ADHD Attention Deficit and Hyperactivity Disorders (2019) 11:363–372
https://doi.org/10.1007/s12402-019-00301-y

ORIGINAL ARTICLE

Comparisons between sluggish cognitive tempo and ADHD-restrictive inattentive presentation phenotypes in a clinical ADHD sample

Gül Ünsel-Bolat[1] · Eyüp Sabri Ercan[2] · Hilmi Bolat[3] · Serkan Süren[4] · Ali Bacanlı[5] · Kemal Utku Yazıcı[6] · Luis Augusto Rohde[7,8]

Received: 19 November 2018 / Accepted: 18 March 2019 / Published online: 25 March 2019

Abstract

There is a debate how different ADHD cases with a comorbid sluggish cognitive tempo (SCT) phenotype are from subjects with a pure inattentive ADHD presentation (ADHD-restrictive inattentive presentation). In this study, 214 patients aged 8–15 years from an ADHD outpatient clinic were assessed, and 100 typically developing controls (TD) were recruited as comparisons. No psychiatric comorbidities except for oppositional defiant disorder were allowed. We compared 29 cases with ADHD + SCT with 34 ADHD-RI cases and 92 TD subjects on sociodemographic profiles, CBCL subscales scores and neurocognitive findings. Regarding sociodemographic profiles (age, gender and parental education) and CBCL subscales, ADHD + SCT and ADHD-RI cases did not differ in any score (all $p > 0.05$). Comparing with SCT cases, ADHD-RI cases presented slower psychomotor speed and worse neurocognitive index ($p < 0.001$). We found that only SCT was independently associated with a lower performance in total memory score. ADHD-RI was independently associated with longer reaction time. Our findings suggest that although SCT might be expected to present longer reaction time, we found that slower psychomotor speed and longer reaction time scores were related to inattention. Overall, SCT and ADHD-RI groups were distinguished by differential associations with measures of memory and reaction time.

Keywords Sluggish cognitive tempo · ADHD · Inattention · Neurocognitive profile · Slow psychomotor speed

Introduction

Sluggish cognitive tempo (SCT) is characterized by daydreaming, mental confusion, staring blankly and hypoactivity (Lee et al. 2014). In the last years, there is a huge interest in a constellation of symptoms of SCT in child psychopathology. Although the precise definition of which symptoms compose the syndrome is not clear, factor analyses performed in the meta-analysis assessing the SCT construct detected 13 items loaded consistently on a so-called SCT factor with a mean factor loading of at least 0.70 across all samples (Becker et al. 2016). Based on the results of this meta-analysis, studies of children, adolescents and adults suggest that SCT scales that include at least 4 of these items tend to have adequate-to-high internal consistency. The following symptoms are commonly used to describe the SCT phenotype in different studies: confused or seems to be in a fog, daydreams or get lost in his/her thoughts, underactive, slow moving or lacks energy and stares blankly (Araujo Jimenez et al. 2015; Bauermeister et al. 2005a, b; Camprodon-Rosanas et al. 2016; Carlson and Mann 2002;

✉ Gül Ünsel-Bolat
gul.unsel.bolat@gmail.com

1 Department of Child and Adolescent Psychiatry, Elazig City Hospital, Elazig, Turkey

2 Department of Child and Adolescent Psychiatry, Faculty of Medicine, Ege University, Izmir, Turkey

3 Department of Medical Genetics, Elazig City Hospital, Elazig, Turkey

4 Department of Child and Adolescent Psychiatry, Medical Park Hospital, Samsun, Turkey

5 Department of Child and Adolescent Psychiatry, Zübeyde Hanım Hospital, Başkent University, Izmir, Turkey

6 Department of Child and Adolescent Psychiatry, Fırat University, Elazig, Turkey

7 ADHD Outpatient Program, Hospital de Clinicas de Porto Alegre, Federal University of Rio Grande do Sul, Porto Alegre, Brazil

8 National Institute of Developmental Psychiatry for Children and Adolescents, São Paulo, Brazil

Raiker et al. 2015). The syndrome seems to occur in 11% of the population in children, and it is associated with global impairment even when the impact of co-occurring attention-deficit/hyperactivity disorder (ADHD) symptoms was controlled (Camprodon-Rosanas et al. 2017; Raiker et al. 2015; Willcutt et al. 2014).

Although most of the studies have found no evidence of substantial sex and age differences in SCT symptoms in children (Belmar et al. 2015; Camprodon-Rosanas et al. 2016; Carlson and Mann 2002; Jarrett et al. 2014; Marshall et al. 2014), results of the meta-analysis mentioned above showed that SCT symptoms were modestly associated with age and female sex (Becker et al. 2016). In addition, lower parental education, annual household income and higher parental unemployment were associated with high levels of SCT (Barkley 2013). SCT shares comorbidity with internalization symptoms and social isolation (Becker and Langberg 2013; Rondon et al. 2018).

