The link between mind wandering and learning in children

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

Published in:
Journal of Experimental Child Psychology

Document Version:
Peer reviewed version

The Link Between Mind Wandering and Learning in Children

Jessica Cherry[1], Teresa McCormack[1], and Agnieszka J. Jaroslawska[1]

[1] Queen's University Belfast

Author Note

Jessica Cherry, School of Psychology, Queen's University Belfast, Belfast, BT7 1NN, email: jcherry05@qub.ac.uk; Teresa McCormack, School of Psychology, Queen's University Belfast, Belfast, BT7 1NN, United Kingdom, e-mail: t.mccormack@qub.ac.uk; Agnieszka J. Jaroslawska, School of Psychology, Queen's University Belfast, Belfast, BT7 1NN, United Kingdom, e-mail: a.jaroslawska@qub.ac.uk

Correspondence should be addressed to Jessica Cherry, School of Psychology, Queen's University Belfast, University Road, Belfast, BT7 1NN, United Kingdom. E-mail: jcherry05@qub.ac.uk. This research was supported by a studentship from the Department for the Economy (Northern Ireland) and approved by the Faculty of Engineering and Physical Science Faculty Research Ethics Committee at Queen's University Belfast (EPS 20_282). The authors declare no conflict of interest. Data are available at https://osf.io/3wv5z/?view_only=8b33a94b1e1b4fad817acbc421ec95dc.

Research Highlights

- We explored the impact of mind wandering on memory recall in 6- to 11-year-olds.
- Mind wandering can be detrimental for children's ability to recall information.
- The effect of topic interest on test performance was mediated by mind wandering.

Abstract

Mind wandering is a common everyday experience during which attention shifts from the here and now; in adults and adolescents it is associated with poorer performance in educationally significant tasks. This study is the first to directly assess the impact of mind wandering on memory retention in children before the adolescent period. A sample of 97 children aged between 6 and 11 years engaged in a listening activity and the frequency of mind wandering was measured using intermittent thought probes. They then completed a memory retention test. Children reported mind wandering on ~25% of the thought probes, and frequency did not increase with age. When controlling for the impact of age and vocabulary skills, mind wandering frequency accounted for a large and significant portion of variance in memory scores. Mind wandering frequency also mediated the relation between children's ratings of topic interest and memory scores. The results indicate that mind wandering can be reliably measured in children and is of educational significance.

Keywords: *mind wandering*, *attention*, *learning*, *memory*, *child development*

The Link Between Mind Wandering and Learning in Children

Mind wandering (MW) is the tendency to shift attention from the here-and-now to the processing of intrinsically generated information (Smallwood et al., 2007); in psychological research it has typically been operationalized as task-unrelated thought (TUT; Murray & Krasich, 2021). It has been estimated that adults spend much of their daily lives engaging in MW (30-50%; Killingsworth & Gilbert, 2010), and a comparable figure (20-33%) has been obtained in the small number of studies that have explored MW in childhood (e.g., Keulers & Jonkman, 2019). Although MW can be viewed as evolutionarily beneficial in allowing individuals to reflect on unmet goals and engage in creative problem solving (e.g., Simonton, 2018), in many situations vigilance is not only expected but also essential for success. In an educational context, if a student fails to attend to instruction because of TUTs, this may impede their chances of acquiring crucial skills or knowledge (Smallwood et al., 2007). Over time, these missed learning opportunities may slow educational progress. Given this, research with adults has examined the challenges MW may pose in educational settings (e.g., Lindquist & McLean, 2011; Kane et al., 2017; Kane et al., 2021a; Wammes et al., 2016).

In adult studies, higher rates of MW have been implicated in poorer performance on a range of learning activities including reading (e.g., Kopp & D'Mello, 2016; Smallwood et al., 2008; Unsworth & McMillan, 2013), listening to live or recorded lectures (e.g., Bianchi & Risko, 2021; Kane et al., 2017, Kane et al., 2021a; Wammes & Smilek, 2017), list learning (e.g., Garlitch & Wahlheim, 2020; Peterson & Wissman, 2020; Smallwood et al., 2003; Thomson et al., 2014; Xu & Metcalfe, 2016), and inductive learning (e.g., Metcalfe & Xu, 2016). For example, studies have revealed that participants who report frequent TUTs are less likely to recall pivotal story components (McVay & Kane, 2012; Smallwood et al., 2008). Similarly, MW during lectures is negatively correlated with educational outcomes, such as memory retention and content comprehension (e.g., Risko et al., 2012). In the last two decades, the link between mind wandering and learning has been studied extensively in adult student populations, generating evidence of instructional strategies that can reduce mind wandering in authentic educational settings (Szpunar, 2017). The majority of these studies used the *probe-caught technique* to measure TUTs, where participants report whether their thoughts are on- or off-task when probed intermittently while carrying out a task.

