

# **Sensitivity of Four Subtests of the Test of Everyday Attention for Children (TEA-Ch) to Stimulant Medication in Children with ADHD**

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Children with attention deficit hyperactivity disorder (ADHD) were examined on four subtests of the Test of Everyday Attention for Children (TEA-Ch) when on and off stimulant medication. Performance was assessed relative to 18 individually age-matched controls. Children with ADHD performed significantly worse on TEA-Ch measures when off compared to when on stimulant medication. This was found in both predominantly inattentive ( $n = 6$ ) and combined inattentive and hyperactive-impulsive ( $n = 12$ ) subtypes. The age-matched controls significantly improved with repeated testing on most TEA-Ch measures. Significant differences were found between the unmedicated children with ADHD and age-matched controls on sustained attention (Score! and Walk Don't Walk) and attention control measures (Same and Opposite Worlds). When the ADHD group was on stimulant medication, with the exception of the Walk Don't Walk subtest, no significant differences were found between them and the age-matched controls. Unlike the TEA-Ch subtests, the significant differences between the two groups on the Test of Word Reading Efficiency (TOWRE) subtests remained when attentional status was altered in the children with ADHD. The study supports further investigations of the TEA-Ch as a measure sensitive to changes in stimulant medication in children with ADHD.

With growing concern about the increase in diagnosis of children with attentional problems, there is an important need for reliable diagnostic measures. Attention deficit hyperactivity disorder (ADHD) affects the ability to regulate activity (hyperactivity), inhibit behaviour (impulsivity), and focus attention on a task (inattention) in a

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developmentally appropriate manner. However, the diagnosis of ADHD remains controversial, given the heterogeneity and high rates of comorbidity seen in this condition (Barkley, 1991; Biederman, Newcorn, & Sprich, 1991; Denckla, 1992; Epstein, Shaywitz, Shaywitz, & Woolston, 1991; Levy, Hay, McLaughlin, Wood, & Waldman, 1996; Schachar & Tannock, 1995), and variation in prevalence with age, race, gender, or socio-economic status (Lord & Paisley, 2000). The DSM-IV (American Psychiatric Association, 1994) criteria for ADHD describe three subtypes: predominantly hyperactive-impulsive (PHI); predominantly inattentive (PI); and a combined type (CT) where both symptoms are displayed. Multiple sources of information on symptoms and their occurrence in different settings (such as school) increase the accuracy and validity of diagnoses and substantiate the criteria set down in DSM-IV. Rating scales such as the SNAP-IV (Swanson, 1992) can assist in obtaining systematic information. The DSM-IV states that no laboratory test has been confirmed for the diagnosis of ADHD.

Manly and colleagues developed a battery of tests to measure attention in children, the Test of Everyday Attention for Children (TEA-Ch; Manly, Robertson, Anderson, & Nimmo-Smith, 1999), adapted from measures assessing adult attention. The subtests resemble games, and age-scaled scores are provided for children aged 6–16 years. Manly et al. (2001) provided evidence for the validity of a subset of TEA-Ch subtests in a study comparing 24 unmedicated boys with ADHD with a control group. Boys with ADHD were significantly poorer than control children on TEA-Ch measures, with the exception of the Sky Search and Sky Search DT, when correction for multiple comparisons was used. When the children with ADHD were matched to control children on age and WISC-III vocabulary performance, the children with ADHD still showed significantly poorer TEA-Ch performance on many measures.

Heaton et al. (2001) investigated the use of the TEA-Ch as a measure of the attentional impairments in children with ADHD; 63 children with ADHD (81% males; mean age 9.67 years) and 23 non-ADHD clinical control children (69.6% males; mean age 9.88 years) were compared on subtests of the TEA-Ch. The children with ADHD performed significantly worse than controls on subtests of sustained attention and attentional control. However, there were no significant differences between the groups on subtests of selective attention. The authors concluded that the TEA-Ch was sensitive to attentional deficits and might be a useful tool in the assessment of ADHD.

