# Methylphenidate improves some but not all measures of ATTENTION, as measured by the TEA-Ch in medication-naïve children with ADHD

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## Abstract

The Test of Everyday Attention for Children (TEA-Ch) is a reliable neuropsychological assessment of attention control in children. Methylphenidate (MPH) is an effective treatment to improve attentional difficulties in children with attention deficit/hyperactivity disorder (ADHD). Previous studies investigating the effects of MPH on attention performance of children with ADHD have produced mixed results and prior MPH usage may have confounded these results. No previous study has tested the effects of MPH on the entire TEA-Ch battery. This study investigated the effects of MPH on attention performance using the entire TEA-Ch in 51 medication-naïve children with ADHD compared with 35 nonmedicated typically developing children. All children were tested at baseline and after 6 weeks: The children with ADHD were medication-naïve at baseline, received MPH for 6 weeks and were tested whilst on medication at the second testing session. A beneficial effect of MPH administration was found on at least one subtest of each of the three forms of attention (selective, sustained, and attentional control) assessed by the TEA-Ch, independent of practice effects. MPH aided performance on the TEA-Ch tasks that were inherently nonarousing and that might require top-down control of attention. It is recommended that the TEA-Ch measures—Sky Search Count (selective attention),Score! (sustained attention), Creature Counting Time Taken for older children (attentional control), and Same Worlds (attentional control) be prioritized for use in future pharmacological studies using MPH.

Clinical tools have been developed to provide reliable neuropsychological assessments of attention control in children and the Test of Everyday Attention for Children (TEA-Ch; Manly, Robertson, Anderson, & Nimmo-Smith, 1999) is one such task. Three forms of attention are measured within the TEA-Ch. *Selective attention* is the ability to focus on a specific stimulus, whilst ignoring others (Manly et al., 2001). *Sustained attention* is the ability to maintain attention over an extended period of time (Betts, McKay, Maruff, & Anderson, 2006). *Attentional control* is the ability to disengage, to shift, and to refocus attention from one item to another (Gardner, Sheppard, & Efron, 2008). Multiple TEA-Ch subtests examine each type of attention. As the TEA-Ch assesses three types of attention, it might be more sensitive to differential effects of Methylphenidate (MPH) on attention than the use of a task that measures only one form of attention.

Seven studies have previously investigated the performance of children with ADHD and typically developing controls on the TEA-Ch (see Table 1 for a review of the results). Mixed results were found for all subtests except Code Transmission, where all four studies that incorporated this subtest found a significantly poorer performance by the attention deficit/hyperactivity disorder (ADHD) group. A variety of factors may explain the inconsistencies of prior research. In some studies, the children with ADHD were on stimulant medication at the time of testing and in some other studies a cohort of medication-naïve children was used. The form of the control groups ranged from a non-ADHD clinical sample of children with other psychiatric diagnoses to the normative sample from the TEA-Ch.

Dysfunctional catecholamine signaling has been posited as a major contributor to the cognitive difficulties associated with ADHD (Solanto, 2002). Dopamine and noradrenaline play important roles in prefrontal cognitive function (Arnsten & Pliszka, 2011). Decreased top-down regulation of attention may occur in individuals with ADHD, resulting in less effective prefrontal cortical regulation of posterior cortical and subcortical structures (Arnsten & Pliszka, 2011). The complex networks involved in regulation of attention are extremely sensitive to the neuro-chemical environment, particularly catecholamine concentrations. Relatively small changes in the levels of dopamine and noradrenaline could produce significant changes in the functioning of the prefrontal cortex (Volkow et al., 2001).

Methylphenidate (MPH) is effective in reducing symptoms in approximately 70% of children with ADHD (Greenhill, Halperin, & Abikoff, 1999). MPH binds to the dopamine transporter in the presynaptic nerve terminals in the striatum, blocking the reuptake of dopamine and noradrenaline from the synaptic cleft into presynaptic terminals, thereby increasing the level of both neurotransmitters in the extra neuronal space (Solanto, 1998). Dopamine is suggested to decrease background firing rates of postsynaptic neurons leading to an improvement in signal-to-noise ratios in target neurons, which may enhance attention (Volkow et al., 2001). By testing medication-naïve children, the exact pharmacological and resulting cognitive effect of MPH on the symptoms of inattention can be elucidated.