The link between MW and learning has also been shown in two studies with adolescents. Mrazek and colleagues (2013) showed that, in both middle school and high school samples, levels of TUT during reading were negatively associated with comprehension. Soemer et al. (2019) reported an association between retrospective reports of MW and poorer reading comprehension in 13- to 14-year-olds and demonstrated that higher topic interest was associated with less MW during reading. Yet, despite its ubiquity and clear educational significance, there are extremely few developmental studies examining MW in the childhood period before adolescence.

Measuring Mind Wandering in Children and Adolescents

We are aware of five reports to date that have looked at MW in typically developing children (Jones, 2019; Keulers & Jonkman, 2019; McCormack et al., 2019; Ye et al., 2014; Zhang et al., 2015). Ye et al. (2014), using a probe-caught technique, found that MW was associated with poorer performance on reaction time and *n*-back tasks in 8- to 14-year-olds. Subsequently, Zhang and colleagues (2015) measured the frequency of MW (33%) during a Sustained Attention to Reaction Time (SART) task in 9- to 11-year-olds. Again, MW was associated with poorer performance on the SART. More recently, McCormack et al. (2019) demonstrated the applicability of the probe-caught technique in children as young as 6 years, whilst Jones (2019) showed the effectiveness of measuring movement as a proxy for MW in 8- to 10-year-olds. Finally, Keulers and Jonkman (2019) measured MW (although not learning) in a classroom setting. A sample of 9- to 11-year-olds performed a classroom listening activity and a computerized battery of executive functions (EF) tasks, both embedded with intermittent thought probes to measure MW. Children reported MW 20-25% of the time in both contexts, and there was a moderate positive correlation between levels of TUT reported during the listening activity and levels during the EF tasks.

Taken together, previous studies of MW in children suggest that MW can be reliably measured using probe-caught methods. However, the impact of MW on learning in childhood remains unstudied, and it remains unclear if the link between MW and memory retention found in adults can be extended to children.

Mind Wandering and Intentionality

Our primary interest in the current study was to examine the link between MW and memory retention in children, but we also considered the distinction between *intentional* and *unintentional* MW. This distinction is theoretically important in accounts of MW (Murray & Krasich, 2021; Seli et al., 2016). Intentional MW occurs when an individual deliberately allows their mind to drift away from the present moment. Unintentional MW is spontaneous, rather than deliberate, and can occur despite an individual's best intentions to focus on the task at hand. Seli and colleagues (2016) argue that these two types of MW dissociate, involve different cognitive processes, and may have different functional significance. Although the occurrence of mind wandering in educational contexts is likely to be detrimental to performance irrespective of the origin of its onset, if intentional and unintentional MW are driven by separate cognitive mechanisms, they may show different developmental patterns. A recent study by Gyurkovics et al. (2020) established that, at the trait level, adolescents report fewer instances of spontaneous MW, but the distinction between intentional and unintentional MW is at present unexplored in children. Speculatively, although even relatively young children can explicitly discriminate between their own intentional and non-intentional actions

(Montgomery & Lightner, 2004), self-reporting on whether one's MW was deliberate may require a level of metacognitive insight that is challenging for children (Simons et al., 2020).

The Current Study

Although a small number of previous studies have examined mind wandering in children, to the best of our knowledge this is the first study to directly assess i) the impact of MW on memory retention in childhood before the adolescence period and ii) whether children are able to distinguish between intentional and unintentional TUTs. The frequency of MW was measured during a listening activity containing intermittent thought probes, which probed children to report on whether they were mentally on- or off-task and, then, if off-task, whether they had been so intentionally or unintentionally. Subsequently, children took a multiple-choice test assessing their memory for the content of the story, completed a measure of verbal ability, and reported their level of interest in the story topic.

We had four predictions. Our key prediction stemming from the literature on MW in the educational environment in adults (e.g., Mrazek et al., 2013; Wammes et al., 2016) was that higher rates of MW would be associated with poorer memory for the story content. Second, consistent with previous estimates, MW during a classroom-style listening activity was predicted to occur between 20-33% of the time (Keulers & Jonkman, 2019; Zhang et al., 2015), and, based on McCormack et al.'s developmental findings, we tentatively predicted that levels of TUT would not change with age. Third, as MW with and without intention are dissociable in adult participants (Seli et al., 2016) we predicted that these may similarly dissociate in children, assuming this distinction is measurable in children. Finally, in accordance with findings from adolescents and adults (Soemer et al, 2019; Unsworth & McMillan, 2013), it was predicted that MW would mediate the relation between topic interest and memory recall.

