Spontaneous Mind-Wandering Tendencies Linked to Cognitive Flexibility in Young Adults

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Abstract

Despite that previous studies have investigated mind wandering using task-switching paradigms, the association between the tendency to mind wander and cognitive flexibility remains largely unexplored. The present study investigated the relationship between self-reported spontaneous mind-wandering tendencies and task-switching performance in young adults. Seventy-nine university students performed a forced task-switching and a voluntary task-switching paradigm and then completed a battery of questionnaires. The results showed that compared to participants with lower spontaneous mind-wandering tendencies, participants with higher spontaneous mind-wandering tendencies demonstrated better performance (evidenced by smaller switch cost reaction times) in the forced task-switching paradigm despite indicating more mind wandering during task performance. Performance on the voluntary task-switching paradigm, on the other hand, did not differ between the two groups. The findings in the forced task-switching paradigm indicate a link between mind wandering and cognitive flexibility, thus providing initial evidence in favor of a role for switching in mind wandering.

Keywords: task-unrelated thoughts; mental set shifting; task switching; exogenous switching; endogenous switching

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1. Introduction

In the last two decades there has been a growing interest in the psychological study of mind wandering—a common phenomenon in which our attention is directed away from the task at hand toward task-unrelated thoughts (for reviews, see Kvavilashvili & Rummel, 2020; Smallwood et al., 2018; Smallwood & Schooler, 2006; 2015). Understanding the nature of mind wandering is important for several reasons. First, mind wandering often impairs task performance, resulting in slower reaction times and lower accuracy (for reviews, see Mooneyham & Schooler, 2013; Stan & Christoff, 2018). Second, in contrast to the first reason, mind wandering has been found to have major benefits such as enhancing creative thinking (e.g., Gable et al., 2019; Zedelius & Schooler, 2015) and facilitating future planning (e.g., Mazzoni, 2019). Third, distinct patterns of mind wandering may signal a number of clinical conditions (for reviews, see Bozhilova et al., 2018; Kvavilashvili et al., 2020). For example, decreases in the frequency of mind wandering have been reported in Alzheimer's disease (e.g., Gyurkovics et al., 2018) and Parkinson's disease (e.g., Walpola et al., 2020), whereas increases in the frequency of mind wandering have been reported in attention-deficit/hyperactivity disorder (ADHD; e.g., Bozhilova et al., 2021; Mowlem, Skirrow, et al., 2019). Collectively, these considerations have motivated a growing interest in research investigating what factors regulate the occurrence and maintenance of mind wandering.

Despite that a number of hypotheses have been put forward to explain why mind wandering occurs (e.g., McVay & Kane, 2009, 2010, 2012; Smallwood, 2013; Smallwood & Schooler, 2006; Thomson et al., 2015), some findings remain difficult to explain by any one single theory. For example, an increasing number of studies have demonstrated that older adults tend to report less mind wandering than healthy young adults (e.g., Jordão et al., 2019;

Maillet et al., 2020; Moran et al., 2021; for a review, see Maillet & Schacter, 2016). This is

puzzling because the occurrence of mind wandering is thought to reflect a failure of executive

control to defend primary-task focus (McVay & Kane, 2009, 2010, 2012), yet older adults

generally have poorer executive control (for reviews, see Craik & Salthouse, 2011; Machado,

2021; McDonald et al., 2018), therefore one would expect the frequency of mind wandering

to increase as people age (due to decreased executive control; Thomson et al., 2015).

Furthermore, mind-wandering studies involving task-switching paradigms in healthy young

adults have consistently demonstrated that switching performance is not adversely affected

by mind wandering (i.e., similar reaction times were obtained for the trials leading up to "on-

task" and "off-task" reports; Arnau et al., 2020; Kam & Handy, 2014; Thomson et al., 2014).

These findings are perplexing because (a) mind wandering is conceived as a resource-

demanding process that should result in impaired task performance due to insufficient

cognitive resources being devoted to the task at hand (Smallwood, 2010; Smallwood &

Schooler, 2006; Thomson et al., 2015); and (b) mind wandering has repeatedly been found to

impair performance on tasks that tap the other core executive control measures—working

memory (e.g., Goller et al., 2020; Schurer et al., 2020; Soemer & Schiefele, 2020) and

inhibition (e.g., Banks & Welhaf, 2021; Groot et al., 2021; Martínez-Pérez et al., 2021).

Taken together, these findings suggest existing theories of mind wandering may need to be

updated to account for these experimental findings.

        To address this, we recently outlined a view of mind wandering that takes into

consideration cognitive flexibility, proposing that instances of mind wandering are in fact

instances of mental set shifting (Wong et al., 2021; for a similar argument, see Murray &

Krasich, 2020). Cognitive flexibility, or mental set shifting, is one of the core executive

functions that enables a person to coordinate thoughts and actions in response to changing

demands or priorities (Buttelmann & Karbach, 2017; Diamond, 2013; Miyake et al., 2000).