An alternative way of examining the validity of the TEA-Ch is to compare children with ADHD when on and when off stimulant medication. If the same children show deficits when off medication, but not when attentional deficits are controlled by medication, this would provide strong evidence that the tests are sensitive to ADHD symptoms.

To date, the main source of treatment for children with ADHD is stimulant medication, with the two most commonly prescribed types being methylphenidate (Ritalin) and dextroamphetamine (Dexedrine). Methylphenidate and dextroamphetamine have proved effective in controlling inattention, hyperactivity, and

impulsivity associated with ADHD in children between 6 and 12 years of age (Biederman, 2002). Ritalin is a central nervous system stimulant, which attenuates impulsive, distractible, and hyperactive episodes, producing an immediate improvement in ADHD symptoms in children (e.g., Munoz-Lillan & Casteel, 1989; Volkow et al., 2001; Wender, 1973; Zametkin & Borcharding, 1989). Ritalin significantly increases levels of dopamine in the brain. Volkow et al. (2001) suggested that by increasing levels of extracellular dopamine through blocking dopamine transporters, methylphenidate activates the motivational circuits and makes tasks more enjoyable. Dextroamphetamine has been found to compare favourably with methylphenidate in the treatment of ADHD; it acts through the release of newly synthesised dopamine (Patrick & Markowitz, 1997). The use of antihypertensive drugs like clonidine (Catapres) has been effective in the treatment of ADHD (Hunt, Minderaa, & Cohen, 1985).

The present study examined attentional performance on four subtests of the TEA-Ch, and on a reading test, in children with ADHD when on and off stimulant medication. Administration of the whole TEA-Ch was not feasible within the time available, so we focused on four subtests that were designed to assess sustained attention and attentional control. Previous studies by Manly et al. (2001) and Heaton et al. (2001) found subtests assessing selective attention were less effective at discriminating children with ADHD from controls. Performance of the ADHD group was contrasted with that of an unmedicated control group who were also tested on two occasions. Three predictions were made. First, in line with Manly et al. (2001), we anticipated that unmedicated children with ADHD would do more poorly than control children on these TEA-Ch subtests. Second, we predicted that children with ADHD would perform significantly better on the TEA-Ch subtests when taking stimulant medication. Third, we predicted that medication status would not affect performance of children with ADHD on the reading test, as this is not designed to tap attentional skills. In addition, we conducted an exploratory analysis to see whether findings in children with ADHD were influenced by ADHD subtype, subdividing children into those with predominantly inattentive (PI) ADHD and combined type (CT).

## Method

### *Participants*

The sample consisted of 36 children aged 6;01–11;09 years ( $M = 98.53$  months,  $SD = 18.17$ , 26 male and 10 female). The sample was split into three groups: ADHD-PI type (6 children aged 7;04–11;09 years,  $M = 104.67$  months,  $SD = 21.64$ , 5 male and 1 female); ADHD-CT type (12 children aged 6;01–11;01 years,  $M = 95.00$  months,  $SD = 16.67$ , 9 male and 3 female); and typically developing controls (18 children aged 6;03–11;09 years,  $M = 98.83$ ,  $SD = 18.43$ , 12 male and 6 female). The children in the attention-disordered groups had no diagnosed comorbid conditions and were recruited via a pediatrician serving a large urban population in Perth,

Western Australia. Children comprising the ADHD group had all been diagnosed by the consultant pediatrician as meeting the DSM-IV (American Psychiatric Association, 1994) criteria for ADHD on the basis of a clinical interview and had subsequently been referred to a clinical psychologist (by the pediatrician) for the assessment of undiagnosed comorbid disorders.

The typically developing control group was recruited from one Perth primary school. An information letter and consent form were sent to the parents of all children in Grades 2–7, resulting in a 25% (38 out of 150) response rate. Children in this group had no identified problems based on the annual screening conducted by the school, in accordance with criteria stipulated by the Education Department of Western Australia to identify students at risk of educational failure and reading disabilities (using the Neale Analysis of Reading Ability; Neale, 1989).

