
The Quarterly Journal of Experimental Psychology

ISSN: 1747-0218 (Print) 1747-0226 (Online) Journal homepage: http://www.tandfonline.com/loi/pqje20

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**To cite this article:** Matthew K. Robison, Katherine I. Gath & Nash Unsworth (2017) The neurotic wandering mind: An individual differences investigation of neuroticism, mind-wandering, and executive control, The Quarterly Journal of Experimental Psychology, 70:4, 649-663, DOI: 10.1080/17470218.2016.1145706

**To link to this article:** http://dx.doi.org/10.1080/17470218.2016.1145706

Accepted author version posted online: 28 Jan 2016.
Published online: 10 Mar 2016.

THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 2017
VOL. 70, NO. 4, 649–663
http://dx.doi.org/10.1080/17470218.2016.1145706

Routledge
Taylor & Francis Group

# The neurotic wandering mind: An individual differences investigation of neuroticism, mind-wandering, and executive control

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**ABSTRACT**

Cognitive psychology and cognitive neuroscience have recently developed a keen interest in the phenomenon of mind-wandering. People mind-wander frequently, and mind-wandering is associated with decreased cognitive performance. But why do people mind-wander so much? Previous investigations have focused on cognitive abilities like working memory capacity and attention control. But an individual's tendency to worry, feel anxious, and entertain personal concerns also influences mind-wandering. The Control Failure × Concerns model of mind-wandering. *Psychological Bulletin, 136,* 188–197] argues that individual differences in the propensity to mind-wander are jointly determined by cognitive abilities and by the presence of personally salient concerns that intrude on task focus. In order to test this model, we investigated individual differences in mind-wandering, executive attention, and personality with a focus on neuroticism. The results showed that neurotic individuals tended to report more mind-wandering during cognitive tasks, lower working memory capacity, and poorer attention control. Thus the trait of neuroticism adds an additional source of variance in the tendency to mind-wander, which offers support for the Control Failure × Concerns model. The results help bridge the fields of clinical psychology, cognitive psychology, affective neuroscience, and cognitive neuroscience as a means of developing a more complete understanding of the complex relationship between cognition, personality, and emotion.

**ARTICLE HISTORY**
Received 21 July 2015
Accepted 19 January 2016
First Published Online 10 March 2016

**KEYWORDS**
Mind-wandering; Neuroticism; Attention; Working memory

The concept of mind-wandering has long been a topic of interest in psychology (Antrobus, Singer, & Greenberg, 1966; Singer & Antrobus, 1963), and it has more recently received a great deal of attention within the fields of cognitive psychology and cognitive neuroscience. Mind-wandering can be described as a shift in thoughts away from a task or the external environment to internal, self-generated thoughts (Smallwood & Schooler, 2015). The study of mind-wandering has aided our ability to understand cognition, as the ability to resist mind-wandering—both in the laboratory and in daily life—is an important predictor of success (Kane et al., 2007; Unsworth, McMillan, Brewer, & Spillers, 2012).

To investigate the phenomenon of mind-wandering in the lab and in daily life, researchers have used a variety of techniques such as questionnaires, thought probes, and experience sampling methods. Together, these results indicate that mind-wandering occurs rather frequently in both the lab and in daily life, mind-wandering impairs performance on both laboratory tasks and everyday settings, and propensities to mind-wander are related to a number of cognitive abilities including working memory capacity, attention control, and fluid intelligence (Kane et al., 2007; Kane & McVay, 2012; McVay & Kane, 2012; McVay, Kane, & Kwapil, 2009; Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012; Risko, Buchanan, Medimorec, & Kingstone, 2013; Unsworth & McMillan, 2013, 2014; Unsworth et al., 2012).

In addition to being related to cognitive abilities, propensities to mind-wander are also related to an individual's context, mood, and disposition. Sometimes, context interacts with cognitive abilities. Specifically, individuals tend to mind-wander more when a task requires low levels of concentration than when a task

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requires a high level of concentration. Although both individuals with high working memory capacity and those with low working memory capacity show decreased mind-wandering when trying to concentrate, individuals with high working memory capacity show a greater reduction in mind-wandering in these situations (Kane et al., 2007). Additionally, working memory capacity seems to offer resistance to mind-wandering and external distraction in a context-specific manner. When reading is in silence, working memory shields individuals from mind-wandering, and in noisy conditions, it shields individuals from external distraction (Robison & Unsworth, 2015). So both context-specific factors and individual differences in cognitive abilities are related to rates of mind-wandering. Sometimes making a task more engaging, such as by adding a memory component to an otherwise simple vigilance task, can reduce mind-wandering rates (Smallwood, Nind, & O'Connor, 2009). Other times cognitive overload can actually lead to more failures of sustained attention (Head & Helton, 2014). However, the complex interaction between cognitive abilities and concentration levels may explain these discrepant findings (Kane et al., 2007).

