien de schaarste en onduidelijkheid van studies die gegevens over SCT presenteren, hebben we het construct SCT op zijn theoretische achtergrond onderzocht. Hoofdstuk 3 omvat een systematische review van de recente literatuur van SCT. In Hoofdstuk 4 hebben we 26 SCT-items op hun psychometrische validiteit in een niet-klinische steekproef van volwassenen onderzocht. De 26 SCT-items zijn items die in eerdere studies gebruikt werden. De daardoor verkregen SCT-schaal en subschalen werden verder getest op hun waarschijnlijke associaties met zelf-beoordeelde aandachts- en timingsfunctionaliteit, om enig bewijs te leveren voor de constructvaliditeit van SCT. In Hoofdstuk 5 wilden we objectief bewijs leveren voor de bewering dat SCT samenhangt met aandachts- en timingfuncties. Hierbij onderzochten wij de gegevens van klinische en niet-klinische volwassenen die enerzijds de nieuw gevalideerde SCT-schaal van Hoofdstuk 4 hebben ingevuld en die aan de andere kant een reeds gevalideerde geautomatiseerde neurocognitieve testbatterij doorliepen. In de algemene discussie in Hoofdstuk 6 van dit proefschrift zullen we reflecteren op de resultaten van de voorgaande hoofdstukken.

Hoofdstuk 2 Selectieve beperkingen in timingsfuncties bij niet-klinische impulsiviteit

Veel onderzoeken hebben laten zien dat er bij personen die hoog scoren op impulsiviteit afwijkingen in de tijdverwerking zijn. Bij deze onderzoeken werd echter vaak gebruik gemaakt van zogeheten 'interval timing taken', waarbij de deelnemers gevraagd worden een bepaalde tijdsspanne te schatten. Meestal wordt dit gedaan door deelnemers te laten schatten of een bepaalde tijdsspanne korter of langer was dan een referentie tijdsspanne. Interval timing wordt op het niveau van sub- (<1) en supra seconden (>1) gemeten. Het doel van onze studie was om te onderzoeken of de relatie tussen tijdverwerking en impulsiviteit (als persoonlijkheidskenmerk, niet als stoornis) ook geldt voor zeer korte tijdsspannen (('temporal event structure coding') temporale gebeurtenis codering) en/of juist lange tijdsspannen (tijdsperspectief). De zeer korte tijdsspannen werden gemeten door gebruik te maken van een

‘perceptuele gelijktijdigheidstaak’ (‘perceptual simultaneity task’), waarbij de deelnemers moeten aangeven of de twee stimuli, die aangeboden werden, gelijktijdig of niet gelijktijdig op de scherm verschenen zijn. De lange tijdsspannen werden gemeten door de subjectieve tijdsperspectieven van de deelnemers (N=48) te achterhalen. De subjectieve tijdsperspectieven gemeten door gebruik te maken van de Zimbardo Time Perspective Inventory (ZTPI), waarbij deelnemers moeten aangeven in welke mate ze over het verleden, het heden of de toekomst reflecteren. Uit de resultaten blijkt dat impulsiviteit en het langere tijdsperspectief sterk gerelateerd zijn. Er werd echter geen verband gevonden tussen impulsiviteit en de metingen van de kortdurende cognitieve processen. De relatie tussen tijdverwerking en impulsiviteit lijkt dus selectief te zijn voor bepaalde timingsfuncties zoals medium lange (interval-timing) en zeer lange tijdsfuncties (tijdsperspectief). Zeer korte tijdsspannen (perceptual simultaneity) staan echter niet in verband met impulsiviteit.

Hoofdstuk 3 Het vertraagd cognitief tempo en zijn neurocognitieve, sociale en emotionele correlaten: een systematisch overzicht van de huidige literatuur

Sluggish Cognitive Tempo (SCT) oftewel een vertraagd cognitief tempo is momenteel een veel besproken onderwerp binnen het kader van de aandachtstekortstoornis met hyperactiviteit (ADHD). SCT is een sociaal-emotionele stijl van cognitief verwerken die gekenmerkt wordt door ‘dagdromen’, ‘in de war zijn’, ‘in het niets staren’, ‘vertraagd reageren’ en ‘ongemotiveerd zijn’. Hoofdstuk 3 geeft een overzicht van de meest recente bevindingen over SCT en ADHD en SCT bij andere aandoeningen (voor een Nederlandse versie van deze review, zie Mueller, Koerts, Tucha, Groen, & Tucha, 2014). Daarnaast wordt ingegaan op de beschikbare meetinstrumenten om SCT te meten, de relatie tussen SCT en cognitief functioneren, de invloed van SCT op internaliserende stoornissen zoals depressie en angst en op de effecten van SCT op de schoolprestaties en het sociaal-emotioneel functioneren. Op basis van het overzicht in Hoofdstuk 3 kan geconcludeerd worden dat de verwijdering van SCT-symptomen uit de DSM-IV-criteria voor ADHD (in 1994) mogelijk voor een kunstmatig toegenomen homogeniteit van de ADHD-diagnose heeft gezorgd, waarbij sommige individuen ten onrechte geen diagnose en dus ook geen behandeling krijgen. Verder werd duidelijk dat SCT-symptomen niet alleen bij ADHD te meten zijn, maar ook bij andere aandoeningen zoals bij patiënten met het foetaal alcoholsyndroom en patiënten die hersteld zijn van acute lymfatische leukemie en bij niet-klinische groepen. Deze observatie laat zien dat meer onderzoek naar SCT in het algemeen, en bij aandoeningen anders dan ADHD van belang is. Voordat het concept SCT op grotere schaal kan worden toegepast in de klinische praktijk en binnen het wetenschappelijk onderzoek