We suggest that mind wandering requires cognitive flexibility (Wong et al., 2021), as it involves a shift from mental sets that are related to the task at hand toward task-unrelated mental sets (Smallwood & Schooler, 2006). According to this account, there should be an association between mind-wandering tendencies and cognitive flexibility, such that individuals who mind wander more frequently should show better mental set shifting abilities.

In the current study, we investigated this newly formulated switching account of mind wandering in a group of young adults. To assess task-switching abilities and task-switching tendencies, we used two task-switching paradigms, one involving forced random task switches (forced task switching; Sudevan & Taylor, 1987) and the other involving self-initiated voluntary task switches (voluntary task switching; Arrington & Logan, 2004). Based on previous studies (Seli, Carriere, et al., 2015; Seli et al., 2016), we treated the tendency to mind wander as a personality trait, which was assessed using the Mind Wandering: Deliberate (MW-D) and Spontaneous (MW-S) self-report scales (Carriere et al., 2013). In several studies of mind wandering, these scales, particularly the MW-S, were found to be valid and reliable instruments for measuring trait-level mind wandering (e.g., Mowlem, Agnew-Blais, et al., 2019; Seli, Smallwood, et al., 2015). Additionally, we measured mind wandering during performance of the task-switching paradigms using the Thinking Content Component of the Dundee Stress State Questionnaire (DSSQ; Matthews et al., 2002), which is a self-report questionnaire widely used to assess mind-wandering frequency (e.g., Barron et al., 2011; Helton & Warm, 2008; Neigel et al., 2019; Smallwood et al., 2009), and a Numerical Rating Scale (NRS) for task-unrelated thoughts, which was purpose-designed for this experiment to measure the frequency of mind wandering during performance of the task-switching paradigms and to confirm the mind-wandering reports collected via the DSSQ using a single direct question. We also measured participants' attentional control abilities

using the Attentional Control Scale (ACS; Derryberry & Reed, 2002) and their motivation to perform the switching paradigms using a NRS for motivation.

The first aim of this study was to investigate the association between cognitive flexibility and mind-wandering tendencies. Based on the cognitive flexibility perspective (Wong et al., 2021), we hypothesized that relative to individuals with lower self-reported spontaneous mind-wandering tendencies, individuals with higher self-reported spontaneous mind-wandering tendencies would: (a) exhibit better performance on the forced task-switching paradigm (as reflected by smaller switch cost reaction times [RTs], which were calculated for each participant by subtracting mean correct RTs on repeat trials from mean correct RTs on switch trials); and (b) mind wander more frequently during performance of the switching paradigms. The second aim of the study was to explore whether individuals with higher self-reported spontaneous mind-wandering tendencies would initiate more switches during performance of the voluntary task-switching paradigm. Based on the idea that frequent mind wanderers are more inclined to allocate their cognitive resources to different mental sets (Wong et al., 2021), we hypothesized that relative to individuals with lower self-reported spontaneous mind-wandering tendencies, individuals with higher self-reported spontaneous mind-wandering tendencies would be more likely to opt to switch tasks. Furthermore, we assessed attentional control and motivation to perform the switching paradigms in an effort to provide insight into whether these factors contributed to any group differences in mind-wandering reports.

2. Method

2.1 Participants

Eighty-four undergraduate students (69 females and 15 males) from the University of Otago completed the experiment in association with a psychology course. All participants

reported being native English speakers and having normal or corrected-to-normal vision without color blindness. Five participants were excluded from the analysis for the following reasons: history of psychiatric disorders ($n = 3$) and excessive errors (> 3 *SDs* above the mean; $n = 2$, in both cases excessive errors during both task-switching paradigms). This resulted in a final sample of 79 participants (65 females and 14 males; age: mean = 19.59 years, *SD* = 1.61 years, range = 18 to 27 years). This study was approved by the University of Otago Human Ethics Committee (reference number: D19/297), and all participants provided written informed consent prior to participation.

The number of participants was based on an a priori power analysis performed using G*power 3.1 (Faul et al., 2009). Using a freely available effect size calculator from Psychometrica (Lenhard & Lenhard, 2016), we inverted the Pearson's correlation coefficient of −.31 reported by Franklin et al. (2016) for the correlation between an individual's mind-wandering score and the individual's implicit learning score (which is similar to the calculation of switch cost RTs; Nissen & Bullemer, 1987) to a Cohen's *d* of −0.6521 based on the formula specified by Dunlap (1994): Common Language Effect Size = $\sin^{-1}(r)/\pi + 0.5$. The power analysis indicated that the minimum required for two-tailed independent-samples *t* tests to achieve 80% power given an alpha of .05 was 76, thus indicating that our final sample size of 79 was sufficient.

