

# Executive and Non-Executive Functions in Attention Deficit Hyperactivity Disorder of the Inattentive Type (ADHD-I): A Cognitive Profile

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## ABSTRACT

**Objective:** This study examined the hypothesis that individuals with attention deficit hyperactivity disorder, predominantly inattentive type (ADHD-I), show both executive function (EF) deficits and non-EF deficits. **Method:** A group with ADHD-I (n = 16) and a paired control group (n = 21) completed a battery of tasks covering the major domains of EF (planning, working memory, flexibility and inhibition) and non-EF (alertness, divided attention, flexibility, sustained attention, visual field and visual scanning). **Results:** EF impairments in planning, spatial working memory, flexibility, and inhibition as well as non-EF impairments in divided attention, flexibility, sustained attention and visual scanning were observed in the ADHD-I group. **Conclusion:** Our results do not support the traditional model of ADHD. Given that neither EF nor non-EF tests typically distinguish ADHD-I from ADHD-C, alternative methodologies are required to confirm the validity of ADHD subtypes in the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition*.

## KEYWORDS

ADHD-I; Executive Function; Non-Executive Function; Cognitive Profile

## 1. Introduction

Executive function (EF) is an umbrella term in psychology that refers to the processes that control other cognitive processes [1]. Researchers have identified four distinct domains of EF: planning, working memory, flexibility, and response inhibition [2-6]. The role of EF is debated, but most researchers agree that EF is involved in deliberately managing an appropriate problem solving set to attain a future goal [7,8].

A deficit in EF is postulated to account for core symptoms in psychiatric patients with no focal frontal lesions, such as those diagnosed with attention deficit hyperactivity disorder (ADHD). The evidence supporting a deficiency in EF domains in ADHD comes from a number of sources [8-14].

Clarification of the neuropsychological similarities and

differences in ADHD subtypes can contribute to understanding their etiological relationship. *The Diagnostic and Statistical Manual of Mental Disorders* [15] categorizes the symptoms of ADHD into three subtypes: ADHD, predominantly inattentive type (ADHD-I); ADHD, predominantly hyperactive-impulsive type (ADHD-H); and ADHD, combined type (ADHD-C). In addition, Barkley postulated a model of ADHD in which only ADHD-C and ADHD-H, but not ADHD-I, were associated with EF deficits [16], yet it remained unclear whether the DSM-IV inattentive subtype involved distinct deficits [17].

Now, nearly all of the neuropsychological literature on ADHD pertains to the group designated as ADHD combined type (ADHD-C), while the primarily inattentive subtype of ADHD (ADHD-I) remains relatively under-investigated with regard to potentially relevant cognitive functions [18-20]. Nigg suggested that further studies of

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children with ADHD-C versus controlling children on many executive measures might no longer be needed. Instead, studies to examine issues such as neuropsychological process theories of ADHD-I have been proposed [19].

Some research suggests that EF weaknesses are primarily associated with inattention [21-23]. If this is the case, we can further hypothesize that EF deficits are not specifically related to ADHD-C and ADHD-H. It is possible that those with ADHD-I suffer from the same neuropsychological impairment. Furthermore, combining the hypothesis that EF weaknesses are neither necessary nor sufficient to cause all cases of ADHD [8], we predict that individuals with ADHD-I not only encounter just difficulties with EF, but also show deficits in other cognitive domains (hereafter termed non-EF).

Thus, the first goal of the present study was to examine the EF weaknesses hypothesis in ADHD-I by comparing children with ADHD-I versus typically developing children in the four distinct EF domains of planning, working memory, flexibility, and inhibition. The second goal was to examine the non-EF deficit hypothesis in children with ADHD-I by comparing them with a control group on six non-EF domains: alertness, divided attention, flexibility, sustained attention, visual field and visual scanning.

## 2. Methods

### 2.1. Participants

The ADHD participants were recruited from several child psychiatry outpatient services across the Zabei district of Shanghai in China. Each sample was referred from the Shanghai Pediatric Hospital where the participants were diagnosed with ADHD, primarily inattentive type, and engaged in twice-a-week attention training for special children at the support and rehabilitation center of the Zabei District of Shanghai.

