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EMPIRICAL RESEARCH

Longitudinal Associations between Metacognition and Spontaneous and Deliberate Mind Wandering During Early Adolescence

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Abstract
Although metacognition plays a pivotal role in theoretical accounts of mind wandering, their longitudinal relationships have not yet been investigated during the important developmental period of early adolescence. This study aimed to examine the developmental trajectories of spontaneous and deliberate mind wandering and the dynamic associations between metacognition and two types of mind wandering in early adolescence. A sample of 4302 Chinese students beginning in Grade 4 (47.4% female; initial $M_{age} = 9.84$, $SD_{age} = 0.47$) completed questionnaires on five occasions over 2.5 years. The results showed that deliberate mind wandering, but not spontaneous mind wandering, gradually increased from Grade 4 to Grade 6. Metacognition was negatively related to spontaneous mind wandering but positively related to deliberate mind wandering. These findings provide empirical evidence for theoretical viewpoints from both individual differences and developmental perspectives.

Keywords Mind wandering · Metacognition · Trajectory · Longitudinal association · Early Adolescence

Introduction

Mind wandering occurs when one's thoughts are unrelated to the current tasks that are being performed; for example, during a biology lecture, Alice is thinking about last night's movie instead of listening to the current lecture. This phenomenon is quite prevalent. An experience-sampling study of 2250 participants from various countries showed that approximately 50% of waking hours involve mind wandering (Killingsworth & Gilbert, 2010). Critically, such a universal experience is generally believed to be associated with negative effects, including low mood and unhappiness (Killingsworth & Gilbert, 2010), poor reading and recorded lecture performance (Unsworth & McMillan, 2013; Wammes & Smilek, 2017), and even increased driving risks (Yanko & Spalek, 2014). Therefore, understanding the antecedents of this ubiquitous thought process is imperative.

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Theoretically, the absence of monitoring thought content (e.g., lower levels of metacognition) is associated with increased mind wandering (Schooler, 2002). However, there is very limited empirical evidence. To address these gaps, this study employed a longitudinal design to examine the dynamic relationship between metacognition and mind wandering during early adolescence—a critical developmental period of metacognition (Flavell et al., 2000). This study provides empirical evidence for the theoretical literature from both individual differences and developmental perspectives.

Types of Mind Wandering

In terms of controllability and purpose, mind wandering can be classified into two subcategories: (1) spontaneous mind wandering, which reflects purposeless, uncontrolled, and unintentional shifts of attention toward inner thoughts, for example, Alice may be trying in earnest to pay close attention to the current biology lecture, but her thoughts unintentionally stray to other things; and (2) deliberate mind wandering, which involves purposeful, controllable, and intentional shifts of attention toward inner thoughts, for example, Alice might find the current biology lecture exceptionally uninteresting, and decide to plan her dinner instead (Carriere et al., 2013).

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Previous studies have demonstrated several important distinctions between these two types of mind wandering (for a review, see Seli et al., 2016). For instance, attention-deficit/hyperactivity disorder (ADHD) symptoms and obsessive-compulsive disorder (OCD) symptoms are positively related to spontaneous but not deliberate mind wandering (Seli, Risko et al., 2017; Seli et al., 2015). Spontaneous mind wandering is associated with poor creative performance, whereas deliberate mind wandering positively predicts creative performance (Agnoli et al., 2018). These findings jointly point to the inference that spontaneous and deliberate mind wandering are distinct types of mind wandering.

Associations between Metacognition and Mind Wandering

Metacognition is defined as cognition about cognition (Nelson, 1996). It is also said to be a "monitoring and controlling system" that is engaged in monitoring and controlling the operations (e.g., attention, memory, and learning) occurring at the cognitive level in a top-down manner (Lyons & Zelazo, 2011).

When considering the attention process, metacognition has been proven to play an important role in it from both theoretical and empirical evidence. Theoretically, metacognition enables individuals to regulate thought processes by monitoring and adjusting information processing. This mechanism has long been demonstrated by the meta-awareness theory (Schooler, 2002). Meta-awareness, involving the ability to take explicit note of the current contents of consciousness (Schooler et al., 2011), is considered a subtype of a larger category of metacognition (Chin & Schooler, 2009). Thus, the meta-awareness theory can also explain the role of metacognition in mind wandering.

According to the meta-awareness theory, individuals are capable of intermittently or periodically monitoring conscious content, evaluating the relation of such content to individuals' goals, and then altering or maintaining the ongoing attentional state. When attention deviates from the current task center, metacognition directly aids in identifying mind wandering lapses, re-engages attention toward the current task through a control function, and interrupts mind wandering (Schooler, 2002). For example, while attending a biology lecture, Alice detects a moment of mind wandering where she notices that "she is thinking of a sunny beach instead of listening to the lecture" (metacognitive monitoring), and then she returns her focus back to the lecture (metacognitive control).