To date, only a few studies have evaluated neuropsychological performance of SCT. These studies reported independent impairment in early selective attention (Huang-Pollock et al. 2005), sustained attention (Wahlstedt and Bohlin 2010; Willcutt et al. 2014) and spatial memory variability (Skirbekk et al. 2011) in subjects with SCT. Specifically, deficits in processing speed and reaction time are expected to be a kind of hallmark for neurocognitive measures related to SCT, because of its phenotypic characteristics. However, there are few studies investigating processing speed and reaction time deficits in SCT, and their results are inconsistent. Several studies did not found any deficits in processing speed and reported that SCT cases are not slow in fact during their performance in neuropsychological tasks (Bauermeister et al. 2012; Wood et al. 2017). However, one study found that only daydreamy SCT (ages 6–9 years) was associated with lower processing speed in younger children (Jacobson et al. 2018). Findings are similar for reaction time. Although one study reported slower reaction time for SCT (Tamm et al. 2016), several studies found no significant differences (Skirbekk et al. 2011; Willcutt et al. 2014). Finally, a meta-analysis indicated that SCT was associated with lower performance on measures of intelligence, response inhibition, working memory, sustained attention and processing speed (Becker et al. 2016). Effect sizes were small to moderate for these findings. Overall, neuropsychological processes underlying SCT have been still controversial and underinvestigated. However, it is important to bear in mind that SCT showed to be associated with executive function (EF) deficits using rating scales (Becker and Langberg 2013; Rondon et al. 2018) opposed to relying in laboratory-based tasks (Bauermeister et al. 2012; Wahlstedt and Bohlin 2010).

One of the main challenges regarding SCT is how to define and separate from ADHD regarding symptom construct and neuropsychological deficits. ADHD is one of the most common mental disorders of childhood with a worldwide prevalence around 3–5% in school-aged children (Polanczyk et al. 2015). SCT was found to be more prevalent in the ADHD–inattentive presentation (ADHD-I) presentation than ADHD-combine (ADHD-C) presentation in initial studies (Bauermeister et al. 2005a, b; Carlson and Mann 2002; McBurnett et al. 2001). However, more recent studies reported similar levels of SCT in both ADHD-I and ADHD-C presentations and suggested that higher levels of SCT symptoms were not able to differentiate ADHD-I and ADHD-C presentations (Harrington and Waldman 2010; Hartman et al. 2004; Skirbekk et al. 2011; Todd et al. 2004). In a study with US children (Barkley 2013), more than half (59%) of those cases that had SCT also had ADHD. Thus, 39% of the children qualifying for ADHD (any type) also qualified for SCT, which is also consistent with prior studies (Garner et al. 2010).

The differences between SCT and DSM-IV ADHD-I were also investigated in previous studies (Capdevila-Brophy et al. 2014; Garner et al. 2010; Marshall et al. 2014). However, very few studies were conducted assessing the differences between SCT and "pure cases" of inattention (e.g., those without or with very low endorsement of hyperactive/impulse symptoms). Previous researches suggest that DSM-IV cases of ADHD-I presentation might include cases that are in reality subthreshold ADHD-C cases (Ercan et al. 2016). So, comparing SCT cases only with ADHD-I may not be sufficient to distinguish from inattention.

In 2010, the working group on ADHD from the American Psychiatric Association (APA) proposed the importance of recognizing a subgroup of patients who present substantial inattentive symptoms but no or very few hyperactive/impulsive symptoms, i.e., fewer than 3 hyperactive/impulsive symptoms. This subgroup was defined as the ADHD-restrictive inattentive (ADHD-RI) presentation. However, the final version of the DSM-5 did not include this ADHD subtype due to lack of investigations to validate it (Ercan et al. 2016). Subjects with ADHD-RI had a significantly different neuropsychological profile compared with the other ADHD groups, including lower psychomotor speed, longer reaction time and the worst overall performance in a global neurocognitive index (Ercan et al. 2016).

We were not aware of any study that compared subjects with ADHD-RI and those with ADHD + SCT to explore similarities and differences in sociodemographic and clinical data, as well as neuropsychological findings. Thus, we conducted a study to provide comparisons in these three areas among ADHD + SCT, ADHD-RI groups and a sample of non-ADHD subjects. Our main hypothesis is that ADHD + SCT will differentiate from ADHD-RI in sociodemographic and neuropsychological characteristics. We hypothesize that ADHD + SCT would be related to lower processing speed scores, total memory scores. In addition, we hypothesized that ADHD + SCT would be associated with the highest CBCL scores on the internalizing domain.

Methods

Sample

In the study, 214 patients were assessed from Ege University ADHD outpatient clinic and 100 typically developing (TD) subjects were recruited between December 2011 and March 2013. The Ethics Committee of the Ege University approval was obtained, and parents provided written informed consent.