**Table 1** A Review of the Previous Literature Investigating the TEA-Ch Performance of Children With and Without ADHD.

| Attention category | Subtest | Study | ADHD deficit compared with control? |
|---|---|---|---|
| Selective attention | Sky Search | Micallef, Anderson, Anderson, Robertson, and Manly (2001) | X |
| | | Manly et al. (2001) | X |
| | | Heaton et al. (2001) | X |
| | | West, Houghton, Douglas, and Whiting (2002) | X |
| | | Wu, Anderson, and Castiello (2002) | X |
| | | Chan, Wang, Ye, Leung, and Mok (2008) | ✓ |
| | | Lemiere et al. (2010) | X |
| | Map Mission | Micallef et al. 2001) | ✓ |
| | | Heaton et al. (2001) | X |
| | | Chan et al. (2008) | X |
| | | Lemiere et al. (2010) | X |
| Sustained attention | Score! | Manly et al. (2001) | ✓ |
| | | Heaton et al. (2001) | ✓ |
| | | West et al. (2002) | X |
| | | Chan et al. (2008) | X |
| | | Lemiere et al. (2010) | X |
| | Sky Search DT | Manly et al. (2001) | ✓ |
| | | Heaton et al. (2001) | X |
| | | West et al. (2002) | X |
| | | Chan et al. (2008) | X |
| | | Lemiere et al. (2010) | X |
| | Score! DT | Manly et al. (2001) | ✓ |
| | | Heaton et al. (2001) | X |
| | | Chan et al. (2008) | ✓ |
| | | Lemiere et al. (2010) | X |
| | Walk, Don't Walk | Manly et al. (2001) | ✓ |
| | | Heaton et al. (2001) | ✓ |
| | | Chan et al. (2008) | X |
| | | Lemiere et al. (2010) | X |
| | Code Transmission | Heaton et al. (2001) | ✓ |
| | | Wu et al. (2002) | ✓ |
| | | Chan et al. (2008) | ✓ |
| | | Lemiere et al. (2010) | ✓ |
| Attentional control | Creature Counting | Heaton et al. (2001) | ✓ |
| | | West et al. (2002) | ✓ |
| | | Chan et al. (2008) | X |
| | | Lemiere et al. (2010) | ✓ |
| | Opposite Worlds | Manly et al. (2001) | ✓ |
| | | Heaton et al. (2001) | ✓ |
| | | Chan et al. (2008) | ✓ |
| | | Lemiere et al. (2010) | X |

*Notes.* ✓ indicates a statistically significant result. X indicates nonsignificant result. DT = Dual Task.

Five studies have used the TEA-Ch to assess the impact of MPH on attention skills in ADHD, and of these studies none used the entire TEA-Ch and none used a full cohort of medication-naïve children. Four of the five studies found significant positive effects of MPH on ADHD performance on at least one of the TEA-Ch subtests, but the pattern of subtest performance was inconsistent across studies (see Table 2).

These varying results may reflect methodological differences between studies, including the use of a limited number of subtests of the TEA-Ch, testing of the baseline and medication sessions within a short period of time, use of a mix of methylphenidate and dextroamphetamine prescriptions, small sample sizes, and the involvement of participants with previously prescribed medication. Potential effects of chronic stimulant medication exposure may have confounded the interpretation of previous findings (Marco et al., 2011; van de Loo-Neus, Rommelse, & Buitelaar, 2011).

The present study investigated the effects of MPH administration on performance on all subtests of the TEA-Ch, with a group of medication-naïve children with ADHD and a gender-and age-comparable control group. Based on previous MPH findings (see Table 2), it was predicted that the medication-naïve children with ADHD would perform significantly more poorly at Time 1 (Baseline) compared with control children on the Sustained Attention and Attention Control subtests of the TEA-Ch and would not perform significantly differently from the control children on the tests of Selective Attention. It was further predicted that there would be an improvement in performance following administration of MPH for children with ADHD at Time 2 (6 weeks) for the Score! and Opposite Worlds subtests and no change in performance for the other TEA-Ch subtests. Finally, it was hypothesized that an improvement in performance of the control children over time (i.e., a practice effect) would occur on the Sky Search Time per Target and Attention measures, the Creature Counting Accuracy measure (Hood, Baird, Rankin, & Isaacs, 2005), the Same and Opposite Worlds and the Walk, Don't Walk subtests (Sutcliffe, Bishop, & Houghton, 2006), but not on the other TEA-Ch subtests.