Previous research has investigated the relationship between metacognition and mind wandering, however, to date, the empirical results are limited and inconsistent. Some studies have demonstrated that high-metacognition individuals experience less mind wandering (Drescher et al., 2018; Deng et al., 2019). Nevertheless, one study reported a positive relationship between the two (Ibaceta & Madrid, 2021). One possible explanation for these mixed results is that these studies were based on unitary mind wandering, in other words, previous studies may have confounded spontaneous and deliberate mind wandering. Hence, whether meta-awareness theory and the above research findings represent spontaneous mind wandering or deliberate mind wandering is unclear.

To mitigate the above limitations, recent theoretical literature has further differentiated the mechanism of monitoring and controlling systems on spontaneous and deliberate mind wandering. Specifically, it has been proposed that these systems play different roles in the initiation and continuation processes of spontaneous and deliberate mind wandering. Individuals experiencing spontaneous mind wandering are initially unaware of it, but they may intermittently monitor mind wandering during its continuation process (see Seli et al., 2017, pp. 7–8). This finding is consistent with the view of the meta-awareness hypothesis, which suggests that mind wandering occurs in the absence of monitoring and that individuals fail to notice that their minds are wandering (Schooler et al., 2011). That is, the type of mind wandering described by the meta-awareness hypothesis is spontaneous mind wandering. In contrast, for deliberate mind wandering, its initiation is monitored by individuals (see Seli, Ralph, Risko et al., 2017, pp. 7–8). That is, individuals intentionally shift their attention from the external task to inner thoughts, and they may also intermittently monitor mind wandering during the continuation process. Such deliberate thoughts, intentionally initiated by individuals themselves, are often more valuable than the external task at hand. Indeed, some studies have shown that intentional mind wandering is less disruptive than when it is not intentional (Seli et al., 2019). Therefore, individuals are more likely to maintain, rather than interrupt, deliberate mind wandering when monitoring occurs intermittently during the continuation process.

As discussed above, theoretically, metacognition may have different relationships with spontaneous and deliberate mind wandering. Specifically, metacognition is negatively associated with spontaneous mind wandering because this type of mind wandering appears to be reflective of unwanted thoughts (Seli et al., 2017). On the other hand, given the value of deliberate mind wandering, it is reasonable to suspect that metacognition might be positively associated with deliberate mind wandering. To date, however, few studies have examined the relationships between metacognition and types of mind wandering.

Long-term Associations between Metacognition and Mind Wandering in Early Adolescence

Mind wandering occurs commonly in early adolescence. A sample of 6- to 11-year-olds reported mind wandering 25% of the time during a listening activity (Cherry et al., 2022). Moreover, 9- to 11-year-olds are estimated to experience mind wandering approximately 20–33% of the time during various contexts, including computerized batteries of executive function (EF) tasks, classroom listening activities, and sustained attention to reaction time (SART) tasks (Keulers & Jonkman, 2019; Zhang et al., 2015). In particular, early adolescence is an important developmental period marked by dramatic improvements in cognition (Flavell et al., 2000). Investigating the dynamic trajectory of mind wandering during this important period is essential for comprehending the nature of the mind-wandering phenomenon.

However, there is very limited research on the extent to which spontaneous and deliberate mind wandering develop during early adolescence. A more recent study examined age-related changes in mind wandering across 8- to 12-year-old children. The participants responded to probe questions embedded in executive function tasks (e.g., flanker task, digit span task, and switch task) and to the Mind-Wandering Questionnaire, which measures the frequency of mind wandering in daily life. This study found that older children reported more frequent mind wandering overall during tasks and in everyday life (Hasan et al., 2024). Another study further distinguished spontaneous and deliberate mind wandering and measured two types of mind wandering across early adolescents (12- to 13-year-olds), mid-adolescents (14- to 15-year-olds), late adolescents (18- to 20-year-olds), and young adults (25- to 27-year-olds). This study found that early adolescents reported less deliberate mind wandering than late adolescents and young adults did, while spontaneous mind-wandering rates did not differ across the four groups (Gyurkovics et al., 2020). Critically, one common limitation of the above two studies is that they utilized a cross-sectional design, leading to the disregard of potential confounding factors across age groups, such as subject heterogeneity, thus, it is difficult to rigorously infer the trajectories of the two types of mind wandering.

On the other hand, from the developmental perspective of individual cognitive ability, the metacognition of youth who enter early adolescence improves dramatically as they become increasingly able to control their thoughts (Lyons & Zelazo, 2011). More specifically, the monitoring skills of conscious individuals are relatively well developed at age 8 (Fox & Riconscente, 2008), and control skills, another essential process of metacognition regulating mind wandering, develop slightly later than monitoring skills (Roebers, 2017).

Inspired by meta-awareness theory, which explains the relationship between metacognition and mind wandering from an individual difference perspective, a seductive inference is drawn: metacognition in early adolescence may play lasting and dynamic roles in mind wandering. That is, the dynamic trajectory of mind wandering may be related to developmental changes in metacognition. Specifically, when adolescents exhibit a high level of metacognition, as well as a faster improvement in metacognition with age, they become more able to detect conscious content, which decreases the frequency of spontaneous mind wandering and leads to a gradual decrease in spontaneous mind wandering. On the other hand, it increases the frequency of maintaining deliberate mind wandering, and individuals exhibit an increase in deliberate mind wandering during early adolescence. Knowledge of the longitudinal associations between metacognition and mind wandering is crucial for enriching theoretical perspectives from single individual differences to dynamic development and for planning effective interventions.