Patients for the ADHD group were included according to following criteria: (1) age between 8 and 15 years; (2) an estimated Intelligence quotient (IQ) score higher than 80; (3) living in his/her own family's house and attending a normal school; (4) no neurological or other serious medical diseases and no constant use of any prescribed medications for medical conditions; (5) no prior use of stimulants; (6) no use of psychotropic medication within the last 6 months; (7) no psychiatric comorbidities except for oppositional defiant disorder (ODD). The inclusion criteria for TD were the same.

Diagnostic procedures

In the first step of the diagnostic assessment, a senior child psychiatry resident applied a semi-structured interview (Kiddie-Schedule for Affective Disorders and Schizophrenia, present and life time version—K-SADS-PL) to parents and all cases. Then, two experienced child psychiatrists, who were blind to the first diagnostic assessment, interviewed the parents to confirm positive ADHD diagnosis in the first K-SADS-PL.

Parents also fulfilled the child behavior checklist (CBCL) and the attention-deficit/hyperactivity disorder rating scale-IV (ADHD-RS-IV), about the emotional and behavior problems of their children. The total numbers of 314 cases were screened. A group of 35 children had missing CBCL items and were excluded from analyses (see Fig. 1). Disagreement between the two interviews existed in 10 cases and 3 cases refused to take part in the second assessment. These 13 cases were also excluded from analyses.

The ADHD-combine presentation (ADHD-C) group included cases with six or more symptoms on both inattention and hyperactivity–impulsivity dimensions; ADHD-I and ADHD-RI presentation groups included individuals with six symptoms or more on inattentive dimension. The ADHD-I group had fewer than six but more than three hyperactive–impulsive symptoms, whereas ADHD-RI presentation group had fewer than three hyperactive–impulsive symptoms. This group definition was made using parental ADHD-RS-IV findings.

Same diagnostic procedures were applied for the TD group that was recruited from the same population. Moreover, as ADHD symptoms are distributed dimensionally in the population (Salum et al. 2015), we requested that subjects in our TD group had ADHD scores one standard deviation below the mean for the child's age on the same scales applied to ADHD cases (CBCL and ADHD-RS-IV) to avoid including subthreshold ADHD cases in the TD group. We

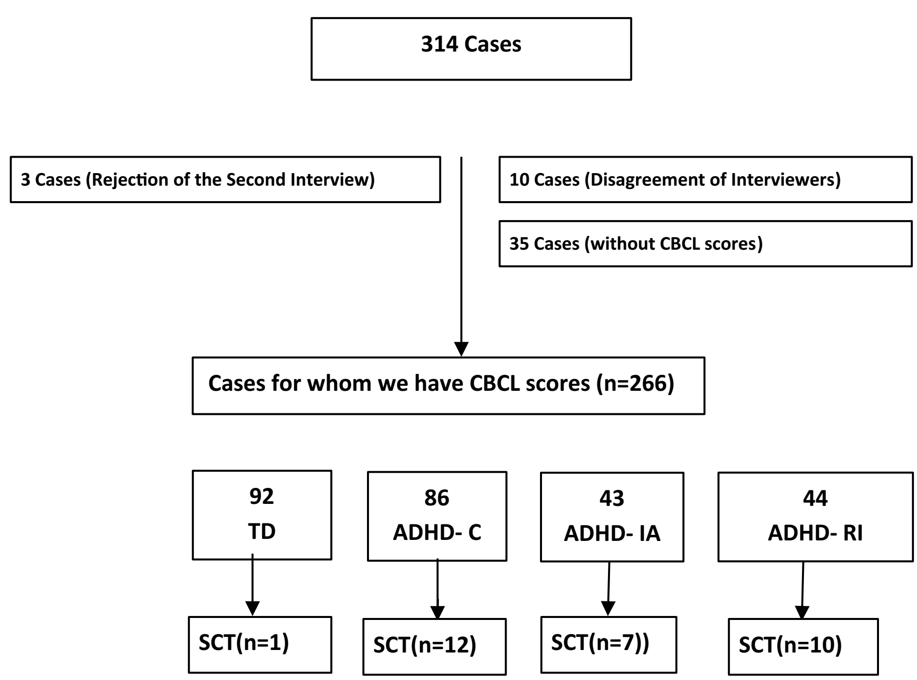

Fig. 1 Distribution of the sluggish cognitive tempo cases in all groups

also excluded one case in the highest 10% SCT score from the TD group (see below).

As extensively done in the previous literature (Araujo Jimenez et al. 2015; Bauermeister et al. 2005a, b; Becker and Langberg 2013; Raiker et al. 2015), we selected 4 CBCL items (confused or seems to be in a fog, daydreams or gets lost in his/her thoughts, stares blankly, and underactive, slow moving or lack of energy) to compose our SCT construct. Each of these items could be rated from 0 to 2. We summed the scores in the 4 items creating a global SCT score (range from 0 to 8). To define SCT diagnosis, we used a 90% threshold in this global SCT score (cutoff score = 4). Thus, our SCT cases had the highest 10% scores in the sample. Similar diagnostic procedures were used before an epidemiological study (Camprodon-Rosanas et al. 2016).