2.2 Procedure and Materials

Participants first performed a forced task-switching paradigm and then performed a voluntary task-switching paradigm, after which they filled out a battery of questionnaires in the order described in the following subsections. The experiment lasted about 50 min per participant: 4 min for the forced task-switching practice block, 18 min for the forced task-switching experimental block, 18 min for the voluntary task-switching experimental block, and 10 min to complete the questionnaires.
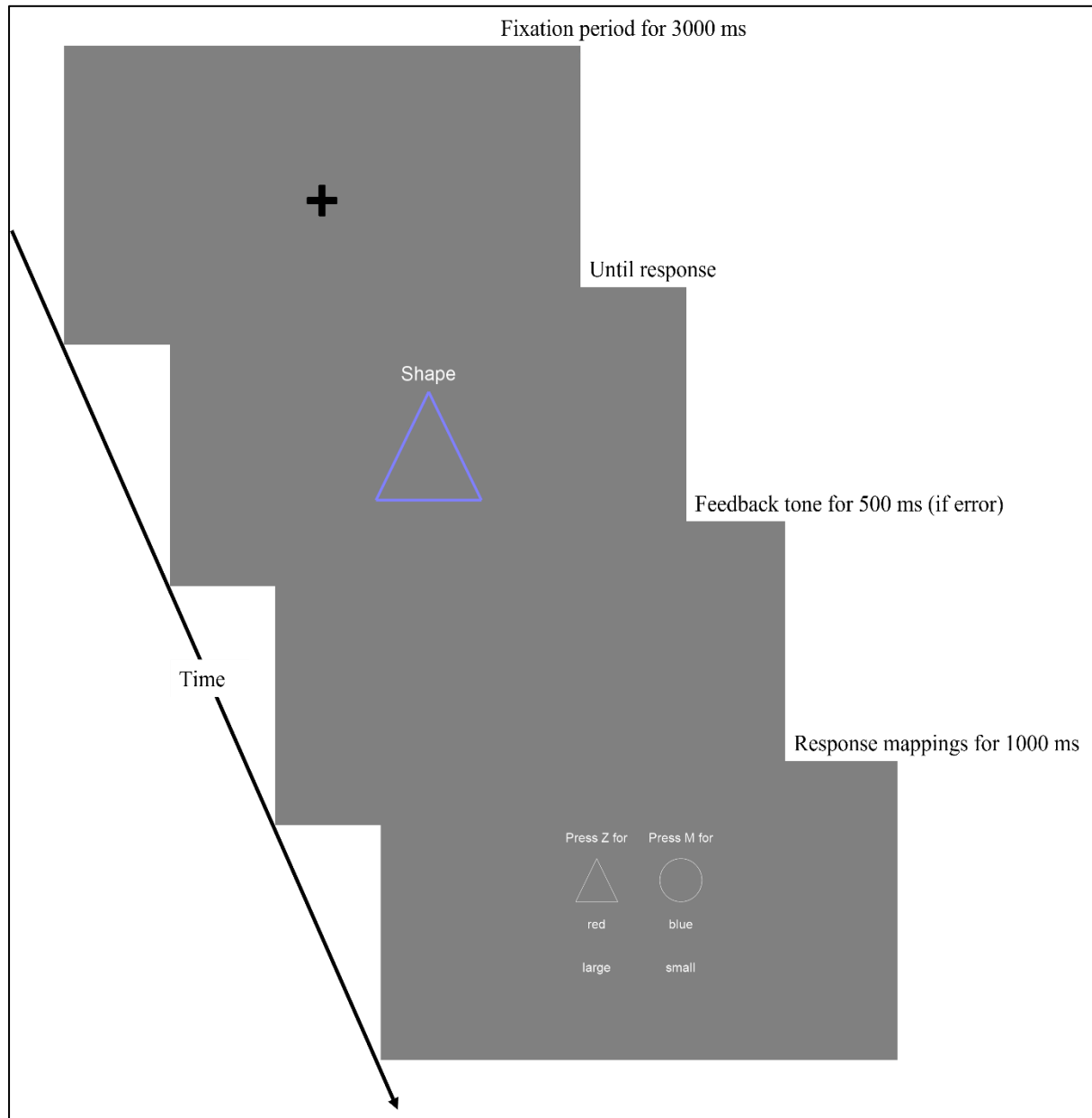
2.2.1 Task-Switching Paradigms

The paradigms and stimuli used were based on Kessler et al. (2009) and were programmed in PsychoPy3 (Peirce et al., 2019). The stimuli were geometric shapes that varied in three dimensions: shape (triangle [shape: triangle, line width: 10] or circle [shape: regular polygon, number of vertices: 100, line width: 10]), color (red [line color: 1, 0, 0] or blue [line color: 0, 0, 1]), and size (large [size: 0.25] or small [size: 0.10]). The shapes always appeared at the center of the screen (position: 0, 0) and were drawn on a grey background. The words "Shape", "Colour", and "Size" served as task cues, indicating the dimension to be responded to. The cues were displayed in white (font style: Arial, letter height: 0.045) and were positioned just above the shapes and centered horizontally (position: 0, 0.17).