Before testing, we confirmed that the children had not been on medication for at least 3 months. Before testing, parents were invited by letter to participate and provided their written informed consent. Each family was invited to participate in an unstructured screening interview based on the Child and Adolescent Psychiatric Assessment [24] at the support and rehabilitation center. Children's general information including medical history, developmental history, performance in family, and general symptoms were recorded. On the basis of the interview results, any child who had any other possible comorbid diagnosis, such as a significant learning disability, autistic spectrum disorder, or significant medical condition such as epilepsy, was excluded from further study.

Furthermore, a short version of Conners' Teacher Rating Scale (CTRS-S) [25] was completed for each child to confirm the pervasiveness of symptoms. The CTRS-S

contains 27 items comprising four subscales: oppositional, cognitive problems/inattention, hyperactivity, and ADHD index. Scoring was performed according to the test manual [26], with each raw score converted to a *t* score dependent on age and sex of the child. Established cutoff points for possible and likely ADHD, primarily inattentive type [26], were imposed, and any child who did not meet CTRS-S criteria was dropped from further study. In addition, all children met DSM-IV (APA) [27] diagnostic criteria for ADHD. Any child with ADHD-H or ADHD-C was excluded. Considering that level of intelligence may affect performance on EF tests, all children were first administered an IQ test (Combined Raven's Test, CRT), and children with mental retardation (IQ scores below 75) were excluded. Finally, a total of 16 children with ADHD-I participated in the experiment. Twenty-one children without ADHD were paired with the ADHD group by gender and age. A teacher completed the CTRS-S [25] for the control group, with *t* scores below 50 used to confirm the children's non-ADHD status. In addition, the non-ADHD group was administered the IQ test (CRT) to confirm that they did not have mental retardation. Information on participants is shown in [Table 1](#).

### 2.2. EF Tests

We chose EF tests according to distinct domains of EF: planning, working memory, flexibility, and response inhibition [2-6]. Four EF tests were conducted in this study: the Spatial Working Memory Test (SWM), Stockings of Cambridge Test (SOC), Wisconsin Card Sorting Test (WCST), and Stroop/reverse-Stroop Test. With regard to response inhibition, Barkley proposed a model suggesting that a deficit in behavioral inhibition, considered a key process in EF, accounts for central impairment of ADHD [16]. In the model, Barkley distinguished three interrelated processes believed to constitute behavioral inhibition: 1) inhibition of a prepotent response; 2) cessation of an ongoing response; and 3) interference control. Researchers have long used Stroop/reverse-Stroop interference as the main paradigm to study interference control. Thus, in this study, we used the Stroop/reverse-

**Table 1. Group means (SDs) for age and IQ.**

	ADHD-I	Control	P value
N	16	21	
Sex ratio (F/M)	12/4	14/7	Ns
Age	12(1.43)	12(1.41)	Ns
Range of age	9-14	9-14	
IQ(CRT-C)	89(11.3)	92(12)	<i>p</i> = 0.51
Range of IQ	75-122	80-123	

Stroop Test [28,29] to evaluate the level of response inhibition.

*Spatial Working Memory Test (altered).* This test was designed based on the SWM in the Cambridge Automated Neuropsychological Test Battery (CANTAB) [30,31]. In this test, participants are asked to search through a number of boxes presented on the screen to find a token. The key instruction states that once a token has been found in a box, that box cannot be used again to hide a token during that particular trial. On each trial, the total number of blue tokens to be found corresponds to the number of boxes on the screen. Once a blue token is found in a particular box, that box cannot be used again to hide a token. Returning to an empty box where a target has already been found is referred to as a “between-search error”.

In the original SWM, there were four types of trials with either three, four, six, or eight boxes in each. Several previous studies showed that children with ADHD made significantly more errors compared with controls only on the eight-box problems [32,33]. Given that between-search errors may appear as a function of the number of boxes in pediatric clinical populations [34], it is possible that children with ADHD also make significantly more errors compared with controls on seven-box problems. Thus, we made a few changes to the original task, in which the independent variable of box consisted of five uninterrupted levels with three, four, five, six, or seven boxes. There were four test trials each with three, four, five, six, and seven boxes. The order of the trials was randomized, with the constraint that the same number of boxes did not occur consecutively. The dependent measure for the SWM test was between-search errors on three-, four-, five-, six-, and seven-box problems.

