



# Inhibitory Control in Adults with Attention-Deficit/Hyperactivity Disorder

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**Objectives:** Children with Attention-Deficit/Hyperactivity Disorder (ADHD) have been found to be deficient in inhibitory control. The purpose of this study was to determine if adults with ADHD are also deficient in this domain.

**Methods:** The performance of 18 adults with ADHD and 18 normal controls was compared on the Stop Signal Paradigm, which is a test of inhibitory control.

**Results:** The adults with ADHD performed more poorly on the Stop Signal Paradigm than did the normal controls. The ADHD subjects exhibited a longer latency to respond to the stop signal than did the control subjects.

**Conclusions:** The individuals with ADHD tested in this study showed an inhibitory control deficit. The results suggest that a deficit in inhibitory control is central to ADHD.

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Researchers have investigated inhibitory control in children and adolescents with Attention-Deficit/Hyperactivity Disorder (ADHD). Results of such studies are quite consistent. These populations perform more poorly on tests of inhibitory control than do normal controls (Trommer, Hoepfner, Lorber, & Armstrong, 1988; Schachar, Tannock, & Logan, 1993; Schachar, Tannock, Marriot, & Logan, 1995; Oosterlaan & Sergeant, 1996; Oosterlaan & Sergeant, 1998; Oosterlaan, Logan, & Sergeant, 1998). A task commonly used to test inhibitory control is the Stop Signal Paradigm (Schachar et al., 1993; Schachar et al., 1995; Oosterlaan & Sergeant, 1996; Oosterlaan & Sergeant, 1998; Oosterlaan, Logan, & Sergeant, 1998), but the Go-No-Go Paradigm has also been used (Trommer et al., 1988). In both these tasks, the subject is asked to inhibit an on-going motor response on the presentation of an aural cue.

Barkley (1994) has suggested that a lack of inhibitory control is the primary deficit in Attention-Deficit/Hyperactivity Disorder. His theory states that all other deficits associated with ADHD stem from a lack of inhibitory control (Barkley, 1994). While the present study does not attempt to refute or support this theory, a finding that an inhibitory control deficit is associated with adult ADHD, as well as childhood ADHD, would provide support for the idea that an inhibitory control deficit is central to the disorder. It is by no means certain, however, that a lack of inhibitory control is specific to ADHD. Children with conduct disorder have also been found to

have poor response inhibition when compared to normal controls (Barkley, 1994).

The present research tested inhibitory control in adults with ADHD. The purpose was to determine if adults and children with the disorder share the same deficit. It used to be thought that ADHD is outgrown in adolescence (Laufer & Denhoff, 1957). Research now indicates that this is not the case and that a large proportion of affected children continue to experience clinically significant symptoms in adulthood (Shekim, Asarnow, Hess, Zaucha, & Wheeler, 1990; Mannuzza, Klein, Bonagura, Malloy, & Addali, 1991). ADHD is considered to be a developmental disorder and cannot be diagnosed in an adult unless a history of the disorder in childhood can be established, however. More knowledge about the course of the disorder is needed. Evidence of continuity of a deficit from childhood through adulthood would provide evidence that this particular deficit is central to the disorder.

## Method

### Subjects

The study tested two groups of subjects. Eighteen adult males with ADHD and 18 normal adult males were included in the study. Only males were included as subjects due to the preponderance of males with the disorder. ADHD subjects were recruited from among the fathers of children with a diagnosis of ADHD confirmed at the Hospital for Sick Children, Toronto, Ontario. Normal controls were

recruited from among staff members of the Hospital for Sick Children, fathers of children taking part as normal controls in other studies of ADHD at the Hospital for Sick Children, and members of the community. ADHD subjects ranged in age from 27 to 58. Normal controls ranged in age from 25 to 59. The mean age of the groups did not differ ( $t = 1.10$ ,  $df = 34$ ,  $p < .279$ ).