Thus, we identified SCT cases based on the definition above in each of the diagnostic groups (ADHD-C, ADHD-I, ADHD-RI and TD). As a result, our sample was composed by 86 cases of ADHD-combine type (ADHD-C), 43 cases of ADHD-I, 44 cases of ADHD-RI and 93 subjects of TD (see Fig. 1). According to the definitions above, the following groups were formed for analyses: ADHD + SCT (29 subjects); ADHD-RI w/o SCT (34 subjects); TD subjects w/o both high SCT and ADHD symptoms (92 subjects). We also run secondary analyses excluding from the ADHD + SCT group those subjects with SCT coming from the ADHD-RI ($n = 10$).

Subjects with a positive ADHD diagnosis were evaluated using vocabulary and block design subtests of WISC-R and a standardized neuropsychological battery (CNS-VS).

Instruments

The CBCL is a standardized parent-report questionnaire designed by Achenbach to assess emotional and behavior problems and social competencies in children with good validity and reliability (Thomas M Achenbach 1991). The CBCL has eight subscales (withdrawn, somatic complaints, anxiety/depression, thought problems, attention problems, social problems, aggressive behavior and delinquent behavior) and two broadband domains: internalizing and externalizing problems. Back translation, bilingual retest assessment and a pretest field study were done for the CBCL Turkish form. The reliability and validity of the American version of the CBCL were confirmed for the Turkish version (Erol et al. 1995).

The ADHD-RS-IV (DuPaul et al. 1998) is an 18-item questionnaire based on the diagnostic criteria for ADHD as described in the 4th edition of the Diagnostic and Statistical Manual of Mental Disorders of the American Psychiatric Association (APA 1994). The ADHD-RS-IV provides Inattention and Hyperactivity–Impulsivity scores, as well as a total score. The symptoms are scored on a 4-point Likert-type scale (namely, 0 = not at all; 1 = just a little; 2 = much; and 3 = very much). Ratings of ''much'' and ''very much'' for each item were considered positive, as done in other similar investigations. The ADHD-RS-IV has shown adequate criterion related to validity and good reliability in different cultures both for parent and teacher reports (DuPaul et al. 1998; Magnusson et al. 1999). The ADHD-RS-IV was translated and adapted in Turkish (Ercan et al. 2001).

K-SADS-PL is a highly reliable semi-structured interview for the assessment of a wide range of psychiatric disorders in children and adolescents according to DSM-III-R and DSM-IV criteria (Kaufman et al. 1997). Turkish reliability and validity results of K-SADS were reported. Validity of K-SADS-PL-T was found to be excellent for elimination disorders, good for attention-deficit and hyperactivity disorder and tic disorders, fair for affective disorders, anxiety disorders and oppositional defiant disorder. The results of the study showed that the K-SADS-PL-T is an effective instrument for diagnosing major childhood psychiatric disorders (Gökler et al. 2004). The Turkish Association of Child and Adolescent Psychiatry provided extensive training on K-SADS-PL administration to child psychiatry residents, assuring a uniform way of applying the interview.

The CNS Vital Signs brief clinical evaluation battery contains seven tests: verbal and visual memory, finger tapping, symbol digit coding, the Stroop test, a test of shifting attention and the continuous performance test. The 7 tests generate 17 primary scores and 5 domain scores. These domain scores are memory (derived from verbal and visual memory), psychomotor speed (from finger tapping and symbol digit coding), reaction time (Stroop test), cognitive flexibility (Stroop test and shifting attention test) and complex attention (Stroop test, shifting attention test, and continuous performance test). Domain scores are generated as raw scores and then computed as standard scores for age. Standard scores have a mean of 100 and a standard deviation of 15. A standard score of 100 represents the 50th percentile. For standard scores, higher is always better (e.g., a lower standard score in the reaction time domain represents a slower response). A Neurocognition Index (NCI) is also computed representing the mean of the 5 domains scores. We also presented here findings for the continuous performance test (CPT) scores separately (correct hits, omission errors, commission errors and reaction time score). In this case, higher scores on correct hits mean better performance. However, lower scores show better performance for reaction time score, omission and commission errors (for more details on the tests, please see (Gualtieri and Johnson 2006).

Statistical analyses

The Chi-square test was used for categorical variables and ANOVA for quantitative variables. When a difference was detected among groups, Tukey was used as post hoc test to localize the difference. The level of significance accepted was 5%. The data were analyzed using the Statistical Package for the Social Sciences—Windows, version 16.0.

