MIND WANDERING AND TIME OF DAY PREFERENCE

MIND WANDERING AND TIME OF DAY PREFERENCE: THE SYNCHRONY EFFECT AND EXECUTIVE CONTROL

By

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ABSTRACT

Individuals often display preferences for the morning or evening; this preference is referred to as a chronotype and is supported by distinct diurnal physiological and behavioural fluctuations. Whereas prior work suggests an increase in individuals executive control throughout the day, the current study assesses the diurnal time course of executive control and the tendency to mind wander as a function of chronotype. Results suggest that executive control processes are modulated by time of day, with chronotype match conditions associated with increased executive control, akin to the 'Synchrony Effect' of chronotypes (Hasher et al., 2002). Results suggest that variations in the level of semantic processing in a task influences time of day effects on non-automatic (executive control) functioning.

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INTRODUCTION

Regardless of awareness, spontaneous thought processes are prevalent in our mental life. Also known as "mind wandering", spontaneous thoughts cause a decoupling of attentional resources and as a result, performance declines on the task to which your attention should be attuned declines (Smallwood & Schooler, 2006; Smallwood et al., 2008). Previous research using brain imaging (fMRI) suggests that mind wandering involves neural recruitment of both the default network (Raichle et al., 2001) and the higher order central executive (Christoff et al., 2009). Executive functioning has been shown to fluctuate throughout the day, however conflicting reports have made it difficult to ascertain TOD influences on executive functioning (Manley et al., 2002). In this paper we attempt to clarify time of day effects on the executive system and one's tendency to mind wander.

The central executive network (including the dorsal anterior cingulate cortex and dorsolateral prefrontal cortex in the case of mind wandering (Christoff et al., 2009)) is a finite capacity system (Baddeley, 1998; Baddeley, 2000; Kane & Engle, 2002; Sabb, Bilder, Chou & Bookheimer, 2007) that mediates conflict resolution (Fan et al., 2002; Matchock & Mordkoff, 2009), preserves ongoing cognitive activity against unexpected distractions (Schmidt et al., 2007), and is supported by the voluntary anterior attention system (Dennis & Chen, 2007). Executive control is strongly associated with inhibitory control (e.g. ability to withhold response to a target stimuli while responding to all other stimuli in the task) (Fan et al., 2002), and during mind wandering is behaviourally associated with failures of response inhibition (Smith et al., 2006) and reduced ability to inhibit spontaneous thought (McVay & Kane, 2009). As a result, the more inhibitory control required to successfully complete the task, the less likely it is that participants will engage in episodes of mind wandering (Smallwood & Schooler, 2006).

The Sustained Attention to Response Task (SART) (Robertson, Manly, Andrade, Baddeley & Yiend, 1997) is an executive control task with a continuous go/no-go paradigm that has been extensively used to behaviourally study mind wandering (Smallwood, Davies, Heim, Finnigan, Sudberry & O'Connor, 2004; Smallwood et al., 2008). Participants are shown a series of non-target stimuli to which they simply have to make a response as soon as possible. On a small proportion of the trails however (low target probability is ~20% and high target probability can be up to ~40% (Smallwood et al., 2007)), a target stimulus appears to which participants must withhold their response. To perform well the participant must maintain enough top-down control over response tendency to avoid making a response on no-go trials. The go/no-go nature of the task allows the researcher to dissociate between automatic and non-automatic (executive) processes (Manley et al., 2002), with participant's reaction time indicating automatic functioning while participant's ability to with hold their response on the target trials indicates non-automatic functioning (Manley et al., 2002). For a subjective measure of mind wandering to corroborate the behavioural measures, participants are interrupted pseudo-randomly by a thought probe to establish whether or not the participant's attention was focused on the task. Overall, the task is used to establish a relatively inattentive response tendency (Manley et al., 2002) and facilitate mind wandering. As a secondary measure of decoupled attention when processing stimuli, a recognition or recollection task for the presented targets is sometimes added at the end of the task. Incidents of mind wandering on the SART have been associated with poorer performance on recollection and recognition tasks (Smallwood et al., 2007).

The default network is characterised by a set of brain regions (medial prefrontal cortex, anterior and posterior cingulate, inferior temporal, lateral parietal, and cerebellar regions) (Bluhm et al., 2007; Raichle et al., 2001) that are active while the brain is at rest (Mason et al., 2007). Default network recruitment is associated with performing easy or well practiced tasks (Mason et al., 2007), and during episodes of endogenously generated stimulus independent thought (Mason et al., 2007; Raichle et al., 2001). Damage to the default network causes "mental emptiness" and reduced stimulus independent thought, evidence for the necessary role of the default network in spontaneous thought processes (Mason et al., 2007). Conversely, default network recruitment is low during attention demanding tasks (Bluhm et al., 2007).

Time of day (TOD) modulation has been found for performance on a wide variety of attention based cognitive tasks (Ciarkowska & Janowski, 2008; Hasher, Chung, May & Foong, 2002). However, manipulations in task requirement and methodology a have yielded a wide range of results, leaving our general understanding of TOD modulation on cognitive performance to be inconclusive (Blatter & Cajochen, 2007). Such inconsistencies suggest that perhaps separate mental processes exist and that these processes are influenced differently by time of day. In an effort to clarify TOD modulation on executive response control, Manley et al. (2002) used the SART task to differentiate between automatic and non-automatic processes of attention. Results from the study suggest that a TOD modulation exists for non-automatic (frontal reliant) processes (e.g. inhibitory control), where functioning has been found to increase throughout the day and declines in the late hours of the evening. Automatic processes (e.g. routine responses) on the other hand, were found not to be influenced by time of day. Manley et al. therefore concluded that automatic and non-automatic processes are disproportionately influenced by time of day.

A factor that complicates the efforts of identifying time of day effects on task performance (and subsequent identification of network functioning) is that there are individual differences in people's preferred time of day. Variations in task performance can thus be due to both the influence of time of day and/or individual differences in time of day preference. To isolate the influence of TOD, it is imperative to control for individual differences in time of day preference. While Manley et al. (2002) successfully differentiated TOD effects on automatic and non-automatic processing, they failed to control for individual differences in time of day preference. The current study aims to differentiate TOD effects on automatic and non-automatic functioning while controlling for TOD preference.

Time of day preference is determined by the phase angle between an individual's circadian rhythm and the light/dark cycle as dictated by the earth's rotation (Beersma & Gordjin, 2007; Boivin, 2000; Cajochen et al., 2007; Ganshirt et al., 1992; Merrow et al., 2003). These preferences manifest as "chronotypes", an attribute that characterizes (along a continuum) whether an individual's peak performance is during the morning or the evening hours (Merrow et al., 2003). Morning types (MT) (commonly referred to as "larks"), are characterized by acme alertness during the morning hours while evening types (ET) (also known as "owls") are at peak alertness during the evening hours (Bouchard et al., 1998). Neutral types (NT) on the other hand, are synchronized with the external experimental and social conditions (Schmidt et al., 2007). Exploring differences between morning and evening types involves isolating performance during preferred time of day verses non-preferred time of day (Blatter & Cajochen, 2007). Testing individuals during non-preferred time of day is termed "chronotype mismatch", while testing individuals during their preferred time of day is termed "chronotype match" (Kruglanski & Pierro, 2008). A great deal of previous research on cognitive control tasks, including negative priming, recognition and recall, judgments and categorization (Hasher et al., 2002; Intons-Peterson, Rocchi West, McLellan, & Hackney, 1998) have shown that morning types and evening types perform worse when tested during their non-optimal time of day. This phenomenon is known as the "Synchrony Effect" (Hasher et al., 2002).