The vocabulary and block design subtests of the WAIS-R (Wechsler, 1981) were administered to each subject in order to ensure a comparable IQ between groups. In the ADHD group, estimated IQ scores (age-scaled) ranged from 94 to 125 (mean = 110,  $SD = 9.23$ ). In the normal control group, estimated scores (age-scaled) ranged from 94 to 131 (mean = 116,  $SD = 11.48$ ). The mean age-scaled scores obtained by the ADHD subjects and the normal controls on the vocabulary subtest were 10.78 ( $SD = 2.31$ ) and 12.61 ( $SD = 2.89$ ) respectively. The mean age-scaled score of the ADHD subjects on the block design was 12.39 ( $SD = 1.61$ ). The mean age-scaled score of the normal control subjects on this subtest was 12.94 ( $SD = 2.55$ ). The study was explained to the participants, and written informed consent obtained.

### Diagnostic Methods

Potential subjects for the ADHD group were assessed for the disorder by means of a semi-structured interview covering lifetime behaviour. Those subjects not meeting research criteria were excluded from the study. In addition, each potential experimental subject was screened for comorbidity using the Structured Clinical Interview for DSM-IV Axis I Disorders: Clinician Version (SCID-I: CV; First, Spitzer, Gibbon, & Williams, 1995). To be included in the research, subjects had to be free of psychosis, major depression, and mania. The SCID-I was also used to screen subjects for current alcohol and drug abuse and dependence. One subject in the ADHD group met criteria for alcohol abuse and dependence within a twelve month period, but not within a month of the study. One subject in the ADHD group met criteria for drug abuse and dependence (crack) in a twelve month period, but not within a month of the study. No other subjects met criteria for current drug or alcohol abuse or dependence.

All potential normal controls were assessed in the same manner as the experimental subjects. The same exclusion criteria applied. No normal control was diagnosed with ADHD. No normal control met criteria for current alcohol or drug abuse or dependence.

Assessments were carried out by a doctoral student trained in psychiatry research diagnostic protocols. Twelve (33%) of the diagnostic interviews were taped. These tapes were

then reviewed by a second researcher (child psychiatrist) as a check on diagnoses. This second diagnosis was based on a clinical opinion, rather than a checklist of DSM-IV symptoms. Diagnostic agreement was .83 (kappa).

### Research Criteria for ADHD

All subjects met DSM-IV criteria for ADHD, combined type (6 symptoms of inattentiveness and 6 symptoms of hyperactivity-impulsiveness).

### General Procedure

The diagnostic interview was conducted first. Individual subjects were interviewed specifically as either experimental subjects or normal controls. It was decided at this time whether or not the subject met research criteria for one of the two groups. No subject crossed over. If a subject did not meet criteria for his particular group, he was dropped from the study. After the diagnostic interview, the vocabulary and block design subtests of the WAIS-R were administered, and then the Stop Signal Paradigm.

### Stop Signal Paradigm

The Stop Signal Paradigm is a laboratory analogue of a situation which requires the inhibition of an ongoing response. In this task, the letters "X" and "O" appear randomly on a computer screen. The subject is instructed to push one button on a button box when the "X" is presented and another button on the button box when an "O" is presented, and to do this as quickly as possible. Periodically, and unpredictably, a "beep" sounds after the presentation of the letter. This "beep" sounds on 25% of the stimulus presentations. When a "beep" sounds, the subject is instructed that he must stop his response and not push the button. There are, thus, two concurrent tasks involved in the Stop Signal Paradigm. There is a "go" response and a "stop" response. The time between the presentation of the letter and the "beep" varies. The computer program is designed to track the subject's responses and allow him to inhibit to 50% of the stop signals. The Stop Signal Paradigm yields two scores in milliseconds. The "go signal reaction time" (GSRT) is the latency to respond to the stimulus letter on trials where no signal is presented. The "stop signal reaction time" (SSRT) is the latency of the response to the stop signal (Schachar et al., 1993; Schachar et al., 1995).

### Statistical Procedures

Results were analysed using two-tailed  $t$  tests for independent samples. Levene's test for equality of variance was employed to determine if any differences in variance existed between the two groups. This test was found to be

significant (0.05 level) for the GSRT, and in this case, a *t* test for groups with unequal variances was used.

## Results

### WAIS-R

The WAIS-R was administered only to ensure an equal mean IQ between the two groups. It is not meant to be viewed as a research measure in this study. The two subtests of the WAIS-R were administered to each subject to obtain an estimated IQ. No significant difference was found between the ADHD group and the normal control group on the combined age-scaled score ( $t = -1.71$ ,  $df = 34$ ,  $p < .096$ ). The ADHD subjects scored significantly lower than the normal controls on the vocabulary subtest ( $t = -2.10$ ,  $df = 34$ ,  $p < .028$ ). The performance of the ADHD subjects and the normal controls did not differ on the block design subtest ( $t = -.78$ ,  $df = 34$ ,  $p < .507$ ).

