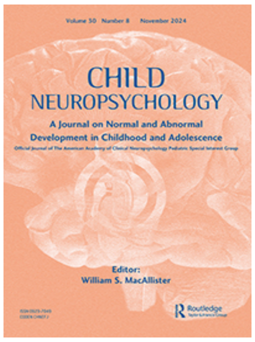

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Unraveling the relationship between executive function and mind wandering in childhood ADHD

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ABSTRACT

Attention Deficit/Hyperactivity Disorder (ADHD) is one of the most prevalent neurodevelopmental disorders in children. According to developmental literature findings, there is a link between executive function (EF) and ADHD. Although EF deficits vary across ADHD presentations in children, working memory capacity is commonly associated with attention impairments. Notably, deficits in working memory capacity are also observed in frequent mind wandering reports for typically developing children. Mind wandering is shifting attention away from a current task to an unrelated thought. To explore the relationship between EF and mind wandering in children with ADHD (n = 47) and further compare our current sample to a typically developing (control) group from a previous study (n = 47), all participants completed three EF-related tasks. They concurrently reported if they were on task or mind wandering. Our results indicate better short-term memory capacity predicted lower mind wandering frequency in children who reported high levels of ADHD symptoms. Similar trends were observed for working memory capacity and ADHD symptomatology. Children with ADHD also reported more overall and unintentional mind wandering on questionnaires compared to children without ADHD. However, the relationship between EF and mind wandering did not differ between these groups. The current study suggests memory-related cognitive abilities may inform our understanding and management of mind wandering in children, driving the development of interventions targeting attention regulation.

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ADHD; executive function; mind wandering; attention regulation; children

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental diagnosis, defined by high levels of inattention, hyperactivity, and impulsiveness. Affecting approximately 7.6% of school-aged children (see Salari et al., 2023 for a review), ADHD is commonly associated with negative impacts on individuals' physical and mental health, including co-occurring with depression (Chang et al., 2016) and suicide (Septier et al., 2019). ADHD presentations include: (1) predominantly inattentive; (2) predominantly hyperactive-impulsive; and (3) combined type (Boshomane et al., 2021). Although some

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studies indicate that children with combined presentations have more severe executive function (EF) deficits than those with a predominantly inattentive presentation, other studies suggest no significant differences between these two subgroups (Geurts et al., 2005; Saydam et al., 2015). Both EF and ADHD have been associated with mind wandering in adults (McVay & Kane, 2012; Seli et al., 2015), characterized by a shift of attention away from a current task toward a task-unrelated thought (Smallwood & Schooler, 2015). However, how the constructs of EF and mind wandering relate to pediatric ADHD remains unexplored.

EF comprises complex cognitive processes that support behavior and emotion regulation, goal setting, problem solving, and attentional focus; many children with ADHD struggle with these skills (Barkley, 1997). The domains commonly recognized as the three primary facets of EF (Miyake et al., 2000) include: (1) *inhibitory control*, which is responsible for self-regulation and controlling prepotent responses (i.e., the ability to control or withhold automatic or recurrent actions); (2) *working memory capacity*, which involves the temporary retention and manipulation of information; and (3) *task switching*, which includes the ability to shift between rules, tasks, or mental processes. In addition to the three core facets, a cognitive domain closely related to working memory capacity is *short-term memory capacity* (Dovis et al., 2013), which refers to the amount of information that can be stored without any active manipulation involved. According to many studies, EF skills can predict children's educational, cognitive, emotional, and social success (Best et al., 2009, 2011; Gerst et al., 2017; Peng et al., 2018). Therefore, better recognition and understanding of the EF facets impaired in children with ADHD is crucial for their development.

Children with ADHD tend to demonstrate poor response inhibition (Barkley, 1997) and task switching failures (e.g., difficulties switching between stimuli or instruction sets; Boshomane et al., 2021). However, the consistency of these findings varies across studies (Kofler et al., 2018; see Willcutt et al., 2005 for a review). Despite EF deficits demonstrating heterogeneity across ADHD presentations (Roberts et al., 2017), working memory impairments are commonly observed in children (Karalunas et al., 2017; Kofler et al., 2018). For instance, parents and teachers of children with working memory deficits report higher levels of attention and hyperactivity/impulsivity problems compared to parents and teachers of children without working memory impairments (Kofler et al., 2018). Similarly, performance on tasks that require short-term memory is worse for children with ADHD as opposed to those without ADHD (Dovis et al., 2013). Given the close nature of short-term and working memory capacity, challenges with one domain may contribute to issues in the other (Dovis et al., 2013).

Notably, reduced working memory capabilities in typically developing children are also linked with frequent mind wandering (Hasan et al., 2024). On average, children spend 20–50% of their waking life engaged in mind wandering (Cherry et al., 2022; Keulers & Jonkman, 2019; Ye et al., 2014; Zhang et al., 2015). While mind wandering can lead to decreased task performance (see Randall et al., 2014 for a review) or reduced affective well-being (see Kam et al., 2024 for a review), it can also positively impact an individual's creativity in problem-solving (Baird et al., 2012). With a growing interest in understanding the occurrence of mind wandering, researchers have proposed a theoretical link between EF and mind wandering in adults (Kam & Handy, 2014; Levinson et al., 2012; McVay & Kane, 2012), and studies have begun examining the relationship in children (Hasan et al., 2024; Keulers & Jonkman, 2019).

In typically developing children, Hasan et al. (2024) found that greater working memory capacity was associated with a decrease in mind wandering frequency for 12-year-olds but not 8- to 11-year-olds. However, Keulers and Jonkman (2019) identified no advantage of a better working memory capacity on children's (aged 9 to 11) mind wandering frequency. Unlike Hasan et al. (2024), they found enhanced performance on tasks measuring inhibitory control and task switching predicted lower mind wandering reports. One plausible explanation for the differences is the settings in which the results were obtained. Hasan et al.'s (2024) study occurred remotely using computerized tasks, whereas Keulers and Jonkman (2019) found poorer inhibitory control predicted higher mind wandering frequency during a classroom lesson. Although the contrasting findings may further be credited to the use of different EF tasks and levels of difficulty of each task, the disparities suggest a nuanced relationship between EF and mind wandering during development.

To date, the two child studies that examined EF and mind wandering have done so in a typically developing population. Therefore, it is unclear whether there is an underlying relationship between EF and mind wandering in childhood ADHD. Prior literature indicates that individuals with ADHD are not only susceptible to external distractors (e.g., loud environments), but also internal distractions, such as mind wandering (Merrill et al., 2022; see Lanier et al., 2021 for a review; Van den Driessche et al., 2017). A commonly studied feature is the intentionality of mind wandering (i.e., intentional versus unintentional) and its link to ADHD. *Intentional mind wandering* refers to deliberately engaging in thoughts unrelated to a task at hand. An intentional shift of attention suggests controlled processing (Carriere et al., 2013) and has not been associated with ADHD (Seli et al., 2015). On the other hand, *unintentional mind wandering* refers to task-unrelated thoughts that occur spontaneously (i.e., without intention) and is typically correlated with ADHD (see Lanier et al., 2021 for a review; Seli et al., 2015). Excessive or unintentional mind wandering and ADHD share common behavioral symptoms, including poor sustained attention (see Randall et al., 2014 for a review; Seli et al., 2013) and hyperactivity (Seli et al., 2013). Additionally, disruption of executive control, particularly working memory, is reflected in both ADHD and mind wandering (Kofler et al., 2018; McVay & Kane, 2012).

Therefore, the current study primarily aimed to investigate the link between EF and mind wandering in the context of pediatric ADHD and understand how symptom severity contributes to this relationship. Our secondary aim was to compare our clinical sample to a typically developing (control) sample from a previous study (Hasan et al., 2024). Given the exploratory nature of our study, we hypothesized there is a relationship between EF and mind wandering in childhood ADHD but made no specific predictions for each of the EF facets. With a high prevalence rate of ADHD diagnosis in recent years (see Salari et al., 2023 for a review), clarifying the link between EF and mind wandering may help improve interventions targeting attention dysregulation associated with ADHD.