However, no empirical research has examined the longitudinal associations between metacognition and mind wandering. Only one recent cross-sectional study among children aged 7–9 years examined the relationship between metacognitive difficulties and mind wandering (Wilson et al., 2022). This study measured children's difficulties with planning, organization, monitoring, and working memory and revealed no association with children's mind wandering. This study has two critical limitations. First, it did not distinguish between spontaneous and deliberate mind wandering, which are two different types of mind wandering (for a review, see Seli et al., 2016). Second, because this study employed a cross-sectional design, the dynamic relationship between metacognition and mind wandering could not be observed. Thus far, the longitudinal associations between metacognition and mind wandering during early adolescence have not been explored.

Current Study

While there is a solid theoretical foundation regarding the relationship between metacognition and mind wandering, few empirical studies have examined this theory. Employing a longitudinal design, the current study aimed to fill that gap by examining two important questions. Specifically, the first concerns the developmental trajectories of spontaneous and deliberate mind wandering. The second question concerns how the trajectory of metacognition relates to the development of types of mind wandering during early adolescence. According to the meta-awareness hypothesis, adolescents with a high level of metacognition should experience less spontaneous but more deliberate mind wandering as well as decreased spontaneous but increased

deliberate mind wandering at subsequent timepoints. In addition, the faster metacognition increases, the faster spontaneous mind wandering should decrease, and the faster deliberate mind wandering should increase during early adolescence.

Method

Participants

The data were taken from a subproject of the Children Academic and Psychological Development Study (CAPS), a broad ongoing longitudinal project designed to investigate the determinants of child academic and psychological development from childhood to adolescence. This project started in November 2016. Participants were recruited from Baoding in Hebei Province, a city with 10.43 million residents and an urbanization rate of 49.0% in 2016 (Baoding People's Government, 2016). The per capita disposable income of Baoding in 2016 was CNY17,802 ($2680) (Baoding People's Government, 2016), which was close to that of Hebei Province (CNY19,717, $2968) and China (CNY23,821, $3586) (National Bureau of Statistics of China, 2016). In terms of these indicators, Baoding was selected as the sample area.

Since the key variable (mind wandering) of this study was not measured in Wave 1 of the CAPS, the present study analyzed data from Wave 2 (Time 1; $n = 3995$; $M = 9.84$, $SD = 0.47$; 52.6% boys), Wave 3 (Time 2; $n = 4025$; $M = 10.37$, $SD = 0.54$; 52.4% boys), Wave 4 (Time 3; $n = 3986$; $M = 10.77$, $SD = 0.50$; 52.5% boys), Wave 5 (Time 4; $n = 3933$; $M = 11.37$, $SD = 0.52$; 52.3% boys), and Wave 6 (Time 5; $n = 3914$; $M = 11.75$, $SD = 0.50$; 52.2% boys). A total of 82.57% of the students participated in all five waves, 6.39% of the students participated in only four waves, 4.18% of the students participated in only three waves, 3.67% of the students participated in only two waves, and 3.18% of the students participated in only one wave. Attrition was caused mainly by transfer, illness, and leave of absence, among other reasons. Attrition analyses showed that the complete dataset included a greater proportion of males, $t\ (4298) = -2.98$, $p < 0.01$.

The data were retained for all the students who provided information on at least one variable during at least one of the five assessment waves. A total of 4302 students were recruited from 95 classes and 36 schools, and they were assessed semiannually at the end of each semester from Grades 4 to 6. Missing data were handled in Mplus using the full information maximum likelihood (FIML) method with MLR estimation, which allows for the use of all data points despite the presence of missing data (Baraldi & Enders, 2010).

Procedure

Voluntary participation was allowed only when written informed consent was provided by the students' parents and local education authorities before each measurement. At each measurement point, the students completed a self-report questionnaire in the classroom under the supervision of two trained postgraduates. All trained postgraduates received an honorarium of approximately CNY200 ($30) for each survey. The current study was approved by the Institutional Review Board of the researchers' institution.

Measures

Mind Wandering

Deliberate and spontaneous mind wandering were measured via the Mind Wandering: Deliberate (MW/D) and Mind Wandering: Spontaneous (MW/S) scales (Carriere et al., 2013). The scales contain 8 items in total, with four assessing deliberate mind wandering (e.g., "*I allow my thoughts to wander on purpose*") and the other four measuring spontaneous mind wandering (e.g., "*I find my thoughts wandering spontaneously*"). Participants responded to each item on a 7-point Likert scale. The alpha reliability estimates for the deliberate mind-wandering scale ranged from 0.69 to 0.83, and those for the spontaneous mind-wandering scale ranged from 0.67 to 0.84. The mean scores, calculated across the four items for each type of deliberate and spontaneous mind wandering, were used in the following analyses. The higher the mean score was, the more frequently a given adolescent experienced spontaneous or deliberate mind wandering.