One particularly common source of mind-wandering is personal concerns (Baird, Smallwood, & Schooler, 2011; Kane et al., 2007; Klinger, 1999, 2009; McVay & Kane, 2010). Thoughts about personal concerns can take a variety of forms including planning, self-reflection about task performance, and reminiscing, as well as more negative thoughts like anxiety, worry, and rumination. Thus, theoretically, one's predisposition to think about personal concerns and think about oneself in a certain way (i.e., one's personality) could potentially impact both the frequency and content of mind-wandering. The Control Failure × Concerns model of mind-wandering proposes that individual differences in propensities to mind-wander are jointly determined by an individual's ability to resist internally generated task-unrelated thoughts in the pursuit of task-relevant cognition and by the salience of an individual's personal concerns.

One personality trait that may be particularly relevant to the study of mind-wandering is neuroticism. A highly neurotic individual may be more likely to entertain personal concerns both in the lab and in daily life, which pulls their thoughts away from the completion of task-relevant goals. Indeed, inducing a negative mood in participants leads them to mind-wander more during a subsequent task (Smallwood, Fitzgerald, Miles, & Phillips, 2009). In general, anxiety is related to lower cognitive performance (Eysenck, Derakshan, Santos, & Calvo, 2007). When individuals feel anxious, they tend to mind-wander more (Kane et al., 2007), individuals who mind-wander more also report being less happy (Killingsworth & Gilbert, 2010), and sad moods predict later instances of mind-wandering (Poerio, Totterdell, & Miles, 2013). In a large-scale individual differences study, Baer, Smith, Hopkins, Krietemeyer, and Toney (2006) found a moderate relationship between neuroticism and questionnaire-based measures of attentional failures. More specifically, Hahn, Buttaccio, Hahn, and Lee (2015) found a negative relationship between neuroticism and the ability to detect changes in real-world scenes. Further, more neurotic individuals tend to have a retrospective bias in their reports of mind-wandering (Jackson, Weinstein, & Balota, 2013). Additionally, across a number of tasks, Robinson and Tamir (2005) found that neuroticism positively predicted response time variability, suggesting that neuroticism introduces an element of "mental noise", which could be indicative of more frequent mind-wandering. Indeed, Perkins, Arnone, Smallwood, and Mobbs (2015) propose a theory that self-generated thought can actually be a cause of neuroticism (but see also Pickering, Smillie, & DeYoung, 2016; Perkins, Arnone, Smallwood, & Mobbs, 2016)

To test their Control Failure × Concerns model, McVay and Kane (2013) cued individuals to their personal concerns and found a small but significant increase in mind-wandering rates compared to personally irrelevant concerns. Additionally, Banks, Tartar, and Tamayo (2015) utilized a stress induction to investigate the impact of state anxiety, physiological reactivity to stress (i.e., cortisol levels), and mind-wandering on working memory. Banks and colleagues found that for individuals with high stress reactivity indicated by high levels of cortisol, a stressful task (writing about negative past experiences) led to decreases in working memory capacity, which was mediated by elevated rates of mind-wandering. Thus, there is experimental evidence for the Control Failure × Concerns model of mind-wandering. The primary goal of the present study was to use an individual differences approach to test this model. By measuring neuroticism, we hoped to measure individual differences in the propensity to feel anxious, to worry, and to entertain personal concerns.

