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ORIGINAL ARTICLE

Co gnitive flexibility and inhibitory control in typically developing children with attention-deficit/hyperactivity disorder: implications of Stroop test

Susmita Halder[a], Akash K. Mahato[b]

[a]Department of Psychology, St. Xavier's University Kolkata, [b]Department of Psychology, Amity University Kolkata, Kolkata, India.

Correspondence to *Susmita Halder, Department of Psychology, St. Xavier's University Kolkata, Kolkata, India*
E-mail: susmitahalder@gmail.com

Background Cognitive flexibility refers to the ability to flexibly shift between multiple incompatible perspectives or descriptions of an object or event. Cognitive flexibility and inhibitory control are components of executive function that contribute to the development of self-regulation (McClelland & Cameron, 2012) and are a key determinant of scholastic achievement and occupational success. Cognitive flexibility and inhibitory control has been postulated as the core deficit in attention-deficit/hyperactivity disorder (ADHD) and an important treatment outcome objective.

Aim The present study investigated the cognitive flexibility associated with symptoms of inattention in typically developing children during the school years.

Methods The Stroop Color–Word test was used to investigate cognitive flexibility and inhibitory control in 70 children diagnosed with ADHD (inattentive type) and 70 healthy control children. Performance differences between neutral and incongruent trials of the Stroop task measured interference and inhibition control.

Results Findings suggest significant difference between the performances of the two groups, indicating that ADHD children had deficit in cognitive flexibility.

Conclusions The Stroop test is simplistic in administration and scoring and gives valuable inputs in assessing cognitive flexibility and inhibitory control without employing other sets of assessments. Its use is highly implicated in the outpatient and community setups where detailed psychological assessment is not feasible.

Keywords Attention-deficit/hyperactivity disorder (inattentive), Cognitive flexibility, Stroop test.
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INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders in children and the comorbidity rate of ADHD is high among psychiatric disorders such as oppositional-defiant disorder, conduct disorder, mood and anxiety disorders, and substance use disorders (Biederman *et al.,* 2006). Symptoms of ADHD can be categorized in terms of a triad of inattention, impulsivity, and hyperactivity. A considerable research finding suggests that abnormalities of brain functioning and structural alterations have an implication of pathophysiology of both childhood and adult ADHD (Martinussen *et al.,* 2005).

Although ADHD largely manifests itself as a functional disorder, the existing literature emphasizes its correlation with abnormalities in neurological functioning. The prefrontal cortex, specifically orbitofrontal and dorsolateral regions, and its connections to the cerebellum and striatum are hypothesized to play a vital role in the psychopathology of ADHD (Arnsten, 2006). Recent advancements in neuroimaging demonstrate a clear brain

basis to the disorder in regions involved in attention, and executive and inhibitory control (Curatolo *et al.,* 2010).

Executive functioning, which is described as the mental control processes to maintain an appropriate problem-solving set for the attainment of a goal and planning and programming of motor and behavioural functioning, is of relevance here. Inhibitory control is an important component of the executive functions and refers to the ability to respond successfully to a task-relevant dimension through the inhibition of inappropriate responses, which are automatic or suppressing interference due to a task-irrelevant dimension (Brydges *et al.,* 2012). It has at least two distinguishable processes that advances to stimulus interference control or interference suppression, and response inhibition (Bunge *et al.,* 2002). In case of ADHD, dysfunction in inhibitory control leads to a secondary disruption of other executive functioning components (Barkley, 1997a, 1997b). It has been found that children with ADHD have more severe deficits in response inhibition than in interference suppression (Nigg, 2001). Inhibition deficit in persons with ADHD causes irrelevant information being processed and also been maintained, that effectively reduces the capacity of working memory and contribute to problems with inappropriate behaviors and controlling affect (Hinshaw, 2002; Slaats-Willemse *et al.,* 2003).

Deficient inhibition further may produce a cascade of secondary impairments in behavior, working memory, and self-regulation of affect, motivation, and arousal.

Deficits in behavioural inhibition could be reflected as poor self-control in social situations. Along with a deficit in planning makes it probably difficult for them to monitor their behaviour in a 'moment of poor self-control' and make corrections in behavior according to situational demands. These act as situational stressors for children with ADHD, making them even more impulsive and further vulnerable to the display of poor emotional behaviour often in the form of externalizing behavior. The impact of these deficits in behavioral inhibition is not only in terms of academic performance but also on social functioning.

Literature suggests that inattention symptoms on its own significantly predicted academic achievement in adolescent ADHD girls, whereas school suspensions or expulsions were predicted by inattention symptoms (ADHD sample only) in addition to noncompliance and negative peer status (Lee and Hinshaw, 2006).The lack of awareness to intervene the child with ADHD effectively along with maladaptive behavior of the chil, often manifests as having severe social behavior deficits. In such a scenario, it becomes important to screen and identify children with ADHD primarily inattentive types in milder severity having a typical development.