Metacognition

Metacognition was measured by the Junior Metacognitive Awareness Inventory (Jr. MAI-Version A; Sperling et al., 2002). The Jr. MAI-Version A consists of 12 items (e.g., "*I ask myself how well I am doing while I am learning something new*"). Participants responded to each item on a scale ranging from 1 (never) to 3 (always). The responses were averaged to form a continuous metacognition score, with higher scores indicating higher levels of metacognition. The Jr. MAI-Version A had good internal consistency across all the measured waves, with αs ranging from 0.79 to 0.91.

Analytic Plan

The data were analyzed using SPSS 24.0 and Mplus 8.3. First, an invariance model was employed to test for strong factorial invariance of each type of mind wandering and

Table 1 Model Fit Indices of the Nested CFA Models

Models	χ^2	*df*	*p*	RMSEA	CFI	ΔCFI	ΔRMSEA
Mind Wandering							
M1: Baseline model	5029.83	615	<0.001	0.041	0.938	—	—
M2: Loading invariance	5096.83	639	<0.001	0.040	0.937	0.001	0.001
M3: Loading and intercept invariance	5485.98	663	<0.001	0.041	0.932	0.005	0.001
Metacognition							
M1: Baseline model	5682.37	1580	<0.001	0.025	0.951	—	—
M2: Loading invariance	5870.50	1624	<0.001	0.025	0.950	0.001	0.000
M3: Loading and intercept invariance	6402.55	1668	<0.001	0.026	0.944	0.006	0.001

metacognition across time (i.e., time-invariant factor loadings and intercepts; for a review, see Meredith, 1993). Second, the intraclass correlation coefficients (ICCs; Bryk & Raudenbush, 1992) were computed to determine whether the nesting of individuals within schools and classes would require multilevel modeling. Multilevel modeling is recommended if the ICC reaches 0.05 or greater (Hox et al., 2017). Finally, latent growth models were established to explore the developmental relationships between metacognition and two types of mind wandering. The model fit criteria were set as follows: root mean square error of approximation (RMSEA) < 0.05, comparative fit index (CFI) > 0.95, Tucker–Lewis index (TLI) > 0.95, and standardized root mean square residual (SRMR) < 0.05 (Brown, 2006).

Invariance was present if the difference in model fit between more- versus less-constrained models met the following thresholds: ΔCFI ≤ 0.010 and ΔRMSEA ≤ 0.015 (Chen, 2007). Measurement invariance was examined using strict models with factor structure, factor loadings, and constrained item intercepts and factor loadings. According to the above-discussed rules, the measures of metacognition and mind wandering had strong measurement invariance (see Table 1).

The computed ICCs for spontaneous mind wandering, deliberate mind wandering, and metacognition at all measurement occasions were less than 0.05 (see Table 2), suggesting little need for multilevel model analyses.

A series of growth models were fitted. First, three latent growth models were developed separately to assess the developmental trajectories of metacognition, spontaneous mind wandering, and deliberate mind wandering. Second, a multivariate latent growth model (MLGM) was used to simultaneously model the growth processes for three variables (metacognition, spontaneous mind wandering, and deliberate mind wandering). The model was developed to determine the typical developmental relationships between metacognition and two types of mind wandering from three aspects. First, a cross-sectional analysis was performed to investigate the relationships between metacognition and each type of spontaneous and deliberate mind wandering during the first survey (e.g., how the intercept of metacognition relates to the intercept of different types of mind wandering). Second, a longitudinal analysis was performed to determine the relationships between metacognition in the first survey and the trajectories of spontaneous and deliberate mind wandering during early adolescence (e.g., how the intercept of metacognition relates to the slope of spontaneous and deliberate mind wandering). Finally, a dynamic analysis was implemented to determine the relationships between metacognition and each type of spontaneous and deliberate mind wandering in terms of developmental slopes (e.g., how the slope of metacognition relates to the slope of spontaneous and deliberate mind wandering) (see Fig. 1).

Results

Descriptive Results

Table 2 presents descriptive statistics and correlations among metacognition, spontaneous mind wandering, deliberate mind wandering, and gender. The cross-time correlations between the predictor (metacognition) and outcome variables (spontaneous and deliberate mind wandering) were significant (*r*s ranging from −0.09 to −0.20 for spontaneous mind wandering; *r*s ranging from 0.07 to 0.22 for deliberate mind wandering). In addition, the correlation coefficient between metacognition and spontaneous mind wandering gradually increased, while the correlation coefficient between metacognition and deliberate mind wandering gradually decreased.