Some individual differences research suggests that there is indeed a relationship between various measures of anxiety, worry, depression, mind-wandering, and cognitive performance. Christoff, Gordon, Smallwood, Smith, and Schooler (2009) found greater activity in default mode regions preceding both subjective reports of mind-wandering and errors on a sustained attention to response task (SART). Forster, Nunez Elizalde, Castle, and Bishop (2015) also observed increased activity in default mode regions related to self-referent processing when individuals made commission errors on the SART. Individuals prone to worry and with higher trait anxiety show increased rates of internally generated task-unrelated thoughts (i.e., mind-wandering). Importantly, they found two distinct predictors of worry: a greater propensity to mind-wander and impoverished attention control. Each of these showed different levels of activation in default mode and attentional networks in the brain. Specifically, dorsolateral prefrontal cortex (DLPFC) activity in error-free and error-made blocks of the SART revealed a pattern in which trait anxiety was related to both impoverished engagement of the DLPFC and increased activation of DLPFC by task-unrelated thought. The extent of the difference in DLPFC activity between error-free and error-made blocks of the SART was related to both trait anxiety and mind-wandering during a vigilance task outside the scanner. Worry was not related to anterior cingulate or DLPFC activity during no-go trials in error-free blocks. But during blocks in which participants committed errors, worry was related to DLPFC–precuneus connectivity and DLPFC–posterior cingulate connectivity. Their resulting model argues that individuals can lie somewhere along two distinct dimensions: one related to more self-generated, negative self-referent thoughts and the other related to attentional control. In combination but independently, these two individual differences impact attention control and default mode networks, both of which lead to task-unrelated thoughts.

Along a similar vein, Hamilton et al. (2011) measured default mode network domination over task positive network activation and found strong correlations between default mode network domination and measures of depressive rumination style among individuals with major depressive disorder. Thus there seems to be reliable relationships among the subjective phenomenon of mind-wandering, neural activation in default mode networks, and clinically significant traits such as anxiety and depressive rumination.

The present study seeks to extend these findings through an individual differences investigation of executive control, mind-wandering, and neuroticism as a means of testing and clarifying the Control Failure × Concerns model. Participants completed multiple measures of working memory capacity and attention control and a personality questionnaire, attempting to tie together measures of cognitive performance, subjective reports of mind-wandering, and neuroticism. During the attention control tasks, participants were presented with thought probes to gauge propensities to mind-wander. An open question is whether the relationship between neuroticism and mind-wandering is attributable to individual differences in executive control, or if neuroticism and executive control are independent sources of mind-wandering. If neuroticism leads individuals to be overly concerned with personal thoughts, then they should show a greater propensity to mind-wander. Along the same vein, individuals with greater levels of neuroticism should show lower working memory capacity estimates and poorer attention control abilities. Another possibility is that neurotic individuals will show higher rates of mind-wandering, but no observable differences in attention control or working memory capacity, as they have developed strategies for dealing with the "mental noise" without having it impact their ability to complete cognitive tasks. The advantage of an individual differences investigation with a relatively large sample is the ability to use structural equation modelling to partition variance in mind-wandering common to executive control and to neuroticism. In this manner, we can separate the influences of the neuroticism-related deficits in executive control to mind-wandering from executive-control-related mind-wandering that is independent of neuroticism. Our hope is that the consideration of personality traits will further aid our understanding of the phenomenon of mind-wandering, as it seems to be an important aspect of both cognitive and emotional functioning.

## Experimental study

### Method

#### Participants

Participants were 213 undergraduate students (128 females) at the University of Oregon with an average age of 19.40 years (*SD* = 2.32). Due to time limitations and computer errors, 201 participants had complete data on the working memory capacity and attention control tasks, mind-wandering probes, and personality questionnaire. All participants gave informed consent and were given course credit for participation. We collected data with the goal of reaching 200 participants to achieve adequate power for confirmatory factor analysis and structural equation modelling.

## Procedure

After giving informed consent, participants completed three measures of working memory capacity, three measures of attention control, and a personality questionnaire. All tasks were completed in a single laboratory session.[1]

## Tasks

**Working memory capacity.** *Operation span*. Participants solved a series of maths operations while trying to remember a set of unrelated letters. Participants were required to solve a maths operation, and after solving the operation, they were presented with a letter for 1 s. Immediately after the letter was presented the next operation was presented. At recall participants were asked to recall letters from the current set in the correct order by clicking on the appropriate letters. For all of the span measures, items were scored correct if the item was recalled correctly from the current list. Participants were given practice on the operations and letter recall tasks only, as well as two practice lists of the complex, combined task. List length varied randomly from three to seven items, and there were two lists of each list length for a maximum possible score of 50. The score was total number of correctly recalled items.