Biologically, these are explained in terms of correlation of ADHD symptoms with decreased structure and function of circuits of the prefrontal cortex, specifically in the right hemisphere. The prefrontal association cortex is involved in a crucial role in the regulation of attention, behavior, and emotion, and the right hemisphere is specialized for behavioral inhibition. The prefrontal cortex is highly dependent on the functioning neurochemical environment mainly on noradrenergic stimulation (Arnsten, 2009). Weaker right inferior prefrontal cortex could be seen in individuals with ADHD, which declines the activities like inhibition or stop movements (Robbins, 2007).

While impairment in response inhibition has been conceptualized as a core of ADHD by pioneer researchers in the field of ADHD, attempts to test this hypothesis experimentally have been controversial (Kropotov, 2009). Certain study findings do not support cognitive inhibition problem in adolescent and adult ADHD participants (Geurts *et al.,* 2004; Engelhardt *et al.,* 2008).

The Stroop Color–Word test is the test often used to measure response inhibition (Stroop, 1935). The Stroop effect is a measure of the ability of individual to inhibit the proponent response (reading) in favor of required task completion (color naming). There are two processes that are involved in this task completion: an automatic response that requires little to no focus/attention for execution, and another response that is controlled and requires attention and is under control voluntarily (Cohen and Dunbar, 1990).

It has been found that individuals with ADHD have more difficulties in attending to the process, which is controlled than age-matched controls. However, in comparison of persons with ADHD with age-matched controls, the performance has been investigated only in the color–word condition (Doyle *et al.,* 2000). The finding that ADHD individuals are slower in this condition is taken as evidence indicating that they have more difficulties in response inhibition than age-matched controls (Van Mourik *et al.,* 2009). It is possible that individuals with ADHD respond slower on color–word trials not because of poorer response inhibition, but simply because of slower naming speed.

While the impact of deficits in cognitive flexibility and inhibitory control is profound in decision-making, it is of importance for typically developing ADHD children attending normal school. In the absence of a formal diagnosis, ADHD children, especially those with mild severity of symptoms are at risk of being deprived of adequate academic support and even disciplinary action in the event of dissatisfactory academic performance.

With the above background, the present study investigated the cognitive flexibility associated with inattention in typically developing ADHD children in school years.

METHODS

Sample

Using purposive sampling, 70 urban school-going children of both sexes in the age range of 7–12 years, attending a mental health clinic in Kolkata city for poor academic grades and behavioral problems and further diagnosed with ADHD, inattentive type were recruited for the study. Diagnosis of ADHD was established using the ICD-10 criteria by consulting a Psychiatrist and a Clinical Psychologist. Children with visual impairment, color blindness, or any comorbid psychiatric condition other than ADHD were excluded. ADHD children with IQ less than the normal range and significant hyperactivity were not considered in the sample. They were compared with healthy controls (n=70) in the same age range recruited from a neighboring locality.

The following measures were used:

(1) Wechsler Abbreviated Scale of Intelligence (WASI-II) (Wechsler, 2011): the WASI-II is designed to assess the specific and overall cognitive capabilities and was used to screen children with ADHD for their IQ scores. The WASI is designed to provide estimates of verbal and performance intelligence consistent with other Wechsler tests.

(2) Conners' ADHD Rating Scale – Parent, III (Conners *et al.,* 2011): the Conners III – Parent (Conners' 3-P) is an assessment tool used to obtain the parent's observations about the youth's behavior. This instrument is designed to assess ADHD, including three groups of inattentive, hyperactive, and combined type and its most common comorbid problems in children and adolescents aged 6–18 years.

(3) Stroop Color–Word Test (Stroop, 1935): the Stroop Color and Word Test (SCWT) is a neuropsychological test used to assess the ability to inhibit cognitive interference that occurs when the processing of a specific stimulus feature impedes the simultaneous processing of a second stimulus attribute, well known as the Stroop effect (Scarpina and Tagini, 2017). Neutral and incongruent trial – interference and inhibition control were measured by the SCWT. The conventional parameter was used, which required the reading name of colors printed in black ink (W), name different color patches (C), and name color words printed in a different color ink (CW).

Procedure

Informed consent and assent was taken from all participant children and their parents. Sociodemographic and clinical history data of the participating children were collected. The sample was screened for their IQ scores on WASI-II and further assessed on the Conner's ADHD rating. The groups were further compared on their performance on the Stroop Color–Word test.

RESULTS

The present study investigated the cognitive flexibility associated with inattention in typically developing children with normal intelligence in school years. Performance differences between neutral and incongruent trials of the Stroop task measures of interference and inhibition control can be seen within the groups. The results are discussed further in reference to existing literature in the section below.

DISCUSSION

Majority of children with ADHD in the sample were male (Table 1), reiterating the higher prevalence of ADHD in boys compared with girls (Ramtekkar *et al.,* 2010; Arnett *et al.,* 2015). Mean IQ scores of children with ADHD though within the normal range was lower than healthy controls. It is important to note that all these students were attending normal school; and were referred for psychological consultation for poor academic grades, behavioral problems, and lack of concentration in studies.