Developmental Trajectories of Metacognition, Spontaneous Mind Wandering, and Deliberate Mind Wandering

All trajectory models of metacognition and spontaneous and deliberate mind wandering had good model fit: for metacognition, $\chi^2(10) = 178.059$, $p < 0.001$, RMSEA = 0.063 [0.055, 0.071], CFI = 0.977, TLI = 0.977, SRMR = 0.068; for spontaneous mind wandering, $\chi^2(10) = 73.434$,

Table 2 Descriptive Statistics, Correlations, and Intraclass Correlations (ICC) According to Gender, Metacognition, Spontaneous Mind Wandering, and Deliberate Mind Wandering

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Gender	—															
2. M-C T1	0.06***	—														
3. M-C T2	0.04*	0.55***	—													
4. M-C T3	0.02	0.48***	0.58***	—												
5. M-C T4	−0.01	0.42***	0.51***	0.61***	—											
6. M-C T5	−0.03	0.38***	0.44***	0.53***	0.60***	—										
7. MW/S T1	−0.05**	−0.10***	−0.11***	−0.12***	−0.11***	−0.12***	—									
8. MW/S T2	−0.04*	−0.14***	−0.09***	−0.14***	−0.12***	−0.14***	0.46***	—								
9. MW/S T3	−0.01	−0.13***	−0.12***	−0.14***	−0.12***	−0.15***	0.43***	0.53***	—							
10. MW/S T4	−0.01	−0.17***	−0.16***	−0.21***	−0.19***	−0.22***	0.38***	0.48***	0.56***	—						
11. MW/S T5	0.01	−0.15***	−0.14***	−0.18***	−0.18***	−0.20***	0.35***	0.46***	0.53***	0.63***	—					
12. MW/D T1	−0.01	0.22***	0.13***	0.11***	0.10***	0.08***	0.46***	0.23***	0.22***	0.16***	0.17***	—				
13. MW/D T2	−0.01	0.10***	0.20***	0.11***	0.09***	0.07***	0.31***	0.53***	0.31***	0.25***	0.23***	0.43***	—			
14. MW/D T3	0.00	0.09***	0.12***	0.16***	0.12***	0.08***	0.29***	0.35***	0.53***	0.29***	0.29***	0.40***	0.51***	—		
15. MW/D T4	0.02	0.01	0.03	0.03*	0.07***	0.02	0.29***	0.36***	0.40***	0.57***	0.42***	0.33***	0.46***	0.53***	—	
16. MW/D T5	0.04**	0.01	0.05**	0.05**	0.05***	0.07***	0.28***	0.33***	0.38***	0.43***	0.59***	0.33***	0.40***	0.50***	0.63***	—
17. *M*	1.47	2.31	2.32	2.34	2.34	2.32	3.60	3.67	3.66	3.57	3.62	4.41	4.42	4.56	4.44	4.46
18. *SD*	0.50	0.35	0.37	0.40	0.41	0.43	1.56	1.57	1.63	1.65	1.66	1.53	1.52	1.55	1.55	1.56
19. *N*	4300	3995	4025	3986	3933	3914	3994	4020	3986	3933	3913	3995	4024	3986	3933	3913
20. ICC-S	—	0.02	0.02	0.02	0.03	0.03	0.00	0.02	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.01
21. ICC-C	—	0.02	0.04	0.04	0.04	0.04	0.01	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.01	0.02

M-C metacognition, *MW/S* spontaneous mind wandering, *MW/D* deliberate mind wandering, *ICC-S* the intraclass correlation coefficient within school, *ICC-C* the intraclass correlation coefficient within class

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

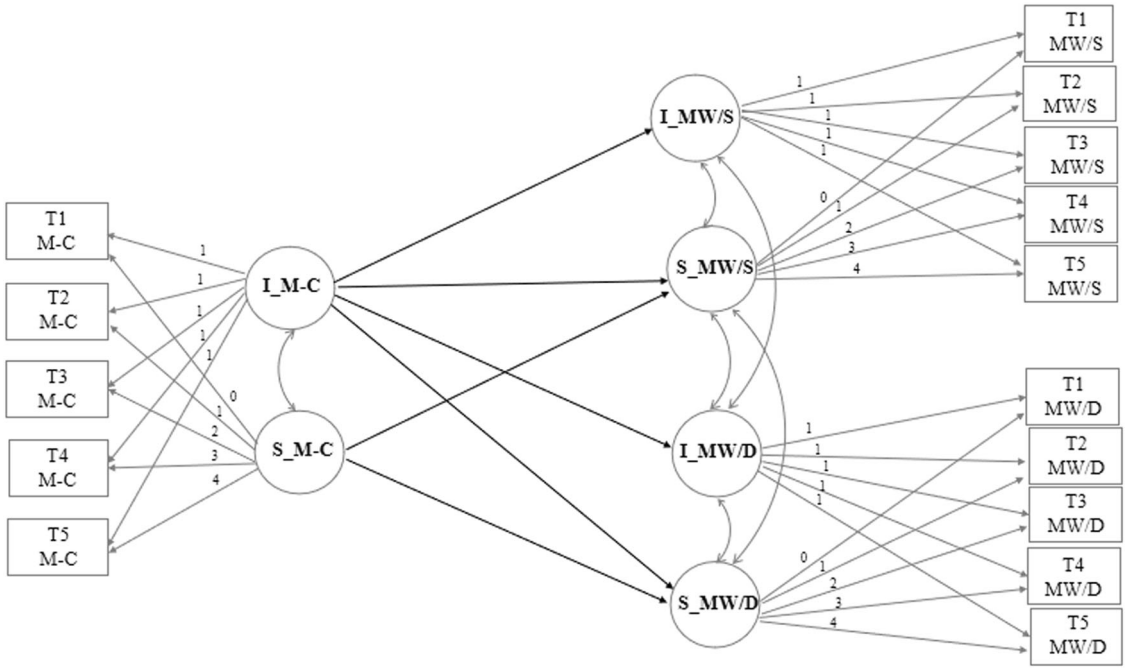

Fig. 1 Models examining the effects of the intercept and slope of metacognition on the intercepts and slopes of spontaneous mind wandering (MW/S) and deliberate mind wandering (MW/D). I represents intercepts, and S represents slopes

$p < 0.001$, RMSEA = 0.038 [0.030, 0.047], CFI = 0.990, TLI = 0.977, SRMR = 0.027; and for deliberate mind wandering, $\chi^2(10) = 137.353$, $p < 0.001$, RMSEA = 0.054 [0.047, 0.063], CFI = 0.978, TLI = 0.978, SRMR = 0.032.