Participants were tested individually in a dimly lit room, seated in front of a 24-inch monitor at a distance of approximately 57 cm. The paradigms began with verbal instructions along with visual illustrations of the stimuli and response mappings. On each trial, participants were instructed to decide, based on the cue presented above the shape, whether the shape was a triangle or a circle (shape cue), whether it was red or blue (color cue), or whether it was large or small (size cue), by pressing the appropriate key ("Z" or "M") on a QWERTY computer keyboard with their left or right index finger, respectively (see Figure 1 for an example trial). Participants were also instructed (similar to Kessler et al., 2009): "Please be accurate in your responses."

Figure 1

Schematic Representation of an Example Trial During the Task-Switching Paradigms.

Fixation period for 3000 ms

Until response

Shape

Feedback tone for 500 ms (if error)

Time

Response mappings for 1000 ms

Press Z for   Press M for

red   blue

large   small

Note. The voluntary task-switching paradigm was identical to the forced task-switching paradigm, except that the task only switched if the participant pressed the spacebar during the fixation period.

Each trial began with the presentation of a black fixation cross (shape: cross, line width: 3, size: 0.07) for 3000 ms, followed by the simultaneous presentation of the cue and

the shape. Whenever participants pressed the wrong button, feedback (pure tone at 350 Hz for 500 ms) was given. The mapping between the stimulus dimensions and the response keys appeared on the screen as the final stimulus event for each trial (1000 ms). The next trial began after the mapping disappeared. Participants first completed 36 practice trials, followed by 180 experimental trials of the forced task-switching paradigm and then 180 experimental trials of the voluntary task-switching paradigm.

In the forced task-switching paradigm only, the task sequences were pseudo-randomized with the constraint that the following were equally probable: (a) shapes (triangle, circle), colors (red, blue), and sizes (large, small); (b) the three possible cue words; and (c) task-switch trials (e.g., from previous trial "Size" task to current trial "Shape" task) and task-repeat trials (e.g., from previous trial "Size" task to current trial "Size" task). In order to control for sequence difficulty and enable direct comparison of task-switching performance across participants, all participants received the same pseudo-randomized trial order and stimulus-response mappings for both the practice and the experimental blocks.

The voluntary task-switching paradigm was identical to the forced task-switching paradigm, except participants were instructed that, if they wished, they could switch to one of the other two tasks by pressing the space bar during fixation cross presentation. They were informed that by pressing the space bar, one of the other two tasks would be selected randomly. For instance, if the current task was "Colour" and the participant pressed the space bar during the fixation period, the task would be switched to either "Shape" or "Size". Finally, participants were further instructed, similar to Kessler et al. (2009), that "If you wish to respond to the same task, do not press anything when the fixation cross is shown". The first trial was set to the "Size" task.

2.2.2 Attentional Control Scale (ACS)

The ACS (Derryberry & Reed, 2002) is a 20-item scale used to assess attentional control. Participants responded to statements such as, "I can quickly switch from one task to another" on a 4-point Likert scale, ranging from 1 (almost never) to 4 (always). Participants were instructed to select the response that most accurately reflects their everyday experience. A higher score on the ACS indicates better attentional control. In the current study ($N = 79$), the ACS demonstrated good internal consistency (Cronbach's alpha = 0.76).

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

Deliberate (intentional) and spontaneous (unintentional) mind wandering were assessed with the MW-D and MW-S scales (Carriere et al., 2013). Both scales have four items scored on a 7-point Likert scale, ranging from 1 (rarely/not at all true/almost never) to 7 (a lot/very true/almost always). Participants were instructed to select the answer that most accurately reflects their everyday experience. A higher score on the MW-D scale items (e.g., *I allow my thoughts to wander on purpose*) indicates a greater tendency to deliberately engage in mind wandering in everyday life, and a higher score on the MW-S scale items (e.g., *I mind wander even when I'm supposed to be doing something else*) indicates a greater tendency to spontaneously engage in mind wandering in everyday life. In the current study ($N = 79$), both the MW-D scale items (Cronbach's alpha = 0.81) and the MW-S scale items (Cronbach's alpha = 0.70) demonstrated good internal consistency.

2.2.4 Numerical Rating Scales (NRSs)

The NRSs, which were purpose-designed for this experiment, required participants to rate the following questions on an 11-point scale, ranging from 0 (not at all) to 10 (very): "How motivated were you to perform the experiment?", "How frequently were you thinking about things unrelated to the task (e.g., personal reflections)?", and "How frequently were you thinking about things related to the task (e.g., I should respond quicker!)?" The highest

score (10) indicates highly motivated/more task-unrelated thoughts (TUTs)/more task-related

thoughts (TRTs), whereas the lowest score (0) indicates not at all motivated/no TUT/no TRT.

The second and third questions were included to confirm the mind-wandering reports

collected via the DSSQ.