Method

Participants

The total sample included 97 children, 31 6- to 7-year-olds (M_{age} = 7 years 0 months, SD_{age} = 7 months), 35 8- to 9-year-olds (M_{age} = 8 years 11 months, SD_{age} = 6 months) and 31 10- to 11-year-olds (M_{age} = 10 years 11 months, SD_{age} = 7 months). Overall, mean age was 8 years 11 months (SD_{age} = 1 year 8 months, Skew = 0.01, Kurtosis = −1.10). All participants were based in the United Kingdom or the Republic of Ireland, with 96.91% of the participants identifying as white, 2.06% as mixed race, and 1.03% identifying as Asian. The required sample size for a linear regression containing three predictors was determined using G*Power (Faul et al., 2009), assuming a medium-sized effect ($f^2 = 0.15$) and adopting a two-tailed α of .05 and a power of .90.

All participants were recruited through parental interest generated by social media advertisements. Children were tested online using video-conferencing software. Most of the time, the parent stayed within close proximity of the child during testing (see Table 1). Average scores obtained on the measure of verbal ability indicated that the participating children were in the higher end of the expected range (*M* = 12.09, *SD* = 2.47, where 10 is the standardized average score).

Materials

Mind wandering task. MW was assessed using a probe-caught method measuring TUTs. Children listened to a pre-recorded story of a fictional Pharaoh in ancient Egypt (see Supplement for details). There were six intermittent thought probes embedded within the story and presented on the screen using PowerPoint. Probes began with a bleep tone and appeared approximately every 100 s, with a range of 75-120 s, and thought probe schedule was set by the experimenter. Each probe consisted of an initial question evaluating whether the participant was on- or off-task (i.e., *What were you thinking about just now? The story or* *something else?*). If the participant reported thinking about something other than the story, they were asked a further two questions about their thoughts. To probe the intentionality of MW participants were instructed to disclose the topic of their thoughts (i.e., *Can you tell me what you were thinking about just now?*). The intentionality of MW was then evaluated using the prompt: *Were you trying to think of [disclosed topic]?.* When participants indicated that their attention was focused on the story, they were instead instructed to answer two simple factual questions by selecting one of two alternatives (e.g., *How many sides does a square have?).* Thus, the number of questions was equal for all participants regardless of level of TUTs, and the overall task completion time comparable across the entire sample. A 5-point scale ranging from *I really didn't like it* to *I really liked it* was presented at the end of the story to gauge topic interest. For a visual representation of the probe layout see Figure 1 in the Supplement.

Memory retention. The memory retention test consisted of 10 items in a multiple-choice format (see Supplementary Materials). The questions were all derived from novel material presented in the listening activity and could not be answered based on participants' prior knowledge. Questions and possible answers were displayed visually but also read out to participants, who gave their answers to the questions verbally. Each question was scored as either correct (1) or incorrect (0).

Verbal ability. The vocabulary subtest from the Wechsler Intelligence Scale for Children (WISC-V; Wechsler, 2014) was used to assess participants' word knowledge and verbal ability. The vocabulary subtest required children to either name or define a range of items with the prompt *What is this?* or *What does… mean?* The first four items were picture items; the subsequent items were all presented orally. Each test item received a score of 0, 1, or 2 depending on the accuracy of the verbal response.

Procedure

The session took approximately 30 minutes over video conferencing software via a series of PowerPoint presentations and participants responded to questions verbally throughout. Children took part in a training activity which introduced a cartoon character (Panda) and first explained the nature of the depictions on each screen in the sequence that would be used in the probes; children then listened to a brief practice story embedded with thought probes. When a thought probe occurred, an audio description of Panda’s thoughts played. Children were asked to make judgments on whether Panda’s thoughts were on-task (‘thinking about the story’) or off-task (‘thinking about something else’). If the character had off-task thoughts, the children would listen to an audio clip describing how Panda’s off-task thought had been initiated (intentional versus non-intentional) and were then asked to judge if Panda had been ‘trying to think about’ the content of the off-task thought or not (see Supplement for details). If children successfully answered all questions about Panda’s thoughts, they could advance to the listening activity; otherwise, an additional training activity commenced. Ninety four percent of children passed the first set of practice questions and 6% of children passed the second set of practice questions; no children were unable to take part in the study due to failure to complete the training.