The intercept and slope for metacognition were significantly different from zero (intercept: $b_{\text{M-C}}$-T1 = 2.315, $p < 0.001$, 95% CI for $b = [2.305, 2.325]$; slope: $b_{\text{M-C}} = 0.006$, $p < 0.001$, 95% CI for $b = [0.003, 0.009]$). The significantly positive slope suggested that metacognition increased as a function of age. Furthermore, the slopes of metacognition were negatively related to the intercepts ($r = -0.003$, $p < 0.001$, 95% CI = [−0.005, −0.002]), implying that the higher the level of metacognition at T1 was, the more slowly metacognition increased across measurement times (see Table 3).

The intercepts for spontaneous mind wandering were significantly different from zero (intercept: $b_{\text{MW/S}}$-T1 = 3.645, $p < 0.001$, 95% CI for $b = [3.602, 3.689]$). There was no significant change in spontaneous mind wandering across the measurement time slopes ($b_{\text{MW/S}} = -0.004$, $p = 0.585$, 95% CI for $b = [-0.018, 0.010]$), reflecting that spontaneous mind wandering was relatively stable during early adolescence. Furthermore, across participants, the slopes of spontaneous mind wandering were negatively related to the intercepts ($r = -0.065$, $p < 0.001$, 95% CI = [−0.089, −0.040]), implying that the more spontaneous mind wandering at T1 was, the more spontaneous mind wandering decreased across measurement times (see Table 3).

Table 3 Parameter Estimates for Intercepts, Slopes, and Variances and Fit Indices for Latent Growth Models

Model estimates	Metacognition	Spontaneous mind wandering	Deliberate mind wandering
Mean			
Intercept	2.315***	3.645***	4.431***
Slope	0.006***	−0.004	0.014*
Relation $_{\text{I-S}}$	−0.003***	−0.065***	−0.083***
Model fit			
χ^2	178.059(10), $p < 0.001$	73.434(10), $p < 0.001$	137.353(10), $p < 0.001$
RMSEA [CI]	0.063, [0.055, 0.071]	0.038, [0.030, 0.047]	0.054, [0.047, 0.063]
CFI	0.977	0.990	0.978
TLI	0.977	0.977	0.978

*$p < 0.05$, ***$p < 0.001$

The intercept and slope for deliberate mind wandering were significantly greater than zero (intercept: $b_{\text{MW/D}}$-T1 = 4.431, $p < 0.001$, 95% CI for $b = [4.388, 4.473]$; slope: $b_{\text{MW/D}} = 0.014$, $p < 0.05$, 95% CI for $b = [0.000, 0.027]$). The significantly positive slope suggested that deliberate mind wandering increased as a function of age during early adolescence. Furthermore, the slopes of deliberate mind wandering were negatively related to the intercepts across participants ($r = -0.083$, $p < 0.001$, 95% CI = [−0.109, −0.058]) (see Table 3).