2.2.5 Awareness of Self-Initiated Task-Switches

Participants were asked to indicate "Regarding the voluntary task-switching

paradigm, every time I pressed the 'SPACEBAR' to switch tasks, I was consciously aware of

it." The response options included "Yes, 100%", "Yes, but not 100%", and "Not applicable,

as I did not switch task". This question served to explore whether all included participants

were consciously aware of the switches they initiated.

2.2.6 Dundee Stress State Questionnaire (DSSQ)

Consistent with previous studies (e.g., Barron et al., 2011; Helton & Warm, 2008;

Neigel et al., 2019; Smallwood et al., 2009), the Thinking Content Component of the DSSQ

(Matthews et al., 2002) was used to retrospectively assess mind wandering. This scale

includes 16 items scored on a 5-point Likert scale, ranging from 1 (never) to 5 (very often).

Participants were instructed to indicate how often they had each type of thought while

performing the task-switching paradigms. A higher score on TRT subscale items (e.g., *I

thought about my level of ability*) indicates more focus on the task, whereas a higher score on

TUT subscale items (e.g., *I thought about personal worries*) indicates more mind wandering

during performance of the switching paradigms. In the current sample ($N = 79$), both the

DSSQ-TRT subscale items (Cronbach's alpha = 0.70, 8 items) and the DSSQ-TUT subscale

items (Cronbach's alpha = 0.85, 8 items) demonstrated good internal consistency.

2.3 Statistical Analyses

All statistical analyses were performed using SPSS v26 (IBM Corp., Armonk, NY, USA). In order to directly compare participants' task-switching performance, we divided participants into high and low mind-wandering tendency groups on the basis of a median split (similar to Biederman et al., 2017; Franklin et al., 2016; Zhang & Kumada, 2018) of MW-S scores. This split was based on the MW-S score (rather than the MW-D, the NRS-TUT, or the DSSQ-TUT scores) because it provided the only measure of trait-level spontaneous mind wandering in the current study.

For both switching paradigms, independent t tests analyzed mean correct RTs, switch cost RTs (i.e., mean correct RTs on switch trials minus mean correct RTs on repeat trials), proportion of incorrect responses (i.e., error rates), and switch cost error rates (i.e., mean error rates on switch trials minus mean error rates on repeat trials), with spontaneous mind-wandering tendency group (high, low) as a between-subject variable. The first trial (neither a repeat nor a switch trial) was removed from analyses. For the forced task-switching paradigm only, similar to Kam and Handy (2014), we excluded from further analysis: trials with RTs less than 200 ms or more than three standard deviations above an individual's mean RT. For the voluntary task-switching paradigm only, independent t tests also analyzed number of task switches, and similar to Mittelstädt et al. (2019), we excluded from further analysis: trials with RTs less than 200 ms or greater than 3000 ms. We did not apply the same exclusion criteria for the voluntary task-switching paradigm because all RTs exceeding three standard deviations above the individual's mean RT were self-initiated switch trials. Thus, excluding them would remove meaningful data. Similar to Proskovec et al. (2019), in the current study, participants with smaller switch cost RTs are considered to have better task-switching performance.

Independent *t* tests assessed between-group differences in the MW-S, ACS, MW-D, NRSs, and DSSQ scores. An alpha of .05 was chosen a priori to signify statistical significance. We report Hedges' *g* as an effect-size estimate for all *t* tests as it is robust to unequal group sizes (Lakens, 2013). Benchmarks of 0.20, 0.50, 0.80 were used to indicate small, medium, and large effect sizes (Cohen, 1988).

3. Results

The mean MW-S scores for the high ($n = 35$, 83% females and 17% males) and low ($n = 44$, 82% females and 18% males) spontaneous mind-wandering tendency groups were 23.20 ($SD = 1.80$, range = 21−28) and 16.34 ($SD = 3.40$, range = 7−20), respectively, $t(67.923) = 11.525$, $p < .001$, 95% *CI* [5.671, 8.047], Hedges' $g = 2.419$. No significant difference was observed between the two groups for age (19.37 ± 1.59 years for the high MW-S group and 19.77 ± 1.63 years for the low MW-S group), $t(77) = -1.100$, $p = .275$, 95% *CI* [−1.128, 0.325], Hedges' $g = -0.246$, or years of education (14.56 ± 1.45 years for the high MW-S group and 14.78 ± 1.05 years for the low MW-S group), $t(77) = -0.807$, $p = .422$, 95% *CI* [−0.787, 0.333], Hedges' $g = -0.175$.