Focus and Predictions of the Present Research

The current research aims to expand and clarify on previous findings suggesting a TOD modulation for automatic and non-automatic (executive control) processes (Manly et al., 2002) and fluctuations in mind wandering while controlling for individual differences in TOD preference. Previous research conducted by Manley et al. (2002) suggests a TOD modulation on non-automatic processes but not for automatic processes. While Manley et al (2002) report an increase in the ability of individuals to inhibit their response to target stimuli (indicative of executive control) throughout the day, research on the Synchrony Effect suggests greater efficiency on cognitive tasks that require executive recruitment during optimal in comparison to non-optimal time of day (Hasher et al., 2002). Manley et al.'s failure to control for individual differences in time of day preference may have therefore skewed their conclusions on TOD influence on non-automatic processes. Enhanced cognitive efficiency during an individual's optimal time of day also applies to meta-cognitive awareness of mind wandering, whereby mind wandering with awareness requires greater resource availability and efficiency in order to indulge in spontaneous thought while maintain control over task performance (Smallwood & Schooler, 2006). Due to decoupling of attention, mind wandering is also associated with less accurate encoding and poorer performance on familiarity or recollection tasks (Smallwood, Baraciaia, Lowe & Obonsawin, 2003b).

The SART task has been shown to be successful in dissociating between automatic and non-automatic processes (Manley et al., 2002) and has been used in a wide variety of mind wandering studies to examine slips in executive control (Smallwood, Davies, Heim, Finnigan, Sudberry & O'Connor, 2004; Smallwood & Schooler, 2006; Smallwood et al., 2008). The study of mind wandering (using the SART task) is therefore a good way to disentangle the issues surrounding TOD modulation on the mechanisms that underlie mind wandering and fluctuations in automatic and non-automatic functioning. Based on the previous research mentioned, it is predicted in the current study that chronotype mismatch condition will lead to 1) a decrease in ability to withhold response to target stimuli, as suggested by the Synchrony Effect (Hasher et al., 2002), 2) unaffected reaction time on go trials, 3) an increase in subjective reporting of mind wandering, 4) an increase in subjective unawareness of mind wandering, and 5) poorer performance on the recognition post-test.

EXPERIMENT 1

Method

Participants

Participants (n= 69, 32 males and 37 females) were undergraduate students from McMaster University. Participants were recruited as either self-identified morning types or evening types. Morning types had to self identify as someone who easily wakes up in the morning and functions better in the morning than the evening. Alternatively, evening types had to self identify as someone who has a difficult time waking up in the morning and functions better in the evening in comparison to the morning. If participants identified as a morning type or an evening type, they signed up for the appropriate group (MT or ET) on the experimental scheduling software used. Half of the students in each group were directed to sign up for morning time slots (8:30am to 9:30am) only and the other half was directed to sign up for evening slots time slots (7:00pm to 8:00pm) only. Each participant was awarded course credit in exchange for participation.

Procedure and Materials

Participants spent approximately 1 hour in the laboratory. After signing informed consent, participants completed the Morningness-Eveningness Questionnaire (MEQ) (Horne & Ostberg, 1976) to establish whether they met the criteria for being a morning or evening person. The MEQ assess the time-of-day preference for sleep and waking, peak performance, mental and physical activities, as well as mood (Beersma et al., 2006; Bouchard et al., 1998; Drennan et al., 1991). Questions include "At what time in the evening do you feel tired and in need of sleep?" and "what time of day do you feel best?" Answers were in multiple choice format. Participants were then given the PANAS-X (Watson & Clark, 1994) to establish current affect state. The PANAS-X expands on two higher-order scales found in the previous PANAS with the addition of 11 subscales for specific affects (Clark & Watson, 1994) and differentiates between participant's level of positive affect (PA) and negative affect (NA). Previous research suggests both PA and NA account for 50-75% of the variance in selfrated mood and is sensitive to fluctuations in endogenous and exogenous conditions (assessment of state affect) (Clark & Watson, 1994). A general questionnaire was then given to acquire demographic (sex, age and handedness) information.

After the questionnaires, participants were given a modified Sustained Attention Response Task (SART; Robertson, Manly, Andrade, Baddeley & Yiend, 1997) to differentiate between automatic and non-automatic functioning, and the tendency for participants to mind wander. Participants are presented with either a target (no-go trials) or non-target stimulus in the middle of a screen. On non-target (go) trials participants were required to respond by pressing the space bar as quickly and accurately as possible. On 10% of the trials participants were presented with the target (no-go) stimuli, and were required to withhold their response. In the modified version of the SART used for this study, the stimuli are greyscale images of everyday objects and were presented on a white screen. The target stimulus was the picture of a ladder. Participants were shown 2 blocks of 253 stimuli. Both blocks contained the same stimuli, however all stimuli appeared in random order, across blocks, and across participants. Stimuli were presented for 950ms regardless of response, with a inter-stimulus interval of 300ms. A practice test was given prior to the task, of 12 targets, two of where target trials.

For a subjective measure of mind wandering, participants were interrupted by a pseudo-random probe (5% occurrence, defined as a low-probability probe (Smallwood et al., 2007)) to establish whether or not the participant's attention was on the task, as per the procedure in Christoff et al., (2009), Teasdale, Dritschel, Taylor, Proctor, Lloyd and Nimmo-Smith (1995), Smallwood and Schooler (2006) and Smith et al. (2006). The probe read "Stop! Was your attention just on the task?" Participants were able to choose from four response options, "My attention was on the task at hand", "My attention was sort of the on the task", "My attention was not on the task and I was not aware of it", and "My attention was not on the task and I was aware of it" The text of the probe was black on a white background and participants made their response on the keyboard. Participants were then given a recognition task, whereby they were shown 30 random stimuli and had to indicate whether they thought the stimuli had appeared earlier in the experiment or not. All questionnaires and experiments were presented using E-prime software (Schneider, Eschmann & Zuccolotto, 2002). Participants used the same computer for both the questionnaire and experiment portion.

Design

The experiment was a 2x2 between-subjects design, with the independent variables of *Chronotype* (Morning Type vs. Evening Type) and *Condition* (Match vs. Mismatch). The dependent variables were reaction time to non-target (go) trials; percent accurate withholding of response to target (no-go) stimuli; a subjective measure of the extent to which participants experienced mind wandering from their response to the probes; and accuracy on the recognition task.

Results

The MEQ scores confirmed that those who self identified as morning types were in fact morning types (Mean = 52.0, SD = 11.7) and that evening types were in fact evening types (Mean = 18.4, SD = 8.2). MEQ scoring protocols (Horne & Ostberg 1976) were modified slightly, where those who scored higher than 51 were classified as moderate morning types and those who scored lower than 49 were classified as moderate evening types. In order to test whether the morning types who signed up for the evening slots (mismatch condition) did not have a weaker preference than morning types who signed up for the morning slots (match condition), we tested whether MEQ scores differed significantly between morning match and mismatch conditions. No significant difference was found in MEQ score between morning match (Mean = 56.4, SD = 5.4) and mismatch conditions (Mean = 55.4, SD = 4.5), $t(33) = 2.12$, $p = ns$, indicating that the two morning groups were comparable. Likewise, no significant difference was found in MEQ score between evening types who signed up for evening time slots (match condition) (Mean = 19.7, SD = 8.8) and evening types that signed up for morning time slots (mismatch condition) (Mean = 17.2, SD = 7.6), either, $t(44) = 1.04$, $p = ns$, indicating that the two evening groups were also comparable.