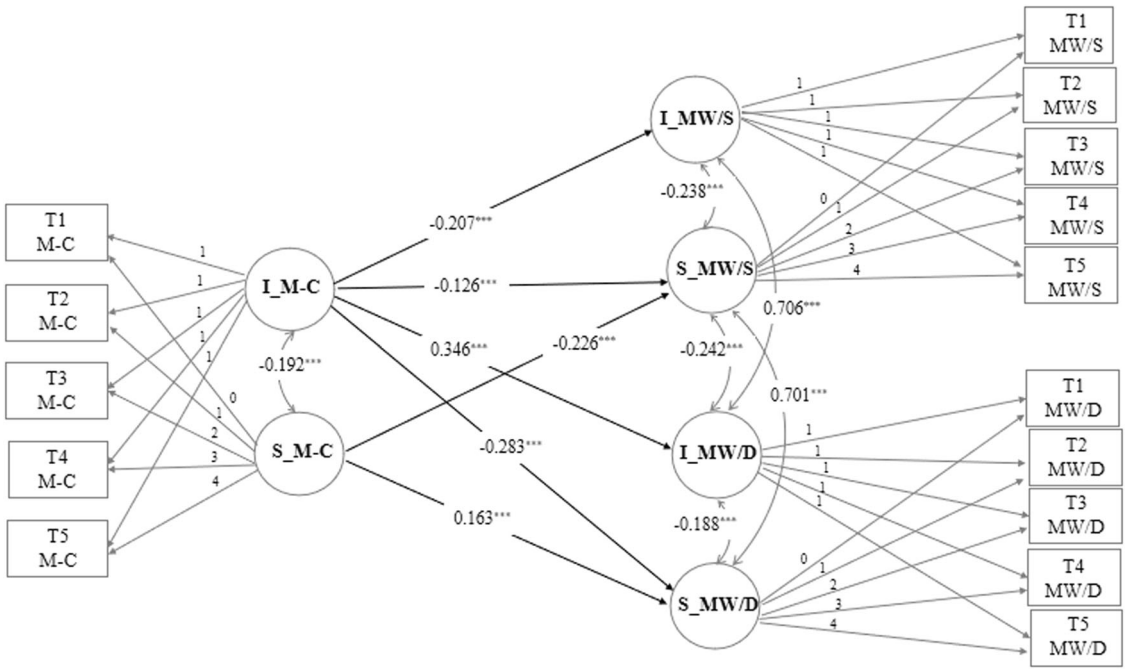

Fig. 2 Multivariate latent growth model examining the typical developmental relationships between metacognition and two types of mind wandering. Standardized and significant coefficients are presented

Multivariate Latent Growth Model for Metacognition, Spontaneous Mind Wandering, and Deliberate Mind Wandering

The multivariate latent growth model had good model fit: $\chi^2(90) = 7.626$, $p < 0.001$, RMSEA = 0.039 [0.037, 0.042], CFI = 0.977, TLI = 0.974, SRMR = 0.036.

First, the intercept of metacognition was negatively associated with the intercept of spontaneous mind wandering across participants ($\beta = -0.207$, SE = 0.022, $p < 0.001$) but positively predicted the intercept of deliberate mind wandering (T1) ($\beta = 0.346$, SE = 0.022, $p < 0.001$). These results imply that at T1, adolescents who reported higher levels of metacognition experienced less spontaneous but more deliberate mind wandering at T1 (see Fig. 2).

Next, negative associations between the intercept of metacognition and the slopes of spontaneous mind wandering and deliberate mind wandering were also observed ($\beta_{MW/S} = -0.126$, SE = 0.029, $p < 0.001$; $\beta_{MW/D} = -0.283$, SE = 0.028, $p < 0.001$). These results suggest that for adolescents who reported higher levels of metacognition at T1, spontaneous mind wandering decreased faster, while deliberate mind wandering tended to increase more slowly (see Fig. 2).

Finally, but importantly, the slope of metacognition was negatively related to the slope of spontaneous mind wandering across participants ($\beta = -0.226$, SE = 0.031, $p < 0.001$) but positively related to the slope of deliberate mind wandering ($\beta = 0.163$, SE = 0.030, $p < 0.001$) across measurement times. These findings demonstrated that as adolescents' metacognition increased with age, their spontaneous mind wandering decreased more quickly, whereas their deliberate mind wandering tended to increase more quickly over time (see Fig. 2). In the robustness analyses, the results of the model with gender as a covariate were nearly identical to the main outcomes reported above. See Appendix S1 in the Supplementary Information for details.

Discussion

Although the theoretical literature clearly addresses the relationship between metacognition and mind wandering (Schooler, 2002), there has been no empirical research investigating their longitudinal associations in early adolescence. To fill this research gap, the current study tracked more than 4000 youth over 2.5 years to examine the developmental trajectories of spontaneous and deliberate mind wandering and the dynamic relationships between metacognition and two types of mind wandering during early adolescence.

Development Trajectories of Spontaneous and Deliberate Mind Wandering During Early Adolescence

The findings demonstrated that deliberate mind wandering gradually increased during this important period, whereas

spontaneous mind wandering was relatively stable over time, further highlighting the distinction between spontaneous and deliberate mind wandering. Specifically, the increasing trend of deliberate mind wandering with age seems to indirectly support the meta-awareness theory. However, the current study failed to reveal that spontaneous mind wandering significantly decreased across the two-and-a-half-year measurement period, which appears inconsistent with the meta-awareness theory. An important factor may engender this finding. That is, there may be other factors, such as cognitive resources, that contribute to mind wandering. Cognitive resource allocation theory proposes that mind wandering, especially spontaneous mind wandering, is a resource-demanding process that requires working memory resources (Smallwood & Schooler, 2006). Mind wandering should be less likely to occur when an ongoing task is demanding because the task requires resources and thus leaves few working memory resources available for mind wandering. Previous research in adults has shown that those with greater working memory resources reported more frequent mind wandering (Levinson et al., 2012). Working memory gradually increases with age during childhood and adolescence (Gonthier et al., 2019; Lyons & Zelazo, 2011), which may lead to an increase in spontaneous mind wandering. Therefore, these two consequences might cancel each other, leading to a relatively stable development trend of spontaneous mind wandering across adolescence. Generally, these findings imply that the development of mind wandering, including spontaneous and deliberate mind wandering, might be influenced by various factors in addition to metacognition.