Results

Consonant with the main objective of this study, we compared our 29 ADHD + SCT cases with 34 ADHD-RI cases and 92 TD subjects on sociodemographic profiles, CBCL subscales and neurocognitive tests. SCT rates across the groups were relatively similar in all ADHD presentations: 14% in the ADHD-C group, 16% in the ADHD-I group and 22% in the ADHD-RI group. Also, we obtained similar SCT mean scores in ADHD-C, ADHD-I and ADHD-RI presentations (4.66, 4.57, 4.90, respectively). Regarding sociodemographic profiles, there was no significant differences among groups ($p > 0.05$, see Table 1). The variables assessed were age, gender and parental education. The mean age for the ADHD + SCT cases was 10.4 years (SD = 1.9), for the ADHD-RI was 10.9 years (SD = 2.1) and for the TD was 10.6 years (SD = 1.8). The male/female ratios in the three groups were 2.22, 1.61 and 1.3, respectively.

Table 1 Socio-demographic characteristics of ADHD + SCT, ADHD-RI and TD cases

	ADHD-RI $n = 34$	ADHD + SCT $n = 29$	TD $n = 92$	*p* value
Age, years (mean ± SD)	10.9 ± 2.1	10.4 ± 1.9	10.6 ± 1.8	0.625
Gender (F/M)	13/21	9/20	40/52	0.477
Maternal education (%)				0.697
No education	–	–	1	
Elementary	35.2	44.8	28.2	
Secondary	14.7	17.2	16.3	
High school	50	37.9	54.3	
Paternal education (%)				0.467
No education	–	–	1	
Elementary	35.2	44.8	23.9	
Secondary	17.6	13.7	19.5	
High School	47	41.3	55.4	

Concerning the CBCL subscales, ADHD + SCT and ADHD-RI cases did not differ in any score ($p > 0.05$). The only significant differences were detected between normal controls and the other two groups (see Table 2) on all 8 CBCL scales ($p < 0.05$).

The performance in the neuropsychological assessment for the 3 groups is shown in Table 2. Comparing ADHD + SCT with ADHD-RI, the results of the domains were mixed. The ADHD + SCT group differed from ADHD-RI for most of them, such as neurocognitive index (mean *T* score for ADHD + SCT group = 81.5, SD = 12; mean *T* score for ADHD-RI group = 73.7, SD = 10.6; $p < 0.001$), total memory score (mean *T* score for ADHD + SCT group = 82.2, SD = 24.6; mean *T* score for ADHD-RI group = 91.3, SD = 17.5; $p = 0.002$), psychomotor speed score (mean *T* score for ADHD + SCT group = 86.7, SD = 16; mean *T* score for ADHD-RI group = 66.5, SD = 16.3; $p < 0.001$), reaction time score (mean *T* score for ADHD + SCT group = 81.2, SD = 19.1; mean *T* score for ADHD-RI group = 48.7, SD = 27.8; $p < 0.001$). For CPT findings, the following scores were significantly different between ADHD + SCT

Table 2 Child behavior checklist subscales

	ADHD-RI $n = 34$	ADHD + SCT $n = 29$	TD $n = 92$	*p* value	Group comparison
Withdrawn	58.3 ± 9	59.5 ± 11.3	50.3 ± 1.2	< 0.001	C < SCT&RI
Somatic complaints	53.5 ± 6.2	54 ± 6.9	52 ± 4.9	< 0.001	C < SCT&RI
Anxiety/depression	57.6 ± 6.1	58.5 ± 7.5	50.8 ± 2.8	< 0.001	C < SCT&RI
Social problems	57.1 ± 6.3	56.8 ± 7.2	50.5 ± 1.7	< 0.001	C < SCT&RI
Thought problems	56.9 ± 7.1	57.8 ± 9.1	50.7 ± 2.6	< 0.001	C < SCT&RI
Attention problems	57.3 ± 5.9	57.3 ± 6.5	50.2 ± 1	< 0.001	C < SCT&RI
Delinquent behavior	53.7 ± 5	55.3 ± 5.9	50.2 ± 1.1	< 0.001	C < SCT&RI
Aggressive behavior	54.9 ± 4.8	56.3 ± 7.4	50.8 ± 3.2	< 0.001	C < SCT&RI
Internalizing problems	56.3 ± 7.5	57.2 ± 9.4	37.8 ± 7.3	< 0.001	C < SCT&RI
Externalizing problems	56.6 ± 9.2	57.3 ± 10.7	41.1 ± 6.5	< 0.001	C < SCT&RI

Data are presented as the means ± standard deviations

ADHD-*RI* attention-deficit/hyperactivity disorder, restrictive inattentive type; *TD* typically developing children; *SCT* sluggish cognitive tempo and ADHD-RI groups: correct hits (mean T score for ADHD + SCT group = 36.1, SD = 4.2; mean T score for ADHD-RI group = 32.1, SD = 3.9; $p < 0.001$), omission errors (mean T score for ADHD + SCT group = 3.6, SD = 4.1; mean T score for ADHD-RI group = 7.8, SD = 3.9; $p < 0.001$) and commission errors (mean score for ADHD + SCT group = 5.4, SD = 4.6; mean score for ADHD-RI = 2.1, SD = 2.3; $p < 0.001$ (see Table 3).