Because the focus of this study was on whether or not TEA-Ch performance was influenced by medication that controlled ADHD symptoms, we did not require that all children took the same type of medication. The three types being used were methylphenidate (Ritalin), dextroamphetamine (Dexedrine), and clonidine hydrochloride (Catapres). All children with ADHD had been taking stimulant medication for a minimum of three months before testing. For the on stimulant medication session parents were instructed to give the medication to their child at the same time as on a typical day. Sessions were arranged so that testing commenced no longer than two hours after ingestion of the medication. The off stimulant medication session required no medication to be administered to the child on the afternoon or evening prior to the testing session, resulting in a minimum of 20 hours medication free. Parents were contacted the day before testing to remind them of this. This was checked immediately prior to testing by verbally asking each parent. All had complied with this request. To be included in the study participants were required to meet the following selection criteria: (1) English was the only language spoken in the home; (2) the participant had no medical problems relating to hearing, speech, or language; and (3) the participant had to pass an auditory screening for pure tones of 0.5, 1.0, 2.0 and 4.0 kHz presented at 25 dB HL in one or both ears.

### *Procedure*

All children with ADHD were tested at the Centre for Attention and Related Disorders at the University of Western Australia in a quiet room, and completed two sessions lasting up to 90 minutes each. Sessions were separated in almost all cases by 14 days (range 14–24 days,  $M = 14.94$ ). However, two children had sessions separated by 21 and 24 days due to illness. The time of day was kept constant in both sessions. The order of the on and off stimulant medication sessions was counterbalanced across participants. The control children were tested at their primary school over two sessions, separated in most cases by 14 days (range 10–16 days,  $M = 13.78$ ).

*Matching procedure.* Each child in the ADHD group was individually matched on age with a control child. Control children nearest in age to the children with ADHD were selected (maximum of five months separating ADHD and age matched controls,  $M = 1.9$  months,  $SD = 1.6$ ). Of the 18 children, 16 were also matched on gender. Individual matching decreases the error variance and prevents matching variables from becoming competing causal factors of any effects (Kirk, 1995).

### *Ratings of Attention*

All parents of children with ADHD completed the SNAP-IV rating scale (Swanson, 1992) twice to indicate their child's attentional state when on and off stimulant medication. The parents of control children completed the SNAP-IV on just one occasion.

In each session both groups of children completed four subtests of the TEA-Ch in the following order: Score!, Same Worlds, Opposite Worlds, and Walk Don't Walk. Two parallel forms of each subtest were used. Type A subtests were used in Session 1 and Type B subtests were used in Session 2. The TEA-Ch subtests are standardised and age-related standard scores are provided (see Manly et al., 1999). Each of the TEA-Ch subtests were expressed as standard scores with a mean of 10 and standard deviation of 3.

*Score!* This task assesses ability to sustain attention to auditory stimuli. Children listen to a sequence of sounds and are required to count how many sounds they heard, as if they were "keeping the score by counting the scoring sounds in a computer game". Over 10 trials a varying number of sounds (9–15 identical tones of 345 ms duration) were played, separated by silent intervals of different durations (between 500 and 5,000 ms), making the task attentionally demanding.

*Same Worlds.* This task was presented in conjunction with the Opposite Worlds task to measure attentional control (Manly et al., 2001). Each participant is presented with a card that displays a path of randomly sequenced digits 1 and 2. The child is asked to name the digits quickly. Following a short practice trial, two such cards are presented, and the time taken to complete each card is summed.

*Opposite Worlds.* Following a short practice trial, two cards are presented which display paths of randomly sequenced digits 1 and 2. The child is required to say the opposite of what is printed, i.e., when "1" is seen the correct response is "two" and when "2" is seen the correct response is "one". If a child makes a mistake they are encouraged to go back and correct their response. The time taken to complete the two cards is summed. The presentation order of the Same and Opposite Worlds cards was: Same World 1, Opposite World 1, Opposite World 2, Same World 2.