Method

Participants

Forty-eight participants (14 females), aged 8 to 12 (M_{age} = 9.98, SD = 1.36), were recruited from Calgary, Canada and the surrounding community. Study advertisement was done through social media (e.g., Facebook), ACCESS Mental Health list, and the Owerko Neurodevelopmental Research Recruitment Database. The latter two contain contact information of families who have previously agreed to be contacted for research studies. All invited participants were (1) between the ages 8 to 12 years with a formal ADHD diagnosis; (2) able to understand spoken and written English; and (3) had no other neurodevelopmental or neurologic conditions (e.g., autism, epilepsy, intellectual disabilities, fetal alcohol spectrum disorder, or genetic conditions linked to neuro-developmental impairment). Children with specific learning disorders (e.g., dyslexia) were not excluded. For both the inclusionary and exclusionary conditions, all information on a child's diagnoses were self-reported by legal guardians as conferred by a medical professional. The study was approved by the Conjoint Health Research Ethics Board. As an honorarium, all participants received an e-gift card.

To address our secondary aim, we also included data from our previous study as a control sample. Of the 100 children in the previous study, 47 participants (18 females; M_{age} = 9.98, SD = 1.36) were age- and sex-matched to the clinical sample. While we successfully age-matched the two groups, sex-matching was imbalanced. Therefore, to ensure our two groups did not differ based on demographics, we conducted statistical tests and found no significant group differences in age ($t(92) = 0.00$, $p = 1.000$) nor sex (X^2 $(1) = 0.75$, $p = .387$). In all subsequent analyses, age and sex were included as covariates. All participant information for our ADHD and typically developing sample is reported in Table 1. Demographic information for each group as divided by age is reported in Supplementary Tables S1 and S2.

Procedure

Preceding the main session, a legal guardian provided written informed consent and completed two questionnaires regarding their child's behavior: a modified version of the Mind Wandering Questionnaire (MWQ; Mrazek et al., 2013) and the Swanson, Nolan,

Table 1. Demographic information for ADHD and typically developing participants.

		ADHD Participants	Typically Developing Participants
Age	Mean	9.98	9.98
	SD	1.36	1.36
Sex (%)	Male	70	62
	Female	30	38
Ethnicity[a] (%)	White or European Canadian	68	60
Guardian Education[b] (%)	Post-secondary (university/college/trade)	60	89

Although not all possible demographic options are detailed in our table, no participants were excluded from the main analyses based on their demographic characteristics.

[a]Other ethnicities that characterize the rest of our participants include Black or African Canadian, Hispanic, Indigenous, South Asian, Southeast Asian, Middle Eastern, and Pacific Islanders and/or Indigenous persons of Hawaii.

[b]Guardian Education is calculated as the average level of education between two primary legal guardians, if both are available. At least one guardian must have completed post-secondary or professional education for that information to be included in this table.

and Pelham-IV 26-Item ADHD symptoms rating scale (SNAP-IV-26; Swanson et al., 2001). Data collection occurred online over video conferencing (i.e., Zoom). An experimenter moderated each session and explained all the on-screen instructions to participants, further ensuring their understanding of the tasks. To reduce distractions for the participants, the experimenter turned off their camera during the completion of each task. The overall procedure was identical to our previous study (Hasan et al., 2024), except for two additional questionnaires assessing ADHD symptoms implemented in the current study.

At the start of each session, after child participants provided verbal assent, they received pictographic definitions and answered comprehension questions on mind wandering and its subtypes (i.e., intentional and unintentional mind wandering) to demonstrate their understanding of the concepts (see Hasan et al., 2024 for full instructions). All participants completed three counterbalanced EF tasks and four questionnaires (verbally administered by an experimenter). Three of the completed questionnaires assessed mind wandering in daily life (MWQ; Mrazek et al., 2013; Mind Excessively Wandering Scale [MEWS]; Mowlem et al., 2019; and Mind Wandering: Deliberate and Spontaneous Scales [MW-D and MW-S]; Carriere et al., 2013), with one scale assessing inattention and hyperactivity/impulsivity behavior (Behavior Assessment System for Children-3 [BASC-3]; Reynolds & Kamphaus, 2015).

Executive function tasks

Based on our previous study examining EF and mind wandering in typically developing children, the current study implemented the same child-friendly tasks programmed using Gorilla Experiment Builder (www.gorilla.sc; Anwyl-Irvine et al., 2020): the Flanker task, measuring inhibitory control; digit span task, measuring short-term memory capacity and working memory capacity; and a color-shape switch task, measuring task switching. Similar to previous studies (Hasan et al., 2024; Keulers & Jonkman, 2019), our main outcome measure was accuracy. We report all reaction time (RT) results in the Supplementary Materials (Supplementary Tables S3–S6).

Flanker task (inhibitory control)

A center target (blue fish facing left or right) was flanked by four identical fish facing the same (i.e., congruent) or opposite (i.e., incongruent) direction. Participants were asked to focus solely on the center fish and press the corresponding computer key that matched the direction the target was facing. Participants completed 197 trials, with the likelihood of congruent and incongruent trials being equally probable and randomly distributed throughout the task. At the start of the trial, a fixation cross appeared for 600 to 800 ms (M = 700 ms). All five fish were displayed on a white background for 2300 ms, during which time participants responded. On average, each trial lasted 3000 ms. Our main outcome measure was inhibitory control as demonstrated by the difference in accuracy (and RT in the Supplementary Materials) between the congruent and incongruent trials. For instance, a larger positive difference score (i.e., higher accuracy for incongruent trials relative to congruent trials) would indicate better inhibitory control.

Digit span task (short-term memory capacity and working memory capacity)

A series of digits appeared on a white background at a rate of one number every 1000 ms, followed by an 850 ms pause between each number and a 10,000 ms response window. Participants were tasked with typing out the numbers in the forward order during the first half of the task and backwards order during the last half of the task. Digit span task began with a sequence length of two digits, increasing by one number after at least one correct response for each sequence. The task ended once two trials for the same sequence length were recalled incorrectly. The forward condition relied on retaining all presented numbers for a short period of time, and thus measured short-term memory capacity. In contrast, the backwards condition was considered an index of working memory capacity as it required the manipulation of information in the participant's mind (Lui & Tannock, 2007; Oberauer et al., 2000; St Clair-Thompson, 2010).

Color-shape switch task (task switching)

In counterbalanced order, participants first learned one instruction set at a time; they either reported the shape or the color of an object. Both shape and color conditions included 49 trials each, with every trial displaying a fixation cross for 700 to 900 ms (M = 800 ms). All stimuli were presented on a white background for 2200 ms, in which time participant responses were recorded. The shape and color conditions were counterbalanced and served to familiarize participants with the task before introducing the mixed condition. In the mixed condition, which included 99 trials, participants saw the instructional cue word "SHAPE" or "COLOR" for 500 ms, before reporting on the shape or the color of an object within 2000 ms. Each trial began with a fixation cross for 400 to 600 ms (M = 500 ms) and lasted approximately 3000 ms. In a switch trial, participants changed from following one instruction set to another (e.g., a shape trial followed by a color trial). In a non-switch trial, participants received the same instruction set as the previous trial (e.g., a shape trial followed by another shape trial). We computed the difference in accuracy (and RT in the Supplementary Materials) for the switch and non-switch trials within the mixed condition.

Experience sampling

Experience sampling is a commonly used and validated methodological approach in capturing occurrences of mind wandering in both adults (Kam & Handy, 2014; Kruger et al., 2021; Smallwood & Schooler, 2006) and children (Cherry et al., 2022; Keulers & Jonkman, 2019). During each task, thought probes were presented between trials at intervals of 40 to 60 seconds in order to reduce predictability. Each thought probe asked participants to report whether their attention was on task or if they were mind wandering. Based on the previous study's design and unintentional mind wandering's link to ADHD (see Lanier et al., 2021 for a review; Seli et al., 2015), when children reported mind wandering, they were further asked whether it was intentional or unintentional.

We included 12 thought probes in the Flanker and color-shape switch tasks. Given that the digit span task terminated if participants incorrectly recalled two sequences of the same span length, the number of thought probes participants answered was contingent upon their performance and ability to recall a given sequence. We report the average number of thought probes completed by each age group in our sample, starting with the forward digit span condition: 8-year-olds (M = 9.25, SD = 0.99, n = 8), 9-year-olds (M = 11.27, SD = 2.16,

n = 11), 10-year-olds (M = 9.80, SD = 2.91, n = 10), 11-year-olds (M = 9.20, SD = 2.67, n = 10), and 12-year-olds (M = 10.00, SD = 3.16, n = 8). The average number of thought probes completed for the backwards digit span condition in each age group was as follows: 8-year-olds (M = 7.38, SD = 2.08, n = 8), 9-year-olds (M = 10.55, SD = 2.73, n = 11), 10-year-olds (M = 8.70, SD = 2.76, n = 10), 11-year-olds (M = 6.90, SD = 3.08, n = 10), and 12-year-olds (M = 10.38, SD = 2.79, n = 8). Our main outcome measure was the percentage of reported mind wandering frequency for each task.