In the secondary analyses evaluating ADHD + SCT group without SCT cases coming from the ADHD-RI ($n = 10$), the sample comprised 19 ADHD + SCT cases, 34 ADHD-RI cases w/o SCT and 92 TD subjects w/o both high SCT and ADHD symptoms. There was only one major difference between first and second analyses on neuropsychological findings. It was for CPT-reaction time score. In the first analysis, both ADHD + SCT group and ADHD-RI group had significantly lower CPT-reaction time scores than controls ($p < 0.001$). When we excluded from the ADHD + SCT group those subjects with SCT coming from the ADHD-RI ($n = 10$), ADHD + SCT group did not differ on CPT-reaction time score than TD controls. Only, ADHD-RI differed from both other groups on the CPT-reaction time score (see Table 4).

Discussion

As far as we are aware, the current study is the first study to compare emotional and behavioral symptoms, demographic characteristics and neuropsychological deficits among cases with ADHD + SCT, ADHD-RI and typically developing controls. First, we demonstrated that our 29 SCT cases originated from all ADHD presentations in a relatively similar proportion. Second, the sociodemographic profiles from the 29 cases of ADHD + SCT and 34 cases of ADHD-RI were not significantly different. Third, scores for the eight CBCL subscales and the two dimensions were significantly higher than typically developing controls for both ADHD-RI and ADHD + SCT group, but none of the CBCL scores differ between ADHD-RI and ADHD + SCT groups. Lastly, we detected main differences between ADHD + SCT and ADHD-RI in the neuropsychological assessment such as in neurocognitive index, psychomotor speed score, reaction time score and total memory score.

Concurrent with previous work, we detected SCT cases in all ADHD presentations (Harrington and Waldman 2010; Hartman et al. 2004; Skirbekk et al. 2011). SCT rates across the groups were relatively similar in all ADHD presentations: 14% in the ADHD-C group, 16% in the ADHD-I group and 22% in the ADHD-RI group. It is important to highlight that our approach to define the SCT phenotype and the cut off to determine SCT cases were similar to the one from a recent epidemiological study on SCT (Camprodon-Rosanas et al. 2016). Moreover, they found that 11% of the participants presented a high level of SCT symptoms (Camprodon-Rosanas et al. 2016). We found similar rate in our total sample as 11% (30/266).

We did not find major sociodemographic differences among ADHD + SCT, ADHD-RI cases and typically developing controls. This was expected considering that this is a clinical sample not randomly selected. Surprisingly few studies have examined SCT in relation to demographic factors (Becker et al. 2016). Several studies showed that SCT cases did not seem to differ from typically developing

Table 3 Neuropsychological findings of the first analyses including subjects with SCT coming from the ADHD-RI in the ADHD + SCT group

	ADHD-RI $n = 34$	ADHD + SCT $n = 29$	TD $n = 92$	p value	Group comparison
CNS-VS domain score, mean ± SD					
Neurocognitive index	73.7 ± 10.6	81.5 ± 12	98.4 ± 12.8	< 0.001	RI < SCT < C
Total memory score	91.3 ± 17.5	82.2 ± 24.6	96.7 ± 18	0.002	SCT < RI&C
Psychomotor speed score	66.5 ± 16.3	86.7 ± 16	102.6 ± 18.4	< 0.001	RI < SCT < C
Reaction time score	48.7 ± 27.8	81.2 ± 19.1	83.5 ± 33.7	< 0.001	RI < SCT&C
Total attention score	78.4 ± 11.7	74.5 ± 20.8	104.1 ± 13.5	< 0.001	RI&SCT < C
Cognitive flexibility score	84 ± 12	83 ± 14.2	105.2 ± 17.44	< 0.001	RI&SCT < C
CPT, mean ± SD					
Correct hits	32.1 ± 3.9	36.1 ± 4.2	39.2 ± 1	< 0.001	RI < SCT < C
Omission errors	7.8 ± 3.9	3.6 ± 4.1	0.7 ± 1	< 0.001	C < SCT < RI
Commission errors	2.1 ± 2.3	5.4 ± 4.6	1.5 ± 1.6	< 0.001	C&RI < SCT
Reaction time score	540.1 ± 78.3	526 ± 62.1	476.8 ± 76.9	< 0.001	C < SCT&RI
Estimated IQ	104.6 ± 17.6	105.1 ± 19.4	111.6 ± 20.9	0.117	