As evident from the result (Table 2), children with ADHD (inattentive type) fared significantly lower than healthy controls on the Stroop test on all tasks and is consistent with available literature, which suggest that ADHD children show significant impairment in comparison to age-matched controls on the Stroop effect. Its worthy to note that children with ADHD fared poorly compared with their healthy counterparts even on the congruous task of the Stroop test. It is consistent with the literature, which suggests that Stroop effect on ADHD is indicative of disrupted interference control over task-relevant stimuli than normal counterparts (Boonstra *et al.,* 2005). The findings are consistent with a study on ADHD children of similar age group as in the present study, where ADHD children had significant difficulty in inhibitory control as assessed on the SCWT (Rahmi and Wimbarti, 2018) further suggesting that there was no difference in inhibitory control between the three ADHD subtypes. Although a causal relationship between Stroop task scores and intelligence scores was not analyzed, the fact that ADHD children had significant difficulty on congruous task of the Stroop only highlights their underlying difficulties with academic tasks reflecting in dissatisfactory academic grades.

Further, when the symptom severity of the children with ADHD was correlated with scores on the Stroop test (Table 3), it revealed that ADHD severity had significant correlation with both C (color task) and CW (color word task). However, the scores were highly significant (0.001 level) in the interference task (CW). The findings are consistent with other studies where children with ADHD are found to exhibit greater interference in reaction time compared with children without ADHD, suggesting deficit in selective attention (Assef *et al.,* 2007). While the Stroop interference has been established in meta-analytic reviews

to be independent of age factor (Schwartz and Verhaeghen, 2008), the relative performance of ADHD children on Stroop subdomains in relation to severity of ADHD symptoms further adds on the utility of the Stroop test for ADHD children.

While the result on deficits in cognitive flexibility in ADHD children might be an expected finding, it is important from a different perspective. Considering the overall behavioral profile, children with ADHD (hyperactive or combined type) in moderate to severe range are relatively easy to identify; however, the inattentive subtypes in milder range could be difficult to identify at times. This may happen in the absence of other characteristic features or poor awareness of family members as well as school teachers. The academic performance of these children is often not as per expectations of the family members and teachers; and is attributed to lack of motivation and poor effort on the part of the child or labelled as slow learners.

The present study finding supports the utility of the Stroop test in this regard, as it clearly separates ADHD children (inattentive types) having typical development from the healthy control. The use of the Stroop test has been suggested as a useful screening tool for ADHD (Thursina *et al.,* 2015). Further, intervention of ADHD may focus on improvement of the 'cognitive flexibility' and 'planning' for children with ADHD, which may lead to improvement of their academic skills and decrease in disruptive behavior as suggested by research (Chakraborty and Halder, 2019) and is also implicated in improving emotional awareness, which may in turn help the children with ADHD in execution and maintenance of socially acceptable behavior (Lakshmi and Halder, 2020).

Table 1: Sociodemographic and clinical details of the sample:

	ADHD [*n* (%)]	Healthy controls [*n* (%)]		
Sex				
Male	58(83)	53(76)		
Female	12(17)	17(24%)		
Age (years)	Mean±SD	Mean±SD	*t* value	*P* value
	10.22±2.02	9.95±1.91	1.03	0.23
IQ (WASI-II)	97.6±5.2	105.2±8.3		

WASI, Wechsler Abbreviated Scale of Intelligence.

Table 2: Comparative scores of the group on the Stroop Color–Word test:

	ADHD (mean±SD)	Healthy controls (mean±SD)	*t* value	P value
Stroop test				
W	54.5±10.11	93.1±7.32	26.08**	0.00001
C	36.8±8.93	63.6±6.37	20.495**	0.00001
CW	21.0±5.91	28.7±4.52	8.65**	0.00001

C, color list; CW, color and word list; W, word list.

Table 3: Correlation between attention-deficit/hyperactivity disorder severity and components of the Stroop Color–Word test:

	Conner's ADHD rating scores (severity)	
	r	*P* value
Stroop test		
W	−0.474	0.074
C	−0.629*	0.012
CW	−0.907**	0.001

ADHD, attention-deficit/hyperactivity disorder; C, color list; CW, color and word list; W, word list. *Significant at 0.05 level. **Significant at 0.001 level.

CONCLUSION

The implications of the Stroop test in terms of Stroop effect as a clinical screening tool have a widespread aspect in the identification of ADHD, including milder inattentive types having typical development with normal intelligence. The present study suggests that typically developing children with ADHD (inattentive type) have deficit in cognitive flexibility compared with healthy controls, which could be a potential factor interfering with their academic and social behavior and may be important in planning the intervention. The Stroop test can be used for screening measures by school counsellors for children with academic difficulties. A precomparison and postcomparison of scores can also be used as a treatment outcome indicator for children undergoing cognitive training.

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CONFLICTS OF INTEREST

There are no conflicts of interest.

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