To establish whether individuals perceived themselves as mind wandering more during their non preferred time of day, we tested the proportion of time participants indicated themselves as mind wandering during their preferred time of day (match condition) in comparison to their non preferred time of day (mismatch condition). Morning types tested in the match condition (Mean = 0.1, SD = 0.7) were significantly less likely to indicate themselves as mind wandering than in the mismatch condition (Mean = 0.3, SD = 0.7), $t(32) = -2.84$, $p < 0.01$. Evening types tested in the match condition (Mean = 0.3, SD = 0.2) were also significantly less likely to indicate themselves as mind wandering than in the mismatch condition (Mean = 0.6, SD = 0.2), $t(45) = -5.89$, $p < 0.01$.

To determine whether meta-cognitive awareness of mind wandering differed across match and mismatch conditions, we tested the proportion of time participants (after saying that their attention was off task) indicated they were unaware that their attention had strayed off task. Results showed that participants in the morning match condition (Mean = 0.7, SD = 0.4) were not significantly more likely to be unaware of their mind wandering in comparison to the morning mismatch condition (Mean = 0.7, SD = 0.3), $t(33) = -1.35$, $p = ns$, and similarly, evening types in the match (Mean = 0.7, SD = 0.4) condition were not significantly more likely to be unaware of their mind wandering in comparison to the evening mismatch condition (Mean = 0.7, SD = 0.3), $t(45) = -0.33$, $p = ns$.

To determine whether there was a TOD modulation on automatic processing for morning or evening types, we tested whether participants in the match conditions had on average longer reaction times than participants in the mismatch conditions. All participant responses that fell outside two standard deviations of the mean were removed from the analyses. Results showed no significant difference in mean RT between match (MT: Mean = 384.4 ms, SD =

51.7 ms; ET: Mean = 347.6 ms, SD = 52.8 ms) and mismatch (MT: Mean = 356.0 ms, SD = 49.1 ms; ET: Mean = 357.4 ms, SD = 49.7 ms) conditions for both morning types, $t(34) = 1.7$, $p = ns$, and evening types, $t(45) = -0.7$, $p = ns$, suggesting that TOD does not influence automatic processing for both morning and evening types.

To ascertain whether there is a TOD modulation on non-automatic processing for morning or evening types, we tested the proportion of times participants in the match conditions were able to withhold their response to the target stimuli in comparison to participants in the mismatch conditions. Results showed no significant difference in ability to withhold response to target stimuli between match (MT: Mean = 0.8, SD = 0.1; ET: Mean = 0.8, SD = 0.2) and mismatch (MT: Mean = 0.7, SD = 0.1; ET: Mean = 0.7, SD = 0.1) conditions for both morning types, $t(35) = -1.64$, $p = ns$, and evening types, $t(45)=0.05$, $p = ns$, suggesting that TOD does not influence non-automatic processing for either morning types and evening types.

As an additional measure of mind wandering during task performance, we compared recognition accuracy on 30 items (hits – false alarms) between match (MT: Mean = 0.3, SD = 0.2; ET: Mean = 0.2, SD = 0.2) and mismatch (MT: Mean = 0.2, SD = 0.2; ET: Mean = 0.7, SD = 0.1) conditions for both morning types and evening types. Results indicate that recognition accuracy did not differ for morning groups across match and mismatch conditions, $t(35) = 0.902$, $p = ns$, and similarly, recognition accuracy did not differ for evening groups across match and mismatch conditions, $t(45) = -0.952$, $p = ns$. The results of Experiment 1 are summarized in Table 1 (morning types) and Table 2 (evening types).

Table 1.

Experiment 1 (Morning Types)

Measure	Match Condition Mean(SD)	Mismatch Condition Mean(SD)	Difference (Match-Mismatch)
MEQ	56.33(5.42)	55.44(4.48)	0.90
Percentage of Time Participants Said They Were Mind Wandering	0.08(0.16)	0.30(0.26)	-0.21 **
Proportion of Unawareness of Mind Wandering	0.71(0.39)	0.70(0.28)	0.01
Reaction Time	384.44(51.70)	356.00(49.06)	28.45
Recognition Accuracy Percentage (Hits-False Alarms)	0.25(0.20)	0.20(0.22)	0.05
Proportion of Correct Inhibition Of Response	0.78(0.11)	0.72(0.12)	0.06

Note. *p<.05, **p<.01

Table 2.

Experiment 1 (Evening Types)

Measure	Match Condition	Mismatch Condition	Difference

	Mean(SD)	Mean(SD)	(Match-Mismatch)
MEQ	19.70(8.83)	17.17(7.58)	2.53
Percentage of Time Participants Said They Were Mind Wandering	0.27(0.20)	0.62(0.21)	-0.35 **
Proportion of Unawareness of Mind Wandering	0.69(0.35)	0.72(0.34)	-0.03
Reaction Time	347.60(52.77)	357.41(49.68)	-9.81
Recognition Accuracy Percentage (Hits-False Alarms)	0.22(0.16)	0.26(0.11)	-0.04
Proportion of Correct Inhibition Of Response	0.75(0.15)	0.74(0.13)	-0.01

Note. *p<.05, **p<.01

Discussion

Morning types that were tested in the morning indicated themselves as mind wandering less than morning types tested in the evening, and likewise, evening types that were testing during the evening indicated themselves as mind wandering less than evening types tested in the morning. The trend for both chronotypes is consistent with our hypothesis that individuals perceive themselves as mind wandering more during their non preferred time of day.

Automatic processes (measured by response time on target trials) were not found to be modulated by the time of day, consistent with previous findings reported by Manley et al. (2002). Non-automatic processes (measured as success in withholding response on non-target trials) however, were also found to not be modulated by time of day, a finding contradictory to our predictions and results reported by Manley et al. (2002) and others (May et al., 1993; West et al., 2002).

A TOD modulation was not found for meta-cognitive awareness of mind wandering for morning types or evening types, however the general trend suggests that individuals are more likely to be unaware of their mind straying off task during their non-optimal time of day as predicted. These results suggest that the mechanisms involved in unconscious shifts in attention are not dependent on time of day preference (Smallwood & Schooler, 2006, Smallwood et al., 2006), and that general reductions in cognitive efficiency associated with non-optimal testing times (Hasher et al., 2002) does not influence an individual's ability to consciously detect deviations in attentional focus.

Performance on the recognition accuracy task failed to show a significant TOD modulation for morning types or evening types. This finding is not surprising considering there was no difference between match and mismatch conditions for mean reaction time, ability to withhold response to target stimuli (omission rate) and meta-cognitive awareness in both the morning and evening conditions, components of which are associated with familiarity and retrieval (Smallwood et al., 2007). Interestingly, regardless of time of day preference, the general trend in performance suggests that participants perform better during the morning hours in comparison to the evening hours. This finding is in accordance with previous research suggesting that the mechanisms involved in immediate memory peak during the morning hours (Carrier & Monk, 2000), rather than being wholly dependent on an individual's optimal time of day.