*Walk Don't Walk.* This subtest examined sustained attention and response inhibition to action. When they hear a tone (called go tones), children are required to take one step along a path of 14 squares drawn on an A4 page, making a mark for each step. Unexpectedly, one tone ends differently from the others (no-go tones), which is a signal not to take another step. The go tones are presented at regular intervals, and the no-go tone occurs between the 2nd and 12th steps. The intervals between the tones start at 1,500 ms for Item 1 and are held constant within each item. The intervals are reduced with each new item, with a maximum of 500 ms interval on Item 20. In order to prevent the no-go step being taken, children are required to sustain attention on the task. One point is recorded when a child avoids the target square; a mark in the square constitutes a failure. The number of correct items reported out of 20 is the final score.

*Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999).* Two subtests were used – vocabulary and matrix reasoning – providing a verbal and non-verbal estimate of ability, and enabling a comparable selection of participants with similar intelligence scores to be entered into each group. Performance was expressed as standard scores with mean of 50 and standard deviation of 10.

*Test of Word Reading Efficiency (TOWRE).* The Test of Word Reading Efficiency (TOWRE) was developed by Torgesen, Wagner, and Rashotte (1999) to measure word reading accuracy and fluency. Two subtests of the TOWRE were administered to examine ability to pronounce real and non-real words accurately and fluently. The Sight Word Efficiency subtest measured the number of real printed words accurately identified in 45 seconds, while the Phonemic Decoding Efficiency subtest, in contrast, measured the number of pronounceable printed non-words accurately decoded in 45 seconds. Two parallel forms of each subtest were used. Type A subtests were used in Session 1 and Type B subtests were used in Session 2. Scores for each subtest were expressed as standard scores with a mean of 100 and standard deviation of 15.

## Results

As can be seen in Table 1, there were no significant differences between the two groups of children in age ( $p = .921$ ) and IQ ( $p = .385$ ).

### *SNAP-IV*

Table 2 shows that the  $t$ -test pair-wise comparisons of parent ratings for children with ADHD when off medication differed significantly from those of controls on: total score ( $t[17] = 7.57, p < .001$ ); inattentive subscale ( $t[17] = 8.20, p < .001$ ); and hyperactive/impulsive subscale ( $t[17] = 6.19, p < .001$ ). However, for ratings of children with ADHD when on medication, there was no significant difference from controls on any of the scales.

Table 1. Mean (*SD*) age and intelligence standard scores in ADHD and control groups

Tasks	ADHD <i>n</i> = 18	Controls <i>n</i> = 18	<i>t</i> value	<i>p</i>
Age	8;2 (0;2)	8;3 (0;2)	-.099	.921
WASI standard scores:				
Vocabulary	44.61 (10.87)	45.44 (8.11)	-.261	.796
Matrix reasoning	47.50 (9.24)	52.11 (10.19)	-1.423	.164
IQ	94.17 (14.59)	98.11(12.20)	-.880	.385

The SNAP-IV essentially confirmed the attentional status of children with ADHD and provided support for their diagnosis based on the DSM-IV. Only one child in the control group overlapped with the ratings of children with ADHD.

### TEA-Ch

For analysis of the psychometric data, the control children were individually matched to the children with ADHD on session (i.e., if a child with ADHD completed the on stimulant medication session first, comparison would be made to the control child's performance in the first session). The two sessions will be referred to as on stimulant medication and off stimulant medication, though it must be remembered that the control children were unmedicated on both sessions.