## METHOD

### Participants

Fifty-one children with ADHD (8 girls, 6 left-handers) and 35 typically developing control children (7 girls, 4 left-handers) participated in the study. The average ages of the ADHD ($M$ = 8.4 years, $SD$ = 2.4, range 6–14 years) and control ($M$ = 9.0 years, $SD$ = 2.3, range 6–14 years) groups did not differ significantly. The intelligence quotients (IQs) of the children with ADHD ($M$ = 90.6, $SD$ = 15.4) were measured at baseline using four subtests (block design, vocabulary, information, picture completion) of the *Wechsler Intelligence Scale for Children*, third edition (WISC-III; Wechsler, 1992). The IQs of the control children ($M$ = 102.7, $SD$ = 14.3) were measured at baseline using four subtests of the *Wechsler Intelligence Scale for Children*, fourth edition (block design, similarities, digit span, coding) (WISC-IV; Wechsler, 2004). There was no significant group difference in terms of gender or handedness.

Exclusion criteria for this study included those children with a known neurological condition, a developmental disorder, or a head injury. All participants had an IQ over 70.

The ADHD data were collected as part of a larger pharmacogenetic study in the Republic of Ireland. At baseline, the children were newly diagnosed with ADHD and were medication-naïve. They were then assessed 6 weeks later while maintained on

Creature Counting is calculated only if the counting Accuracy score is 3 or greater; hence, the number of children with ADHD included in the Timing score was reduced by 10.

### Statistics

A paired samples *t*-test was conducted to compare the Conners' ADHD Index for the ADHD group at baseline versus 6 weeks. One-way analyses of variance (ANOVAs) were conducted to compare the Conners' ADHD Index for the children with ADHD (both medication-naïve and on medication) with the control group. Response to medication was translated into a categorical variable to facilitate analysis. A 25% or greater reduction in symptoms from baseline to 6 weeks, measured by the Conners' ADHD Index, was used to define a good response to medication. The TEA-Ch measures were analyzed using repeated-measures mixed-factorial two-way ANOVAs, with Group (ADHD, control) and Time (baseline, 6 weeks) as the factors. The test-retest reliability of the TEA-Ch was assessed using the control group data with Pearson's product-moment correlation coefficient. The alpha level was set at .05 and Bonferroni adjustments were made for all pairwise analyses.

## RESULTS

### Conners' ADHD Index

The Conners' ADHD Index scores of the ADHD group when medication-naïve ($M = 76.8$, $SD = 7.4$) were significantly higher than those of the control group ($M = 46.2$, $SD = 5.4$), $F(1, 84) = 442.61$, $p < .001$, $\eta_p^2 = .84$. There was a significant decrease in the Conners' ADHD index scores of children with ADHD when medicated ($M = 58.2$, $SD = 9.3$) compared with when medication-naïve, $t(1, 49) = 11.61$, $p < .001$. When the children with ADHD were on medication, the Conners' ADHD index scores were still significantly higher than those of the control children, $F(1, 83) = 47.34$, $p < .001$, $\eta_p^2 = .36$.

### Selective Attention: Sky Search – Count of Identified Targets

A significant Time main effect, $F(1, 84) = 9.710$, $p = .003$, $\eta_p^2 = .104$, was further explained by a significant a Group by Time interaction, $F(1, 84) = 4.13$, $p = .045$, $\eta_p^2 = .047$ (see Table 4). Pairwise comparisons suggested that whilst the ADHD group significantly improved in performance from baseline to 6 weeks ($p < .001$), there was no significant change in performance of the control group. There was no significant difference in performance between the two groups at baseline ($p = .774$) or at 6 weeks ($p = .059$).