It was then explained to children that they were going to listen to a story and that during the story they would themselves be probed about their thoughts. Children were then played a recording of a story about ancient Egypt, which contained six thought probes triggered by the experimenter at intervals of approximately 100 s. The thought probe schedule was identical for all participants. When the story had ended participants completed a memory test based on the story material and indicated their situational interest in the story and. Lastly, participants completed the vocabulary subtest from the WISC - V. The study was conducted in accordance with the guidelines of the Faculty Ethics Committee of the authors’ university. All children received achievement e-certificates for their participation.

Results

A summary of sample characteristics and task performance is provided in Table 1. Overall, children reported MW 25.09% of the time, but very rarely reported it was intentional. There was no significant association between age group and MW frequency, $\chi^2(10) = 11.16$, $p = .345$. Raw mind wandering reports ($M = 1.51$, $SD = 1.09$, Skew = 0.45, Kurtosis = 0.02) and raw vocabulary scores ($M = 26.44$, $SD = 6.21$, Skew = –0.17, Kurtosis = –0.24) had appropriate variance to assume normality. Overall, participants rated their enjoyment of the story favorably ($M = 3.96$, $SD = 0.83$, Skew = -0.60, Kurtosis = 0.58) and scored highly on the memory test ($M = 7.62$, $SD = 1.70$, Skew = –0.62, Kurtosis = –0.11). The multiple-choice test was deemed to have good split-half reliability (Spearman-Brown coefficient = .68). The thought probes had lower than optimal split-half reliability (Spearman-Brown coefficient = .29), however, the inter-item correlation value ($r = .17$) suggest the probes correlated to some extent with one another.

Prior to the analyses, proportional data were arcsine transformed to stabilize the variance and meet the required assumptions for linear models. First, a correlation matrix was computed for all variables to explore emerging patterns within the data. Topic interest was positively associated with memory retention, $r(95) = .28$, $p = .006$, but linked negatively with MW, $r(95) = –.32$, $p = .001$, indicating that children who were more interested in the story engaged in MW less and performed better on the memory retention test. Notably, there was a strong negative relationship between MW and memory retention, $r(95) = –.64$, $p < .001$. Memory retention did not share a significant relationship with either age ($p = .783$) or raw vocabulary score ($p = .062$).

Table 1 Sample characteristics and task performance split by age group. When not presented as a percentage, values represent the mean and standard deviation (in parentheses).

	Age group			
	6-7 years old	8-9 years old	10-11 years old	Total
N	31	35	31	97
Male	58.06%	34.29%	45.16%	45.36%
Age (in years)				
Mean (SD)	6.98 (0.60)	8.90 (0.52)	10.94 (0.55)	8.94 (1.68)
Parent proximity				
Beside child	61.25%	51.45%	35.50%	49.50%
Same room	32.25%	31.45%	35.50%	33.00%
Other room	6.50%	17.10%	29.00%	17.50%
WISC Vocabulary				
Raw	21.13 (4.01)	25.94 (4.96)	32.32 (3.79)	26.44 (6.21)
Scaled	12.84 (2.57)	11.69 (2.60)	11.81 (2.10)	12.09 (2.47)
MW proportion				
Total	0.25 (0.19)	0.20 (0.18)	0.31 (0.16)	0.25 (0.18)
Intentional	0.04 (0.07)	0.02 (0.05)	0.01 (0.04)	0.02 (0.06)
Unintentional	0.22 (0.17)	0.18 (0.16)	0.30 (0.15)	0.23 (0.16)
Memory retention (0-10)	7.30 (1.88)	7.97 (1.60)	7.55 (1.61)	7.62 (1.70)
Topic interest (1-5)	4.03 (1.08)	3.97 (0.66)	3.87 (0.72)	3.96 (0.83)

Our key aim was to investigate the link between MW and memory performance (depicted in Figure 1). To this end, a hierarchical linear regression was conducted to assess how MW, age, and vocabulary ability impacted memory performance (see Table 2). In step 1, age and raw vocabulary score accounted for 5% of the variance in memory recall, $R^2_{adjusted}$ = .05, $F(2, 94) = 3.31$, $p = .041$. In this step, only vocabulary score was a significant predictor of memory retention ($\beta = 0.39$, $p = .012$). In step 2, MW was added as a predictor, $R^2_{adjusted}$ = .38, $F(3, 93) = 20.85$, $p < .001$, and significantly increased the predictive value of the model ($\Delta R^2 = .34$, $p < .001$). Vocabulary ability remained a significant predictor in this step (β = 0.37, $p = .003$). These findings indicate that those participants who mind wandered less remembered more about the story than those who mind wandered more frequently. Furthermore, participants with higher verbal ability performed better on the memory test.