*Stocking of Cambridge Test (altered).* This test was designed based on the SOC in the CANTAB [30,31]. This test is closely related to the Tower of London task developed by Shallice and McCarthy [35]. In this test, two sets of three colored balls (one green, one blue, and one red) were presented on the screen. Participants were asked to rearrange the balls in the bottom display such that their positions matched the “goal” arrangement in the top half of the screen. The starting position of the balls was varied so that in any particular trial the solution could only be reached after a minimum of two, three, four, or five moves. Participants were instructed to examine the position of the balls at the beginning of each problem and attempt to solve it in the minimum possible number of moves. The time to complete the pattern is taken as a measure of the participant’s planning ability.

In the original SOC task, there were four test trials each with two, three, four, and five moves. However, some studies failed to find that children with ADHD made significantly more extra moves than typically de-

veloping children on this task [32,33,36]. It is possible that the short range of the minimum moves to goal state can account for the above conclusion. Thus, we made a few changes to the original task, such that the minimum moves to goal state ranged from three to seven moves. There were four test trials each with of three, four, five, six, and seven moves, and the order of the trials was randomized. The dependent measure for the SWM test was thinking time on three-, four-, five-, six-, and seven-move problems.

*Wisconsin Card Sorting Test.* Flexibility was assessed with the Computerized WCST [37-39], a widely used test to measure cognitive flexibility or set shifting. In this test, participants were asked to match a series of stimulus cards to a set of four target cards that differed by form, color, and number. The display remained until a choice was made. Feedback followed the response, and consisted of a “×” sign if the response was correct, or a “○” sign if the response was incorrect. Response cards could be matched by color (red, green, blue, yellow), shape (triangle, star, cross, circle), or number (1, 2, 3, 4). After participants determined one of the correct dimensions, referred to as “categories,” 10 correct responses were required before the category was shifted to the next one. The task was terminated after a maximum of 128 trials was reached. The order of the sorting principles was randomized, with the constraint that the same sorting principles did not occur consecutively.

Continued matching to a category that is no longer correct is considered a perseverative error. Other errors that occur when a participant is required to switch to another sorting principle are referred to as non-perseverative errors. The variables of interest were the number of categories achieved, percentage of perseverative errors and percentage of non-perseverative errors.

*The Stroop/reverse-Stroop Test.* The Stroop/reverse-Stroop Test [28,29,40] was used to evaluate the level of both Stroop interference and reverse-Stroop interference. The test comprised four subtests in which all color-word combinations and color patches were printed on four separate sheets of paper. Test 1 was the reverse-Stroop interference control condition, in which all the color-word combinations were written in black ink, requiring participants to make a choice from five matching colors printed on the right side of the test sheet corresponding to the color-word patches on the left side of the test sheet. Test 2 was the reverse-Stroop interference condition, in which incongruent color-word combinations were shown on the left side of the test sheet, requiring participants to make a choice from five matching color patches on the right side of the test sheet corresponding to the semantic meaning of the word on the left side of the test sheet. Test 3 was the Stroop interference control condition in which the color patch was shown on the left side of the

test sheet, requiring participants to make a choice from five matching color-word patches (written in black ink) on the right side of the test sheet corresponding to the color of the color patch on the left side of the test sheet. Test 4 was the Stroop interference condition, in which incongruent color-word cards were shown on the left side of the test sheet, requiring participants to make a choice from five matching color-word patches (printed with black ink) according to the ink color of the color-word combination on the left side of the test sheet.

Each test consisted of 10 practice trials and 100 test trials. On the basis of the number of correct responses in each subtest (C1, C2, C3, C4), two interference ratios were calculated using the following formulas: Stroop interference ratio,  $(SI) = (C3 - C4) / C3$ , and reverse-Stroop interference ratio,  $(RI) = (C1 - C2) / C1$ .

