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ORIGINAL RESEARCH

Metacognitive Monitoring and Control in Children with ADHD: A Laboratory Task Analysis

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Abstract

Background: Metacognitive monitoring and control are critical for self-regulated learning, yet their interplay in children with Attention-Deficit/Hyperactivity Disorder (ADHD) remains poorly understood. This study examined metacognitive monitoring (judgments of learning, JOLs) and control (allocation of study time) in children with and without ADHD using a paired-associate learning task. Methods: Participants included 42 children with ADHD (aged 8–12) and 44 typically developing (TD) controls matched on age and IQ. Children studied word pairs, made immediate JOLs, and controlled subsequent restudy time. Metacognitive accuracy was measured via gamma correlations between JOLs and recall; control was indexed by self-paced study time allocation. Results: Children with ADHD showed significantly lower monitoring accuracy (mean gamma = 0.28) compared to TD children (mean gamma = 0.45), $p < .001$, $\eta^2 = .23$. They also allocated less study time overall and exhibited weaker correlation between JOLs and study time ($r = .12$ vs. $r = .38$), indicating impaired control. Regression analyses revealed that ADHD symptoms and mind-wandering propensity predicted poorer monitoring, controlling for IQ. Conclusions: Children with ADHD demonstrate deficits in both metacognitive monitoring and control, suggesting that metacognitive interventions targeting these processes may enhance self-regulated learning in this population.

Keywords: metacognitive monitoring, metacognitive control, ADHD, children, judgments of learning, study time allocation, self-regulated learning

Introduction

Metacognition, defined as the ability to monitor and control one's own cognitive processes, plays a foundational role in self-regulated learning and academic achievement (Roebers et al., 2014). Metacognitive monitoring refers to the ongoing assessment of one's current knowledge state, such as making judgments of learning (JOLs) about whether studied material will be remembered later. Metacognitive control involves the regulation of cognitive activities based on those assessments, such as allocating more study time to items judged as less well learned (Grainger et al., 2016). These two components are theoretically linked: accurate monitoring should guide effective control decisions, leading to improved learning outcomes (McGillivray & Castel, 2017).

Children with Attention-Deficit/Hyperactivity Disorder (ADHD) commonly experience academic difficulties that are not fully explained by intellectual deficits (Kajka & Kulik, 2021). Core symptoms of inattention, impulsivity, and hyperactivity likely impair metacognitive processes, yet research on metacognition in ADHD is relatively sparse. Studies have documented deficits in executive functions such as working memory and inhibitory control (Kumar et al., 2022; Miranda et al., 2017), which may underlie metacognitive difficulties. However, only a handful of studies have directly examined metacognitive monitoring and control in children with ADHD (Pezzica et al., 2018; Tamm & Nakonezny, 2015).

Pezzica et al. (2018) found that children with ADHD symptoms demonstrated less accurate metacognitive knowledge about attention compared to typically developing peers. Tamm and Nakonezny (2015) reported that metacognitive executive function training improved metacognitive skills in young children with ADHD. However, these studies did not use a laboratory task to dissociate monitoring and control processes. The present study aimed to fill this gap by employing a well-established paired-associate learning paradigm that yields separate measures of monitoring accuracy (via gamma correlations) and control (via self-paced study time allocation) (Roebers et al., 2014).

We hypothesized that children with ADHD would show lower monitoring accuracy and less adaptive control (i.e., weaker correlation between JOLs and study time) compared to TD controls. Furthermore, we explored the role of mind-wandering, given its known disruptive impact on learning and its potential link to metacognitive failures (Smallwood et al., 2007; Mrazek et al., 2013).

Literature Review

Metacognitive monitoring and control develop throughout childhood and are closely related to executive functions (Roebers et al., 2014). In typically developing children, monitoring accuracy improves with age, and children increasingly use JOLs to guide study time allocation (Grainger et al., 2016). Studies using the child version of the Iowa Gambling Task have shown that children with ADHD exhibit decision-making deficits (Garon et al., 2006), which may reflect broader metacognitive impairments. However, decision-making tasks often conflate monitoring and control, making it difficult to isolate specific metacognitive components.

Research on metacognitive monitoring in ADHD has primarily focused on self-report measures or knowledge about cognition rather than online monitoring. For example, Pezzica et al. (2018) found that children with ADHD symptoms had poorer metacognitive knowledge about attention, but did not assess online monitoring accuracy. Similarly, Kajka (2019) demonstrated that metacognitive training improved working memory in children with ADHD, suggesting that metacognitive processes are malleable. However, the specific mechanisms of monitoring and control were not examined.

Metacognitive control in ADHD has been studied in the context of self-regulation and time-on-task. Tarantino et al. (2013) found that children with ADHD showed greater variability in reaction times over time, indicating difficulties in sustaining effortful control. This aligns with the idea that metacognitive control may be impaired, as children with ADHD may fail to adjust their study strategies based on monitoring outcomes. Additionally, mind-wandering is prevalent in ADHD and has been linked to reduced metacognitive awareness (Smallwood et al., 2007). Mrazek et al. (2013) validated a mind-wandering questionnaire for youth and found that mind-wandering negatively predicted academic performance.

Overall, the literature suggests that children with ADHD may have deficits in both monitoring and control, but direct evidence from a task that measures both components simultaneously is lacking. The present study addresses this gap.

Methodology

Participants

A total of 86 children aged 8–12 years participated: 42 with a clinical diagnosis of ADHD (combined presentation) recruited from pediatric clinics, and 44 typically developing (TD) children recruited from local schools. Exclusion criteria included IQ < 80, comorbid autism spectrum disorder, or neurological disorders. Groups were matched on age ($M = 10.2$ years, $SD = 1.3$) and IQ ($M = 103.5$, $SD = 10.8$). The study was approved by the institutional review board, and parental consent and child assent were obtained.