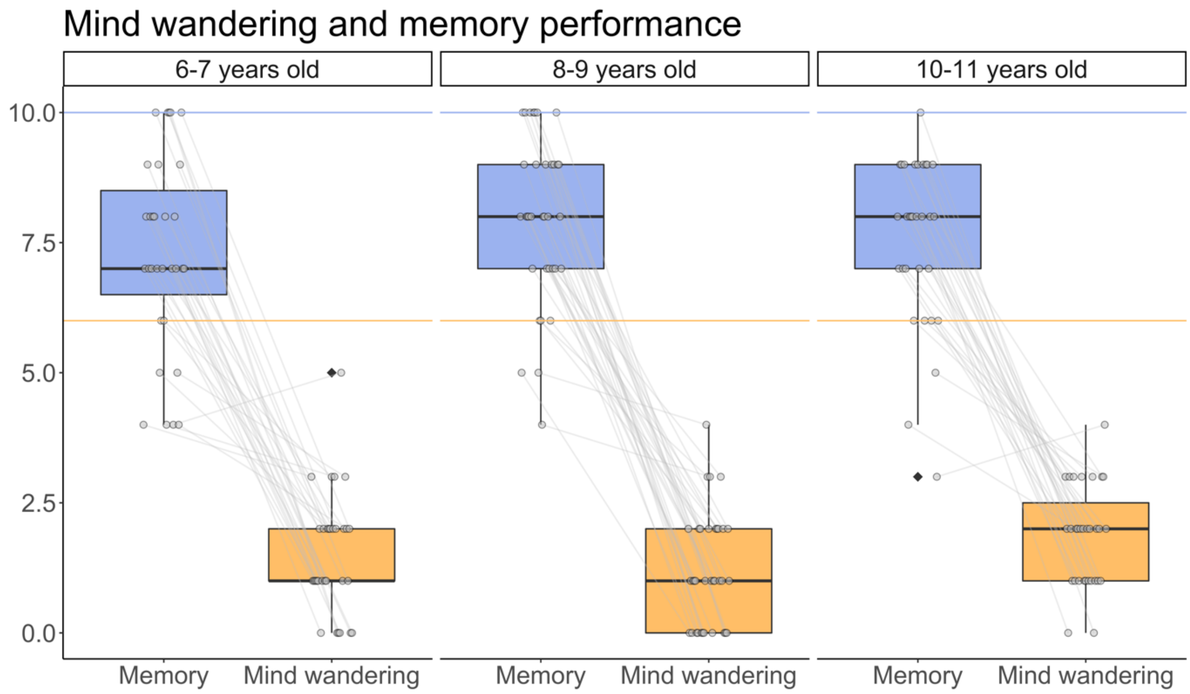

Figure 1 Paired-points graph demonstrating the links between MW (raw score out of 6 probes, max highlighted with a yellow line) and memory performance (score out of 10 questions, max highlighted with a blue line), split by age group. Black lines indicate median; the lower and upper hinges correspond to the first and third quartiles; whiskers depict maximum and minimum values within 1.5 times the interquartile range.

Next, we ran a mediation analysis using the bootstrapping technique to establish whether topic interest had an indirect effect on memory performance via MW (see Table 3). Topic interest was entered as the predictor, MW was the mediator, and memory retention was the outcome variable. There was a significant indirect effect of topic interest on memory retention mediated by MW (b = 0.34, SE = 0.12, 95% CI [0.17, 0.59], p = .005). Children who judged the story to be more interesting reported fewer instances of MW and, in turn, performed better on the memory retention test. Topic interest explained 10% of the variance in MW reports; topic interest and MW together explained 34% of the variance in memory retention.

Table 2 Regression analysis assessing the impact of mind wandering, age, and vocabulary ability on memory performance.

	Memory retention							
	Step 1				Step 2			
	Estimate (SE)	β	95% CI	*p*	Estimate (SE)	β	95% CI	*p*
Intercept	71.79 (9.21)		53.51, 90.07	<.001	79.34 (7.48)		64.49, 94.19	< .001
Age	–0.22 (0.13)	–0.26	–0.47, 0.03	.087	–0.12 (0.10)	-0.14	–0.33, 0.08	.244
Vocabulary	1.06 (0.41)	0.39	0.24, 1.88	.012	1.02 (0.33)	0.37	0.36, 1.68	.003
Mind wandering					–36.63 (5.06)	-0.59	–46.67, –26.56	< .001
$R^2_{adjusted}$	.05			.041	.38			< .001
ΔR^2					.34			

Table 3 Mediation model for the effect of topic interest on memory retention via mind wandering.