The dissociation in significant results between the subjective (mind wandering probe) and behavioural (RT, omission rate, recognition accuracy) measures is curious and unexpected. One explanation could be that time of day preference affects only an individual's self-perceived amount of mind wandering, but not their overt performance. Alternatively, the results may be due to the structure of the probe. Providing a series of alternative forced choices (participants having to choose between whether they were mind wandering or not, and if mind wandering, whether they were aware of it or not) rather than a Likert-like scale may be problematic in accurately measuring a participant's experience during the task.

Another potential reason for the (lack of) results could be due to processing demands of the pictorial stimuli. Previous research by Smallwood, Riby, Heim and Davies (2006) suggests that individuals are less likely to engage in task-unrelated thought during conceptual and semantic processing of stimuli in comparison to perceptual processing of stimuli (e.g. words vs. letter strings). The reduced tendency to mind wander (measured behaviourally as increased reaction time and ability to withhold response to target stimuli (Manley et al., 1999; Robertson et al., 1997; Smallwood et all., 2007)) when presented with conceptually or semantically rich stimuli is interpreted as a "benefit". In light of this performance benefit, processing pictorial stimuli (like processing words) may influence a participant's tendency to mind wander and thus influence participants' cognitive efficiency in completing the task.

EXPERIMENT 2

In an effort to clarify the lack of TOD modulation for non-automatic processes found in Experiment 1, the SART was modified in Experiment 2 to include numbers as stimuli rather than images of objects. Previous research has been successful in using the numerical SART to identify mind wandering episodes (Christoff et al., 2009; Robertson et al., 1997, Smallwood et al., 2004; Smallwood et al., 2008; Smith et al., 2006). The mind wandering probe was also modified to include two separate Likert scales rather than a singular forced alternative choice probes. The first scale determined the extent to which participants' attention was on the task. If their attention was not on the task, the second scale determined the extent to which participants were aware that their attention had shifted.

It was predicted that the pictorial stimuli would show a performance benefit in comparison to the numerical stimuli, whereby participants will mind wander more when presented with numbers rather than pictures. We predicted that the increase in mind wandering in Experiment 2 would manifest as overall lower mean RTs and lower omission rate in comparison to results from Experiment 1. This modification was therefore adopted to investigate a) whether a benefit exists for pictorial stimuli, and b) whether the benefit lead to the lack of TOD influence on non-automatic processing found in Experiment 1.

It was predicted that automatic processes would continue to show no TOD modulation. Based on the results from Experiment 1, it was predicted that meta-cognitive awareness of mind wandering would not be influenced by time of day, however it is possible that results may vary due the modifications made to the probe.

Method

Participants

Participants (n=45, 19 males and 26 females) were undergraduate students from McMaster University. Recruitment and group assignment procedures were the same as in Experiment 1.

Procedure

The procedure is the same as Experiment 1. The Sustained Attention Response Task (SART) was modified so that the non-target stimuli were the numbers 0 through 9, and the target stimulus was the number 3, as per the procedure in prior studies (Christoff et al., 2009; Robertson et al., 1997; Smallwood et al., 2004; Smallwood et al., 2008; Smith et al., 2006). Participants were shown two blocks of 179 stimuli. Stimuli were presented for 950ms regardless of response, with a fixation period of 300ms. The numbers were presented in black print and projected on a white screen. Participants were also given a practice test with 12 trials, 2 of which were target trials. Response instructions were the same as in Experiment 1.

The mind wandering probe was the same as Experiment 1, except the probe was modified to include two questions. The first question was "Stop! Where was your attention focused before this question?" where participants scored their response on a scale of 1 (on task) to 7 (off task). The second question was "How aware were you of where your attention was?" where participants scored their response on a scale of 1 (Unaware) to 7 (Aware) as used in Smith et al. (2006). All questionnaires and experiments were presented using E-prime software (Schneider et al., 2002).

Design

The experiment was a 2x2 between-subjects design, with the independent variables of *Chronotype* (Morning Type vs. Evening Type) and *Condition* (Match vs. Mismatch). The dependent variables were reaction time (indicator of automatic processing) on go trials, the proportion of no-go trials erroneously responded to (indicator of non-automatic processing) on no-go trials, mind wandering score (subjective indicator of attentional focus) and awareness score (subjective indicator of meta-cognitive awareness of attentional focus).

Results

The MEQ scores confirmed that those who self identified as morning types were in fact morning types (Mean = 55.7, SD = 3.3) and that evening types were in fact evening types (Mean = 40.9, SD = 5.3). MEQ scoring protocols

(Horne & Ostberg 1976) were modified slightly, where those who scored higher than 51 were classified at moderate morning types and those who scored lower than 49 were classified as moderate evening types. In order to test whether the morning types who signed up for the evening slots (mismatch condition) did not have a weaker preference than morning types who signed up for the morning slots (match condition), we tested whether MEQ scores differed significantly between morning match and mismatch conditions. No significant difference was found in MEQ score between morning match (Mean = 56.1, SD = 3.3) and mismatch conditions (Mean = 55.3, SD = 3.4), $t(20) = 0.53$, $p = ns$, indicating that the two morning groups are comparable. Likewise, no significant difference was found in MEQ score between evening types who signed up for evening time slots (match condition) (Mean = 41.0, SD = 5.2) and evening types that signed up for morning time slots (mismatch condition) (Mean = 39.3, SD = 6.4) either, $t(21) = 0.67$, $p = ns$, indicating that the two evening groups are also comparable.

To establish whether individuals perceived themselves as mind wandering more during their non preferred time of day, we tested whether participants indicated themselves as mind wandering more during their preferred time of day (match condition) in comparison to their non preferred time of day (mismatch condition). Both morning types and evening types indicated their attention as being off task more in the mismatch condition (MT: Mean = 0.2, SD = 0.3; ET: Mean = 0.1, SD = 0.5) in comparison to the match condition (MT: Mean = 0.2, SD = 0.3; ET: Mean = 0.3, SD = 0.3), however this trend was not significant for either groups, $t(21) = -0.20$, $p = ns$, $t(21) = -1.62$, $p = ns$.

During episodes of mind wandering as indicated by response on the first probe, we tested the proportion of times individuals were more likely to be unaware during their non preferred time of day in comparison to their preferred time of day. Morning types in the match condition (Mean = 0.7, SD = 0.2) were significantly more likely to be unaware of their attention being off the task than morning types in the mismatch condition (Mean = 0.4, SD = 0.3), $t(20) = 2.05$, $p < 0.05$. Individuals in the Evening condition showed a similar trend (Match: Mean = 0.6, SD = 0.3; Mismatch: Mean = 0.6, SD = 0.2), however the relationship did not reach significance, $t(21) = 0.27$, $p = ns$.

To determine whether there was a TOD modulation on automatic processing for morning or evening types, we tested whether participants in the match conditions on average took longer to respond to non-target stimuli than participants in the mismatch conditions. As with Experiment 1, results showed no significant difference in mean RT between match (MT: Mean = 242.6 ms, SD = 19.3 ms; ET: Mean = 234.5 ms, SD = 15.5 ms) and mismatch (MT: Mean = 234.7 ms, SD = 31.6 ms; ET: Mean = 234.1, SD = 19.5 ms) conditions for both morning types, $t(20) = 0.69$, $p = ns$, and evening types, $t(20) = 0.05$, $p = ns$.