### 2.3. Non-EF Tests

Previous studies have shown that individuals with ADHD-I have a deficit in focused or selective attention [41,42], while the deficit in ADHD-C has been characterized as sustained persistence and distractibility [16]. To fully assess non-EF in this study, performance was assessed by a set of computer-assisted psychological tests, the Test for Attentional Performance (TAP), version 2.2, published by Zimmermann and Fimm [43]. The six subtests of alertness, divided attention, flexibility, sustained attention, visual field, and visual scanning were administered.

*Alertness Test (TAP, subtest 1).* A simple reaction time (RT) task measures response readiness to a simple visual target on the computer screen. Simple reaction time has been shown to be a valid measure of general slowness. In this test, a cross (2 cm) appeared in the middle of the screen, and the participant had to press a button as rapidly as possible. The interval between the warning and the imperative stimulus varied randomly between 300 and 700 ms. The reaction times (RTs) were automatically recorded by the program (a total of 40 trials were presented in this subtest).

*Divided Attention Test (TAP, subtest 5).* In this subtest, participants had to deal with one visual simultaneous task. The visual task consisted of a matrix of  $4 \times 4$  dots (size:  $10 \times 10$  cm). Seven small Xs were superimposed randomly over the  $4 \times 4$  dots. When four Xs formed a square, the participants had to react as quickly as possible by pressing a button. The task contained 20 visual targets out of 20 visual non-targets.

*Flexibility Test (TAP, subtest 6).* In this subtest, one letter and one digit were presented simultaneously, one on the left and one on the right. The digit always represented the targets stimulus (50 trials). Participants needed to respond to each trial by pressing the corresponding left or right response button as quickly and as

accurately as possible to judge which side of the target was displayed. The placement of the target was randomized so that participants could not anticipate where it would be displayed.

*Sustained Attention Test (TAP, subtest 9).* In this subtest, a sequence of stimuli was presented on the monitor. The stimuli varied in a range of feature dimensions: color, shape, size and filling. A target stimulus occurred whenever it corresponded in one predetermined stimulus dimension with the preceding stimulus (e.g., the same shape but with different color, size and filling), participants needed to respond to each trial by pressing the space key as quickly as possible (test time lasted 10 minutes).

*Visual Field Test (TAP, subtest 11).* To record vision in circumscribed areas of the visual field, a stimulus was presented at different points of the screen and at varying intervals. Participants were required to fixate on the middle of the screen throughout the entire test run. Whenever the peripheral stimulus appeared the patient was to press the reaction key as quickly as possible. The RTs to targets were recorded automatically. A total of 40 stimuli were presented in this subtask.

*Visual scanning Test (TAP, subtest 12).* In this subtest, a matrix-like arrangement of  $5 \times 5$  stimuli was used. Participants were required to detect whether this arrangement included a critical stimulus. One reaction key was used for the answer "present" and another for the answer "not present". The task contained 20 visual targets out of 20 visual non-targets.

### 2.4. Procedure

Testing took place on four different occasions and was administered in a fixed order for both groups. During the first session, the Stroop/reverse-Stroop Test was administered. In the second testing session, the TAP battery was administered individually. In the third testing session, the WCST and SOC were administered individually. Finally, the SWM was administered individually.

## 3. Results

In this section, we briefly provide the statistical analyses, focusing on the performance on the EF tests (working memory, planning, flexibility and inhibition) and non-EF tests (alertness, divided attention, flexibility, sustained attention, visual field and visual scanning) between children with ADHD-I and typically developing children.

### 3.1. EF Tests

The means and standard deviations (SD) on EF tests are shown in **Table 2**.