	Estimate (SE)	β	95% CI	*z*-value	*p*
Direct effect	0.23 (0.18)	0.14	–-0.18, 0.59	1.29	.199
Indirect effect	0.34(0.12)	0.20	0.17, 0.59	2.83	.005
Total effect	0.57(0.20)		0.14, 0.96	2.83	.005

Discussion

This study of 6- to 11-year-olds sought to establish, for the first time, whether MW during a listening task in children predicts memory retention, to measure the frequency and developmental profile of TUTs, to explore the distinction between intentional and unintentional MW in childhood, and to examine if topic interest played a role in mind wandering frequency. To summarize the key findings: probe-caught MW strongly predicted how well children remembered components of the story; children self-reported engaging in TUTs around 25%, a figure that did not change significantly with age; topic interest had significant indirect effect on memory recall via MW; and children very rarely reported intentional MW. Each of these findings will be discussed in turn.

When controlling for the impact of age and vocabulary ability, MW predicted 34% of the variance in memory performance. To the best of our knowledge, this is the first study to show the robust link between MW and learning in a child sample. These results fit with a growing body of research with adults and adolescents (e.g., Bianchi & Risko, 2021; Kane et al., 2017; Kane et al., 2021a; Mrazek et al., 2013; Risko et al., 2012) that clearly demonstrates that MW is detrimental during educationally significant activities. Although we are interpreting our findings as indicating a causal link between TUTs in children and subsequent memory performance, we acknowledge that we did not control for other cognitive skills (other than vocabulary) that might explain the association between these two measures. Working memory ability is perhaps the most plausible candidate skill, but we note that Keulers and Jonkman (2019) found no relation between working memory in children and TUTs in a listening task. Indeed, research with adults implies that MW itself may at least partially mediate any relation between working memory ability and long-term learning (e.g., McVay & Kane, 2012; Soemer & Schiefele, 2020), suggesting an interesting direction for further educationally significant research with children.

We found that children reported TUTs 20-30% of the time during a classroom-style listening activity. These estimates fall within the expected range, as per previous reports (20-33%; Keulers & Jonkman, 2019; Zhang et al., 2015). This addition to the extant literature is encouraging as it further indicates that MW can be reliably measured in young children. According to our findings, while MW was comparatively frequent it did vary greatly across individuals (see Figure 1). This evidence of marked individual variability is in line with data collected from adult samples (Kane et al., 2017; Seli et al., 2016). Although the probe-caught technique is not without its critics (see Kane et al., 2021b), an important benefit is that it provides a ‘state’ measure of MW that seems to be more tightly linked to task-specific learning in educational contexts than ‘trait’ measures which are used to assess propensity to mind wander in everyday life (Mrazek et al., 2013).

Indeed, engagement in any learning task is in part a function of situational interest; more interested individuals have a lower propensity to mind wander (e.g., Soemer et al., 2019). Accordingly, in the present study, MW significantly mediated the relationship between topic interest and memory recall. That is, children’s interest in the topic influenced the level of MW, which, in turn, influenced participants’ ability to recall facts from the story. The consistency of this finding with those from studies with adolescents/adults again suggests that MW can be successfully measured in children using the probe-caught technique.

A further aim of the present study was to establish whether intentional and unintentional MW can be separated in children when using a probe-caught method. Although estimates of the ratio of intentional and unintentional TUTs vary in the literature, the rates of voluntary MW recorded in the present study were considerably lower (1-3%) than those typically reported (~8%, Seli et al., 2016). Our training procedure indicated that participants were able to distinguish between someone else’s intentional and unintentional MW when presented with examples of how a fictional character’s thoughts had been instigated. However, we are less confident that our participants were able to reliably introspect on their MW experiences, or were willing to admit that they were deliberately engaging in TUTs. We also note that a recent study has also called into question the reliability of adults’ intentionality judgments for TUTs (Kane et al., 2021b). While we still believe that it is worth exploring developmental patterns in intentional versus non-intentional MW, we accept that it may not be easy to measure this distinction in children.