*Symmetry span*. Participants recalled sequences of red squares within a matrix while performing a symmetry-judgment task. In the symmetry-judgment task, participants were shown an 8 × 8 matrix with some squares filled in black. Participants decided whether the design was symmetrical about its vertical axis. The pattern was symmetrical half of the time. Immediately after determining whether the pattern was symmetrical, participants were presented with a 4 × 4 matrix with one of the cells filled in red for 650 ms. At recall, participants recalled the sequence of red-square locations by clicking on the cells of an empty matrix. Participants were given practice on the symmetry-judgment and square recall task as well as two practice lists of the combined task. List length varied randomly from two to five items, and there were two lists of each list length for a maximum possible score of 28. We used the same scoring procedure as that used in the operation span task.

*Reading span*. While trying to remember an unrelated set of letters, participants were required to read a sentence and indicated whether or not it made sense. Half of the sentences made sense, while the other half did not. Nonsense sentences were created by changing one word in an otherwise normal sentence. After participants gave their response, they were presented with a letter for 1 s. At recall, participants were asked to recall letters from the current set in the correct order by clicking on the appropriate letters. Participants were given practice on the sentence judgment task and the letter recall task, as well as two practice lists of the combined task. List length varied randomly from three to seven items, and there were two lists of each list length for a maximum possible score of 50. We used the same scoring procedure as that used in the operation span and symmetry span tasks.

**Attention control.** *Psychomotor vigilance task (PVT)*. The psychomotor vigilance task (Dinges & Powell, 1985) was used as the primary measure of sustained attention. Participants were presented with a row of zeros on screen, and after a variable amount of time the zeros began to count up in 1-ms intervals from 0 ms. The participants' task was to press the spacebar as quickly as possible once the numbers started counting up. After the space bar had been pressed, the response time was left on screen for 1 s to provide feedback to the participants. Interstimulus intervals were randomly distributed and ranged from 2 s to 10 s. Prior to each trial, there was a 2-s fixation period with "+++++" in the centre of the screen. The entire task lasted for 10 min for each individual (roughly 75 total trials). The dependent variable was the average reaction time for the slowest 20% of trials (Dinges & Powell, 1985). Thought probes were randomly presented after 20% of trials.

*Stroop*. Participants were presented with a colour word (red, green, or blue) presented in one of three different font colours (red, green, or blue). The participants' task was to indicate the font colour via key press (red = 1, green = 2, blue = 3). Participants were told to press the corresponding key as quickly and accurately as possible. Participants received 15 trials of response mapping

[1]In an original dataset, 119 participants completed the attention control tasks on a Tobii T120 eyetracker. At the suggestion of a reviewer, we collected data from a new group of participants to achieve a minimum sample size of 200. The new group of participants did not complete the attention control tasks on an eyetracking monitor, but in nearly identical conditions (on an LCD computer monitor in a quiet, dark room).

practice and six trials of practice with the real task. Participants then received 100 real trials. Of these trials, 67% were congruent such that the word and the font colour matched (i.e., red printed in red), and the other 33% were incongruent (i.e., red printed in green). The dependent variable was the average reaction time for incongruent trials. Thought probes were randomly presented after 36% of incongruent trials.

*Antisaccade*. In this task (Kane, Bleckley, Conway, & Engle 2001), participantswere instructed to stare at a fixation point,which was onscreen for a variable amount of time(200–2200 ms). A flashing white "=" was then flashedeither to the left or to the right of fixation (11.33° ofvisual angle) for 100 ms. This was followed by thetarget stimulus (a B, P, or R) on screen for 100 ms. This was followed by masking stimuli (an H for 50ms followed by an 8, which remained on screenuntil a response was given). The participants' taskwas to identify the target letter by pressing a key forB, P, or R (the keys 1, 2, or 3) as quickly and accuratelyas possible. In the prosaccade condition the flashingcue ( = ) and the target appeared in the same location.In the antisaccade condition the target appeared inthe opposite location to the flashing cue. Participantsreceived, in order, 10 practice trials to learn theresponse mapping, 15 trials of the prosaccade condition,and 60 trials of the antisaccade condition. Thedependent variable was proportion correct on theantisaccade trials. Thought probes were randomlyadded after one sixth of trials.

*Thought probes*. During the attention control tasks, participants were periodically presented with thought probes asking them to classify their immediately preceding thoughts. The thought probes asked participants to press one of five keys to indicate what they were thinking just prior to the appearance of the probe. Specifically, participants saw:

Please characterize your current conscious experience.