*Working memory.* We performed a two-way analysis

**Table 2. Means and standard deviations (SD) on EF tests.**

EF domain	Tasks	ADHD-I	Control	Contrast
Working Memory	SWM			
	BSE on 3-box problems	0.13(.34)	0.01(.22)	Ns
	BSE on 4-box problems	1.31(1.85)	0.43(1.03)	Ns
	BSE on 5-box problems	0.88(1.41)	0.71(1.82)	Ns
	BSE on 6-box problems	4.38(4.56)	1.81(2.52)	ADHD-I > NC
Planning	SOC			
	TT on 3-move problems	17.27(6.71)	14.20(3.41)	Ns
	TT on 4-move problems	27.76(15.18)	33.14(11.80)	Ns
	TT on 5-move problems	62.81(38.92)	37.05(31.08)	ADHD-I > NC
	TT on 6-move problems	70.68(30.00)	49.24(20.64)	ADHD-I > NC
Flexibility	WCST			
	Categories	6.50(2.00)	8.29(1.55)	ADHD-I < NC
	Perseverative errors	13.94(9.47)	6.76(8.31)	ADHD-I > NC
	Non-perseverative errors	25.44(5.97)	23.10(5.88)	Ns
Inhibition	Stroop/reverse-Stroop Test			
	SI	0.23(.21)	0.19(.13)	Ns
	RI	0.30(.15)	0.17(.11)	ADHD-I > NC

Note: ADHD-I = ADHD Pre-dominantly Inattentive type; SWM: Spatial Working Memory ; SOC = Stocking of Cambridge; WCST = Wisconsin Card Sorting Test; TT: Thinking Times; BSE = Between Search Errors; SI = Stroop Interference ratio; RI reverse-Stroop Interference ratio.

of variance (ANOVA) with *Planning*. We performed a two-way ANOVA with the group type (ADHD-I or difficulty (three- to seven-box problems) as a within participants factor. Results showed that the two main effects of group type,  $F(1, 35) = 10.37, p < 0.01$ , and task difficulty,  $F(4, 140) = 27.54, p < 0.01$ , were significant. The interaction effect between group type and task difficulty was significant,  $F(4, 140) = 9.01, p < 0.01$ . Furthermore, the simple main effect of group type was only significant in six-box problems,  $F(1, 35) = 4.77, p = 0.04$  and seven-box problems,  $F(1, 35) = 12.18, p < 0.01$ . It was not significant in three-box problems,  $F(1, 35) = 0.70, p = 0.41$ , four-box problems,  $F(1, 35) = 3.42, p = 0.07$ , or five-box problems,  $F(1, 35) = .01, p = 0.77$ .

*Planning*. We performed a two-way ANOVA with the group type (ADHD-I or control) as a between-participants factor and the task difficulty (three- to seven-move problems) as a within participants factor. Results showed that the two main effects of group type,  $F(1, 35) = 10.17, p < 0.01$ , and task difficulty,  $F(4, 140) = 21.32, p < 0.01$ , were significant. The interaction effect between group type and task difficulty was significant,  $F(4, 140) = 2.77, p < 0.05$ . Furthermore, the simple main effect of group type was only significant in five-move problems,  $F(1, 35) = 5.02, p < 0.05$ , six-move problems,  $F(1, 35) = 6.63, p < 0.05$ , and seven-move problems,  $F(1, 35) = 3.80, p < 0.05$ . It was not significant in three-move problems,  $F(1, 35) = 3.29, p = 0.08$ , and four-move problems,  $F(1, 35) = 0.48, p = 0.23$ .

*Flexibility*. We performed an independent-samples t test on the categories achieved by the two groups. Re-

sults showed that the effect of group type,  $t(35) = 3.06, p < 0.01$ , was significant. In addition, we performed a two-way ANOVA with the group type as a between-participants factor and the error type (perseverative errors and non-perseverative errors) as a within participants factor. Results showed that the two main effects of group type,  $F(1, 35) = 4.20, p < 0.05$ , and error type,  $F(4, 140) = 233.91, p < 0.01$ , were significant. The interaction effect between group type and test condition was significant,  $F(4, 140) = 7.05, p < 0.01$ . Furthermore, the simple main effect of group type was only significant in perseverative errors,  $F(1, 35) = 6.01, p < 0.05$ . It was not significant in non-perseverative errors,  $F(1, 35) = 1.42, p = 0.24$ .

*Inhibition*. We performed a two-way ANOVA with the group type (ADHD-I or control) as a between-participants factor and the interference type (SI and RI) as a within participants factor. Results showed that the two main effects of group type,  $F(1, 35) = 3.63, p = 0.06$ , and interference type,  $F(1, 35) = 0.76, p = 0.39$ , were not significant. The interaction effect between group type and interference type was significant,  $F(1, 35) = 3.52, p < 0.05$ . Furthermore, the simple main effect of group type was only significant in reverse-Stroop interference,  $F(1, 35) = 7.52, p < 0.01$ , whereas Stroop interference was not significant,  $F(1, 35) = .37, p = 0.55$ .

