



Association between early attention-deficit/hyperactivity symptoms and current verbal and visuo-spatial short-term memory[☆]

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ARTICLE INFO

Article history:

Received 18 August 2012

Received in revised form 6 October 2012

Accepted 9 October 2012

Available online 5 November 2012

Keywords:

ADHD

Inattention

Short-term memory

Hyperactivity

Impulsivity

Verbal

Visuo-spatial

ABSTRACT

Deficits in short-term memory are common in adolescents with attention-deficit/hyperactivity disorder (ADHD), but their current ADHD symptoms cannot well predict their short-term performance. Taking a developmental perspective, we wanted to clarify the association between ADHD symptoms at early childhood and short-term memory in late childhood and adolescence. The participants included 401 patients with a clinical diagnosis of *DSM-IV* ADHD, 213 siblings, and 176 unaffected controls aged 8–17 years (mean age, 12.02 ± 2.24). All participants and their mothers were interviewed using the Chinese Kiddie Epidemiologic version of the Schedule for Affective Disorders and Schizophrenia to obtain information about ADHD symptoms and other psychiatric disorders retrospectively, at an earlier age first, then currently. The participants were assessed with the Wechsler Intelligence Scale for Children – 3rd edition, including Digit Span, and the Spatial working memory task of the Cambridge Neuropsychological Test Automated Battery. Multi-level regression models were used for data analysis. Although crude analyses revealed that inattention, hyperactivity, and impulsivity symptoms significantly predicted deficits in short-term memory, only inattention symptoms had significant effects (all $p < 0.001$) in a model that included all three ADHD symptoms. After further controlling for comorbidity, age of assessment, treatment with methylphenidate, and Full-scale IQ, the severity of childhood inattention symptoms was still significantly associated with worse verbal ($p = 0.008$) and spatial (p ranging from 0.017 to 0.002) short-term memory at the current assessment. Therefore, our findings suggest that earlier inattention symptoms are associated with impaired verbal and visuo-spatial short-term memory at a later development stage. Impaired short-term memory in adolescence can be detected earlier by screening for the severity of inattention in childhood.

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1. Introduction

Attention deficit/hyperactivity disorder (ADHD) is a common, developmental neuropsychiatric disorder of childhood, with a prevalence rate of 7.5% in the Taiwanese child and adolescent population (Gau, Chong, Chen, & Cheng, 2005). ADHD is

[☆] ClinicalTrials.gov number: NCT00417781; NCT00529906.

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characterized by early-onset functional impairment with lifelong executive function deficits (Seidman, 2006). Executive functions often include working memory, planning, organization, inhibitory control, sustained attention, and set shifting. Among these executive functions, working memory is one of the most consistently reported deficits in ADHD (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Working memory, the ability to store information in mind temporarily and manipulate it in auditory-verbal or visuo-spatial systems, is recognized as a key component underlying other executive functions and mental activities (Baddeley, 2003), and is associated with social function (Kofler et al., 2011), peer relationships (Diamantopoulou, Rydell, Thorell, & Bohlin, 2007), academic performance (Gathercole, Pickering, Knight, & Stegmann, 2004; Gropper & Tannock, 2009; Rogers, Hwang, Toplak, Weiss, & Tannock, 2011) and occupational achievement (Biederman et al., 2006; Stavro, Ettenhofer, & Nigg, 2007) in children (Diamantopoulou et al., 2007; Gathercole et al., 2004; Kofler et al., 2011; Rogers et al., 2011) and adults with ADHD (Biederman et al., 2006; Gropper & Tannock, 2009; Stavro et al., 2007).