(1) I am totally focused on the current task
(2) I am thinking about my performance on the task
(3) I am distracted by sights/sounds/temperature or by physical sensations (hungry/thirsty)
(4) I am daydreaming/my mind is wandering about things unrelated to the task
(5) I am not very alert/my mind is blank

During the introduction to the task, participants were given specific instructions regarding the different categories. Responses 4 and 5 were considered mind-wandering, and sums of these reports for each task were used in all subsequent analyses.

*Personality questionnaire*. Participants completed a 44-item Big Five Inventory questionnaire (see Appendix; John, Naumann, & Soto, 2008). The form has eight items measuring Extraversion and Neuroticism, nine items measuring Agreeableness and Conscientiousness, and 10 items measuring Openness. Participants completed the form after completing all of the other measures. Because the present study was specifically interested in neuroticism, only the eight items measuring the Neuroticism factor were analysed in the following section.

## Results

Descriptive statistics for all measures are shown in Table 1. The measures of working memory capacity, attention control, and neuroticism items from the questionnaire all showed a good deal of variability. Zero-order correlations (Table 2) suggested relationships among performance on the working memory capacity tasks and attention control tasks, mind-wandering reports, and self-reported levels of neuroticism. Correlations among items within a theoretical construct were slightly higher than correlations among items between constructs, indicating both convergent and discriminant validity. To better examine the relationships among the constructs at the latent level, we utilized confirmatory factor analysis.

In an initial model (Figure 1), we allowed the three complex span tasks to load onto a working memory capacity (WMC) latent variable, accuracy on the antisaccade task, reaction times to accurate incongruent Stroop trials, and the slowest 20% of trials on the psychomotor vigilance task to load onto an attention control (AC) latent variable, mind-wandering and inattention reports from each of the three attention control tasks to load onto a mind-wandering (MW) latent variable, and the eight neuroticism items from the Big Five Inventory to load onto a neuroticism (Neurot) latent variable. Because they utilize identical memoranda, we allowed the residual variances for operation span and reading span to correlate. Although it may not be depicted, this path was freed in all subsequent models, as well. All latent variables were allowed to correlate. The fit of the resulting model was acceptable [$\chi^2(112) = 224.37$, CFI = 0.92, RMSEA = 0.07, SRMR = 0.06] (Kline, 1998).[2] All paths between

[2]CFI = Comparative Fit Index, RMSEA = Root Mean Squared Error of Approximation, SRMR = Standardized Root Mean Square Residual.

**Table 1.** Descriptive statistics for all measures.

| Measure | Mean (*SD*) | Range | Skewness | Kurtosis |
|---|---|---|---|---|
| OSpan | 37.15 (8.69) | 6–50 | −0.77 | 0.19 |
| SymSpan | 19.64 (5.01) | 5–28 | −0.58 | −0.01 |
| RSpan | 36.66 (8.99) | 3–50 | −0.99 | 1.19 |
| Antisaccade | 0.57 (0.18) | 0.00–0.96 | −0.17 | −0.74 |
| Stroop | 827.33 (177.17) | 492.43–1575.90 | 0.83 | 1.45 |
| PVT | 465.62 (87.39) | 308.53–873.09 | 1.29 | 2.63 |
| MW-Anti | 3.04 (3.50) | 0–11 | 1.06 | −0.14 |
| MW-Stroop | 3.83 (3.65) | 0–12 | 0.80 | −0.51 |
| MW-PVT | 4.03 (3.48) | 0–15 | 0.89 | 0.34 |
| bfi4 | 1.97 (1.10) | 1–5 | 0.94 | −0.10 |
| bfi9 | 3.37 (1.17) | 1–5 | −0.41 | −0.69 |
| bfi14 | 3.40 (1.16) | 1–5 | −0.30 | −0.62 |
| bfi19 | 3.41 (1.30) | 1–5 | −0.39 | −0.97 |
| bfi24 | 3.74 (1.12) | 1–5 | −0.58 | −0.53 |
| bfi29 | 3.14 (1.16) | 1–5 | −0.12 | −0.96 |
| bfi34 | 3.73 (1.04) | 1–5 | −0.49 | −0.51 |
| bfi39 | 3.19 (1.20) | 1–5 | −0.16 | −0.98 |

Note. N = 201. *SD* = standard deviation. Reliabilities are split-half Spearman–Brown coefficients; $\alpha$ = Cronbach's alpha; OSpan = operation span; SymSpan = symmetry span; RSpan = reading span; Stroop = reaction times on incongruent trials; PVT = psychomotor vigilance task; MW-Anti = mind-wandering reports on antisaccade task; MW-Stroop = mind-wandering reports on Stroop task; MW-PVT = mind-wandering reports on psychomotor vigilance task.

measures and latent variables were significant, and all latent variables showed significant covariances with one another. Individuals high in neuroticism showed poorer attention control, lower working memory capacity, and more frequent mind-wandering.