3.1 Forced Task-Switching Paradigm

Group performance in the forced task-switching paradigm is summarized in Table 1. Prior to the analyses, we removed 0.01% of the correct trials due to the RT being less than 200 ms and 1.47% of the correct trials due to the RT exceeding three standard deviations above the individual's mean RT. Compared to the low MW-S group, the high MW-S group had smaller switch cost RTs, $t(77) = -2.125$, $p = .037$, 95% *CI* [−65.406, −2.120], Hedges' $g = -0.464$, and higher error rates on repeat trials, $t(54.053) = 2.175$, $p = .034$, 95% *CI* [0.061, 1.497], Hedges' $g = 0.515$. No significant group differences were observed for repeat trial RTs, $t(77) = 0.406$, $p = .686$, 95% *CI* [−75.160, 113.674], Hedges' $g = 0.090$, switch trial

RTs, $t(77) = -0.268$, $p = .789$, 95% *CI* [−122.849, 93.689], Hedges' $g = -0.062$, error rate on

switch trials, $t(77) = 0.600$, $p = .550$, 95% *CI* [−1.050, 1.955], Hedges' $g = 0.134$, or switch

cost error rates, $t(77) = -0.447$, $p = .656$, 95% *CI* [−1.791, 1.134], Hedges' $g = -0.101$.

Table 1

Forced Task-Switching Paradigm Performance by Spontaneous Mind-Wandering Tendency Group

	Mean correct RTs (ms)				Error rate (%)		
Mind-wandering group	Repeat trial *(SD)*	Switch trial *(SD)*	Switch cost *(SD)*	Switch frequency *(SD)*	Repeat trial *(SD)*	Switch trial *(SD)*	Switch cost *(SD)*
High MW-S	1072	1174	102	90	1.92	5.07	3.15
(*n* = 35)	(225)	(250)	(52)	(0)	(1.85)	(2.91)	(2.59)
Low MW-S	1053	1189	135	90	1.14	4.62	3.48
(*n* = 44)	(196)	(232)	(82)	(0)	(1.15)	(3.63)	(3.68)
Difference	**19**	**−15**	**−33***	**0**	**0.78***	**0.45**	**−0.33**

Note. MW-S = Mind Wandering-Spontaneous Scale; Repeat trial RTs = mean correct reaction times in repeat trials; Switch trial RTs = mean correct reaction times in switch trials; Switch cost RTs = mean correct reaction times in switch trials – mean correct reaction times in repeat trials; Switch frequency = frequency of task switches; Repeat trial error rate = proportion of incorrect responses in repeat trials; Switch trial error rate = proportion of incorrect responses in switch trials; Switch cost error rate = mean error rate in switch trials – mean error rate in repeat trials.

* $p < .05$.

3.2 Voluntary Task-Switching Paradigm

Group performance in the voluntary task-switching paradigm is summarized in Table 2. Prior to the analyses, we removed 0.35% of the correct trials due to the RT exceeding 3000 ms. There were five participants (two in the high MW-S group and three in the low MW-S group) who did not switch tasks at all (i.e., performed the "Size" task only). Thus, these five participants did not contribute any data to the analysis of switch trial RTs, switch cost RTs, switch trial error rates, and switch cost error rates. No significant difference was observed between the two groups for any of the measures (repeat trial RTs, $t(77) = 0.116$, $p = .908$, 95% CI $[−63.762, 71.637]$, Hedges' $g = 0.026$, switch trial RTs, $t(72) = 0.196$, $p = .845$, 95% CI $[−136.589, 166.397]$, Hedges' $g = 0.046$, switch cost RTs, $t(72) = 0.170$, $p = .865$, 95% CI $[−131.978, 156.592]$, Hedges' $g = 0.042$, switch frequency, $t(77) = −0.970$, $p = .335$, 95% CI $[−5.654, 1.949]$, Hedges' $g = −0.218$, error rate on repeat trials, $t(77) = −0.628$, $p = .532$, 95% CI $[−0.794, 0.413]$, Hedges' $g = −0.141$, error rate on switch trials, $t(72) = −0.015$, $p = .988$, 95% CI $[−3.170, 3.122]$, Hedges' $g = −0.003$, and switch cost error rates, $t(72) = 0.131$, $p = .896$, 95% CI $[−3.031, 3.458]$, Hedges' $g = 0.030$).

Table 2

Voluntary Task-Switching Paradigm Performance by Spontaneous Mind-Wandering Tendency Group

Mind-wandering group	Mean correct RTs (ms)				Error rate (%)		
	Repeat trial *(SD)*	Switch trial *(SD)*	Switch cost *(SD)*	Switch frequency *(SD)*	Repeat trial *(SD)*	Switch trial *(SD)*	Switch cost *(SD)*
High MW-S	647	1304[a]	663[a]	6.94	1.24	2.95[a]	1.64[a]
(*n* = 35)	*(124)*	*(334)*	*(301)*	*(8.54)*	*(1.16)*	*(7.53)*	*(7.86)*
Low MW-S	643	1289[b]	650[b]	8.80	1.43	2.97[b]	1.43[b]
(*n* = 44)	*(168)*	*(317)*	*(316)*	*(8.34)*	*(1.46)*	*(6.05)*	*(6.14)*
Difference	**4**	**15**	**13**	**−1.86**	**−0.19**	**−0.02**	**0.21**

Note. MW-S = Mind Wandering-Spontaneous Scale; Repeat trial RTs = mean correct reaction times in repeat trials; Switch trial RTs = mean correct reaction times in switch trials; Switch cost RTs = mean correct reaction times in switch trials – mean correct reaction times in repeat trials; Switch frequency = frequency of task switches; Repeat trial error rate = proportion of incorrect responses in repeat trials; Switch trial error rate = proportion of incorrect responses in switch trials; Switch cost error rate = mean error rate in switch trials – mean error rate in repeat trials.