### Selective Attention: Sky Search – Time Per Target

The control group took significantly less time to identify each Sky Search target ($M = 10.5$, $SD = 2.3$) than the ADHD group ($M = 6.9$, $SD = 3.1$),[1] $F(1, 84) = 47.09$, $p < .001$, $\eta_p^2 = .36$. Performance at 6 weeks for all participants ($M = 9.3$, $SD = 3.1$) was significantly better than performance at baseline ($M = 7.4$, $SD = 3.2$), $F(1, 84) = 42.338$, $p < .001$, $\eta_p^2 = .34$). There was no significant interaction.

[1] With the TEA-Ch age-scaled scoring system, a higher score represents better performance.

**Table 4** Means (With Standard Deviations) of the Two Groups for Each Attention Measure of the TEA-Ch and the Test-Retest Reliability of the TEA-Ch Subtests for the Control Group.

| Attention construct | Measure | Group | Number of participants | Baseline Mean (*SD*) | Week 6 Mean (*SD*) | ADHD deficit at baseline? | Positive effect of MPH for ADHD group? | ADHD deficit at Week 6? | Possible practice effect? | Pearson product-moment correlation coefficient for test-retest reliability of control group |
|---|---|---|---|---|---|---|---|---|---|---|
| Selective attention | Sky Search Count of Targets | ADHD | 51 | 9.9 (3.0) | 11.6 (2.7) | No | Yes | No | No | .533 ($p < .001$) |
| | | Control | 35 | 10.1 (3.5) | 10.5 (3.0) | | | | | |
| Selective attention | Sky Search Time per Target | ADHD | 51 | 5.9 (2.8) | 8.0 (3.0) | Yes | No | Yes | Yes | .606 ($p < .001$) |
| | | Control | 35 | 9.7 (2.2) | 11.2 (2.2) | | | | | |
| Selective attention | Sky Search Attention | ADHD | 51 | 6.0 (3.1) | 7.9 (3.2) | Yes | No | Yes | Yes | .684 ($p < .001$) |
| | | Control | 35 | 10.0 (2.4) | 11.3 (2.6) | | | | | |
| Selective attention | Map Mission | ADHD | 50 | 6.2 (2.5) | 8.9 (2.8) | Yes | No | Yes | Yes | .272 (*ns*) |
| | | Control | 35 | 8.0 (2.0) | 10.0 (2.0) | | | | | |
| Sustained attention | Score! | ADHD | 49 | 8.1 (2.6) | 9.5 (3.6) | No | Yes | No | No | .461 ($p = .005$) |
| | | Control | 35 | 8.9 (2.9) | 8.1 (2.9) | | | | | |
| Sustained attention | Sky Search DT | ADHD | 48 | 5.6 (4.6) | 6.9 (4.7) | No | No | No | Yes | .026 (*ns*) |
| | | Control | 35 | 6.8 (3.2) | 7.7 (3.5) | | | | | |
| Sustained attention | Score! DT | ADHD | 45 | 7.9 (3.7) | 9.4 (3.6) | No | No | No | Yes | .604 ($p < .001$) |
| | | Control | 35 | 9.1 (3.4) | 10.1 (3.6) | | | | | |
| Sustained attention | Walk, Don't Walk | ADHD | 47 | 6.9 (3.3) | 9.3 (3.8) | No | No | No | Yes | .516 ($p < .001$) |
| | | Control | 35 | 7.9 (3.0) | 9.9 (2.6) | | | | | |
| Sustained attention | Code Transmission | ADHD | 29 | 7.1 (3.8) | 9.1 (4.1) | No | No | No | Yes | .560 ($p < .001$) |
| | | Control | 32 | 7.6 (2.3) | 8.7 (2.8) | | | | | |
| Attentional control | Creature Counting Accuracy | ADHD | 37 | 8.6 (3.6) | 10.1 (3.0) | No | No | No | Yes | .293 (*ns*) |
| | | Control | 31 | 9.2 (2.6) | 10.5 (2.7) | | | | | |
| Attentional control | Creature Counting Time Taken | ADHD | 28 | 7.8 (3.1) | 9.9 (3.3) | No | Yes | No | No | .799 ($p < .001$) |
| | | Control | 28 | 8.6 (2.9) | 9.2 (2.6) | | | | | |
| Attentional control | Same Worlds | ADHD | 48 | 7.7 (2.3) | 9.1 (2.5) | Yes | Yes | No | No | .749 ($p < .001$) |
| | | Control | 35 | 8.9 (2.3) | 8.6 (2.3) | | | | | |
| Attentional control | Opposite Worlds | ADHD | 47 | 7.8 (3.1) | 9.4 (3.2) | No | No | No | Yes | .712 ($p < .001$) |
| | | Control | 35 | 8.5 (3.0) | 9.1 (2.8) | | | | | |

*Note*. DT = dual task.