Perceived task difficulty rating

At the end of every task, participants reported the perceived task difficulty level on a 7-point Likert scale: 1 (extremely easy) to 7 (extremely difficult). Since previous child and adult studies indicated mind wandering frequency was influenced by task difficulty (Hasan et al., 2024; Seli et al., 2018), we also assessed perceived task difficulty in our study. However, given that perceived difficulty of a task displayed moderate to high correlations with task accuracy/capacity in our study, we did not include task difficulty in our analyses reported here. For the purpose of comparison with past findings (Hasan et al., 2024), we report the models including task difficulty as a covariate in the Supplementary Materials (Supplementary Tables S7–S10).

Questionnaires

Mind Wandering Questionnaire (MWQ)

The Mind Wandering Questionnaire (MWQ) evaluates the frequency of daily mind wandering based on five self-reported items on a 6-point Likert scale: 1 (almost never) to 6 (almost always; Mrazek et al., 2013). We computed the mean score across all five items for MWQ. Although previous studies with adolescents and adults showed adequate internal consistency (Cronbach's alpha = .85; Mrazek et al., 2013), we verbally modified some of the items to fit our younger sample's understanding (see Supplementary Materials). To gauge the relationship between a child's self-report and their guardian's report, a legal guardian also completed a modified version of the questionnaire (MWQg), evaluating their child's mind wandering tendencies (see Supplementary Materials for revised wording).

Mind Excessively Wandering Scale (MEWS)

The Mind Excessively Wandering Scale (MEWS) explores mind wandering based on 12 self-reported items, rated on a 4-point Likert scale: 0 (not at all or rarely) to 3 (nearly all of the time or constantly; Mowlem et al., 2019). We modified item 7 ("I experience ceaseless mental activity" to "I feel my brain is constantly running") to ensure children's full understanding (as done by Frick et al., 2020). We calculated the mean score for all items. The MEWS displayed adequate internal consistency in a pediatric sample of 8- to 13-year-olds (Cronbach's alpha = .80; Frick et al., 2020).

Mind Wandering: Deliberate and Spontaneous Scales (MW-D and MW-S)

The Mind Wandering: Deliberate and Spontaneous Scales (MW-D and MW-S) assess an individual's tendency to engage in intentional or unintentional mind wandering with eight self-reported items, rated on multiple 7-point Likert scales: 1 (rarely; not at all true;

almost never) to 7 (a lot; very true; almost always; Carriere et al., 2013). We computed the mean score across all items. The scales demonstrated adequate internal consistency for adult participants (Cronbach's alpha = .84 for MW-D, .86 for MW-S; Carriere et al., 2013). To align with the definitions participants received at the beginning of the session, all references to "deliberate" and "spontaneous" mind wandering in the questionnaires were verbally adapted to "intentional" and "unintentional" mind wandering, respectively.

Swanson, Nolan, and Pelham-IV 26-Item (SNAP-IV-26)

The Swanson, Nolan, and Pelham-IV 26-Item (SNAP-IV-26) scale measures the severity of inattention, hyperactivity/impulsivity, and opposition symptoms based on 26 guardian-reported items, rated on a 4-point Likert scale: 0 (not at all) to 3 (very much; Swanson et al., 2001). We calculated the mean score across all items for the questionnaire. Inattention and hyperactivity/impulsivity were evaluated by nine items each, where an additional eight items measured opposition symptoms. The SNAP-IV-26 demonstrated high internal consistency for a previous study (Cronbach's alpha = .94; Bussing et al., 2008).

Behavior Assessment System for Children-3 (BASC-3)

The Behavior Assessment System for Children-3 (BASC-3) comprises 16 primary scales, but we focused on the inattention and hyperactivity/impulsivity subscales (Reynolds & Kamphaus, 2015). Participants answered 17 self-reported items using a true-false format or a 4-point Likert scale: never to almost always. Total raw scores were converted to scaled (age-normative) *t*-scores. The BASC has previously displayed high internal consistency (Cronbach's alpha = .89 to .95; Reynolds & Kamphaus, 2015).

Statistical analyses

Preliminary analyses

We examined group differences between children with ADHD taking medication and those that were not via a *t*-test. Additionally, all correlation analyses for questionnaires and EF tasks were conducted within the ADHD sample using the Spearman correlation coefficient.

Primary analyses

For our primary aim, we first implemented linear regression analyses for each EF task, with accuracy/capacity and RT entered as separate predictors to evaluate how performance influenced the frequency of mind wandering specific to that task (i.e., the outcome variable). Furthermore, we included both the forward and backwards conditions of the digit span task as separate predictors, resulting in a total of eight regressions (four for accuracy/capacity reported below, and four for RT reported in the supplementary tables). To investigate how ADHD symptoms influenced the relationship between EF and mind wandering, we included one BASC subscale at a time (inattention and hyperactivity/impulsivity) as an additional predictor to the above regressions and also examined its interaction with each task in predicting mind wandering frequency.

Our secondary aim explored the differences in EF and mind wandering for children with and without ADHD through linear regressions. When specifically analyzing EF accuracy/capacity or RT, the outcome variable was the mind wandering reported for that task, similar to our primary aim. However, we observed a significant correlation between mind wandering frequency across all tasks (Table 2). Therefore, we derived a composite measure of mind wandering averaged across the three tasks to examine overall group differences for our clinical and typically developing samples. We also assessed mind wandering frequency as reported by all questionnaires in common across the two studies: MWQ, MW-D, and MW-S. For all analyses, age and sex served as covariates. Analyses were performed using R (version 4.3.2) in R Studio (version 2024.10.25; RStudio Team, 2024).

Results

The final clinical sample included 47 participants, excluding one participant with missing data due to technical difficulties. We first implemented a *t*-test to compare composite mind wandering frequency during tasks in children with ADHD when grouped by medication status (i.e., yes or no) and found no significant differences ($t(45) = 0.37$, $p = .714$). Accordingly, for subsequent analyses, all children with ADHD, regardless of whether they were on or off medication, were collapsed into one group. In Table 2, we present correlation values for our ADHD sample, age, mind wandering as evaluated by questionnaires and experience sampling during EF tasks, and ADHD symptoms as measured by questionnaires. There was a positive correlation between age and the child-reported MWQ ($p = .008$), MW-D ($p = .020$), and MEWS ($p = .048$), suggesting that older children with ADHD reported more frequent mind wandering across the three measures in daily life compared to younger children with ADHD. Additionally, all child-reported mind wandering scales were significantly correlated (all $p < .050$). Apart from the MW-D scale ($p = .092$), all child-reported mind wandering scales further correlated with the BASC self-report subscales (all $p < .050$). Although the guardian reported measures (i.e., MWQ and SNAP-IV-26) were positively correlated ($p < .001$), they did not correlate with their respective child's self-reported mind wandering tendencies as measured by the questionnaires and during the EF tasks, or self-reported behavioral ADHD symptoms (all $p \geq .151$). To further evaluate differences in guardian- and child-reported questionnaires, we examined the mean ratings on the MWQ and found that guardians ($M = 4.16$, $SD = .98$) reported higher levels of mind wandering compared to their child's report ($M = 3.42$, $SD = 1.21$).

EF and mind wandering in childhood ADHD

We conducted two sets of analyses to explore our primary aim of evaluating the relationship between EF and mind wandering in children with ADHD. First, linear regressions examined the overall relationship between task accuracy/capacity and mind wandering frequency during that specific task, with age and sex as covariates (Table 3). We found that accuracy and capacity was not significantly associated with mind wandering for any EF tasks (all $p \geq .109$). Additionally, age and sex were not significantly linked to mind wandering for any tasks (all $p \geq .063$).

To evaluate the influence of symptom severity, we examined the interaction between EF task performance and ADHD symptoms (measured via BASC – inattention [BASC-IA] and – hyperactivity/impulsivity [BASC-HI] subscales) in predicting

Table 2. Spearman correlations between age, mind wandering, and ADHD symptoms.