Because we were not specifically interested in the relative contributions of working memory capacity and attention control to mind-wandering, but rather in the relative contributions of neuroticism and executive control to mind-wandering, we next specified a model with a single executive attention factor (Figure 2). In the model we allowed operation span, symmetry span, reading span, accuracy on the antisaccade task, reaction times on accurate incongruent Stroop trials, and the slowest 20% of trials on the psychomotor vigilance task to load onto an executive attention (ExAttn) latent variable, the eight neuroticism items from the Big Five Inventory to load onto a neuroticism (Neurot) latent variable, and mind-wandering and inattention reports to load onto a mind-wandering (MW) latent variable. The fit of this model was also acceptable [$\chi^2(115) = 256.25$, CFI = 0.90, RMSEA = 0.08, SRMR = 0.07]. Similar to the model in Figure 1, individuals higher in neuroticism showed poorer executive attention and more frequent mind-wandering.

Because the goal of the present study was to understand why and how individuals mind-wander, we created a structural equation model in which neuroticism and executive attention predicted mind-wandering. This model is shown in Figure 3. Executive attention and neuroticism latent variables were entered as predictors of a mind-wandering (MW) latent variable and were allowed to correlate. As can be seen in the diagram, it appears as if neuroticism does not significantly predict mind-wandering. However because neuroticism and executive attention correlate, it is possible that they share variance that is predicting mind-wandering, or that executive attention is mediating the neuroticism-mind wandering relationship.

To examine the possible mediating relationship, our next model specified direct paths between neuroticism, executive attention, and mind-wandering (Figure 4). Although the direct path between neuroticism and mind-wandering was not significant, there was a significant indirect path through executive attention (indirect path coefficient = −0.19, $p < .001$). This suggests that neuroticism is related to poor executive control, which is in turn related to more frequent mind-wandering.

Our final model attempted to separate shared and unique variance among neuroticism and executive attention in predicting mind-wandering. In this model (Figure 5), we allowed all measures to load onto a common latent variable (Common), and the complex span and attention control tasks to load onto an executive attention (ExAttn) latent variable. These two variables were entered as predictors of mind-wandering in a regression. In this model, we are able to separate variance that is shared between neuroticism and executive attention, which would

**Table 2.** Zero-order correlations among all measures.

| Measure | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. OSpan | — | | | | | | | | | | | | | | | |
| 2. SymSpan | .41 | — | | | | | | | | | | | | | | |
| 3. RSpan | .57 | .33 | — | | | | | | | | | | | | | |
| 4. Anti | | .11 | .09 | .24 | — | | | | | | | | | | | |
| 5. Stroop | −.27 | −.20 | −.29 | −.39 | — | | | | | | | | | | | |
| 6. PVT | | −.18 | −.19 | −.16 | −.46 | .45 | — | | | | | | | | | |
| 7. MW-A | −.11 | −.09 | −.23 | −.39 | .23 | .35 | — | | | | | | | | | |
| 8. MW-S | −.08 | −.08 | −.14 | −.26 | .33 | .27 | .65 | — | | | | | | | | |
| 9. MW-P | −.03 | −.01 | −.13 | −.24 | .22 | .39 | .56 | .61 | — | | | | | | | |
| 10. bfi4 | −.11 | .02 | −.07 | −.06 | .03 | .07 | .02 | .03 | .06 | — | | | | | | |
| 11. bfi9 | .05 | .17 | .10 | .22 | −.15 | −.14 | −.15 | −.13 | −.15 | −.27 | — | | | | | |
| 12. bfi14 | .002 | −.03 | −.14 | −.05 | −.05 | −.03 | .02 | .07 | .02 | .16 | −.34 | — | | | | |
| 13. bfi19 | −.04 | −.04 | −.14 | −.28 | .16 | .10 | .16 | .21 | .15 | .27 | −.47 | .47 | — | | | |
| 14. bfi24 | .15 | .10 | .25 | .17 | −.19 | −.13 | −.15 | −.08 | −.14 | −.28 | .50 | −.29 | −.35 | — | | |
| 15. bfi29 | −.04 | −.003 | −.02 | −.13 | .10 | .10 | .12 | .08 | .12 | .31 | −.24 | .43 | .28 | −.30 | — | |
| 16. bfi34 | −.20 | .21 | .27 | .19 | −.16 | −.08 | −.10 | −.06 | −.04 | −.12 | .57 | −.17 | −.31 | .45 | −.14 | — |
| 17. bfi39 | −.09 | −.14 | −.17 | −.18 | .14 | .10 | −.02 | .13 | .09 | .18 | −.31 | .30 | .49 | −.21 | .19 | −.30 |