moeten de psychometrische- en empirische validiteit van het concept worden vastgesteld. Er zijn verschillende SCT schalen beschikbaar, die echter nogal onderling verschillen. Na het bestuderen van de SCT literatuur werd duidelijk, dat er drie items zijn die alsnog consistent leken bij te dragen aan het vaststellen van SCT bij kinderen en volwassenen, namelijk 'dagdromen', 'vertraagd reageren/slaperig zijn' en 'verminderd actief/apathisch'. Deze drie items zouden dan ook zeker geïmplementeerd moeten worden in toekomstig onderzoek. Wat het cognitief functioneren betreft werd er redelijk consistent over studies heen een verband tussen beperkingen in de volgehouden aandacht (vigilantie) en SCT gevonden. De resultaten over een mogelijk verband tussen SCT en informatieverwerkingssnelheid, en SCT en executieve functies zijn echter niet eenduidig. Het werd aangetoond dat SCT bij kinderen een negatieve invloed op de schoolprestaties kan hebben. Het meest zorgwekkende is echter toch wel de invloed van SCT op het sociaal-emotioneel functioneren. Er kan dus worden geconcludeerd dat SCT binnen het kader van ADHD, maar ook binnen andere klinische populaties, een belangrijk concept is waarnaar nog veel meer onderzoek moet worden gedaan. Voor de juiste diagnostiek van SCT moet dan echter eerst consensus worden bereikt over welke dimensies nu eigenlijk onderdeel zijn van SCT. Vervolgens is het van belang om in meer detail te bepalen in hoeverre SCT voorkomt bij ADHD en andere aandoeningen en wat de invloed van SCT is op het cognitief en sociaal-emotioneel functioneren, schoolprestaties en mogelijke behandelingen. In het komende hoofdstuk hebben wij ons op het valideren van een vragenlijst gericht, die de meest gebruikelijke SCT items uit eerdere onderzoeken weergeeft.

Hoofdstuk 4 Het vertraagd cognitief tempo bij volwassenen: een validatiestudie van de Sluggish Cognitive Tempo vragenlijst voor volwassenen (SCT-QA)

De studie in Hoofdstuk 4 richt zich op het valideren van 26 SCT-items die in eerdere studies gebruikt werden. Een schaal van deze 26 items werd bij 577 niet-klinische volwassenen afgenomen. De uitkomsten hiervan zijn geanalyseerd door gebruik te maken van een factoranalyse. De factoranalyse reduceerde de voormalige 26 SCT-items tot een schaal van 16 items. Deze nieuwe schaal liet een hoge interne consistentie (Cronbach's $\alpha = .84$) zien. Verder konden er drie subschalen geïdentificeerd worden (subschaal 1: traagheid & slaperigheid, Cronbach's $\alpha = .78$; subschaal 2: gebrek aan volharding en motivatie, Cronbach's $\alpha = .75$; en subschaal 3: gedachten dwalen & gebrek aan concentratie, Cronbach's $\alpha = .59$). De resultaten van Hoofdstuk 4 suggereren dat SCT een multidimensionaal construct is met ten minste twee subschalen (traagheid en slaperigheid en gebrek aan volharding en motivatie). Cronbach's α van de derde subschaal is twijfelachtig. Toekomstige studies zouden zich kunnen richten op het vinden van meer bewijs tegen of voor

de derde subschaal, mogelijk door meer items toe te voegen die passen bij gedrag dat typisch is voor het afdwalen van gedachten en het gebrek aan concentratie. Om iets te kunnen zeggen over de convergente validiteit van SCT werd in een tweede stap de somscore van de SCT-schaal en de somscores van de subschalen gecorreleerd met schalen die het functioneren van aandacht en timing in het alledaagse leven meten. De effectgroottes van de bivariate associaties tussen algemene SCT-scores en aandachts- en alledaagse timingsgedrag waren hoog. Hetzelfde kan gezegd worden over de bivariate associaties tussen de SCT-subschalen en alledaagse alledaagse processen van aandacht en timing. Er zijn sterke aanwijzingen gevonden voor een relatie tussen SCT en aandachtsklachten, waardoor de convergente validiteit van de huidige SCT-schaal wordt ondersteund. Bovendien werd een interessant verband gevonden tussen SCT en timing. Deze bevindingen vormen een goede reden om in verder onderzoek timing bij volwassenen met SCT objectief met behulp van cognitieve tests te meten.