Data are presented as the means ± standard deviations

RI attention-deficit/hyperactivity disorder, restrictive inattentive type, *TD* typically developing children, *SCT* = sluggish cognitive tempo, *CNS-VS* computerized neuropsychological test-vital signs, *CPT* continuous performance test, *IQ* intelligence quotient

Table 4 Neuropsychological findings in secondary analyses excluding from the ADHD + SCT group those subjects with SCT coming from the ADHD-RI

	ADHD-RI $n = 34$	ADHD + SCT $n = 19$	TD $n = 92$	p value	Group comparison
CNS-VS domain score, mean ± SD					
Neurocognitive index	73.7 ± 10.6	83.6 ± 12.3	98.4 ± 12.8	< 0.001	RI < SCT < C
Total memory score	91.3 ± 17.5	82.4 ± 27.9	96.7 ± 18	0.012	SCT < RI&C
Psychomotor speed score	66.5 ± 16.3	91.9 ± 15.2	102.6 ± 18.4	< 0.001	RI < SCT < C
Reaction time score	48.7 ± 27.8	88.2 ± 13.5	83.5 ± 33.7	< 0.001	RI < SCT&C
Total attention score	78.4 ± 11.7	73 ± 24.5	104.1 ± 13.5	< 0.001	RI&SCT < C
Cognitive flexibility score	84 ± 12	82.5 ± 12.2	105.2 ± 17.44	< 0.001	RI&SCT < C
CPT, mean ± SD					
Correct hits	32.1 ± 3.9	36.3 ± 4.2	39.2 ± 1	< 0.001	RI < SCT < C
Omission errors	7.8 ± 3.9	3.2 ± 3.9	0.7 ± 1	< 0.001	C < SCT < RI
Commission errors	2.1 ± 2.3	7.1 ± 4.8	1.5 ± 1.6	< 0.001	C&RI < SCT
Reaction time score	540.1 ± 78.3	517.9 ± 67.6	476.8 ± 76.9	< 0.001	C&SCT < RI
Estimated IQ	104.6 ± 17.6	106.3 ± 21.1	111.7 ± 21	0.176	

Data are presented as the means ± standard deviations

RI attention-deficit/hyperactivity disorder, restrictive inattentive type, *TD* typically developing children, *SCT* sluggish cognitive tempo, *CNS-VS* computerized neuropsychological test-vital signs, *CPT* continuous performance test, *IQ* intelligence quotient

The only significant difference between the first and second analysis was marked as bold in the group comparison

subjects on age and gender, whereas ADHD cases do (Jarrett et al. 2014; Marshall et al. 2014). However, two studies found a higher prevalence of girls in the high SCT groups than in the ADHD-only groups and Barkley reported an association between older age and higher SCT symptoms (Barkley 2013; Ludwig et al. 2009). Also, in contrast to ADHD, an association between SCT and lower parental education was found in children in the previous literature (Barkley 2013). However, no previous study investigated these characteristics between ADHD + SCT and ADHD-RI groups. Our findings of similar intergroup sociodemographic characteristics also protect our analyses on emotional and behavioral problems and neuropsychological performance against confounding effects of those variables.

Previous studies have showed that frequent ADHD comorbid conditions like mood and anxiety disorders produce, as expected, increase in CBCL subscales scores (Biederman et al. 1993, 1996). In addition, previous findings suggest an association between higher levels of SCT symptoms and higher levels anxiety and depression even after controlling for ADHD-I (Becker et al. 2016; Belmar et al. 2015; Burns et al. 2013; Lee et al. 2014; Penny et al. 2009; Servera et al. 2016). These studies showed that SCT was strongly associated with internalizing symptoms, and it is therefore critical for studies to control for internalizing problems when seeking to evaluate SCT construct (Marshall et al. 2014). In our study, there were not any significant difference between ADHD + SCT and ADHD-RI cases in any CBCL subscales and domains (internalizing and externalizing problems). However, it is important to note that we excluded all comorbidities except ODD from our cases. Even with these exclusions, both SCT and ADHD-RI groups exhibited significantly higher scores than the TD group on all CBCL subscales scores and domains.

Meta-analytic findings in children and adolescents suggest that SCT is associated with significant functional impairment in a wide range of important domains, even after symptoms of ADHD and other psychopathology are controlled (Becker et al. 2016). The use of neurocognitive measures could be beneficial to identify potential factors underlying impairments associated with the SCT group. However, a smaller number of studies have examined the neurocognitive correlates of SCT (Becker et al. 2016). In our study, ADHD + SCT cases performed significantly worse than the typically developing controls on CPT (correct hits, reaction time, omission and commission errors) and the all domains of CNS-VS (neurocognitive index, psychomotor speed, total memory score, total attention score and cognitive flexibility score) except for reaction time. In general, our findings are consistent with results of the meta-analysis demonstrating lower scores for SCT on measures of response inhibition, working memory and sustained attention (Becker et al. 2016).