Longitudinal Associations between Metacognition and Spontaneous and Deliberate Mind Wandering

Another objective of the current study was to examine the dynamic relationships between metacognition and two types of mind wandering. The findings suggest that adolescents with high levels of metacognition in Grade 4 experienced less spontaneous mind wandering over the next two years than those with low metacognition. Additionally, adolescent metacognition gradually increased over time, and adolescents exhibited a decline in spontaneous mind wandering over time. These findings support the meta-awareness theory. Specifically, this theory suggests that metacognition intermittently monitors attention, when attention deviates from an external task during the continuation process of uncontrolled spontaneous mind wandering, it interrupts the inner-generated content and reorients attention back to the external task (Schooler, 2002). As metacognition increases with age, adolescents gradually become more able to frequently monitor their conscious content. Therefore, individuals are more likely to detect and interrupt spontaneously generated thoughts, leading to a decrease in spontaneous mind wandering as age increases.

The positive relation between deliberate mind wandering and metacognition is also consistent with the meta-awareness theory. Specifically, the current study revealed that the higher the initial level of metacognition was, the more frequently the adolescents experienced deliberate mind wandering. Furthermore, an increasing speed of metacognition positively predicted an increasing speed of deliberate mind wandering during early adolescence. Deliberate mind wandering is initiated by individuals themselves (Seli et al., 2017), and such thought is more likely to be meaningful to them (Agnoli et al., 2018). For example, individuals with higher metacognition may intentionally shift their attention from an external task to planning the future and setting a goal or intended action. Intentional future thinking supports prospection from the initial conception of a possible future event to the process of attaining the goal of planned actions (Kvavilashvili & Rummel, 2020), which is essential for successful daily functioning (Suddendorf & Corballis, 2007). Therefore, adolescents with higher levels of metacognition are more likely to initiate and maintain, rather than interrupt, those valuable thoughts.

In conclusion, the current study confirms that metacognition plays different roles in spontaneous mind wandering and deliberate mind wandering. Specifically, metacognition negatively predicted spontaneous mind wandering, whereas it was positively associated with deliberate mind wandering. More importantly, this study identifies the lasting and dynamic impact of metacognition on two types of mind wandering from Grades 4 to 6, providing empirical evidence for the development of metacognition theory for the first time. In other words, the current study expands the explanatory perspective of the meta-awareness theory to longitudinal development research.

Limitations and Future Directions

Even so, the findings documented here need to be interpreted in light of several limitations. First, the study period from Grade 4 to Grade 6 was rather short for investigating changes in mind wandering and the dynamic relationships between metacognition and the types of mind wandering. It is possible that the relationships between spontaneous and deliberate mind wandering and metacognition vary across life stages. For example, metacognition continues to develop well into late adolescence; thus, the positive relationship between deliberate mind wandering and metacognition might be stronger for late adolescents and adults. Therefore, future research should further explore this relationship throughout late adolescence and adulthood.

Second, the assessment of metacognition and mind wandering in the current study relies on self-reports. While previous studies have demonstrated positive associations between children's self-reports of mind wandering in daily life and probe-caught incidence of mind wandering in tasks (Keulers & Jonkman, 2019), supporting convergence across different self-report measures, this method may be subject to social desirability, as mind wandering is often considered an undesirable state (Hasan et al., 2024). Future studies might benefit from including objective measures simultaneously (such as functional magnetic resonance imaging and eye-tracking) and exploring whether they can replicate the current findings. Moreover, although meta-awareness is a subtype of metacognition (Chin & Schooler, 2009), metacognition nevertheless represents a broader domain of processes, and it may encompass knowledge beyond the contents of consciousness (e.g., what one is likely to remember) (Schooler, 2002). Therefore, future research should separate meta-awareness from metacognition when examining the meta-awareness theory, and compare the effects of meta-awareness and metacognition on types of mind wandering.

Finally, the current study did not consider the factors that might mediate the relationships between metacognition and the types of mind wandering. For example, in the case of highly demanding tasks, deliberate mind wandering might be interrupted when metacognition occurs because task performance is sensitive to mind wandering (Smallwood & Schooler, 2006). Future research should simultaneously measure task demand to directly determine its role in the relationships between metacognition and each type of spontaneous and deliberate mind wandering.

Conclusion

Theoretical research clearly reveals the relationship between metacognition and mind wandering, but the related empirical evidence is very limited. By analyzing longitudinal data, the present study sought to address this gap by examining the relationships between metacognition and both types of mind wandering during the important developmental period of early adolescence. The results reveal that deliberate mind wandering increases but spontaneous mind wandering is relatively stable during early adolescence. Adolescents with greater levels of metacognition experience less spontaneous but more deliberate mind wandering. The faster metacognition increases with age, the faster spontaneous mind wandering decreases, and deliberate mind wandering increases during early adolescence. These findings provide empirical evidence for the meta-awareness theory. Furthermore, inspired by these findings that highlight the important roles of metacognition in spontaneous and intentional mind wandering, it is important to enhance metacognition during the malleable period of early adolescence.

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Data Sharing Declaration The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author upon reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare no competing interests.

Ethical approval All procedures performed in the present study were in accordance with the recommendations of the Research Ethics Committee of the Beijing Normal University and with the Declaration of Helsinki.

Informed consent Written informed consent was obtained from the involved schools and parents of the participating youth.

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