To determine whether there was a TOD modulation on non-automatic processing for morning or evening types, we tested the whether there was a difference in the proportion of times participants successfully withheld their response to target stimuli for the match and mismatch conditions. Results showed a significant difference in morning types' ability to withhold a response to target stimuli between match (Mean = 0.6, SD = 0.1) and mismatch conditions (Mean = 0.4, SD = 0.2), $t(20) = 2.29$, $p < 0.05$. Evening types did not show a significant difference in the ability to withhold their response to target stimuli between match (Mean=0.35, SD=0.15) and mismatch (Mean = 0.3, SD = 0.1) conditions, $t(21) = 1.36$, $p = ns$. Results of Experiment 2 are summarized in Table 3 (morning types) and Table 4 (evening types).

Table 3.

Experiment 2 (Morning Types)

Measure	Match Condition Mean(SD)	Mismatch Condition Mean(SD)	Difference (Match-Mismatch)
MEQ	56.1(3.34)	55.33(3.39)	0.77
Proportion of Time Participants Attention Was Off Task	0.19(0.31)	0.21(0.26)	-0.02
Proportion of Unawareness of Mind Wandering	0.67(0.22)	0.42(0.31)	0.24 *
Reaction Time	242.64(19.30)	234.71(31.61)	7.93
Proportion of Correct Inhibition Of Response	0.62(0.14)	0.44(0.22)	1.83 *

Note. *p<.05, **p<.01

Table 4.

Experiment 2 (Evening Types)

Measure	Match Condition Mean(SD)	Mismatch Condition Mean(SD)	Difference (Match-Mismatch)
MEQ	41.0(5.22)	39.3(6.40)	1.64
Proportion of Time Participants Attention Was Off Task	0.12(0.50)	0.27(0.25)	-0.14
Proportion of Unawareness of Mind Wandering	0.60(0.25)	0.57(0.22)	0.03
Reaction Time	234.47(15.50)	234.12(19.50)	0.35
Proportion of Correct Inhibition Of Response	0.35(0.15)	0.28(0.09)	0.07

Note. *p<.05, **p<.01

Comparing Results from Experiment 1 and Experiment 2. To determine whether a conceptual benefit exists for the pictorial stimuli used in Experiment 1 in comparison to the numerical stimuli used in Experiment 2, we analysed the difference between mean RT and omission rate in Experiment 1 and Experiment 2 for morning types and evening types in both match and mismatch conditions.

Mean RT data for Experiment 1 and Experiment 2 are shown in Figure 1. When comparing mean RT for morning types, there was a significant difference between Experiment 1 and Experiment 2 in both participants tested during the morning hours (match condition), $t(36) = 9.148$, $p < 0.001$, and participants tested during the evening hours (mismatch condition), $t(25) = -7.41$, $p < 0.001$. Comparing mean RT for evening types revealed a similar trend, with significant differences between Experiment 1 and Experiment 2 in both participants tested during the evening (match condition), $t(33) = 7.22$, $p < 0.001$, and participants tested during the morning hours (mismatch condition), $t(32) = -7.55$, $p < 0.001$.

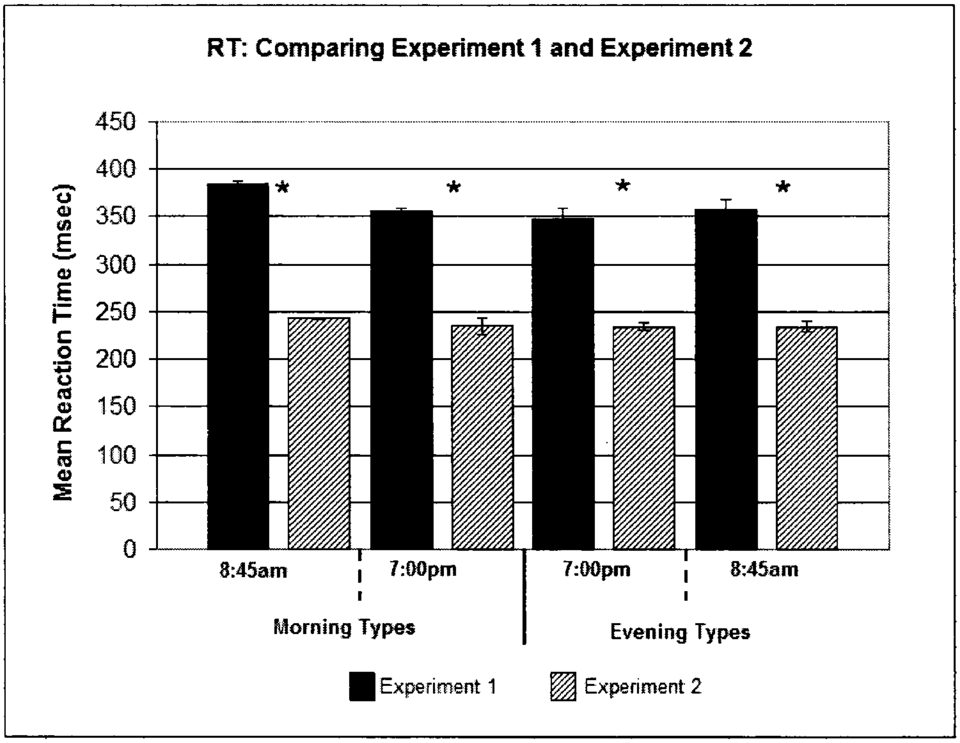

Figure 1. Comparison between morning and evening RT data for Experiment 1 and Experiment 2.

Morning type mean omission rate (proportion of trials on which participants were successfully able to withhold their response to the target stimuli) for Experiment 1 and Experiment 2 are shown in Figure 2. Results revealed a significant difference between Experiment 1 and Experiment 2 in both participants tested in the match condition, $t(36) = 3.91$, $p < 0.001$, and participants tested in the mismatch condition, $t(26) = -4.44$, $p < 0.001$. Comparing omission rate for evening types revealed a similar trend, with significant differences between Experiment 1 and Experiment 2 in both participants tested in the match condition, $t(33) = 7.25$, $p < 0.001$, and participants tested in the mismatch condition, $t(33) = -10.55$, $p < 0.001$. Results of comparing Experiment 1 and Experiment 2 are summarized in Figure 1 (RT data) and Figure 2 (Omission rate).