### 3.2. Non-EF Tests

The means and standard deviations (SD) on Non-EF tests are shown in [Table 3](#).

**Table 3. Means and standard deviations (SD) on non-EF tests.**

	Tasks	ADHD-I	Control	Contrast
Alertness	TAP, subtest 1	350.67(54.44)	345.17(64.88)	Ns
Divided attention	TAP, subtest 4	1434.17 (432.73)	1097.09 (265.93)	ADHD-I < NC
Flexibility	TAP, subtest 6	560.75(92.43)	480.00(74.42)	ADHD-I < NC
Sustained attention	TAP, subtest 9	560.56(59.50)	515.96(61.07)	ADHD-I < NC
Visual field	TAP, subtest 11	503.97(107.96)	496.36(90.83)	Ns
Visual scanning	TAP, subtest 12	5454.91(1270.07)	4114.94 (898.77)	ADHD-I > NC

Note: TAP = Test for Attentional Performance.

We performed multivariate analysis (Pillai's trace) with group type (ADHD group or non-ADHD group) as a fixed factor and RTs on the sixsubtests as a dependent factor. Results showed that the effect of group type,  $F(6, 28) = 4.42$ ,  $p < 0.01$ , was significant. The tests of between-subjects effect indicated that the group type effect was significant for divided attention,  $F(1, 35) = 8.18$ ,  $p < 0.01$ , flexibility,  $F(1, 35) = 8.15$ ,  $p < 0.01$ , sustained attention,  $F(1, 35) = 4.57$ ,  $p < 0.05$ , and visual scanning,  $F(1, 35) = 13.41$ ,  $p < 0.01$ . It was not significant for alertness,  $F(1, 35) = 0.07$ ,  $p = 0.98$ , or visual field,  $F(1, 35) = 0.06$ ,  $p = 0.79$ .

## 4. Discussion

### 4.1. EF Domains

*Working memory.* Results of the two-way ANOVA indicated a significant group-by-task difficulty interaction: the ADHD-I differed significantly from controls only on six- and seven-box problems. In contrast to three- and four-box problems, in six- and seven-box problems there is a higher memory load of the task. Our findings indicate that the higher memory load task affected the ADHD-I group more than the controls. This result is consistent with several previous studies in which children with ADHD-C exhibited deficits in multiple components of working memory [44,32,45]. These results suggest that working memory is impaired in both ADHD-C and ADHD-I.

*Planning.* Analysis of thinking times on three-, four-, five-, six- and seven-move problems indicated that children with ADHD-I took more time to complete the five-, six- and seven-move problems than controls. The current findings are in contrast to previous studies [46, 47] that failed to find a significant divergence between ADHD-C and controls on three difficulty levels of SOC: two or three moves necessary to solve the problem (lowest difficulty level), four moves (medium difficulty level), and five moves (highest difficulty level). We argued that the short level range (the maximum move to goal state is five) may account for the no-difference findings in these studies. Numerous studies [8,33] have reported poor performance on planning tasks in individuals with ADHD-C.

Evidence from our research and previous studies support the hypothesis that planning is impaired in both ADHD-C and ADHD-I.

*Flexibility.* Results showed that the categories achieved by the ADHD group were fewer than the categories achieved by controls, and the simple main effect of group type was only significant for perseverative errors and not significant for non-perseverative errors. This indicates that the ADHD-I group exhibited a deficit in flexibility relative to typically developing children. Although a few studies have shown no statistically significant differences from controls on the WCST in individuals with ADHD [46,48,49], more than half of the investigations have shown statistically significant differences from controls [14,50-53]. Moreover, Houghton *et al.* found no differences between inattentive and combined subtypes on WCST [23,54]. These results support the hypothesis that flexibility is impaired in both ADHD-C and ADHD-I.