[a] Data from 33 participants.

[b] Data from 41 participants.

3.3 ACS, MW-D, NRSs, Awareness of Self-Initiated Task-Switches, and DSSQ

Questionnaire scores are summarized by spontaneous mind-wandering tendency group in Table 3. Compared to the low MW-S group, the high MW-S group indicated poorer

attentional control, $t(77) = -2.511$, $p = .014$, 95% *CI* [−6.967, −0.805], Hedges' $g = -0.564$, higher deliberate mind-wandering tendencies, $t(77) = 2.013$, $p = .048$, 95% *CI* [0.023, 4.353], Hedges' $g = 0.452$, higher NRS-TUT, $t(77) = 3.560$, $p = .001$, 95% *CI* [0.874, 3.091], Hedges' $g = 0.796$, and higher DSSQ-TUT, $t(77) = 2.988$, $p = .004$, 95% *CI* [1.473, 7.355], Hedges' $g = 0.670$. We did not observe any significant between-group differences in NRS-motivation, $t(77) = -0.259$, $p = .796$, 95% *CI* [−0.864, 0.665], Hedges' $g = -0.058$, NRS-TRT, $t(77) = -1.203$, $p = .233$, 95% *CI* [−1.650, 0.407], Hedges' $g = -0.269$, or DSSQ-TRT, $t(77) = 1.632$, $p = .107$, 95% *CI* [−0.437, 4.408], Hedges' $g = 0.367$.

Table 3

Questionnaire Scores by Spontaneous Mind-Wandering Tendency Group

Mind-wandering group	ACS (SD)	MW-D (SD)	NRS-Motivation (SD)	NRS-TRT (SD)	NRS-TUT (SD)	DSSQ-TRT (SD)	DSSQ-TUT (SD)
High MW-S	49.11	22.14	6.51	6.63	6.91	26.49	20.80
(*n* = 35)	(7.24)	(5.13)	(1.92)	(2.40)	(2.36)	(5.56)	(6.52)
Low MW-S	53.00	19.95	6.61	7.25	4.93	24.50	16.39
(*n* = 44)	(6.49)	(4.52)	(1.50)	(2.18)	(2.54)	(5.21)	(6.52)
Difference	**−3.89***	**2.19***	**−0.10**	**−0.62**	**1.98****	**1.99**	**4.41****

Note. MW-S = Mind Wandering-Spontaneous Scale; ACS = Attentional Control Scale; MW-D = Mind Wandering-Deliberate Scale; NRS-Motivation = Numerical Rating Scale-Motivation; NRS-TRT = Numerical Rating Scale-Task-Related Thought; NRS-TUT = Numerical Rating Scale-Task-Unrelated Thought; DSSQ-TRT = Dundee Stress State Questionnaire-Task-Related Thought; DSSQ-TUT = Dundee Stress State Questionnaire-Task-Unrelated Thought.

* $p < .05$.

** $p < .01$.

Regarding the awareness of self-initiated task-switches, all participants selected "Yes, 100%" (including those who did not switch tasks at all), except for three participants who selected "Yes, but not 100%" and pressed the spacebar 25, six, and five times, respectively. As we were unable to identify switches initiated without awareness, no switch trials were removed.

4. Discussion

The purpose of this study was to examine whether healthy young adults with higher self-reported spontaneous mind-wandering tendencies demonstrate better performance on the forced task-switching paradigm and initiate more switches during performance of the voluntary task-switching paradigm. Consistent with our hypothesis, the results showed that compared to participants with lower self-reported spontaneous mind-wandering tendencies, participants with higher self-reported spontaneous mind-wandering tendencies demonstrated smaller switch cost RTs in the forced task-switching paradigm despite indicating more mind wandering during performance of the switching paradigms. The higher levels of mind wandering during the switching paradigms could not be attributed to lower motivation, but could at least in part reflect poorer ability to maintain the current task goal (McVay & Kane, 2009, 2010, 2012). However, in contradiction to our hypothesis, the number of self-initiated task switches on the voluntary task-switching paradigm did not differ between the two mind-wandering tendency groups.