Table 3 shows the TEA-Ch age-related performance for the ADHD and control groups. A mixed ANOVA with one between subjects factor (group) and two

Table 2. Mean (*SD*) for SNAP-IV inattention, hyperactive-impulsive scales, and total scores for medicated and non-medicated conditions

SNAP-IV measures	ADHD CT	ADHD PI	Controls ADHD vs control	<i>t</i> value	<i>p</i>
On stimulant medication					
Inattention scale	1.15 (.65)	.85 (.39)	.80(.58)*	1.19	.25
Hyperactive scale	1.00 (.78)	.48 (.54)	.59(.59)*	.98	.34
Total	1.07 (.68)	.67 (.53)	.70(.53)*	1.13	.28
Off stimulant medication					
Inattention scale	2.43 (.56)	2.15 (.30)	.80 (.58)	8.20	< .001
Hyperactive scale	2.39 (.60)	1.39 (.74)	.59 (.59)	6.19	< .001
Total	2.43 (.52)	1.79 (.54)	.70 (.53)	7.57	< .001

Note:  $p < .0125$  required to reach significance with correction for multiple comparisons.

\*Control data was obtained off medication, completed on one occasion by child's parents.

Table 3. Mean (SD) TEA-Ch standard scores in the ADHD and control groups when on and off stimulant medication\*

Tasks	ADHD	Controls	<i>t</i> value ADHD vs control	<i>p</i>
On stimulant medication				
TEA-Ch standard scores				
Score!	9.17 (3.81)	10.72 (3.86)	-1.217	.232
Same World	9.56 (3.32)	11.89 (3.20)	-2.145	.039
Opposite World	9.33 (3.58)	11.33 (3.63)	-1.664	.105
Walk Don't Walk	7.17 (2.55)	10.83 (2.98)	-3.970	< .001
Off stimulant medication				
TEA-Ch standard scores				
Score!	6.50 (3.15)	11.00 (3.12)	-4.304	< .001
Same World	7.39 (2.91)	12.00 (3.41)	-4.360	< .001
Opposite World	6.89 (3.74)	11.68 (3.26)	-4.096	< .001
Walk Don't Walk	6.00 (2.83)	10.39 (3.20)	-4.359	< .001

Note:  $p < .0125$  required to reach significance with correction for multiple comparisons

\*Session categorised according to medication status of ADHD group; controls were unmedicated in both sessions.

repeated measures (TEA-Ch subtest [Score!; Same Worlds; Opposite Worlds; Walk Don't Walk] and session [On; Off]) revealed a significant main effect of TEA-Ch subtest ( $F[2.55, 86.83] = 3.98, p < .007$ ), session ( $F[1, 34] = 11.02, p < .002$ ), and group ( $F[1, 34] = 18.78, p < .001$ ). There was a significant interaction between session and group ( $F[1, 34] = 12.64, p < .001$ ), but no significant interaction between TEA-Ch subtest and group ( $F[3, 102] = .41, p = .714$ ). The Mauchly test of sphericity showed sphericity could not be assumed for the TEA-Ch subtest ( $p < .05$ ); hence some *df* values were fractionalised following the use of Greenhouse-Geisser.

The interaction between session and group was further explored using independent samples *t*-tests to compare the age-scaled scores of the children with ADHD and the age-matched controls. The *t* statistics and *p* value are shown in Table 3. The children with ADHD performed significantly more poorly than controls on the TEA-Ch subtests when off stimulant medication. In contrast, during the on stimulant medication session, no significant differences were found in the Score! and Opposite Worlds subtests. With Bonferroni correction for multiple comparisons the Same Worlds subtest failed to meet corrected significance levels. There was a significant difference between the children with ADHD and controls on the Walk Don't Walk subtest.

To examine further whether attentional status affected performance, a comparison between the on and off stimulant medication sessions was made using a paired samples *t*-test. The children with ADHD performed significantly worse in the off

compared to the on stimulant medication session on: Score! ( $t[17] = 2.77, p < .013$ ); Same Worlds ( $t[17] = 3.90, p < .001$ ); and Opposite Worlds ( $t[17] = 3.72, p < .002$ ). There was no significant difference between sessions on the Walk Don't Walk subtest ( $t[17] = 1.96, p = .067$ ).