### Selective Attention: Sky Search Attention Score

The Attention Score of the control group ($M = 10.7$, $SD = 2.5$) was significantly higher than that of the ADHD group ($M = 6.9$, $SD = 3.3$), $F(1, 84) = 44.44$, $p < .001$, $\eta_p^2 = .35$. The Attention score for all participants was significantly higher at 6 weeks ($M = 9.3$, $SD = 3.4$) than at baseline ($M = 7.6$, $SD = 3.5$), $F(1, 84) = 26.36$, $p < .001$, $\eta_p^2 = .24$. There was no significant interaction.

### Selective Attention: Map Mission

For all participants, the count of identified targets was significantly higher at 6 weeks ($M = 9.4$, $SD = 2.6$) than at baseline ($M = 6.9$, $SD = 2.5$), $F(1, 83) = 87.80$, $p < .001$, $\eta_p^2 = .51$. The control group ($M = 9.0$, $SD = 2.3$) identified significantly more targets than the ADHD group ($M = 7.5$, $SD = 3.0$), $F(1, 83) = 9.68$, $p = .003$, $\eta_p^2 = .10$. There was no significant interaction.

### Sustained Attention: Score!

A significant Group by Time interaction for the number of correct Score! games was found, $F(1, 82) = 6.48$, $p = .013$, $\eta_p^2 = .07$. Pairwise comparisons suggested that the ADHD group significantly improved in performance ($p = .013$), whereas the control group showed no significant difference between performances ($p = .239$). There was no significant difference in performance on the number of correct Score! games between the two groups at baseline ($p = .242$) or at 6 weeks ($p = .062$).

### Sustained Attention: Sky Search Dual Task (DT)

Performance of all participants was significantly higher at 6 weeks ($M = 7.2$, $SD = 4.2$) than at baseline ($M = 6.1$, $SD = 4.1$), $F(1, 81) = 4.02$, $p = .048$, $\eta_p^2 = .047$. There was no significant difference in performance between the two groups and no significant interaction.

### Sustained Attention: Score! Dual Task DT

For all participants, the Score! DT score was significantly higher at 6 weeks ($M = 9.7$, $SD = 3.6$) than at baseline ($M = 8.4$, $SD = 3.6$), $F(1, 78) = 8.52$, $p = .005$, $\eta_p^2 = .10$. There was no significant difference between the two groups and there was no significant interaction.

### Sustained Attention: Walk, Don't Walk

For all participants, the number of games correct was significantly higher at 6 weeks ($M = 9.5$, $SD = 3.3$) than at baseline ($M = 7.3$, $SD = 3.2$), $F(1, 80) = 34.734$, $p < .001$, $\eta_p^2 = .30$. There was no significant difference between the two groups and there was no significant interaction.

### Sustained Attention: Code Transmission

For all participants, performance significantly improved at 6 weeks ($M = 8.9$, $SD = 3.5$) compared with the baseline test session ($M = 7.4$, $SD = 3.1$), $F(1, 59) = 16.66$,

$p < .001$, $\eta_p^2 = .22$. There was no significant difference in performance between the groups and there was no significant interaction.

### Attentional Control: Creature Counting – Accuracy of Counting

All participants performed the counting with significantly greater accuracy at 6 weeks ($M = 10.3$, $SD = 2.8$) compared with baseline ($M = 8.9$, $SD = 3.2$), $F(1, 66) = 13.12$, $p < .001$, $\eta_p^2 = .17$. There was no significant difference between the two groups and there was no significant interaction.

### Attentional Control: Creature Counting – Time Taken

A significant Time main effect was further explained by a significant Group by Time interaction, $F(1, 54) = 8.11$, $p = .006$, $\eta_p^2 = .13$. Pairwise comparisons suggested that the interaction was driven by the improvement in performance of the ADHD group ($p <$ .001), as there was no significant difference in performance by the control group ($p =$ .149). There was no significant difference in time taken to complete the Creature Counting between the two groups at baseline ($p = .272$) or at the 6-week ($p = .397$) testing sessions.