Comparing ADHD-RI group with controls, we detected slower psychomotor speed, longer reaction time and worse overall performance assessed by the global neurocognitive index. Both ADHD + SCT and ADHD-RI groups had lower scores than TD subjects on neurocognitive index and psychomotor speed. However, ADHD-RI cases presented slower psychomotor speed and reaction time and worse neurocognitive index compared with ADHD + SCT cases. It is important to note that although SCT might be expected to have the slowest psychomotor speed and reaction time in tests because of its symptom profile, we found that ADHD-RI cases were slower compared to ADHD + SCT cases. Although studies investigating processing speed performance for SCT are few, interestingly several previous studies also did not find any deficits in processing speed and reported that SCT cases are not slow in fact during their performance in neuropsychological tasks (Bauermeister et al. 2012; Wood et al. 2017). Similar findings were reported by studies evaluating executive functioning. These studies have generally found SCT to be significantly associated with deficits of executive functioning reported by parent rating scales, but failed to detect any difference in executive functioning by a computerized task (Araujo Jimenez et al. 2015; Barkley 2013; Becker and Langberg 2013). It is important to highlight that only ADHD-RI was independently associated with longer reaction times. Deficits in reaction time were associated with ADHD symptoms in previous studies (Castellanos et al. 2005; Wahlstedt 2009). In addition, previous studies were not able to found a correlation between SCT and reaction time, likewise our study (Skirbekk et al. 2011; Willcutt et al. 2014). Only one study reported slower reaction time for SCT associated with teacher-rated SCT scores (Tamm et al. 2016).

Although both ADHD + SCT and ADHD-RI cases had lower scores on the global neurocognitive index compared with the TD group, ADHD-RI had the worst scores. In the same direction, Barkley reported that both ADHD and SCT are impairing disorders. However, ADHD was reported to be even more impaired, especially in Home-School domains. SCT was most impairing in Community-Leisure domains (Barkley 2013).

Comparing with TD group, ADHD + SCT group seems to be impaired in different neuropsychological domains. When we examined specifically, we found that only ADHD + SCT was independently associated with a lower performance in total memory score.

Our study should be understood in the context of some limitations. Our SCT cases were derived from an ADHD sample, and they are not representative of the population of individuals who exhibit high levels of SCT. In their meta-analysis of SCT, Becker et al. 2016 pointed that most of the previous studies examining SCT and neuropsychological functioning relied only in ADHD-defined samples. Like previous studies, we were not able to exclude potential effects of ADHD diagnosis and different presentations of ADHD. However, we went one step further in our study investigating differences between pure cases of inattention and SCT cases comorbid with ADHD. Although approximately 59% of SCT cases were reported to be comorbid with ADHD (Barkley 2013), we need further population-based studies including pure SCT cases. As another limitation, we would not able to have a greater sample size. Although there was not a significant gender difference between all groups, we would not able to completely match our groups according to age. Also, to better understand clinical effects of some neuropsychological deficits that we found to be independently associated with SCT, future studies should also evaluate functional impairment. Our SCT symptoms were assessed using four items commonly used in previous work rather than SCT scales (Araujo Jimenez et al. 2015; Bauermeister et al. 2005a, b; Raiker et al. 2015).

Overall, our findings suggest that some neuropsychological deficits might be more pronounced in SCT and others in ADHD-RI. SCT neuropsychological deficits might be more pronounced memory domain apart from inattention, and inattention dimension might be more associated with reaction time. It may be important to examine improvements in these deficits with ADHD medications. Our results might help in improving interventions specific to SCT.

Our results are important to understand clinical heterogeneity in ADHD. Some previous studies failed to distinguish neuropsychological deficits among ADHD presentations (Bauermeister et al. 2005a, b; Guerts et al. 2005). Future studies may benefit for also including an assessment for SCT. We also need more studies to understand differences between SCT and inattention.

Compliance with ethical standards

Conflict of interest Eyüp Sabri Ercan is on advisory boards for Sanofi Turkey. Luis A. Rohde has received honoraria, has been on the speakers' bureau/advisory board and/or has acted as a consultant for Eli-Lilly, Janssen-Cilag, Medice, Novartis and Shire in the last three years. He receives authorship royalties from Oxford Press and ArtMed. He also received travel awards for taking part of 2014 APA and 2015 WFADHD meetings from Shire and 2016 AACAP meeting from Novartis. The ADHD and Juvenile Bipolar Disorder Outpatient Programs chaired by him received unrestricted educational and research support from the following pharmaceutical companies in the last three years: Eli-Lilly, Janssen-Cilag, Novartis and Shire. Gül Ünsel Bolat received travel award for taking part of 2018 Turkish Child and Adolescent Psychiatry Congress from Sanofi. The other authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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