Examining the ADHD subtypes separately, the ADHD-PI group performed significantly worse in the off compared to the on stimulant medication session on Score! ( $t[5] = 3.05, p < .028$ ) and Opposite Worlds ( $t[5] = 2.65, p < .045$ ), while there was no significance for the Same Worlds subtest ( $t[5] = 3.05, p = .053$ ). No significant differences were evident on the Walk Don't Walk subtest ( $t[5] = .19, p = .856$ ). The ADHD-CT children performed significantly worse in the off compared to the on stimulant medication session on Same Worlds ( $t[11] = 2.87, p < .015$ ) and Opposite Worlds ( $t[11] = 2.60, p < .025$ ), and there was no significant difference on the Walk Don't Walk subtest ( $t[11] = 2.19, p = .051$ ). There was no significant difference on the Score! subtest ( $t[11] = .13, p = .206$ ).

In contrast the control group showed significant improvements on three of the TEA-Ch subtests in the second session: Same Worlds ( $t[17] = -4.62, p < .001$ ); Opposite Worlds ( $t[17] = -3.73, p < .002$ ); and Walk Don't Walk ( $t[11] = -2.38, p < .029$ ). There was no significant improvement on the Score! subtest ( $t[17] = .07, p = .947$ ). With Bonferonni correction for multiple comparisons the significant difference between the sessions on the Walk Don't Walk subtest was removed.

## TOWRE

Children with ADHD showed no significant difference between the on and off stimulant medication sessions for the TOWRE word efficiency ( $t[17] = .34, p = .741$ ) or phonemic decoding subtests ( $t[17] = .87, p = .395$ ) (see Table 4). Controls were matched to the session of children with ADHD and there was no significant difference between the sessions for the word efficiency ( $t[17] = -1.34, p = .199$ ) and phonemic decoding subtests ( $t[1, 17] = .72, p = .479$ ). Examination of the total of standard scores over the two sessions for the controls and two ADHD subgroups gave a significant effect ( $F[2, 32] = 8.33, p < .001$ ). Post-hoc Tukey HSD analysis revealed significant differences between the controls and both ADHD

Table 4. Mean (*SD*) TOWRE age-related scores in the ADHD and control groups when on and off stimulant medication

TOWRE age-related scores	ADHD	Controls	<i>t</i> value	<i>p</i>
On stimulant medication				
Word efficiency	94.22 (14.70)	112.11 (13.81)	-3.764	< .001
Phonemic decoding	94.11 (12.79)	112.33 (14.94)	-3.931	< .001
Off stimulant medication				
Word efficiency	93.89 (14.52)	113.50 (13.89)	-4.142	< .001
Phonemic decoding	93.06 (12.75)	111.67 (13.36)	-4.275	< .001

subgroups. However, the ADHD-PI and ADHD-CT groups were not significantly different ( $p > .05$ ).

## **Discussion**

Our first aim was to replicate the study of Manly et al. (2001), who found that most of the TEA-Ch subtests discriminated between unmedicated children with ADHD and control children. Our results were in good agreement, showing significant differences on the TEA-Ch subtests between controls and ADHD children when off stimulant medication.

Our second aim was to consider whether performance on the TEA-Ch improved in children with ADHD when they were taking stimulant medication. We found that this was the case, both for predominantly inattentive and combined inattentive and hyperactive-impulsive ADHD subtypes. In the off stimulant medication session the children with ADHD and age-matched controls performed significantly differently on both the sustained attention (Score! and Walk Don't Walk) and attention control measures of the TEA-Ch (Same and Opposite Worlds). However, in the on stimulant medication session the Walk Don't Walk subtest produced the only significant difference between the controls and children with ADHD. In addition, we noted that age-matched control children improved with practice on the TEA-Ch measures.