	Age	MWQc	MWQg	MEWS	MW-D	MW-S	BASC-IA	BASC-HI	SNAP-IV-26	Task – MW	Flanker- MW	FDS – MW	BDS – MW	Switch – MW
Age	–													
MWQc	.39*	–												
MWQg	−.03	.00	–											
MEWS	.29*	.54**	−.14	–										
MW-D	.34*	.42*	−.03	.46*	–									
MW-S	.26	.62**	.00	.66**	.48**	–								
BASC-IA	.04	.48*	.04	.47*	.21	.43*	–							
BASC-HI	.43*	.39*	−.06	.55**	.25	.48*	.48*	–						
SNAP-IV-26	.04	.06	.64**	−.07	.09	.11	.04	−.05	–					
Task – MW	.28	.49*	−.21	.48*	.45*	.41*	.29*	.45*	−.08	–				
Flanker – MW	.23	.27	−.20	.45*	.37*	.29*	.10	.38*	−.09	.88**	–			
FDS – MW	.14	.40*	−.04	.36*	.20	.26	.35*	.45*	−.03	.70**	.59**	–		
BDS – MW	.09	.46*	.09	.20	.31*	.33*	.34*	.24	.27	.75**	.61**	.72**	–	
Switch – MW	.28	.45*	−.21	.44*	.42*	.42*	.31*	.44*	−.11	.92**	.73**	.51**	.58**	–

MWQc = Mind Wandering Questionnaire (child), max. range = 1–6; MWQg = Mind Wandering Questionnaire (guardian), max. range = 1–6; MEWS = Mind Excessively Wandering Scale (child), max. range = 0–3; MW-D = Mind Wandering: Deliberate (child), max. range = 1–7; MW-S = Mind Wandering: Spontaneous (child), max. range = 1–7; BASC-IA = Behavior Assessment System for Children – Inattention (child); BASC-HI = Behavior Assessment System for Children – Hyperactivity/Impulsivity (child); SNAP-IV-26 = Swanson, Nolan and Pelham-IV 26-Item (guardian), max. range = 0–3; Task – MW refers to an overall composite frequency of mind wandering across all three EF tasks.

MW = mind wandering frequency during executive function tasks; FDS = Forward Digit Span task; BDS = Backward Digit Span task.

*$p < .05$; **$p < .001$.

Table 3. Executive function task performance (accuracy/capacity) predicting mind wandering.

	β	*SE*	95% *CI* [*LB, UB*]	p_β	*F*	p_F	R^2
Flanker (Inhibitory control)					1.19	.323	.01
Accuracy	−0.01	0.04	[−0.09, 0.06]	.724			
Age	0.03	0.03	[−0.02, 0.09]	.231			
Sex	0.10	0.08	[−0.05, 0.26]	.188			
Forward digit span (Short-term memory capacity)					1.25	.302	.02
Capacity	−0.06	0.04	[−0.14, 0.01]	.109			
Age	0.01	0.03	[−0.04, 0.07]	.607			
Sex	0.01	0.08	[−0.15, 0.18]	.859			
Backward digit span (Working memory capacity)					0.94	.430	−.00
Capacity	−0.04	0.03	[−0.10, 0.03]	.243			
Age	0.00	0.02	[−0.04, 0.04]	.987			
Sex	0.07	0.07	[−0.07, 0.20]	.315			
Switch (Task switching)					2.68	.059	.10
Accuracy	0.04	0.03	[−0.02, 0.11]	.182			
Age	0.04	0.02	[−0.00, 0.09]	.063			
Sex	0.12	0.07	[−0.02, 0.25]	.087			

The dependent variable was the mean mind wandering frequency during a given task. For the forward and backward digit span task, the average percentage of mind wandering for each condition served as the dependent variable in the respective models. For Flanker and switch, accuracy was the difference in correct responses between incongruent and congruent trials, or switch and non-switch trials.

β = standardized regression coefficient; *SE* = standard error of the mean; 95% *CI* = confidence intervals; *LB* = lower bound; *UB* = upper bound; p_β = *p*-value associated with the standardized coefficient; p_{F} = *p*-value associated with the *F* test. R^2 = value associated with its corresponding model.

mind wandering, with age and sex as covariates (as reported in Tables 4 and 5, respectively). There was a significant main effect of inattention, such that BASC-IA positively predicted mind wandering, for the short-term (p = .008) and working (p = .018) memory capacity models but not the inhibitory control (p = .214) or task switching (p = .100) models. Moreover, the interaction between short-term memory capacity and inattention symptoms significantly predicted task mind wandering (p = .016). In our follow-up analyses, participants were stratified into two subsets: those scoring above the median on BASC-IA were assigned to the high inattention group, with those scoring below the median being assigned to the low inattention group. In the high inattention group, greater short-term memory capacity predicted less mind wandering (b = −0.17, SE = 0.07, p = .020), whereas in the low inattention group, it did not (b = 0.02, SE = 0.02, p = .193). Similarly, the interaction between working memory capacity and inattention symptoms significantly predicted task mind wandering (p = .041). After conducting the same follow-up analyses as described for short-term memory capacity, we observed a trend toward enhanced working memory capacity and reduced mind wandering in the high inattention group (b = −0.08, SE = 0.05, p = .092) but not the low inattention group (b = 0.03, SE = 0.03, p = .361). The interaction effects for inhibitory control (p = .586) and task switching (p = .296) were not significant. As well, age and sex were not significant in any of the models (all $p \geq .105$).

In the interaction models examining EF and hyperactivity/impulsivity, there was a main effect of BASC-HI in positively predicting mind wandering for inhibitory control (p = .006), short-term memory capacity (p = .047), and task switching (p = .003) but not working memory capacity (p = .110). We further found that short-term memory capacity significantly interacted with hyperactivity/impulsivity symptoms in predicting decreased mind wandering

Table 4. Executive function task performance (accuracy/capacity) and ADHD symptoms (BASC-inattention subscale) predicting mind wandering.

	β	*SE*	95% *CI* [*LB, UB*]	p_β	*F*	p_F	R^2
Flanker (Inhibitory control)					1.10	.374	.01
Accuracy	−0.07	0.09	[−0.26, 0.11]	.436			
BASC-IA	0.11	0.08	[−0.06, 0.28]	.214			
Age	0.03	0.03	[−0.02, 0.09]	.244			
Sex	0.09	0.08	[−0.07, 0.25]	.257			
Accuracy x BASC-IA	0.04	0.08	[−0.12, 0.20]	.586			
Forward digit span (Short-term memory capacity)					3.65	.008	.22
Capacity	0.14	0.09	[−0.04, 0.31]	.116			
BASC-IA	0.20	0.07	[0.06, 0.35]	.008			
Age	0.01	0.02	[−0.04, 0.05]	.781			
Sex	−0.00	0.07	[−0.15, 0.15]	.965			
Capacity x BASC-IA	−0.19	0.07	[−0.34, −0.04]	.016			
Backward digit span (Working memory capacity)					2.54	.043	.14
Capacity	0.13	0.08	[−0.03, 0.28]	.111			
BASC-IA	0.16	0.06	[0.03, 0.29]	.018			
Age	−0.01	0.02	[−0.06, 0.03]	.499			
Sex	0.06	0.06	[−0.06, 0.18]	.348			
Capacity x BASC-IA	−0.13	0.06	[−0.26, −0.01]	.041			
Switch (Task switching)					2.28	.065	.12
Accuracy	0.11	0.08	[−0.06, 0.27]	.200			
BASC-IA	0.13	0.08	[−0.03, 0.28]	.100			
Age	0.04	0.02	[−0.01, 0.08]	.105			
Sex	0.09	0.07	[−0.04, 0.23]	.161			
Accuracy x BASC-IA	−0.07	0.07	[−0.21, 0.07]	.296			

The dependent variable was the mean mind wandering frequency during a given task. For the forward and backward digit span task, the average percentage of mind wandering for each condition served as the dependent variable in the respective models. For Flanker and switch, accuracy was the difference in correct responses between incongruent and congruent trials, or switch and non-switch trials.