Hoofdstuk 5 Het vertraagd cognitief tempo (SCT) en zijn manifestatie in cognitief functioneren en timing

Eerdere studies naar SCT hebben gesuggereerd dat SCT geassocieerd is met een aanzienlijke vertraging in de cognitieve verwerkingssnelheid. De meeste onderzoeken die een verminderde verwerkingssnelheid bij SCT rapporteerden, maakten echter geen gebruik van objectieve cognitieve tests, maar baseerden hun resultaten op zelfbeoordelingen van gedrag of subjectieve observaties van anderen. In de studie in Hoofdstuk 5 zijn de prestaties van klinische en niet-klinische deelnemers op objectieve, gestandaardiseerde, cognitieve taken gemeten waarbij vooral de timing-gerelateerde variabelen in cognitief functioneren (bijv. reactietijden en reactiefouten in verschillende cognitieve domeinen) van interesse waren. De cognitieve prestaties van de klinische en niet-klinische volwassenen werden in eerste instantie onderzocht op hun associatie met SCT. We vonden een marginaal significant effect van SCT op cognitieve taakprestaties, maar dit verband verdween toen de factor Groep (klinisch versus niet-klinisch) in de analyse werd opgenomen. Bovendien werd er geen bewijs gevonden voor een verband tussen SCT en een objectief gemeten verwerkingssnelheid. We concluderen dat als er een relatie is tussen SCT en objectieve cognitieve prestaties bij volwassenen, inclusief verwerkingssnelheid, deze erg zwak is.

Conclusie:

Dit proefschrift was gericht op het onderzoeken van aandachtsprocessen en informatieverwerking (met name timing functioneren) door middel van verschillende

benaderingen. De verschillende onderzoeken toonden het volgende aan: (i) Zeer basale timingfuncties die verband houden met cruciaal menselijk gedrag, zoals perceptie van spraak, muziek en motorische controle, worden niet beïnvloed door psychologische eigenschappen die verband houden met aandachtstekorten. (ii) SCT, een veelbesproken fenomeen in het wetenschappelijke veld, lijkt verband te houden met aandachtstekorten en tijdsperceptie wanneer alle variabelen met dezelfde methode (zelfbeoordeling middels vragenlijsten) gemeten worden, maar zelf-beoordeeld SCT was niet geassocieerd met de uitkomsten van objectieve neurocognitieve tests. (iii) Het idee dat SCT op zichzelf een valide klinische aandoening zou kunnen zijn moet met de nodige voorzichtigheid worden behandeld aangezien de bevindingen niet eenduidig zijn. (iv) Het feit dat SCT-symptomen verband hielden met aandacht tekorten en problemen met alledaags timinggedrag wanneer alle parameters (SCT, aandacht, alledaags timinggedrag) subjectief werden beoordeeld (zelfbeoordelingen), maar niet wanneer sommige parameters objectief werden beoordeeld, suggereert dat SCT zijn effecten zou kunnen laten zien op (reflectieve) processen van een hogere cognitieve orde en niet zozeer op fundamentele cognitieve processen. Of deze veronderstelling kan worden ondersteund door resultaten van toekomstige studies, blijft open.

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CURRICULUM VITAE

Anna Katharina Toussaint was born on 25 September in Langenhagen, Germany. She completed her secondary education and obtained her Abitur (Certificate of General Qualification for University Entrance) at the Hölty Gymnasium in Wunstorf, Germany (2001-2007). During her secondary education she developed a strong interest in health and human behavior in general. This led her to pursue a career in psychology. She started her Bachelor's degree in psychology at the University of Groningen, the Netherlands, in 2007, and completed her Master's degree in psychology with a specialisation in the field of neuropsychology in 2011. In her master's thesis, she investigated the presence or absence of stigmatization towards adults diagnosed with attention-deficit/hyperactivity disorder. After completing her Master's degree, she started as a PhD candidate at the Department of Clinical- and Developmental Neuropsychology at the University of Groningen, in 2011. Her PhD project „Attention- and Timing Functioning in adults with and without Sluggish Cognitive Tempo“ was supervised by dr. Christine M. Falter and promoted by Prof. dr. O.M. Tucha (2011-2015). After several changes in the project's subject and supervisors, Prof. dr. John C. J. Hoeks and dr. Yfke P. Ogena from the Faculty of Arts stepped in to support Anna Katharina in finishing her PhD thesis. The non-clinical data for her project was collected at the Faculty of Behavioral and Social Sciences of the University of Groningen and at the University of Regensburg, Germany. The clinical data was collected in collaboration with the SRH Clinic Karlsbad-Langensteinbach in Germany. The clinical work at the SRH clinic motivated Anna Katharina to start a career in clinical psychology. She started working as a psychologist at a clinic specialised in the care of cardiac- and pulmonary diseases (Fachklinik Weserland) in Bad Pyrmont, Germany, in 2015. While working full-time at the clinic, she started her clinical training as a therapist with a specialization in existentialism and logotherapy (2015-2020) and completed a training as a cardiopsychologist (2019-2020). Next to her clinical career as a psychologist, she became the representative of the quality management at the Fachklinik Weserland in 2019.

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