Our findings that participants with higher self-reported spontaneous mind-wandering tendencies demonstrated smaller switch cost RTs in the forced task-switching paradigm despite indicating more mind wandering during the tasks may provide insight into the lack of performance costs associated with mind wandering in previous task-switching studies (e.g., Arnau et al., 2020; Kam & Handy, 2014; Thomson et al., 2014): mind wandering (i.e., switching between task-related and task-unrelated mental sets) during task-switching performance (i.e., a context in which one is required to switch between task-related mental sets) may in fact promote cognitive flexibility (for a review, see Dreisbach & Fröber, 2019). Consistent with this conjecture, a recent study provided evidence that when task/mental sets change more frequently, an increase in cognitive flexibility is triggered to improve task-set reconfiguration, which can lead to better task-switching performance (Zhuo et al., 2021). In

relation to this, we propose that in our study, participants with higher self-reported spontaneous mind-wandering tendencies, who also indicated higher rates of mind wandering during performance of the switching paradigms, may have triggered an increase in cognitive flexibility to a greater extent than participants with lower self-reported spontaneous mind-wandering tendencies. Taken together, the current results provide initial empirical evidence suggesting that when those with higher spontaneous mind-wandering tendencies mind wander during performance of a forced task-switching paradigm, they may engage in a "set-switching mode" and consequently can maintain, if not improve, task switching performance.

The failure to support our hypothesis that those with higher self-reported spontaneous mind-wandering tendencies would initiate more switches during performance of the voluntary task-switching paradigm (due to a higher propensity for shifting mental sets) may relate to participants in the current study choosing to switch tasks unusually infrequently. In contrast to a previous study (Kessler et al., 2009) that used the same voluntary task switching paradigm and instructions and observed a mean switch rate of 10% in Experiment 1 (i.e., on average, a self-initiated switch occurred every 10 trials) and 13% in Experiment 2 (i.e., on average, a self-initiated switch occurred every 7.5 trials), we observed a mean switch rate of only 4% across the two mind-wandering tendency groups (i.e., on average, a self-initiated switch occurred every 22.4 trials). The considerably lower number of self-initiated task switches may have limited our ability to explore the association between spontaneous mind-wandering tendencies and voluntary task-switching behavior. To induce higher levels of voluntary task-switching behavior in an unconstrained environment (i.e., where the participant is allowed to perform the same task as often as they prefer), future research should consider the use of the self-organized task-switching paradigm (Mittelstädt et al., 2018), as in several recent studies, this paradigm was found to be powerful enough to

induce high levels of voluntary task-switching behavior (a mean switch rate of 16% to 49%;

Mittelstädt et al., 2018; 2019; Mittelstädt et al., 2021).

While the current study offers initial evidence of an interrelationship between mind

wandering tendencies and switching abilities (Wong et al., 2021), several limitations are

noteworthy. First, we did not collect mind-wandering data immediately after participants

completed each paradigm, thereby making it impossible to identify whether participants mind

wandered more frequently during performance of a relatively effortless task (i.e., the

voluntary task-switching paradigm; Seli et al., 2018; Smallwood et al., 2013; Thomson et al.,

2013) or during performance of a relatively effortful task (i.e., the forced task-switching

paradigm; Xu & Metcalfe, 2016). Second, it remains unknown whether the current findings,

namely that the high MW-S group demonstrated better switching performance despite

indicating poorer attentional control and more mind wandering during performance of the

switching paradigms, have relevance to other populations (e.g., children, older adults, and

clinical populations). Furthermore, like many psychology studies, our participants were

primarily female (e.g., Groot et al., 2021; Martínez-Pérez et al., 2021; Mazzoni, 2019) and

restricted to young undergraduates in a single Western, educated, industrialized, rich, and

democratic cultural context (for a review, see Henrich, 2020). Therefore, future studies

should explore the generalizability of the present findings and further validate, or challenge,

the switching account of mind wandering.

In addition, we encourage future researchers to examine the role of inhibitory

control and working memory in mind wandering, as executive control functions are

moderately associated with one another (Miyake et al., 2000) and cannot operate entirely

independently (Diamond, 2013). Determining the interrelationships with these other

executive functions may help answer two important questions: first, why some populations

experience excessive mind-wandering episodes (e.g., individuals with ADHD; Bozhilova et

al., 2018), while others experience fewer episodes (e.g., individuals with Parkinson's disease; Walpola et al., 2020); and second, why young adults show a negative correlation between mind-wandering rate and working memory capacity (e.g., McVay & Kane, 2009, 2012; Randall et al., 2014; Robison & Unsworth, 2018) given that they also show a negative association between working memory capacity and task-switching performance (Miyake et al., 2000; Oberauer et al., 2003; Shipstead et al., 2015; for more details, see Draheim et al., 2016).

In conclusion, the current study represents the first attempt to test the switching perspective of mind wandering. Notwithstanding the limitations in the representativeness of the sample, the results suggest that healthy young adults with higher self-reported spontaneous mind-wandering tendencies outperform those with lower self-reported spontaneous mind-wandering tendencies when required to switch between tasks, providing initial support to the newly forwarded switching perspective (Wong et al., 2021). Although much research is needed to fully understand the role of cognitive flexibility in mind wandering, this first step towards highlighting the relevance of cognitive flexibility in mind wandering may help researchers towards gaining a more nuanced and holistic understanding of past findings (e.g., Arnau et al., 2020; Kam & Handy, 2014; Thomson et al., 2014).

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