BASC-IA = BASC-Inattention; β = standardized regression coefficient; *SE* = standard error of the mean; 95% *CI* = confidence intervals; *LB* = lower bound; *UB* = upper bound; p_β = *p*-value associated with the standardized coefficient; p_F = *p*-value associated with the *F* test. R^2 = value associated with its corresponding model.

frequency (p = .007). Follow-up analyses revealed enhanced short-term memory capacity predicted less mind wandering in the high hyperactivity/impulsivity group (b = −0.15, SE = 0.06, p = .028) but not for the low hyperactivity/impulsivity group (b = 0.02, SE = 0.04, p = .637). The interaction between working memory capacity and hyperactivity/impulsivity symptoms also significantly predicted mind wandering (p = .038). Specifically, there was a trend toward better working memory capacity and reduced mind wandering in the high hyperactivity/impulsivity group (b = −0.11, SE = 0.06, p = .078) but not the low hyperactivity/impulsivity group (b = −0.03, SE = 0.03, p = .294). The interaction effects for inhibitory control (p = .928) and task switching (p = .916) were not significant. As well, age and sex were not significant in any of the models (all $p \geq .090$).

After applying the conservative Bonferroni correction for multiple comparisons separately for BASC-IA and -HI subscales, our adjusted critical alpha was .05/4 tasks = .013. Consequently, only our interaction for short-term memory capacity with hyperactivity/impulsivity symptoms remained significant. The interactions between short-term memory and inattention symptoms, as well as working memory capacity and both inattention and hyperactivity/impulsivity symptoms were no longer significant.

Table 5. Executive function task performance (accuracy/capacity) and ADHD symptoms (BASC-hyperactivity/impulsivity subscale) predicting mind wandering.

	β	*SE*	95% *CI* [*LB*, *UB*]	p_β	*F*	p_F	R^2
Flanker (Inhibitory control)					2.59	.040	.15
Accuracy	−0.03	0.07	[−0.17, 0.10]	.639			
BASC-HI	0.19	0.07	[0.06, 0.32]	.006			
Age	0.00	0.03	[−0.05, 0.06]	.964			
Sex	0.10	0.07	[−0.05, 0.25]	.203			
Accuracy x BASC-HI	−0.00	0.05	[−0.10, 0.09]	.928			
Forward digit span (Short-term memory capacity)					4.59	.002	.28
Capacity	0.15	0.08	[−0.01, 0.31]	.062			
BASC-HI	0.13	0.06	[0.00, 0.25]	.047			
Age	−0.01	0.03	[−0.06, 0.04]	.732			
Sex	−0.01	0.07	[−0.16, 0.13]	.879			
Capacity x BASC-HI	−0.16	0.06	[−0.28, −0.05]	.007			
Backward digit span (Working memory capacity)					2.50	.046	.14
Capacity	0.09	0.06	[−0.04, 0.22]	.157			
BASC-HI	0.09	0.05	[−0.02, 0.20]	.110			
Age	−0.02	0.02	[−0.06, 0.03]	.488			
Sex	0.07	0.06	[−0.05, 0.19]	.242			
Capacity x BASC-HI	−0.10	0.05	[−0.19, −0.01]	.038			
Switch (Task switching)					4.09	.004	.25
Accuracy	0.05	0.07	[−0.09, 0.19]	.516			
BASC-HI	0.17	0.05	[0.06, 0.28]	.003			
Age	0.01	0.02	[−0.03, 0.06]	.575			
Sex	0.11	0.06	[−0.02, 0.23]	.090			
Accuracy x BASC-HI	−0.00	0.05	[−0.10, 0.09]	.916			

The dependent variable was the mean mind wandering frequency during a given task. For the forward and backward digit span task, the average percentage of mind wandering for each condition served as the dependent variable in the respective models. For Flanker and switch, accuracy was the difference in correct responses between incongruent and congruent trials, or switch and non-switch trials.

BASC-HI = BASC-Hyperactivity/Impulsivity; *β* = standardized regression coefficient; *SE* = standard error of the mean; 95% *CI* = confidence intervals; *LB* = lower bound; *UB* = upper bound; p_β = *p*-value associated with the standardized coefficient; p_F = *p*-value associated with the *F* test. R^2 = value associated with its corresponding model.

EF and mind wandering in children with and without ADHD

To address our secondary aim, we first compared differences in mind wandering as assessed by experience sampling and questionnaires between the clinical and typically developing samples (Table 6). With age and sex as covariates, the linear regressions yielded significant differences between children with and without ADHD in their self-reports on overall mind wandering via the MWQ ($p < .001$) and unintentional mind wandering as assessed by the MW-S ($p = .024$). In particular, those with ADHD diagnoses reported more overall levels of mind wandering as well as unintentional mind wandering than those without. However, we observed no significant differences between the two groups in the composite task mind wandering measure ($p = .161$) and in their self-reported frequency of intentional mind wandering measured via the MW-D ($p = .116$). Age emerged as a significant predictor of mind wandering frequency in the majority of analyses (all $p \leq .012$), except for intentional mind wandering ($p = .074$). For these analyses, older children tended to report higher mind wandering frequency compared to younger children.

Table 6. Mind wandering frequency between groups (ADHD and typically developing participants), assessed by experience sampling and questionnaires.

	β	*SE*	95% *CI* [*LB, UB*]	p_β	*F*	p_F	R^2
Task MW					3.18	.028	.07
Group	0.05	0.04	[−0.02, 0.12]	.161			
Age	0.03	0.01	[0.01, 0.06]	.012			
Sex	0.04	0.04	[−0.04, 0.11]	.329			
MWQ					11.26	<.001	.25
Group	0.77	0.21	[0.35, 1.19]	<.001			
Age	0.35	0.08	[0.20, 0.50]	<.001			
Sex	0.01	0.22	[−0.43, 0.45]	.968			
MW-D					2.11	.105	.03
Group	0.47	0.30	[−0.12, 1.06]	.116			
Age	0.20	0.11	[−0.02, 0.41]	.074			
Sex	−0.19	0.31	[−0.80, 0.43]	.548			
MW-S					4.64	.005	.11
Group	0.66	0.29	[0.09, 1.24]	.024			
Age	0.31	0.11	[0.10, 0.52]	.005			
Sex	−0.10	0.30	[−0.71, 0.50]	.734			

MW = mind wandering; MWQ = Mind Wandering Questionnaire (children); MW-D = Mind Wandering: Deliberate; MW-S = Mind Wandering: Spontaneous; Task – MW refers to an overall frequency of mind wandering across all three EF tasks.
β = standardized regression coefficient; *SE* = standard error of the mean; 95% *CI* = confidence intervals; *LB* = lower bound; *UB* = upper bound; p_β = *p*-value associated with the standardized coefficient; p_F = *p*-value associated with the *F* test. R^2 = value associated with its corresponding model.

We further implemented linear regressions to assess the task-specific relationship between EF and mind wandering in children with and without ADHD (Table 7). Interactions between the two groups (i.e., children with and without ADHD) and EF task accuracy/capacity revealed no significant relationships in predicting mind wandering frequency for inhibitory control (p = .507), short-term (p = .227) and working (p = .852) memory capacities, or task switching (p = .551). Within the inhibitory control (p = .007) and task switching (p = .005) models, an increase in age significantly corresponded with an increase in mind wandering. In all other models, age and sex were not significant (all $p \geq .222$). In the Supplementary Materials, we report analyses between ADHD symptoms, EF task performance measured via RT, and mind wandering (Supplementary Tables S3– S6).

Discussion

The current study investigated the association between EF and mind wandering in children with ADHD. Although we found no evidence for task performance predicting mind wandering frequency independently, when coupled with higher ADHD symptomatology (as characterized by reports of inattention and hyperactivity/impulsivity symptoms), those with enhanced short-term memory capacity and higher ADHD symptoms reported lower mind wandering. Better working memory capacity demonstrated similar trends for predicting lower mind wandering in those who reported high levels of inattention and hyperactivity/impulsivity. For our comparison across the clinical and control samples, children with ADHD scored higher in their reports of overall and unintentional mind wandering compared to those without ADHD. However, EF task performance and mind wandering frequency was not differentially related between the two groups.

Table 7. Executive function task performance (accuracy/capacity) and groups (ADHD and typically developing participants) predicting mind wandering.