According to the Baddeley's model, working memory consists of the central executive and the two slave systems, for temporary storage of phonologically based material (the phonological loop) and of visuospatial material (the visuospatial sketchpad) respectively (Baddeley, 1996). Performance of short-term memory primarily reflects phonological and visuospatial storage process. In longitudinal studies, working memory impairment is long-lasting in patients with ADHD (Halperin, Trampush, Miller, Marks, & Newcorn, 2008). Attention problems (Sarver et al., 2012) and working memory (Alloway, Gathercole, & Elliott, 2010) are good predictors of subsequent academic performance. The negative association between inattention and long-term scholastic achievement is attenuated by short-term memory (Sarver et al., 2012). However, the association between severity of ADHD symptoms and short-term memory impairment is still not well understood with a developmental perspective. Previous research has shown that ADHD symptoms had a strong cross-sectional correlation with short-term memory, such as digit span backward, in childhood (McInnes, Humphries, Hogg-Johnson, & Tannock, 2003), but the same cross-sectional association does not exist in adolescence (Gau, Chiu, Shang, Cheng, & Soong, 2009; Miller, Ho, & Hinshaw, 2012). Adolescents with childhood diagnosis of ADHD had similar impairment in verbal and visuo-spatial working memory and other executive functions whether they currently had persistent ADHD symptoms or not in our previous study (Gau et al., 2009) and other's (Miller et al., 2012). In other words, short-term memory impairment persisted from childhood to adolescence, but such impairment cannot be completely explained by current ADHD symptoms in adolescence. Therefore, it is clinically worthwhile to explore whether symptoms of ADHD in early childhood are associated with later working memory impairment, and to identify their specific clinical and educational needs in early childhood.

ADHD patients had central executive deficits (Kofler, Rapport, Bolden, Sarver, & Raiker, 2010), which were related to increased level of activity (Rapport et al., 2009), inattention (Kofler et al., 2010) and impulsivity (Raiker, Rapport, Kofler, & Sarver, 2012) by objective measurements. In contrast to working memory and other executive functions, relatively few studies focused on impaired short-term memory in patients with ADHD (Quinlan & Brown, 2003). The impaired short-term memory may contribute to many inattentive symptoms of ADHD according to the DSM-IV diagnostic criteria, such as "often forgetful in daily activities" and "often does not follow through on instructions" (American Psychiatric Association, 1994). Kofler et al. has demonstrated that inattention in ADHD can be explained by not only central executive deficits, but also the increased short-term memory demands within the context of working memory (Kofler et al., 2010). In contrast, hyperactivity (Rapport et al., 2009) and impulsivity (Raiker et al., 2012) are mostly attributed to central executive deficits relative to storage impairment with working memory. Additionally, the severity of inattention symptoms increased significantly more from conditions at/below to exceeding storage capacity in patients with ADHD, compared to the non-ADHD (Kofler et al., 2010). These studies implied that ADHD tend to have lower storage capacity of working memory, reflected on the performance of short-term memory deficits, is mainly associated with inattention, rather than hyperactivity and impulsivity in patients with ADHD.

Studies using symptom dimensions might be more appropriate than subtype approach for understanding the predictive value of a specific ADHD symptom on neuropsychological deficits (Taylor, 2009). According to the DSM-IV symptom criteria, ADHD can be categorized into 3 subtypes: Predominantly Inattentive Type (ADHD-I), Predominantly Hyperactive-Impulsive Type (ADHD-HI), and Combined Type (ADHD-C) (American Psychiatric Association, 1994). Studies examining the association between ADHD subtypes and short-term memory revealed inconsistent findings (Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2005). Geurts et al. reported that children with ADHD-C, compared to children with ADHD-I, showed more difficulties with one kind of visual short-term memory task (Benton Visual Retention Test) but no difference between subtypes in Corsi Block Tapping Test (Geurts et al., 2005). Other studies with symptomatic approach showed that inattention, but not hyperactivity and impulsivity, is best associated with short-term memory deficit (Kofler et al., 2010). To the best of our knowledge, no previous study has focused on the correlation of early ADHD core symptoms with later short-term memory deficit.

Previous studies on short-term memory impairment or other executive function deficits have been limited by small sample size (Geurts et al., 2005; Schachar et al., 2007), exclusion of ADHD-HI in a subtype approach (Geurts et al., 2005; Willcutt et al., 2005), lack of identification of a specific ADHD core symptom (using ADHD symptoms as a whole) (Friedman et al., 2007), lack of control for psychiatric comorbidities (Pennington & Ozonoff, 1996), failure to evaluate both verbal and visuo-spatial working memory in one paper (Pennington & Ozonoff, 1996), and without using standard test batteries with established psychometric properties (Engelhardt, Nigg, Carr, & Ferreira, 2008). Herein, we adopted a dimensional approach to explore the correlations between the three ADHD core symptoms in early childhood and later short-term memory in a

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