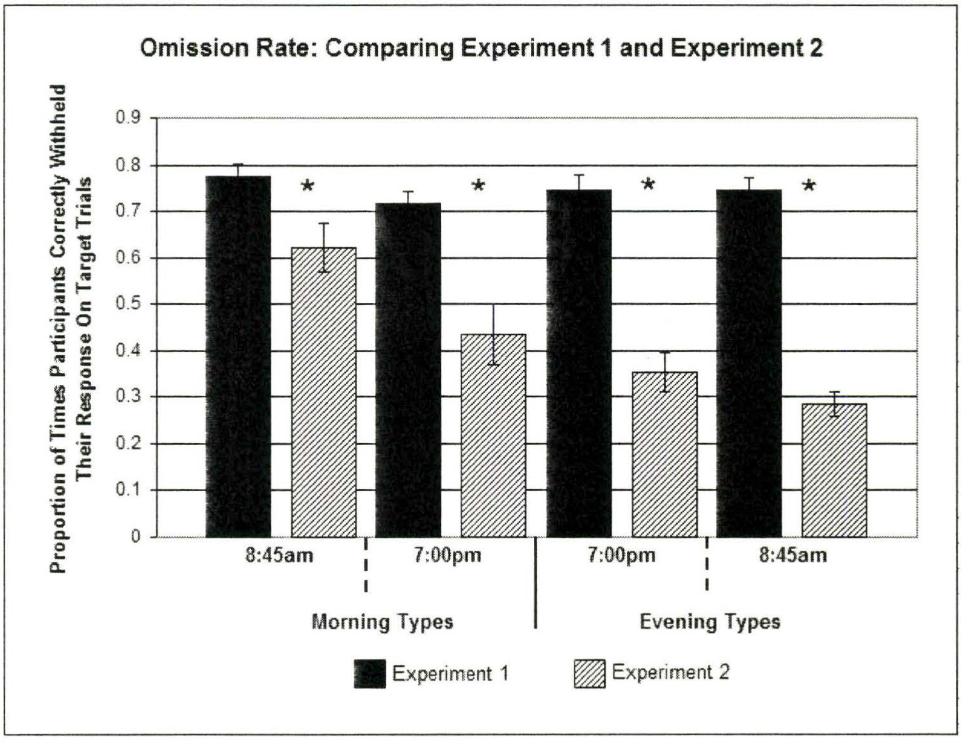

Figure 2. Comparison between morning and evening types in their ability to withhold responses to target stimuli for Experiment 1 and Experiment 2.

Discussion

As with Experiment 1, both morning and evening types indicated their attention to be off task more during mismatch conditions in comparison to match conditions, however this trend did not reach significance in Experiment 2. While the difference in significance between Experiment 1 and Experiment 2 may be due to the fact that participants were mind wandering less in Experiment 2 than Experiment 1 (although this is not behaviourally observed when comparing the experiments, as discussed in the next paragraph), the difference may also highlight that providing participants with an alternative forced choice (either their attention was on task or off task) may be a less ambiguous indicator of participants mind wandering experience and provide more accurate results. It should be noted however, that separating the probe in Experiment 1 into two separate probes (ontask/offtask and aware/unaware) for Experiment 2 was beneficial in dissociating the participant's subjective experience.

In concordance with Experiment 1 and results reported in Manley et al. (2002), automatic processes (response time) did not show a TOD modulation. Non-automatic processes (inhibition of response), on the other hand, were found to be modulated by time of day, a result we predicted to contradict Experiment 1 after changing the stimuli from pictorial to numerical. In direct contradiction to Experiment 1, morning and evening types (although ET data did not reach significance) were more likely to be unaware of spontaneous thought processes during match in comparison to mismatch conditions. These somewhat unexpected results are addressed in the General Discussion.

Comparing results from Experiment 1 and Experiment 2 revealed that participants in Experiment 1 (picture stimuli) on average took longer to respond and were less likely to respond to a target stimuli in comparison to individuals in Experiment 2 (number stimuli), as predicted. These results suggest that the participants who were shown pictorial stimuli were less likely to engage in mind wandering (as indicated by the decreased mean RT and omission rate (Manley et al., 1999; Robertson et al., 1997; Smallwood et all., 2007)). Unfortunately, due to the modification of the mind wandering probe in Experiment 2 we were unable to directly compare the extent to which participants indicated themselves as mind wandering between the two experiments. Based on the behavioural measures alone (mean RT and omission rate), it appears that participants in Experiment 2 overall performed better on the task in comparison to participants in Experiment 1. Enhanced task performance indicates that participants in Experiment 1 were better able to maintain top-down control over task performance to avoid the adverse consequences of diverted attention, suggesting that perhaps the pictorial stimuli granted a performance benefit for participants in comparison to the numerical stimuli.

General Discussion

The current research attempted to clarify and expand on previous findings that suggest a TOD modulation of automatic and non-automatic processes (Manly et al., 2002). To provide such clarification we examined the cognitive mechanisms involved in spontaneous thought process during match vs. mismatch conditions for both morning and evening types.

In Experiment 1 a pictorial SART task was used to examine automatic and non-automatic processes and measure participants' tendency to mind wander. As expected, both morning and evening types showed their attention as more likely to be off task during mismatch conditions in comparison to match conditions. Automatic processes (measured by mean RT) were not influenced by TOD. Contradictory to prediction, non-automatic processing (measured by successful inhibition of response on target trials) was also not influenced by TOD.

In an effort to clarify why non-automatic (executive) processes failed show a TOD modulation, we modified the SART in Experiment 2 to include numbers as stimuli rather than pictures. The modification was used to establish whether perceiving the pictorial stimuli masked the TOD modulation for executive control and provided participants with a performance benefit on the SART task. The subjective probe was also modified to include two separate Likert-like scales (whether their attention was on task or off task and whether they were aware or unaware that they were mind wandering) to better understand our participants' mind wandering experience and conform with previous mind wandering research methods.

As expected, automatic processing was not influenced by time of day and non-automatic processing was influenced by time of day, although the effect on non-automatic processing was significant only for morning types. Specifically, we found that morning types showed enhanced non-automatic (executive) functioning during their optimal time of day (match condition) in comparison to their non-optimal time of day (mismatch condition), suggesting that executive control in morning types fluctuates in accordance with the Synchrony Effect. This finding contradicts results reported by Manley et al (2002) which suggest a steady increase in non-automatic functioning throughout the day. The current results therefore propose that the extent to which TOD influences non-automatic functioning is dependent on an individual's chronotype, highlighting the importance of controlling for individual differences in TOD preference when examining TOD influence on cognitive processes.

As predicted, TOD modulation on non-automatic processing only surfaced once the SART task was modified to include numerical rather than pictorial stimuli. Modifying the task also, as predicted, highlighted a performance benefit for conditions when participants perceived the pictorial stimuli in comparison to the numerical stimuli. The performance benefit, indicated by a higher mean RT and omission rate, was apparent when comparing participant's performance in Experiment 1(picture stimuli) and Experiment 2 (number stimuli). Participants who were presented with the pictorial stimuli took significantly more time to make a response on go-trials than participants who were shown the numerical stimuli, and comparably, participants presented the pictorial stimuli were more likely to accurately withhold their response on no-go trials than participants who were shown the numerical stimuli. One interpretation for the performance benefit is that perceiving pictures requires greater processing than perceiving numbers. Numbers have predictable shape and structure, have no background, and are relatively simple to perceive. The stimuli set in the current study was also composed entirely of the numbers 0 through 9, enhancing participant's familiarity (and perhaps ease of processing) with the task stimuli. Picture stimuli on the other hand, requires that participants dissociate the object from the background, process the differential hues, shading and form of the 2D object, and be able to recognize and identify the object in the picture. Each picture was only shown twice throughout the experiment, decreasing participant's familiarity and enhancing the novel experience of perceiving each picture. It is also likely that pictures are conceptually rich and induce more memory or emotionally based associations than numbers. Seeing a picture of a cat, for example, may conjure thoughts of a childhood pet or the sound a cat makes when requesting food. The increase in processing demand for the pictures may therefore influence the amount of executive resources focused or dedicated to task performance, thereby enhancing participant's performance on the task.