As a check, the Pearson product-moment correlation coefficient was used to determine if any of the IQ measures were correlated with performance on the Stop Signal Paradigm. None of the correlations were found to be significant (see Table 1).

### Stop Signal Paradigm

The mean GSRT of the ADHD group did not differ significantly from that of the normal control group ( $t = -1.73$ ,  $df = 24.79$ ,  $p < .096$ ). The mean SSRT of the ADHD group was longer than that of the normal control group ( $t = 3.77$ ,  $df = 34$ ,  $p < .001$ ; see Table 2).

## Discussion

The results of this study demonstrate that adults with ADHD do have a deficit in inhibitory control. The ADHD subjects performed more poorly than the normal controls on the experimental task. The subjects with ADHD had significantly longer SSRTs than did the normal controls. This would indicate that the individuals with ADHD had a more difficult time inhibiting their ongoing behaviour.

The inferior inhibitory control exhibited by the ADHD subjects was not due to a difference in reaction time to the letter stimulus (GSRT). The GSRTs of the normal control group tended to be longer, but the two groups did not differ significantly on this measure.

The ability to stop an ongoing action is necessary in everyday situations. It has been speculated that the lack of inhibitory control demonstrated by ADHD individuals in the performance of this task reflects a lack of inhibitory control in daily behaviour. A child with ADHD, for example, may find it difficult to stop the action of chasing

**Table 1. Correlations**

	GSRT			SSRT		
	<i>r</i>	<i>df</i>	<i>p</i>	<i>r</i>	<i>df</i>	<i>p</i>
Vocabulary	-.12	34	.483	.01	34	.937
Block design	.00	34	.980	.20	34	.245
IQ	-.07	34	.683	-.11	34	.502

*Note.* Vocabulary = vocabulary subtest, Block design = block design subtest, and IQ = estimated IQ.

**Table 2. Stop Signal Paradigm**

	ADHD ( <i>n</i> = 18)		Controls ( <i>n</i> = 18)		<i>t</i>	<i>df</i>	<i>p</i>
	mean	<i>SD</i>	mean	<i>SD</i>			
GSRT	472.20	70.43	537.31	143.02	-1.73	34	.096
SSRT	179.36	43.23	135.04	24.78	3.77	34	<.001

*Note.* GSRT = Go Signal Reaction Time; SSRT = Stop Signal Reaction Time

a ball across the street at the approach of a car (Logan, 1994).

The adults with ADHD tested in this study displayed the same deficiency commonly found in children with the disorder. This result suggests that an inhibitory control deficit is central to ADHD. In this, the study supports Barkley's (1994) theory. The study does not, however, prove that all deficits associated with ADHD stem from a lack of inhibitory control as Barkley postulates.

Research using the Stop Signal Paradigm has been conducted examining inhibitory control in children and adolescents with ADHD. Different variations of the test have been used in different studies, but all show the same result; these individuals are deficient in inhibitory control (Schachar, Tannock, & Logan, 1993; Schachar et al., 1995; Oosterlaan & Sergeant, 1996; Oosterlaan & Sergeant, 1998; Oosterlaan, Logan, & Sergeant, 1998; Konrad, Gauggel, Manz, & Scholl, 2000; Schachar, Mota, Logan, Tannock, & Klim, 2000). The present study extends this research by testing inhibitory control in adults.

This study is somewhat unique in that it examines inhibitory control not only in adults with ADHD, but also in adults with ADHD children. To ensure inhibitory control deficit heterogeneity of the sample, only fathers diagnosed with ADHD combined type were included in the study. It would be of interest to test inhibitory control in mothers of children with the disorder.

It is true that only 18 adults with ADHD and 18 normal controls participated in the study. Although a larger number of subjects would have been desirable, the number of subjects included in each group was not unusually small

for this type of study (Oosterlaan & Sergeant, 1996; Oosterlaan & Sergeant, 1998).

The GSRT and SSRT were chosen for analysis because these are the measures most commonly taken from this test, and because they are of the greatest interest. In light of the results, it may be interesting to look at other aspects of the test.

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