*Inhibition.* We found an asymmetric phenomenon between Stroop interference and reverse-Stroop interference for ADHD-I participants. This finding replicated our recent results reporting an ADHD-I impairment in reverse-Stroop interference but not in Stroop interference [40]. A number of studies have used the Stroop test to examine interference control in ADHD, but results have been inconsistent. Recently, Mourik, Oosterlaan, Sergeant completed a meta-analytic review that systematically examined 17 studies of Stroop interference control in ADHD [55]. They concluded that the Stroop color-word task does not provide strong evidence for a deficit in interference control in ADHD. Lansbergen, Kenemans, and Van Engeland conducted another meta-analytic review of 19 studies that administered the Stroop tests to groups with ADHD [56]. In contrast, consistency analysis of ratio scores across those 19 studies revealed that interference control was consistently compromised in individuals with ADHD. We have few studies available on reverse-Stroop interference in ADHD-C. This is possibly because the reverse-Stroop has seldom been discussed in ADHD because it cannot be observed in oral responses [57]. It is difficult to conclude that individuals with ADHD-I or ADHD-C exhibit the same deficit in reverse-Stroop interference until more studies on this

question are conducted.

## 4.2. Non-EF Domains

Deficits in divided attention, flexibility, sustained attention, and visual scanning relative to controls indicate that individuals with ADHD-I also exhibited impairment on the non-EF domains. Willcutt *et al.* suggested that EF weaknesses are neither necessary nor sufficient to cause all cases of ADHD [8]. Our research confirms that ADHD-I is associated with deficits in EF as well as non-EF domains. The DSM-IV does not provide specific examples of the cognitive difference between ADHD-C and ADHD-I. With regard to non-EF domains, previous studies have suggested that ADHD-I shows a deficit in speed of information processing, generally, and in focused or selective attention, specifically [41,42], while deficits in ADHD-C are characterized as sustained persistence. In the present research, we found that ADHD-I is also associated with a sustained attention deficit [16]. Moreover, Geurts, Vert'e, Oosterlaana, Roeyers, and Sergeant found no differences between inattentive and combined ADHD subtypes on non-EF tasks, such as response execution, short-term memory, visual-motor integration and categorization [47]. Based on combined results of the current research and previous studies, we posit that deficits in non-EF cognitive ability in ADHD-I may be the same as those found in ADHD-C.

## 5. General Discussion

The present study was designed to investigate the hypothesis that those with ADHD-I exhibit both EF deficits and non-EF deficits by comparing typically developing controls with boys carefully diagnosed with ADHD-I on an extensive battery of tasks that cover the major EF and non-EF domains.

With regard to the EF domains, results are consistent with findings in previous studies of EF and ADHD. That is, ADHD is associated with weaknesses in several key EF domains, but the strongest and most consistent effects are obtained on measures of response inhibition, vigilance, spatial working memory and some measures of planning [8,22,46,47,58]. The deficits on EF domains revealed in ADHD-I also suggest that the pathology of ADHD-I is related to deficits in managing an appropriate problem or attaining a future goal. Furthermore, results did not yield evidence for the model of ADHD in which only ADHD-C and ADHD-H, but not ADHD-I, are associated with EF deficits [16].

With regard to non-EF domains, findings revealed that the children with ADHD-I also demonstrated deficits in these domains, such as divided attention, flexibility, sustained attention and visual scanning. This suggests that children with ADHD-I not only show deficits in EF, but

also experience deficits in other non-EF domains.

Discriminating among disorders is particularly important. However, there are no objective diagnostic tests for ADHD-I [59]. Considering the fact that neither EF nor non-EF domains distinguish ADHD-I from ADHD-C, examination of other factors, such as social, emotional and behavioral characteristics [60,61] may be needed to support the validity of ADHD subtypes in the DSM-IV.

## 6. Limitations

A limitation of our study findings is the small sample size and potential response bias from those who agreed to participate. To gather more reliable data and validate the results of the present study, future research should focus on selecting larger samples to engage in the same tasks. Furthermore, to examine whether EF and non-EF tests can distinguish ADHD-I from ADHD-C, it would be useful to make a direct comparison between ADHD-C and ADHD-I in the battery of EF and non-EF tests used in the study. Future studies should be conducted by using the same tasks with an ADHD-C group.

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