### Attentional Control: Same Worlds Total Time

A significant Time main effect was further explained by a significant Group by Time interaction, $F(1, 81) = 14.03$, $p < .001$, $\eta_p^2 = .15$. Pairwise comparisons indicated that the ADHD group improved in performance ($p < .001$), whereas there was no significant difference in performance of the control group between the two sessions ($p = .399$). At baseline, the ADHD group performed significantly more slowly than the control group ($p = .026$), but at 6 weeks there was no significant difference in performance between the two groups ($p = .350$).

### Attentional Control: Opposite Worlds Total Time

All participants improved in performance between the baseline ($M = 8.1$, $SD = 3.0$) and the 6-week session ($M = 9.3$, $SD = 3.0$), $F(1, 80) = 16.435$, $p < .001$, $\eta_p^2 = .17$. There was no significant difference between the two groups and there was no significant interaction. A strong trend for a Group by Time interaction was noted, $F(1, 80) = 3.75$, $p = .056$, $\eta_p^2 = .045$.

### Test-Retest Reliability

The reliability of the TEA-Ch measures was measured using the data of the control children and is presented in Table 4. Most of the TEA-Ch measures showed strong test-retest reliability with the exceptions of Map Mission, Sky Search DT, and Creature Counting Accuracy.

### Response to Medication

Thirty children with ADHD showed a clinically significant (25% or greater) reduction in ADHD symptoms, as measured by the Conners' ADHD Index. Further analyses were conducted to assess the performance of these children on the TEA-Ch subtests compared with the control group. The results of this analysis were consistent with the full sample analysis on all TEA-Ch subtests except for the Sky Search-Count of Identified Targets and Score!. For Sky Search-Count a Time main effect was evident, $F(1, 63) = 4.305$, $p = .042$, $\eta_p^2 = .064$, but there was no significant main effect or interaction involving group. For the Score! measure, a trend for a Group by Time interaction was found, $F(1, 61) = 3.636$, $p = .061$, $\eta_p^2 = .056$, with the means trending in the same direction as per the whole group analysis. Differences between these and the full group results may be explained by a reduction in power with the reduced number of participants.

## DISCUSSION

This study investigated the effects of MPH on attention performance of newly diagnosed medication-naïve children with ADHD, compared with a control group using the entire TEA-Ch battery. There were five main findings. First, a positive effect of MPH administration was found on at least one subtest of each of the three forms of attention, independently of practice effects (see Table 4). Second, practice effects were suggested in 9 out of the 13 measures. Third, on three out of the four subtests with a beneficial effect of MPH, the children with ADHD did not demonstrate deficits at baseline. Fourth, the ADHD group showed a deficit at baseline and at 6 weeks on three of the four selective attention measures. Fifth, on six subtests no deficit in ADHD performance was found at baseline, MPH had no significant effect on performance, and there was no ADHD deficit demonstrated at 6 weeks. These results suggest that MPH has a beneficial effect on only some measures of selective and sustained attention and attention control performance. MPH can aid the performance of children with ADHD on certain tasks, even when no deficit was exhibited by these children when medication-naïve. These results suggest that children with ADHD showed deficits primarily in selective attention (at baseline and at 6 weeks) and attention control (at baseline), but not with sustained attention as tested by the TEA-Ch. It is suggested that only four subtests of the TEA-Ch ought to be used in future pharmacological studies on the effects of MPH on attention in children with ADHD—Sky Search Count (selective attention), Score! (sustained attention), Creature Counting Time Taken (for older children, attentional control), and Same Worlds (attentional control)—as the control group did not demonstrate a practice effect on these tasks.