Our third aim was to consider whether effects of medication would be seen on a reading test. If stimulant medication exerts an effect simply by increasing children's motivation and making tasks more enjoyable, we might expect to see similar benefits on the TOWRE, which involves speeded reading and is not designed specifically to tax attentional skills. There were no significant differences on the TOWRE reading subtests in the children with ADHD when on and off stimulant medication. Unlike the TEA-Ch subtests, the significant differences between the two groups on the TOWRE subtests remained when attentional status was altered in the children with ADHD. This provides support for the claim that the TEA-Ch subtests used were sensitive to changes in attention brought about by medication.

Although our study supports the sensitivity of several TEA-Ch subtests, not all measures produced significant differences when medication status was changed in children with ADHD. Differences between subtests should, however, be treated with caution, given the small sample size and variable performance of children with ADHD in this study. It has been recognised that children with ADHD can vary from situation to situation and from moment to moment (Tannock, 1999, cited in Gladwell, 1999), and it is possible that a different profile of results would be obtained if this study were to be repeated.

As noted above, all children with ADHD had been receiving medication for at least three months, but they varied in the type of medication prescribed. In addition they were prescribed different amounts (5–40 mg) and had been taking the stimulant medication for different lengths of time (three months to four years). Two children were also taking Catapres in addition to the stimulant medication. It is possible, therefore, that the different amounts of medication affected the degree of

improvement in TEA-Ch performance. However, the dosage being prescribed for each child's needs was the level considered optimum by their paediatrician for age and weight, thus providing a condition when the child's attention would be at its best. Although the time period between ingestion of the medication and testing was not fully controlled, parents were instructed to give their child's stimulant medication as they would on a usual day so as to prevent disruption to the child's day pattern. All testing took place during a period when medication would be working (i.e., within two hours of ingestion).

One limitation of this study is that the experimenter and children were not blind to the child's medication status. A double-blind procedure, which would involve using a placebo rather than removing the stimulant medication in the off stimulant medication session, would remove the possibility that knowledge of the child's medication status could influence results. However, preparation of placebo tablets was not feasible, given the different medications and dosages used in this study. Also, a disadvantage of using a traditional double-blind study, with all children having the same medication, is that children with ADHD do not all show the same response to a given medication. Our design ensured that we were studying children who were taking medication that had been identified as clinically effective for each individual.

A further point to note is that we used only a subset of the TEA-Ch subtests, focusing on measures that loaded on factors of sustained attention and attentional control. Inclusion of the remaining subtests (Score DT; Code Transmission; Sky Search DT; Sky Search; Map Mission; and Creature Counting) was not practicable within the time available. It is noteworthy that while medication abolished differences between children with ADHD and control children on the Score! and Same/Opposite Worlds tasks, significant impairments were still seen in medicated children in the sustained attention task, Walk Don't Walk. This task differs from the others in requiring inhibition of a prepotent motor response; our results suggest that inhibitory processes may be less affected by medication than other aspects of attention switching and control.

In conclusion, the findings reported here provide support for some of the TEA-Ch subtests as useful assessment tools for attentional difficulties. Altering the attentional status of children with ADHD has reconfirmed the differences found between children with ADHD and age-matched controls by Manly and colleagues on certain TEA-Ch subtests. What is now required is a larger scale investigation to determine whether the complete battery of TEA-Ch subtests are sensitive to changes in stimulant medication in children with ADHD.