	β	*SE*	95% *CI* [*LB, UB*]	$p_β$	*F*	p_F	R^2
Flanker (Inhibitory control)					1.85	.112	.04
Accuracy	0.02	0.03	[−0.05, 0.08]	.636			
Group	0.03	0.05	[−0.06, 0.12]	.534			
Age	0.05	0.02	[0.01, 0.08]	.007			
Sex	0.05	0.05	[−0.05, 0.15]	.358			
Accuracy x Group	−0.03	0.05	[−0.13, 0.06]	.507			
Forward digit span (Short-term memory capacity)					1.79	.124	.04
Capacity	−0.01	0.03	[−0.07, 0.06]	.818			
Group	0.06	0.04	[−0.02, 0.14]	.136			
Age	0.02	0.02	[−0.01, 0.05]	.284			
Sex	0.01	0.04	[−0.08, 0.09]	.846			
Capacity x Group	−0.05	0.04	[−0.13, 0.03]	.227			
Backward digit span (Working memory capacity)					1.54	.184	.03
Capacity	−0.03	0.03	[−0.08, 0.03]	.375			
Group	0.05	0.03	[−0.02, 0.12]	.129			
Age	0.01	0.01	[−0.01, 0.04]	.272			
Sex	0.04	0.04	[−0.03, 0.12]	.222			
Capacity x Group	−0.01	0.04	[−0.08, 0.07]	.852			
Switch (Task switching)					2.42	.042	.07
Accuracy	0.01	0.03	[−0.06, 0.08]	.777			
Group	0.06	0.04	[−0.03, 0.14]	.181			
Age	0.04	0.02	[0.01, 0.07]	.005			
Sex	0.03	0.04	[−0.06, 0.12]	.471			
Accuracy x Group	0.03	0.04	[−0.06, 0.11]	.551			

The dependent variable was the mean mind wandering frequency during a given task. For the forward and backward digit span task, the average percentage of mind wandering for each condition served as the dependent variable in the respective models. For Flanker and switch, accuracy was the difference in correct responses between incongruent and congruent trials, or switch and non-switch trials.

β = standardized regression coefficient; *SE* = standard error of the mean; 95% *CI* = confidence intervals; *LB* = lower bound; *UB* = upper bound; $p_β$ = *p*-value associated with the standardized coefficient; p_F = *p*-value associated with the *F* test. R^2 = value associated with its corresponding model.

EF and mind wandering in childhood ADHD

Our analyses suggest that no EF was linked to the occurrence of mind wandering in childhood ADHD. Although previous child and adult studies have observed nuance in how EF facets relate to mind wandering frequency (Hasan et al., 2024; Kam & Handy, 2014; Keulers & Jonkman, 2019; McVay & Kane, 2012), our lack of significant findings may be due to the studied population. Literature exploring EF and ADHD demonstrate heterogeneity in the link between the two constructs (Geurts et al., 2005; Kofler et al., 2019; Roberts et al., 2017). In a similar vein, ADHD is commonly linked to unintentional mind wandering but not intentional mind wandering in adults (Seli et al., 2015). Therefore, it is likely that the association between EF and mind wandering in pediatric ADHD is modulated by different variables (e.g., symptom severity and type of mind wandering).

Indeed, we found significant interactions between children's self-reported ADHD symptoms (i.e., inattention and hyperactivity/impulsivity symptoms) and short-term memory capacity. Similar trends were observed between working memory capacity and ADHD symptoms. These findings parallel memory impairments frequently reported in children with ADHD (Dovis et al., 2013; Karalunas et al., 2017; Kofler et al., 2018). As proposed by Lui and Tannock (2007), deficits in memory, particularly working memory capacity, make children prone to distractions and contribute to behavioral inattention. In the context of the current study, among children with high levels of ADHD symptoms, those with stronger short-term and working memory capacities may resist external and internal distractions (e.g., mind wandering) to successfully retain and process information for the memory task.

However, it is important to note that only the interaction between short-term memory capacity and hyperactivity/impulsivity in predicting mind wandering was significant after correcting for multiple comparisons. The interaction between short-term memory capacity and inattention, working memory capacity and inattention, as well as hyperactivity/impulsivity did not survive multiple comparisons correction. Therefore, we caution readers in interpreting these findings. More work is needed to explore the role of EF facets and ADHD symptoms in predicting mind wandering.

EF and mind wandering in children with and without ADHD

The analyses on self-reported questionnaires for our ADHD and typically developing groups revealed significant differences in their reports of overall and unintentional mind wandering, wherein those with ADHD scored higher than their counterparts without ADHD. Self-reported differences may stem from the challenges children with ADHD encounter in their ability to control, maintain, and direct attention (Frick et al., 2020; Merrill et al., 2022). However, why these differences did not extend to their task mind wandering is unclear. Despite children with ADHD reporting a slightly higher frequency of average mind wandering during the three EF tasks (14–23%) compared to the control sample (7–19%), the variation did not contribute to significant differences during the specific tasks. It is possible that reported mind wandering frequency is moderated by context and the methodology used. Specifically, we relied on questionnaires to explore retrospective mind wandering experiences in daily life and an experience sampling approach to capture in-the-moment experiences during laboratory tasks. Therefore, an overlap in task mind wandering reports may suggest that in a time-limited and controlled setting, both children with and without ADHD can remain on task while avoiding distractions or lapses of inattention. In comparison, an ecological environment with both internal *and* external distractions, may make difficulties with attention regulation more apparent for children with ADHD. Environmental stimuli, such as posters or other children in the classroom, could act as triggers for off task thoughts (i.e., mind wandering) in those with ADHD.

Similarly, in exploring the differential relationship between working memory capacity and mind wandering frequency for children with and without ADHD, we found no main effect of group and no interaction between group and memory abilities. As such, despite ADHD symptoms interacting with short-term and working memory to predict mind wandering, there was no interaction between group and memory abilities in predicting mind wandering. The absence of an interaction suggests that the relationship between working memory and mind wandering is comparable in our child participants across both clinical and typically developing samples. Further investigation of the connection between mind wandering, EF performance, and behavioral traits (e.g., observed inattention or hyperactivity/impulsivity), including children both with and without an ADHD diagnosis (i.e., not dividing into diagnostic groups) may extend our insight into how mind wandering contributes to real world outcomes in children.

Strengths, limitations, and future directions

We utilized questionnaires and experience sampling to corroborate self-reports of mind wandering in children ages 8 to 12 and found moderate to strong links between the two modalities. The findings extend the established notion that children can provide accurate reports of their subjective mind wandering tendencies (Van den Driessche et al., 2017; Ye et al., 2014; Zhang et al., 2015). In addition to the observed congruence across mind wandering reports, the correlation between unintentional mind wandering and ADHD symptomatology also supports previous results (see Lanier et al., 2021 for a review; Seli et al., 2015). Mind wandering and ADHD presentations share commonalities, including attention dysregulation and their potential association with deficits in short-term and working memory capacities. Therefore, the current findings may guide development of interventions beyond medical treatment, such as games aimed at enhancing children's short-term and working memory capacities to regulate their attention (see Rapport et al., 2013 for a review). Furthermore, an absence of significant interaction between working memory capacity and group for children with and without ADHD in predicting mind wandering could demonstrate that non-pharmacological treatments may be beneficial for a broad range of children.

In the current study, we also relied on both guardian- and child-reported questionnaires for mind wandering and ADHD symptoms. There was no correlation between the child and guardian versions of the questionnaires, and guardians typically reported higher levels of mind wandering compared to children. In accordance with our previous study, we also found no correlation between children's thought probes and guardian-reported questionnaires. Naturally, reporting on someone else's internal experiences, such as mind wandering, can be challenging. Another plausible explanation for the difference could be that the reliability of reports may be conditional upon the situational context. For instance, children's evaluation of their mind wandering and ADHD symptoms may be contingent on school settings, whereas guardians rely on observations at home to assess their child's symptoms.

One potential caveat of our study concerns measuring EF and mind wandering during the same tasks. The approach was replicated from our previous study to facilitate standardized comparisons across our ADHD and typically developing samples. Using separate tasks to measure EF and mind wandering would limit interference between measures; however, the feasibility of study completion would be challenged by the increased cognitive load and fatigue for children, especially those with ADHD. Additionally, we interpreted our findings as EF predicting mind wandering frequency, though we recognize an alternative way of assessing the relationship is to examine how mind wandering predicts EF. Owing to the fact that developmental changes in EF are robust and better understood across studies compared to developmental changes in mind wandering, we sought to ground our analyses and interpretations in existing literature. Nonetheless, we encourage future studies to utilize diverse methodologies to explore the impact of mind wandering on EF task performance.