The performance benefit, while highlighting the importance of processing demand and conceptual content of stimuli, may also be the primary reason for the lack of TOD influence on non-automatic processing found in Experiment 1. Regardless of chronotype or condition, participants shown picture stimuli were relatively similar in their ability to withhold their response on no-go trials. When shown numerical stimuli on the other hand, participants in the match conditions were better able to withhold their response than participants in the mismatch conditions, and morning types were more successful in withholding their response than evening types. These results suggest a "masking effect" for pictorial (or conceptually rich) stimuli, whereby the effect of TOD and TOD preference was eliminated when participants were presented with pictorial stimuli. These results suggest that the influence of TOD on non-automatic (executive control) processing can be manipulated by modifying the level of conceptual or deep processing in the task. These results highlight the importance of choosing stimuli that will most accurately reflect the goal of the research, and those conceptually rich stimuli or stimuli that require greater processing may influence TOD effects on non-automatic or executive processing.

Isolating the influence of TOD on automatic and non-automatic processing revealed an important assumption we make when attempting to empirically measure mind wandering. When using the SART task to measure an individual's tendency to mind wander, the subjective measure is corroborated behaviourally by participant's RT and omission rate. However, if RT (an automatic process) and omission rate (a non-automatic process) are influenced differently by TOD (and this influence of TOD differs between morning types and evening types), how can we be sure that our interpretations of the behavioural measures of mind wandering are accurate if we do not control for TOD effects or preference? In addition, it is also important to note morning types and evening types are differently affected by TOD. While morning types showed a TOD modulation for non-automatic processing that varies as a function of processing demand, evening types failed to show such results. Such divergent results also demonstrate the necessity of controlling for individual differences in TOD preference when examining the effects of TOD on cognitive performance. Future mind wandering research should include individual's chronotype as a covariate when analyzing SART performance. Controlling for individual differences in TOD preference will remove the influence of diurnal fluctuations in SART task performance and allow researchers to clearly define the mechanisms that underlie spontaneous thought processes.

Behavioural and subjective measures of mind wandering require separate assumptions that allow us to infer the function of underlying networks or mechanisms. When Experiment 1 yielded minimal results, we were able to make minute modifications to the task based on theoretical ideas proposed in previous research and be able to comfortably make predictions about the subsequent changes in behavioural measures of mind wandering. Modifications to the subjective measure however, generated confusing and unexpected results. It is reasonable to assume that when interrupted by the probe that participants are able to accurately recall whether or not they were engaged in spontaneous thought. Expecting that participants are accurately able to recall their meta-cognitive awareness of mind wandering is not so transparent as the expectation assumes that participants have equal access and retrieval of both a conscious and an unconscious experience. Future research reporting variations in meta-cognitive awareness of mind wandering should acknowledge this assumption when making inferences based on self-report data.

Limitations of the current study include not being able to compare mind wandering measures between Experiment 1 and Experiment 2. If this flaw had been avoided the argument for the pictorial performance benefit would have been much more persuasive. In addition, we modified the MEQ protocols for categorizing participants as moderate morning or evening types (Horne & Ostberg, 1976) in order to deal with the constraints of the university student population. Future research should look at clinical populations or extreme morning and evening types to discern whether the results would have changed. Another limitation was that participant's chronotype was only identified by MEQ score. Corroborating core body temperature measures would have been an appropriate and desirable additional measure for classifying participants as either morning types or evening types.

Conclusion. Morning types showed a time of day modulation for non-automatic functioning and meta-cognitive awareness of mind wandering, while evening types failed to show TOD modulation on any measure. These results suggest that evening types are less influenced by time of day preference in comparison to morning types. Participants' ability to withhold their response on target trials (executive control or non-automatic processing) was highest during preferred in comparison to non preferred time of day, a result that critically differs from results reported in Manley et al. (2002). Differentiating between Experiment 1 and Experiment 2 suggests that the processing demand of the task stimuli may play a mediatory role in the relationship between chronotype match and mismatch conditions on executive control functioning. Future research should investigate the role of meta-cognitive awareness and TOD effects on mind wandering, focusing on how variations in awareness of mind wandering fluctuate throughout the day.

BIBLIOGRAPHY

Antrobus, J., S., Singer, J. L., Goldstein, S., & Fortgang, M (1970). Mind wandering and cognitive structure. *Trans N Y Academy of Science*, 32, 242-252.

Baddeley, A. (1998). Recent Developments in Working Memory. Current Opinion in Neurobiology, 8, 234-238.

Baddeley, A. (2000). The episodic buffer: a new component of working memory? Trends in Cognitive Science, 4, 417-423.

Beersma, D. G. M., Daan, S., Gordijn, M. C. M., Ruger, M., & de Vries, B. (2006).Time-of-day-dependent effects of bright light exposure on human psychophysiology: comparison of daytime and night time exposure. *AJP-Regulatory, Integrative, Comparative Physiology*, 290, 1413-1420.

Beersma, D. G. M., & Gordijn, M. C. M. (2007). Circadian control of the sleep-wake cycle. *Physiology and Behaviour*, 90, 190-195.

Blatter K., & Cajochen, C. (2007). Circadian rhythms in cognitive performance: methodological constrains, protocols, theoretical underpinnings. *Physiology and Behaviour*, 90, 196-208.

Bluhm., R. L., Miller, J., Lanius, R. A., Osuch, E. A., Cokdman, K., Neufeld, R. W. J., Theberge, J., Schaefer, B., & Williamson, P. (2007). Spontaneous low-frequency fluctuations in the BOLD signal in Schizophrenic patients: Anomalies in the default network. *Schizophrenia Bulletin.*

Boivin, D. W., Czeisler, C. A., Duffy, J. F., Kronauer, R. E., Rimmer, D. W., & Shanahan, T. L. (2000). Dynamic resetting of the human circadian pacemaker by Intermittent bright light. *AJP Regulatory Integrative Comparative Physiology*, 279, 1574-1579.

Bouchard, T. J., Hur, Y., & Lykken, D. T. (1998). Genetic and environmental changes on morningness-eveningness. *Personality and Individual Differences*, 25, 917-925.

Cajochen, C., Collette, F., Peigneux, P., & Schmidt, C. (2007). A time to think: circadian rhythms in human cognition. *Cognitive Neuropsychology*, 27(7), 755-789.

Carrier, J., & Monk, T. H. (2000). Circadian rhythms of performance: New trends. *Chronbiology International*, 17, 6, 719-732.

Christoff, K., Ream, J. M., & Gabrieli, J., D. (2004). Neural basis of spontaneous thought processes, *Cortex*, 40, 4-5, 623-630.

Christoff, K., Gordon, A. M., Smallwood, J., Smith, R., & Schooler, J. (2009). Experience sampling during fMRI reveals default netwok and executive system contributions to mind wandering. *PNAS*, 106, 21, 8719-8724.

Ciarkowska, W., & Janowski, K. S. (2008). Diurnal variation in energetic arousal, tense arousal and hedonic tone in extreme morning and evening types. *Chronbiology International*, 25(4), 577-595.

Dennis, T. A., & Chen, C. C. (2007). Neuropsychological mechanisms in the emotional modulation of attention: the interplay between threat sensitivity and attentional control. *Biol. Psychol.*, 1-2, 1-10.

Drennan, M. D., Goyette, L. M., Klauber, M. R., & Kripe, D. F. (1991).The effects of depression and age on the Horne-Ostberg morningness-eveningness score. *Journal of Affective Disorders*, 23, 93-98.

Duarte, L., Menna-Barreto, L., & Porto, R. (2006). Circadian variation of mood: comparison between different chronotypes. *Biological Rhythm Research*, 37(5), 425-431.