Although the current findings suggest that it is possible to examine children’s mind wandering and its impact on learning, clearly there is a need for further investigation. In order to further validate the use of probe-caught methodology with children, future studies should examine the consistency of the percentage of off-task judgments across multiple sessions, both at the age group and the individual level, and model within-person fluctuation across testing sessions taking into account children's self-reported interest in the topic of the activity. To provide a more precise estimate of children's mind wandering in educational contexts, future investigations should also introduce more specific thought probes to distinguish between task-unrelated thoughts (e.g., reminiscing about past events or contemplating future events), task-related thoughts (e.g., evaluating one's performance on the task), and attentional failures rooted in external distraction (Stawarczyk et al., 2011; Stawarczyk et al., 2014; Unsworth & McMillan, 2014). A more nuanced classification of attentional lapses will be informative when tailoring interventions aimed at reducing mind wandering in real-world settings (Unsworth & McMillan, 2017). For example, although task-related thoughts could reduce students' learning of information in the short-term, frequent performance monitoring could prompt remedial action (e.g., the revision of material judged to have been poorly understood or missed). Finally, given that socio-economic status has important implications for learning opportunities (e.g., Rindermann et al., 2010), it is important to acknowledge that due to the COVID-19 pandemic, all testing was conducted online and a stable internet connection was a prerequisite for participation. Future studies should probe mind wandering in diverse school settings and collect socio-economic data to account for potential sampling bias.

Conclusion

This study has identified that MW during a classroom-style listening activity is not only pervasive but also detrimental for memory recall in children. It remains inconclusive if intentional and unintentional MW are dissociable from one another in childhood. Our findings indicate that assessing MW during educational activities for children will potentially be a very fruitful line of research.

References

Bianchi, L. J., & Risko, E. F. (2021). The Role of Graphics in Video Lectures. *The Journal of Experimental Education*, 1-21.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149-1160.

Garlitch, S. M., & Wahlheim, C. N. (2020). The role of attentional fluctuation during study in recollecting episodic changes at test. *Memory & Cognition*, 1-15.

Gyurkovics, M., Stafford, T., & Levita, L. (2020). Cognitive control across adolescence: Dynamic adjustments and mind-wandering. *Journal of Experimental Psychology: General, 149,* 1017-1031.

Jones, P. R. (2019). Sit still and pay attention: Using the Wii Balance-Board to detect lapses in concentration in children during psychophysical testing. *Behavior Research Methods*, *51*(1), 28-39.

Kane, M. J., Carruth, N. P., Lurquin, J. H., Silvia, P. J., Smeekens, B. A., von Bastian, C. C., & Miyake, A. (2021a). Individual differences in task-unrelated thought in university classrooms. *Memory and Cognitio*n, 49(6), 1247-1266.

Kane, M. J., Smeekens, B. A., Meier, M. E., Welhaf, M. S., & Phillips, N. E. (2021b). Testing the construct validity of competing measurement approaches to probed mind-wandering reports. *Behavior Research Methods*, 1-40.

Kane, M. J., Smeekens, B. A., Von Bastian, C. C., Lurquin, J. H., Carruth, N. P., & Miyake, A. (2017). A combined experimental and individual-differences investigation into mind wandering during a video lecture. *Journal of Experimental Psychology: General*, *146*(11), 1649–1674.

Keulers, E. 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.

Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science*, *330*(6006), 932-932.

Kopp, K., & D'Mello, S. (2016). The impact of modality on mind wandering during comprehension. *Applied Cognitive Psychology*, *30*, 29-40.

Lindquist, S. I., & McLean, J. P. (2011). Daydreaming and its correlates in an educational environment. *Learning and Individual Differences*, *21*(2), 158-167.

McCormack, T., Burns, P., O'Connor, P., Jaroslawska, A. J., & Caruso, E. M. (2019). Do children and adolescents have a future-oriented bias? A developmental study of spontaneous and cued past and future thinking. *Psychological Research*, *83*(4), 774-787.

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.

Metcalfe, J., & Xu, J. (2016). People mind wander more during massed than spaced inductive learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *42*(6), 978-984.

Montgomery, D. E., & Lightner, M. (2004). Children's developing understanding of differences between their own intentional action and passive movement. *British Journal of Developmental Psychology*, *22*(3), 417-438.

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,* 560.

Murray, S., & Krasich, K. (2021). Can the mind wander intentionally? *Mind & Language*. (DOI:10.1111/mila.12332)

Peterson, D. J., & Wissman, K. (2020). Using tests to reduce mind-wandering during learning review. *Memory, 28*(4), 582-587.