Another consideration is the variability in the number of questions participants encountered via experience sampling. When participants reported being on task, they responded to only one question (i.e., were they mind wandering or not), whereas those who reported mind wandering responded to two questions (i.e., one about mind wandering and another about its intentionality). However, each thought probe followed a break, providing all participants, regardless of whether they answered one or two questions, an opportunity to rest before continuing into a new block. Thus, it is unlikely that the number of questions significantly influenced task performance but future studies could consider providing all options in one question (i.e., on task and mind wandering with and without intention) to minimize potential interference with task performance.

While we conducted analyses to detect group variations in clinical factors, such as medication treatment, we observed no significant patterns. On one hand, the absence of significant findings could reflect a genuine lack of differences. Alternatively, they could stem from an inadequate sample size within each group. Furthermore, despite collecting socioeconomic status (i.e., guardian income and educational levels), we chose not to include this information in our analyses because the findings on socioeconomic status and ADHD (Russell et al., 2016), as well as EF (Lawson et al., 2018) are varied and suggest small effect sizes. However, we do note that Gearin et al. (2018) indicate socioeconomic status may be associated with mind wandering and contribute to academic achievement gaps. Finally, all our participants were recruited from the Calgary, Canada area and the surrounding community. An opportunity for future research could be to broaden recruitment to allow for generalizable results across different populations.

Conclusion

Overall, the current study is the first to explore the relationship between EF and mind wandering in the context of pediatric ADHD. Our findings posit that among children with higher ADHD symptomatology, namely hyperactivity/impulsivity, enhanced short-term memory capacity may be tied to less frequent mind wandering. Similar trends were observed with enhanced short-term memory capacity and inattention. Additionally, working memory capacity was linked to less mind wandering in children with higher levels of inattention and hyperactivity/impulsivity; however, these results did not survive multiple comparisons correction. Further research investigating factors that impact mind wandering and its underlying cognitive processes can provide insight on attention dysregulation and potential treatments. Our results suggest that targeting memory-related cognitive abilities may advance our understanding of mind wandering in children with ADHD and can contribute to the development of non-pharmacological treatments.

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References

Anwyl-Irvine, A. L., Massonié, J., Flitton, A., Kirkham, N. Z., & Evershed, J. K. (2020). Gorilla in our midst: An online behavioural experiment builder. *Behavior Research Methods*, *52*, 388-407. https://doi.org/10.3758/s13428-019-01237-x

Baird, B., Smallwood, J., Mrazek, M. D., Kam, J. W. Y., Franklin, M. S., & Schooler, J. W. (2012). Inspired by distraction: Mind wandering facilitates creative incubation. *Psychological Science*, *23*(10), 1117–1122. https://doi.org/10.1177/0956797612446024

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*(1), 65–95. https://doi.org/10.1037/0033-2909.121.1.65

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review*, *29*(3), 180–200. https://doi.org/10.1016/j.dr.2009.05.002

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning & Individual Differences*, *21*(4), 327–336. https://doi.org/10.1016/j.lindif.2011.01.007

Boshomane, T. T., Pillay, B. J., & Meyer, A. (2021). Mental flexibility (set-shifting) deficits in children with ADHD: A replication and extension study. *Journal of Psychology in Africa*, *31*(4), 344–349. https://doi.org/10.1080/14330237.2021.1952637

Bussing, R., Fernandez, M., Harwood, M., Wei, H., Garvan, C. W., Eyberg, S. M., & Swanson, J. M. (2008). Parent and teacher SNAP-IV ratings of attention deficit hyperactivity disorder symptoms: Psychometric properties and normative ratings from a school district sample. *Assessment (Odessa, Fla)*, *15*(3), 317–328. https://doi.org/10.1177/1073191107313888

Carriere, J. S. A., Seli, P., & Smilek, D. (2013). Wandering in both mind and body: Individual differences in mind wandering and inattention predict fidgeting. *Canadian Journal of Experimental Psychology*, *67*(1), 19–31. https://doi.org/10.1037/a0031438

Chang, Z., D'Onofrio, B., Quinn, P., Lichtenstein, P., & Larsson, H. (2016). Medication for Attention deficit/hyperactivity disorder and risk for depression: A nationwide longitudinal cohort study. *Biological Psychiatry*, *80*(12), 916–922. https://doi.org/10.1016/j.biopsych.2016.02.018

Cherry, J., McCormack, T., & Graham, A. J. (2022). The link between mind wandering and learning in children. *Journal of Experimental Child Psychology*, *217*, 105367. https://doi.org/10.1016/j.jecp.2021.105367

Dovis, S., Van der Oord, S., Wiers, R. W., & Prins, P. J. M. (2013). What part of working memory is not working in ADHD? Short-term memory, the central executive and effects of reinforcement. *Journal of Abnormal Child Psychology*, *41*(6), 901–917. https://doi.org/10.1007/s10802-013-9729-9

Frick, M. A., Asherson, P., & Brocki, K. C. (2020). Mind-wandering in children with and without ADHD. *British Journal of Clinical Psychology*, *59*(2), 208–223. https://doi.org/10.1111/bjc.12241

Gearin, B., Fien, H., & Nelson, N. J. (2018). Mind wandering: A potentially generative idea for understanding the socioeconomic status academic achievement gap. *Translational Issues in Psychological Science*, *4*(2), 138–152. https://doi.org/10.1037/tps0000156

Gerst, E. H., Cirino, P. T., Fletcher, J. M., & Yoshida, H. (2017). Cognitive and behavioral rating measures of executive function as predictors of academic outcomes in children. *Child Neuropsychology*, *23*(4), 381–407. https://doi.org/10.1080/09297049.2015.1120860

Geurts, H. M., Verté, S., Oosterlaan, J., Roeyers, H., & Sergeant, J. A. (2005). ADHD subtypes: Do they differ in their executive functioning profile? *Archives of Clinical Neuropsychology*, *20*(4), 457–477. https://doi.org/10.1016/j.acn.2004.11.001

Hasan, F., Hart, C. M., Graham, S. A., & Kam, J. W. Y. (2024). Inside a child's mind: The relations between mind wandering and executive function across 8- to 12-year-olds. *Journal of Experimental Child Psychology*, *240*, 240. https://doi.org/10.1016/j.jecp.2023.105832

Kam, J. W. Y., & Handy, T. C. (2014). Differential recruitment of executive resources during mind wandering. *Consciousness and Cognition*, *26*(1), 51–63. https://doi.org/10.1016/j.concog.2014.03.002

Kam, J. W. Y., Wong, A. Y., Thiemann, R. F., Hasan, F., Andrews-Hanna, J. R., & Mills, C. (2024). On the relationship between unprompted thought and affective well-being: A systematic review and meta-analysis. *Psychological Bulletin*, *150*(5), 621–641. https://doi.org/10.1037/bul0000428

Karalunas, S. L., Gustafsson, H. C., Dieckmann, N. F., Tipsord, J., Mitchell, S. H., & Nigg, J. T. (2017). Heterogeneity in development of aspects of working memory predicts longitudinal attention deficit hyperactivity disorder symptom change. *Journal of Abnormal Psychology*, *126*(6), 774–792. https://doi.org/10.1037/abn0000292

Keulers, E. H. H., & Jonkman, L. M. (2019). Mind wandering in children: Examining task-unrelated thoughts in computerized tasks and a classroom lesson, and the association with different executive functions. *Journal of Experimental Child Psychology*, *179*, 276–290. https://doi.org/10.1016/j.jecp.2018.11.013

Kofler, M. J., Irwin, L. N., Soto, E. F., Groves, N. B., Harmon, S. L., & Sarver, D. E. (2019). Executive functioning heterogeneity in pediatric ADHD. *Journal of Abnormal Child Psychology*, *47*(2), 273–286. https://doi.org/10.1007/s10802-018-0438-2

Kofler, M. J., Sarver, D. E., Harmon, S. L., Moltisanti, A., Aduen, P. A., Soto, E. F., & Ferretti, N. (2018). Working memory and organizational skills problems in ADHD. *Journal of Child Psychology and Psychiatry*, *59*(1), 57–67. https://doi.org/10.1111/jcpp.12773

Kruger, T. B., Dixon, M. J., Graydon, C., Larche, C. J., Stange, M., Smith, S. D., & Smilek, D. (2021). Contrasting mind-wandering, (dark) flow, and affect during multiline and single-line slot machine play. *Journal of Gambling*, *38*(1), 185–203. https://doi.org/10.1007/s10899-021-10027-0

Lanier, J., Noyes, E., & Biederman, J. (2021). Mind wandering (internal distractibility) in ADHD: A literature review. *Journal of Attention Disorders*, *25*(6), 885–890. https://doi.org/10.1177/1087054719865781