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the Efficiency and Independence of Attentional Networks. *Journal of Cognitive Neuroscience*, 14(3), 340 – 347.

Folkard, S., Knauth, P., & Monk, T. H. et al. (1976). The effect of memory load on the circadian variation in performance efficiency under a rapidly rotating shift system. *Ergonomics*, 19, 479-488.

Ganshirt, G., Meijer, J. H., & Rusak, B. (1992). The relation between light-induced discharge in the suprachiasmatic nucleus and phase shifts of hamster circadian rhythms. *Brain Research*, 598, 257-263.

Grady, C. L., McIntosh, A. R., Rajah, M. N., Craik, F. I. M., (1998). Neural correlates of episodic encoding pictures and words. *PNAS*, 95, 5, 2703-2708.

Grafton, S. T., Mason, M. F., Macrae, C. N., Norton, M. L., Van Horn, J. D., Wegner, D. M. (2007). Wandering minds: the default network and stimulus-independent thought. *Science*, 315, 393 – 395.

Hasher, L., Chung, C., May, C. P., & Foong, N. (2002). Age, time of testing, and proactive interference. *Canadian Journal of Experimental Psychology*, 56, 3, 200-207.

Horne, J. A. & Ostberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International Journal of Chronbiology*, 4, 97-110

Intons-Peterson, M. J., Rocchi, P., West, T., McLellan, K., & Hackney, A. (1999). Age, testing at preferred or nonpreferred times (Testing optimally), and false memory. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 25, 1,23-40.

Kane, M. J., Brown, L, H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when. *Psychological Science,* 18, 7,614-621.

Kane, M. J., & Engle, R. W. (2002). The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual differences perspective. Psychonomic Bulletin & Review, 9, 637-671.

Klinger, E. C. (1978). Modes of normal conscious flow. In K.S Pope & J. L Singer (Eds.), *The stream of consciousness: Scientific investigations into the flow of human experience*, pp. 225-228. New York: Plenum.

Kruglanski, A. W., & Pierro, A. (2008). Night and day, you are the one: on circadian mismatches and the transference effect in social perception. *Psychlogical Science*, 19(3), 296-301.

Marrington, S., & Martin, P. Y. (2005). Morningness-eveningness orientation, optinal time of day and attitude change: Evidence for the systematic processing of a persuasive communication. *Personality and Individual Differences*, 39, 367-377.

Matchock, R. L., & Mordkoff, J. T. (2009). Chronotype and time-of-day influences on alerting, orienting, and executive components of attention. *Experimental Brain Research*, 192, 189-198.

Manly, T., Robertson, I. H., Galloway, M., & Hawkins, K. (1999). The absent mind: Further investigations of sustained attention to response. Neuropsychologia, 37, 661–670.

Manly, T., Lewis, G. H., Robertson, I. H., Watson, P. C., & Datta, A. K. (2002). Coffee in cornflakes: Time of day as a modulator of executive response control. *Neuropsychologia*, 40, 1-6.

Mason, M. F., Norton, M. I., Can Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C. N. (2007). Wandering minds: The default network and stimulus-independent thought, *Science*, 315, 393-395.

May, C. P., Hashler, L., & Stoltzfus, E, R. (1993). Optimal time of day and the magnitude of age differences in memory. *Psychological Science*, 4, 326-330.

McSpadden, M., Schooler, J. W., & Smallwood, J. (2007). The light are on by no one is home: Meta-awareness and the decoupling of attention when the mind wanders. *Psychonomic Bulletin & Review,* 14(3), 527-533.

McVay, J. C., & Kane, M. J. (2009). Conducting the train of thought: Working memory capacity, goal neglect, and mind wandering in an executive control task. *Journal of Experimental Psychology: Learning, Memory, Cognition*, 35, 1, 196-204.

Merrow, M., & Roennenberg, T. (2005). Circadian clocks – the fall and rise of physiology. *Nature Reviews Molecular Cell Biology*, 6, 965-971.

Merrow, M., Roennenberg, T., & Wirz-Justice, A. (2003). Life between clocks: daily temporal patterns of human chronotypes. *Journal of Biological Rhythms*, 18(1), 80-90.

Randler, C. (2008). Morningness – eveningness and satisfaction with life. *Social Indicators Research,* 86, 297-302.

Robertson, I. H., Manley, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). 'Oops!' Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects, *Neuropsychologia*, 35, 6, 747-758.

Sabb, F. W., Bilder, R. M., Choi, M., & Bookheimer, S. Y. (2007). Working memory effects on semantic processing: Priming differences in pars orbitalis. *NeuroImage*, 37, 311-322.

Schmidt, C., Collette, F., Cajochen, C., & Peigneux, P. (2007). A time to think: Circadian rhythms in human cognition. *Cognitive Neuropsychology*, 24, 7, 755-789.

Schneider, W., Eschmann, A., & Zuccolotto, A. (2002). E-Prime user's guide. Pittsburgh, PA: Psychology Software Tools, Inc..

Schooler, J. W. (2002). Re-representing consciousness: Dissociations between experience and metaconsciousness. *Trends in Cognitive Sciences*, 6, 8, 339-344.

Smallwood, J., Baraciaia, S. F., Lowe, M., & Obonsawin, M. C. (2003b). Task-unrelated thought whilst encoding information. Consciousness and Cognition, 12, 452–484.

Smallwood, J., et al. (2004). Subjective experience and the attentional lapse: Task engagement and disengagement during sustained attention. *Conscious Cognition*, 13, 657-690.

Smallwood, J., & Schooler, J. (2006). The restless mind. *Psychological Bulletin*, 132, 949-958.

Smallwood, J., McSpadden, M., & Schooler, J. W. (2007). The lights are one but no one's home: Meta-awareness and the decoupling of attention when the mind wanders. *Psychonomic Bulletin & Review*, 14, 3, 527-533.

Smallwood, J., Beach, E., Schooler, J. W., & Handy, T. C. (2008). Going AWOL in the brain: Mind wandering reduces cortical analysis of external events. *Journal of Cognitive Neuroscience*, 20, 3, 458-469.

Smith, R., Keramatian, K., Smallwood, J., Schooler, J., Luus, B., Christoff, K. (2006). Mind wandering with and without awareness: An fMRI study of spontaneous thought processes. Proceedings of the 18th Annual Conference of the Cognitive Science Society (Ed. R. Sun): 804-809. Vancouver: Erlbaum.

Sudberry, M, O'Connor, R. et al. (2004). Subjective experience and the attentional lapse: Task engagement and disengagement during sustained attention. *Consciousness & Cognition*, 13, 4, 657-690.

Teasdale, J. D., Dritschel, B. H., Taylor, M. J., Proctor, L., Lloyd, C. A., Nimmo-Smith, I., et al. (1995). Stimulus-independent thought depends on central executive resources. *Memory and Cognition*, 23, 5, 551-559.

Teasdale, J. D., Prctor, L., Lloyd, C. A. & Baddeley, A. D. (1993). Working memory and stimulus-independent thought: Effects of memory load and presentation rate. *European Journal of Cognitive Psychology*, 5, 417-433.

West, R., Murphy, K. J., Armilio, M. L., Craik, F. I., & Stuss, D. T. (2002).

Effects of time of day on age differences in working memory. *Journal of Gerontology Series B: Psychological Sciences and Social Sciences*, 57, 3-10.