Rindermann, H., Flores-Mendoza, C., & Mansur-Alves, M. (2010). Reciprocal effects between fluid and crystallized intelligence and their dependence on parents' socioeconomic status and education. *Learning and Individual Differences, 20(5),* 544-548.

Risko, E. F., Anderson, N., Sarwal, A., Engelhardt, M., & Kingstone, A. (2012). Everyday attention: Variation in mind wandering and memory in a lecture. *Applied Cognitive Psychology*, *26*(2), 234-242.

Seli, P., Wammes, J. D., Risko, E. F., & Smilek, D. (2016). On the relation between motivation and retention in educational contexts: The role of intentional and unintentional mind wandering. *Psychonomic Bulletin & Review*, *23*(4), 1280-1287.

Simons, C., Metzger, S. R., & Sonnenschein, S. (2020). Children's metacognitive knowledge of five key learning processes. *Translational Issues in Psychological Science, 6*(1), 32-42.

Simonton, D. K. (2018). Spontaneity in evolution, learning, creativity, and free will: Spontaneous variation in four selectionist phenomena. In Fox, K. C. R., & Christoff, K. (Eds.), *The Oxford Handbook of Spontaneous Thought: Mind-Wandering, Creativity, and Dreaming* (pp. 113-122). Oxford University Press.

Smallwood, J. M., Baracaia, S. F., Lowe, M., & Obonsawin, M. (2003). Task-unrelated thought whilst encoding information. *Consciousness and Cognition*, *12*(3), 452-484.

Smallwood, J., Fishman, D. J., & Schooler, J. W. (2007). Counting the cost of an absent mind: Mind wandering as an underrecognized influence on educational performance. *Psychonomic Bulletin & Review*, *14*(2), 230-236.

Smallwood, J., McSpadden, M., & Schooler, J. W. (2008). When attention matters: The curious incident of the wandering mind. *Memory & Cognition*, *36*(6), 1144-1150.

Soemer, A., Idsardi, H. M., Minnaert, A., & Schiefele, U. (2019). Mind wandering and reading comprehension in secondary school children. *Learning and Individual Differences*, *75*, 101778.

Soemer, A., & Schiefele, U. (2020). Working memory capacity and (in) voluntary mind wandering. *Psychonomic Bulletin & Review*, *27*, 758-767.

Stawarczyk, D., Majerus, S., Catale, C., & D'Argembeau. (2014). Relationships between mind-wandering and attentional control abilities in young adults and adolescents. *Acta Psychologica*, 148, 25-36.

Stawarczyk, D., Majerus, S., Maj, M., Van der Linden, M., & D'Argembeau. (2011). Mind-wandering: Phenomenology and function as assessed with a novel experience sampling method. *Acta Psychologica*, 136, 370-381.

Szpunar, K., K. (2017). Directing the wandering mind. *Current Directions in Psychological Science, 26*, 40-44.

Thompson, D. R., Smilek, D., & Besner, D. (2014). On the asymmetric effects of mind-wandering on levels of processing at encoding and retrieval. *Psychonomic Bulletin & Review, 21*, 728-733.

Unsworth, N., & McMillan, B. D. (2013). Mind wandering and reading comprehension: Examining the roles of working memory capacity, interest, motivation, and topic experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(3), 832-842.

Unsworth, N., & McMillan, B. D. (2014). Similarities and differences between mind-wandering and external distraction: A latent variable analysis of lapses of attention and their relation to cognitive abilities. *Acta Psychologica*, 150, 14-25.

Unsworth, N., & McMillan, B. D. (2017). Attentional disengagements in education contexts: A diary investigation of everyday mind-wandering and distraction. *Cognitive Research: Principles and Implications*, 2, 32.

Wammes, J. D., Seli, P., Cheyne, J. A., Boucher, P. O., & Smilek, D. (2016). Mind wandering during lectures II: Relation to academic performance. *Scholarship of Teaching and Learning in Psychology*, *2*(1), 33-48.

Wammes, J. D., & Smilek, D. (2017). Examining the influence of lecture format on degree of mind wandering. *Journal of Applied Research in Memory and Cognition, 6(2),* 174-184.

Wechsler, D. (2014). *WISC-V: Technical and interpretive manual*. NCS Pearson, Incorporated.

Xu, J., & Metcalfe, J. (2016). Studying in the region of proximal learning reduces mind wandering. *Memory and Cognition, 44,* 681-695.

Ye, Q., Song, X., Zhang, Y., & Wang, Q. (2014). Children’s mental time travel during mind wandering. *Frontiers in Psychology*, *5*, 927.

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.