Note. $N = 201$. OSpan = operation span; SymSpan = symmetry span; RSpan = reading span; Anti = antisaccade task; Stroop = reaction times on incongruent Stroop trials; PVT = psychomotor vigilance task; MW-A = mind-wandering and inattention reports on the antisaccade task; MW-S = mind-wandering and inattention reports on the Stroop task; MW-P = mind-wandering and inattention reports on the psychomotor vigilance task; bfi = items from 44-item Big Five Inventory assessing neuroticism. Correlations with absolute values greater than .14 are significant at $p < .05$.

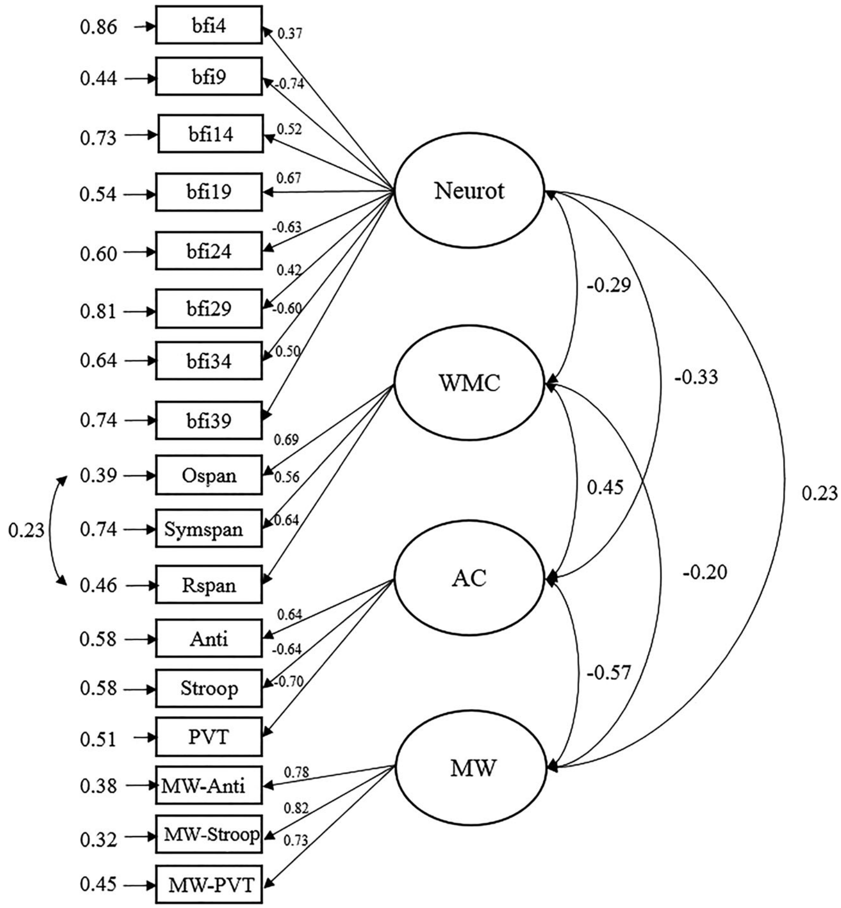


**Figure 1.** Confirmatory factor analysis with the neuroticism items from the Big Five Inventory loading on a neuroticism latent variable (Neurot), the three complex span tasks loading on a working memory capacity latent variable (WMC), the antisaccade, Stroop, and psychomotor vigilance tasks loading onto an attention control latent variable (AC), and mind-wandering and inattention reports from the attention control tasks loading on a mind-wandering latent variable (MW). All paths and correlation between latent variables were significant at $p < .05$. $N = 201$. $\chi^2(112) = 224.37$, CFI = 0.92, RMSEA = 0.07, SRMR = 0.06, where CFI = Comparative Fit Index, RMSEA = Root Mean Squared Error of Approximation, SRMR = Standardized Root Mean Square Residual.