Lawson, G. M., Hook, C. J., & Farah, M. J. (2018). A meta-analysis of the relationship between socioeconomic status and executive function performance among children. *Developmental Science*, *21*(2). https://doi.org/10.1111/desc.12529

Levinson, D. B., Smallwood, J., & Davidson, R. J. (2012). The persistence of thought: Evidence for a role of working memory in the maintenance of task-unrelated thinking. *Psychological Science*, *23*(4), 375–380. https://doi.org/10.1177/0956797611431465

Lui, M., & Tannock, R. (2007). Working memory and inattentive behaviour in a community sample of children. *Behavioral and Brain Functions*, *3*(1), 12–12. https://doi.org/10.1186/1744-9081-3-12

McVay, J. C., & Kane, M. J. (2012). Why does working memory capacity predict variation in reading comprehension? On the influence of mind wandering and executive attention. *Journal of Experimental Psychology: General*, *141*(2), 302–320. https://doi.org/10.1037/a0025250

Merrill, B., Raiker, J. S., Mattfeld, A. T., Macphee, F. L., Ramos, M. C., Zhao, X., Altszuler, A. R., Schooler, J. W., Coxe, S., Gnagy, E. M., Greiner, A. R., Coles, E. K., & Pelham, W. E. (2022). Mind-wandering and childhood ADHD: Experimental manipulations across laboratory and naturalistic settings. *Journal of Abnormal Child Psychology*, *50*(9), 1139–1149. https://doi.org/10.1007/s10802-022-00912-6

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Mowlem, F. D., Skirrow, C., Reid, P., Maltezos, S., Nijjar, S. K., Merwood, A., Barker, E., Cooper, R., Kuntsi, J., & Asherson, P. (2019). Validation of the mind excessively wandering scale and the relationship of mind wandering to impairment in adult ADHD. *Journal of Attention Disorders*, *23*(6), 624–634. https://doi.org/10.1177/1087054716651927

Mrazek, M. D., Phillips, D. T., Franklin, M. S., Broadway, J. M., & Schooler, J. W. (2013). Young and restless: Validation of the Mind-Wandering Questionnaire (MWQ) reveals disruptive impact of mind-wandering for youth. *Frontiers in Psychology*, *4*, 1–7. https://doi.org/10.3389/fpsyg.2013.00560

Oberauer, K., Süß, H.-M., Schulze, R., Wilhelm, O., & Wittmann, W. W. (2000). Working memory capacity – Facets of a cognitive ability construct. *Personality & Individual Differences*, *29*(6), 1017–1045. https://doi.org/10.1016/S0191-8869(99)00251-2

Peng, P., Barnes, M., Wang, C. C., Wang, W., Li, S., Swanson, H. L., Dardick, W., & Tao, S. (2018). Meta-analysis on the relation between reading and working memory. *Psychological Bulletin*, *144*(1), 48–76. https://doi.org/10.1037/bul0000124

Randall, J. G., Oswald, F. L., & Beier, M. E. (2014). Mind-wandering, cognition, and performance: A theory-driven meta-analysis of attention regulation. *Psychological Bulletin*, *140*(6), 1411–1431. https://doi.org/10.1037/a0037428

Rapport, M. D., Orban, S. A., Kofler, M. J., & Friedman, L. M. (2013). Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. *Clinical Psychology Review*, *33*(8), 1237–1252. https://doi.org/10.1016/j.cpr.2013.08.005

Reynolds, C. R., & Kamphaus, R. W. (2015). *Behavior assessment system for children* [Assessment instrument] (3rd ed.). NCS Pearson.

Roberts, B. A., Martel, M. M., & Nigg, J. T. (2017). Are there executive dysfunction subtypes within ADHD? *Journal of Attention Disorders*, *21*(4), 284–293. https://doi.org/10.1177/1087054713510349

RStudio Team. (2024). *RStudio: Integrated development for R* (Version 2024.10.25). http://www.rstudio.com

Russell, A. E., Ford, T., Williams, R., & Russell, G. (2016). The association between socioeconomic disadvantage and Attention Deficit/Hyperactivity Disorder (ADHD): A systematic review. *Child Psychiatry and Human Development*, *47*(3), 440–458. https://doi.org/10.1007/s10578-015-0578-3

Salari, N., Ghasemi, H., Abdoli, N., Rahmani, A., Shiri, M. H., Hashemian, A. H., Akbari, H., & Mohammadi, M. (2023). The global prevalence of ADHD in children and adolescents: A systematic review and meta-analysis. *Italian Journal of Pediatrics*, *49*(1), 48–48. https://doi.org/10.1186/s13052-023-01456-1

Saydam, R. B., Ayvaşik, H. B., & Alyanak, B. (2015). Executive functioning in subtypes of attention deficit hyperactivity disorder. *Noro-Psikiyatri Arsivi*, *52*(4), 386–392. https://doi.org/10.5152/npa.2015.8712

Seli, P., Cheyne, J. A., & Smilek, D. (2013). Wandering minds and wavering rhythms: Linking mind wandering and behavioral variability. *Journal of Experimental Psychology*, *39*(1), 1–5. https://doi.org/10.1037/a0030954

Seli, P., Konishi, M., Risko, E. F., & Smilek, D. (2018). The role of task difficulty in theoretical accounts of mind wandering. *Consciousness and Cognition*, *65*, 255–262. https://doi.org/10.1016/j.concog.2018.08.005

Seli, P., Smallwood, J., Cheyne, J. A., & Smilek, D. (2015). On the relation of mind wandering and ADHD symptomatology. *Psychonomic Bulletin & Review*, *22*(3), 629–636. https://doi.org/10.3758/s13423-014-0793-0

Septier, M., Stordeur, C., Zhang, J., Delorme, R., & Cortese, S. (2019). Association between suicidal spectrum behaviors and attention-deficit/hyperactivity disorder: A systematic review and meta-analysis. *Neuroscience Biobehavioral Reviews*, *103*, 109–118. https://doi.org/10.1016/j.neubiorev.2019.05.022

Smallwood, J. M., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, *132*(6), 946–958. https://doi.org/10.1037/0033-2909.132.6.946

Smallwood, J. M., & Schooler, J. W. (2015). The science of mind wandering: Empirically navigating the stream of consciousness. *Annual Review of Psychology*, *66*(1), 487–518. https://doi.org/10.1146/annurev-psych-010814-015331

St Clair-Thompson, H. L. (2010). Backwards digit recall: A measure of short-term memory or working memory? *The European Journal of Cognitive Psychology*, *22*(2), 286–296. https://doi.org/10.1080/09541440902771299

Swanson, J. M., Kraemer, H. C., Hinshaw, S. P., Arnold, L. E., Conners, C. K., Abikoff, H. B., Clevenger, W., Davies, M., Elliott, G. R., Greenhill, L. L., Hechtman, L., Hoza, B., Jensen, P. S., March, J. S., Newcorn, J. H., Owens, E. B., Pelham, W. E., Schiller, E., Severe, J. B., . . . Wu, M. (2001). Clinical relevance of the primary findings of the MTA: Success rates based on severity of ADHD and ODD symptoms at the end of treatment. *Journal of the American Academy of Child and Adolescent Psychiatry*, *40*(2), 168–179. https://doi.org/10.1097/00004583-200102000-00011

Van den Driessche, C., Bastian, M., Peyre, H., Stordeur, C., Acquaviva, É., Bahadori, S., Delorme, R., & Sackur, J. (2017). Attentional lapses in attention-deficit/hyperactivity disorder: Blank rather than wandering thoughts. *Psychological Science*, *28*(10), 1375–1386. https://doi.org/10.1177/0956797617708234

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: A meta-analytic review. *Biological Psychiatry*, *57*(11), 1336–1346. https://doi.org/10.1016/j.biopsych.2005.02.006

Ye, Q., Song, X., Zhang, Y., & Wang, Q. (2014). Children's mental time travel during mind wandering. *Frontiers in Psychology*, *5*, 1–9. https://doi.org/10.3389/fpsyg.2014.00927

Zhang, Y., Song, X., Ye, Q., & Wang, Q. (2015). Children with positive attitudes towards mind-wandering provide invalid subjective reports of mind-wandering during an experimental task. *Consciousness and Cognition*, *35*, 136–142. https://doi.org/10.1016/j.concog.2015.05.006