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## References

- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.
- Barkley, R. A. (1991). Diagnosis and assessment of attention-deficit-hyperactivity disorder. *Comprehensive Mental Health Care, 1*, 27–43.
- Biederman, J. (2002). Practical considerations in stimulant drug selection for the attention-deficit/hyperactivity disorder patient: Efficacy, potency and titration. *Today's Therapeutic Trends, 20*, 311–328.
- Biederman, J., Newcorn, J., & Sprich, S. (1991). Comorbidity of attention deficit hyperactivity disorder with conduct, depressive, anxiety, and other disorders. *American Journal of Psychiatry, 148*, 564–577.
- Denckla, M. B. (1992). Commentary: The myth of ADHD. *Journal of Child Neurology, 7*, 458–461.
- Epstein, M. A., Shaywitz, S. E., Shaywitz, B. A., & Woolston, J. L. (1991). The boundaries of attention deficit disorder. *Journal of Learning Disabilities, 24*, 78–85.
- Gladwell, M. (1999). Running from Ritalin, *The New Yorker*, February 2, 1999, p. 82.
- Heaton, S. C., Reader, S. K., Preston, A. S., Fennell, E. B., Puyana, O. E., Gill, N., & Johnson, J. H. (2001). The Test of Everyday Attention for Children (TEA-Ch): Patterns of performance in children with ADHD and clinical controls. *Child Neuropsychology, 7*, 251–264.
- Hunt, R. D., Minderaa, R. B., & Cohen, D. J. (1985). Clonidine benefits children with attention deficit disorder and hyperactivity. *Journal of the American Academy of Child Psychiatry, 24*, 617–629.
- Kirk, R. E. (1995). *Experimental design: Procedures for the behavioural sciences* (3rd ed.). Pacific Grove, CA: Brooks/Cole.
- Levy, F., Hay, D., McLaughlin, M., Wood, C., & Waldman, I. (1996). Twin-sibling differences in parental reports of ADHD, speech, reading and behaviour problems. *Journal of Child Psychology and Psychiatry, 37*, 569–578.
- Lord, J., & Paisley, S. (2000). *The clinical effectiveness and cost-effectiveness of methylphenidate for hyperactivity in childhood* (Version 2). London: National Institute for Clinical Excellence.
- Manly, T., Anderson, V., Nimmo-Smith, I., Turner, A., Watson, P., & Robertson, I. H. (2001). The differential assessment of children's attention: The Test of Everyday Attention for Children (TEA-Ch), normative sample and ADHD performance. *Journal of Child Psychology and Psychiatry, 42*, 1065–1081.
- Manly, T., Robertson, I. H., Anderson, V., & Nimmo-Smith, I. (1999). *The Test of Everyday Attention for Children (TEA-Ch)*. Bury St Edmunds, UK: Thames Valley Test Company.
- Munoz-Lillan, R. J., & Casteel, C. R. (1989). Attention deficit hyperactivity disorder: Recent literature. *Hospital and Community Psychology, 40*, 699–707.
- Neale, M. D. (1989). *Neale Analysis of Reading Ability* (2nd ed.). London: Macmillan.
- Patrick, K. S., & Markowitz, J. S. (1997). Pharmacology of methylphenidate, amphetamine enantiomers and pemoline in attention-deficit hyperactivity disorder. *Human Psychopharmacology, 12*, 527–546.
- Schachar, R., & Tannock, R. (1995). Test of four hypotheses for the comorbidity of attention deficit hyperactivity disorder and conduct disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 34*, 639–648.
- Swanson, J. M. (1992). *School-based assessments and interventions for ADD students*. Irvine, CA: K. C. Publishing.
- Torgesen, J. K., Wagner, R., & Rashotte, C. (1999). *Test of Word Reading Efficiency (TOWRE)*. New York: Psychological Corporation.

- Volkow, N. D., Wang, G. J., Fowler, J. S., Logan, J., Gerasimov, M., Maynard, L., et al. (2001). Therapeutic doses of oral Methylphenidate significantly increase extracellular dopamine in the human brain. *The Journal of Neuroscience*, *21*, 1–5.
- Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence Manual*. New York: The Psychological Corporation.
- Wender, P. H. (1973). *The hyperactive child: A handbook for parents*. New York: Crown Publishers.
- Zametkin, A. J., & Borcharding, B. G. (1989). The neuropharmacology of attention deficit hyperactivity disorder. *Annual Review of Medicine*, *40*, 447–451.