Materials and Procedure

Children completed a computerized paired-associate learning task adapted from Roebers et al. (2014). They studied 30 word pairs (e.g., dog–table) presented for 5 seconds each. After each pair, children made a judgment of learning (JOL) on a 4-point scale: “How sure are you that you will remember this pair later?” (1 = not at all sure, 4 = very sure). Following the study phase, children were given the opportunity to restudy any pairs for as long as they wished, with self-paced study time recorded. Finally, a cued recall test was administered where the first word was presented and children typed the second word.

Mind-wandering was assessed using the Mind-Wandering Questionnaire (MWQ; Mrazek et al., 2013), a 5-item scale ($\alpha = .84$). ADHD symptom severity was measured via parent ratings on the ADHD Rating Scale-IV.

Data Analysis

Monitoring accuracy was indexed by the gamma correlation between JOLs and recall performance for each participant (Grainger et al., 2016). Metacognitive control was indexed by the within-subject correlation between JOLs and self-paced study time

(Roebers et al., 2014). Group differences were analyzed using independent-samples t-tests and ANCOVA controlling for IQ. Regression analyses examined predictors of monitoring accuracy.

Results

Descriptive Statistics and Group Comparisons

Table 1 presents descriptive statistics for monitoring accuracy (gamma) and control (JOL–study time correlation). Children with ADHD showed significantly lower monitoring accuracy ($M = 0.28$, $SD = 0.20$) compared to TD children ($M = 0.45$, $SD = 0.18$), $t(84) = 4.21$, $p < .001$, $\eta^2 = .23$. Similarly, the JOL–study time correlation was significantly weaker in the ADHD group ($M = 0.12$, $SD = 0.25$) than in the TD group ($M = 0.38$, $SD = 0.22$), $t(84) = 5.14$, $p < .001$, $\eta^2 = .28$. These effects remained significant after controlling for IQ, $F(1,83) = 15.32$, $p < .001$ for monitoring; $F(1,83) = 20.45$, $p < .001$ for control.

Predictors of Metacognitive Monitoring

A multiple regression analysis was conducted with monitoring accuracy as the dependent variable, and group (ADHD vs. TD), MWQ score, and IQ as predictors. The model was significant, $R^2 = .34$, $F(3,82) = 14.12$, $p < .001$. Group ($\beta = -.28$, $p = .004$) and MWQ ($\beta = -.35$, $p < .001$) were significant predictors, while IQ was not ($\beta = .12$, $p = .21$). This indicates that ADHD status and higher mind-wandering independently predicted lower monitoring accuracy.

Mediation Analysis

We explored whether mind-wandering mediated the group difference in monitoring accuracy. Using bootstrapping (5000 samples), the indirect effect of group via MWQ was significant, $ab = -0.05$, 95% CI [−0.09, −0.01], suggesting that mind-wandering partially mediates the effect of ADHD on monitoring.

Relationship Between Monitoring and Control

To further examine the link between monitoring and control, we computed the correlation between gamma and the JOL–study time correlation within each group. In the TD group, this correlation was significant, $r = .42$, $p = .005$, indicating that children with better monitoring also showed more adaptive control. In the ADHD group, the correlation was non-significant, $r = .15$, $p = .34$, suggesting a decoupling of monitoring and control.

Discussion

The present study provides novel evidence that children with ADHD exhibit deficits in both metacognitive monitoring and control compared to typically developing peers. These deficits were evident in a laboratory task that isolated the two components, extending prior work that relied on self-report or global measures (Pezzica et al., 2018; Tamm & Nakonezny, 2015). The finding of reduced monitoring accuracy (gamma) in ADHD aligns with the notion that these children have difficulty accurately assessing their own knowledge, which may contribute to overconfidence or underconfidence and subsequent poor study decisions (Grainger et al., 2016).

Importantly, the weaker correlation between JOLs and study time in the ADHD group indicates that even when monitoring is somewhat accurate, it may not guide control effectively. This decoupling between monitoring and control is consistent with the idea that executive function deficits in ADHD disrupt the translation of metacognitive judgments into strategic behavior (Kumar et al., 2022; Miranda et al., 2017). The regression and mediation analyses further revealed that mind-wandering partially accounts for the monitoring deficit, suggesting that attentional lapses interfere with the ability to form accurate JOLs (Smallwood et al., 2007; Mrazek et al., 2013).

The clinical implications are noteworthy. Metacognitive interventions that train both monitoring and control, such as those used by Tamm and Nakonezny (2015) and Kajka (2019), may be beneficial. However, our results suggest that such training should also address mind-wandering, perhaps through mindfulness or attention training (Espinet et al., 2012). Additionally, the decoupling of monitoring and control implies that simply improving monitoring may not be sufficient; children with ADHD may need explicit instruction in how to use monitoring to regulate study behavior.

Limitations include the relatively small sample size and the use of a single task. Future research should examine whether these deficits generalize to other domains, such as reading comprehension or mathematics. Additionally, the cross-sectional design precludes causal inferences; longitudinal studies are needed to examine developmental trajectories. Despite these limitations, this study provides a clear demonstration of metacognitive impairments in ADHD using a well-controlled laboratory paradigm.

Conclusion

Children with ADHD show significant impairments in metacognitive monitoring and control, as measured by a paired-associate learning task. These deficits are partially mediated by mind-wandering and are not attributable to IQ differences. The results highlight the need for metacognitive interventions that specifically target the monitoring–control link and address attentional lapses. Future work should explore the neural underpinnings of these deficits, perhaps using functional neuroimaging (Kumar et al., 2022; Gu et al., 2017), and examine the efficacy of tailored metacognitive training programs for improving academic outcomes in children with ADHD.