The pattern of findings within this study demonstrated a fair degree of consistency with prior MPH TEA-Ch studies (see Table 1). For the baseline data, full agreement with the previous literature was reached regarding the lack of a significant group difference for the Score! DT and Creature Counting Time Taken measures. These measures may not be sensitive enough to detect possible ADHD deficits in these attention realms. The current findings contrast with previous literature and the hypotheses, in that no group difference was found for the Walk, Don't Walk measure and a significant group difference was found for the Sky Search Time Per Target and Attention scores and Map Mission. These differences may reflect the methodological differences between the previous studies and this current study that used medication-naïve, newly diagnosed children with ADHD. This study presents novel findings of no significant group difference for Code Transmission at baseline.

On the question of improvement associated with MPH administration, the positive effect of MPH on the measures of Sky Search Count and Creature Counting Time Taken ran in contrast with the previous literature and the hypotheses. This might reflect the use of medication-naïve participants in this study. The positive effect of MPH on the Score! and Same Worlds measures was consistent with the majority of the previous literature and the hypotheses, confirming that these short subtests are sensitive to cognitive improvement while on medication. The current study and the previous literature were in agreement in terms of no significant effect of MPH on the measures of Sky Search Time Per Target, Sky Search Attention, Map Mission, Sky Search DT, Score DT, Walk, Don't Walk (bar the Hood et al. (2005) study), and Creature Counting Accuracy. For the Opposite Worlds measure, the null result of this study contrasts with the three previous studies that found a significant effect of MPH. Our study indicated a strong (.056) trend in the direction of previous research. This study is the first to report no effect of MPH on the Code Transmission measure.

For several subtests, improvement in performance was reported for both groups at Week 6. As no interaction effects were found between the groups, it is likely that these effects were due to practice. These findings are consistent with evidence of practice effects for some, but not all, TEA-Ch subtests (Hood et al., 2005; Sutcliffe et al., 2006) and support the hypothesis. Practice effects were identified by the test authors (Manly et al., 1999); however, previous studies have not systematically reviewed the magnitude of practice effects across the full range of TEA-Ch subtests. These practice effects have limited the ability to explain fully the effects of MPH on children with ADHD.

The results of this study suggest that children with ADHD exhibit some impairment when medication-naïve on measures of selective attention and attentional control. The results do not, however, indicate an initial impairment for children with ADHD for measures of sustained attention. The TEA-Ch measures of sustained attention were often exogenously arousing: Two tasks were performed concurrently (Sky Search DT, Score! DT) and one task increased in difficulty over time (Walk, Don't Walk). This has the potential of spoiling the measurement of endogenous conscious processing of stimuli that is nonarousing and repetitive (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). In addition, the Code Transmission task concurrently measured elements of working memory. The TEA-Ch measures of sustained attention may not provide a true reflection of the deficits in sustained attention of children with ADHD. It is noted that this same group of children demonstrated sustained attention deficits as measured by the Sustained Attention to Response Task (SART; Johnson et al., 2008).

Previous research had consistently found a positive effect of MPH on the Score! and Same and Opposite Worlds. This study found a positive effect of MPH on Score! and Same Worlds and a trend for Opposite Worlds. In addition, this study, for the first time, found a positive MPH effect for Sky Search Count and Creature Counting Time Taken. None of these five measures was exogenously arousing, which contrasts with the DTs, the tasks where the task increased in difficulty over time (Walk, Don't Walk), and where another executive function was also examined (Code Transmission). Map Mission was the only task that could be considered nonarousing in nature and performance on this task did not show a response to MPH. MPH may primarily aid performance on tasks that are inherently nonarousing and that require top-down control of attention.

This study has a number of limitations. First, due to the naturalistic focus of the pharmacogenetic study, there was no untreated ADHD group to act as a control for the treated ADHD group. Second, the average IQ of the typically developing children was significantly greater than the children with ADHD; however, IQ accounts for little of the variance in most TEA-Ch subtests for children (Baron, 2001). The assessment of the IQ of the two groups using different versions of the WISC could also be viewed as a limitation (O'Reilly & Carr, 2007). IQ scores were used solely to determine participation eligibility (i.e., above 70) and testing of the children was conducted using the versions of the WISC that were current at the time of testing. Third, children with ADHD were from Ireland and the children in the control group were from Melbourne, Australia.

Some evidence for an initial impairment for both selective attention and attention control is demonstrated in children with ADHD. A significant effect of MPH on measures of attentional control and sustained attention is illustrated. MPH may be most beneficial on tasks that require endogenous control of attention.

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