theoretically represent deficits in executive attention attributable to neurotic personality traits, from variance that is unique to executive attention. The fit of this model was also acceptable [$\chi^2(110) = 247.75$, CFI = 0.90, RMSEA = 0.08, SRMR = 0.07]. The common variance between neuroticism and executive attention accounted for significant variance in mind-wandering. This proportion of variance in mind-wandering is probably due to a subset of individuals who are high in neuroticism who show poor executive control and mind-wander frequently. However, there is also a significant amount of variance accounted for by executive attention independently. This proportion of variance in mind-wandering is due to the previously observed relationship between executive control and mind-wandering.[3] Specifically, individuals with poor

[3]We also ran an alternative bifactor model with a mind-wandering latent variable on which the reports of mind-wandering were allowed to load, a common latent variable on which all working memory, attention control, and neuroticism measures were allowed to load, an executive attention residual latent variable on which the working memory and attention control measures were allowed to load, and a neuroticism residual latent variable on which the Big Five Inventory (BFI) items were allowed to load. This model produced a non-significant path ($\beta = 0.13$, $p = .13$) between the neuroticism residual and mind-wandering latent variables. This suggests that the relationship between neuroticism and mind-wandering is captured by neuroticism's covariance with executive attention. This is possibly due to the fact that mind-wandering was measured during the attention control tasks in the present study.

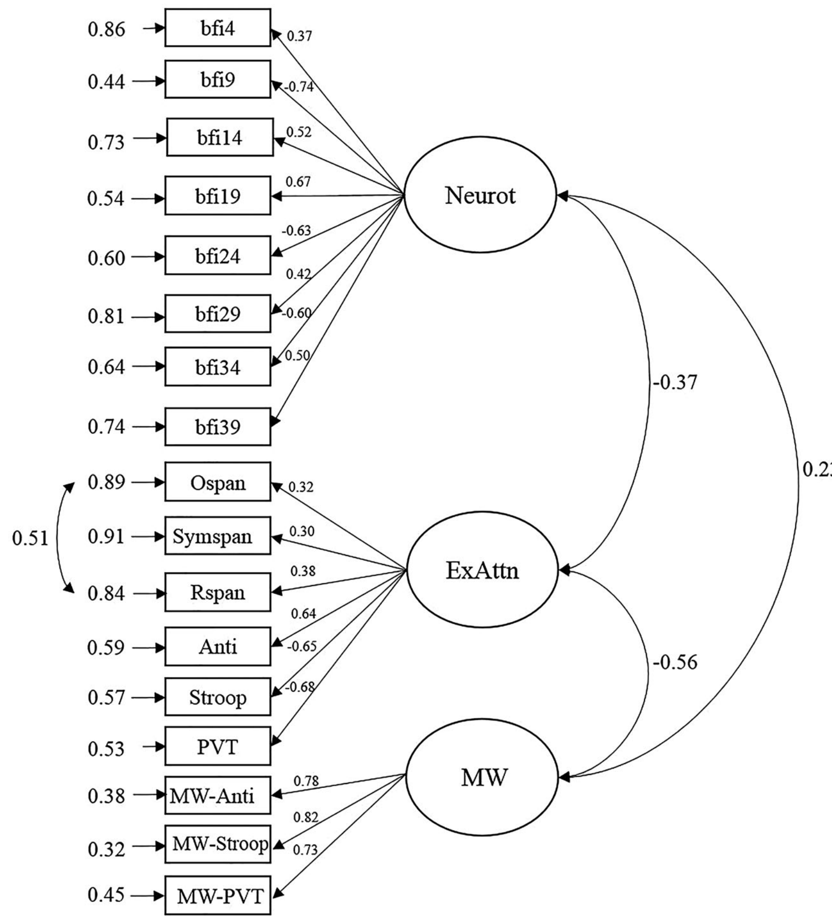


**Figure 2.** Confirmatory factor analysis with the neuroticism items from the Big Five Inventory loading on a neuroticism (Neurot) latent variable, the complex span and attention control tasks loading on an executive attention (ExAttn) latent variable, and the mind-wandering and inattention reports loading on a mind-wandering (MW) latent variable. All paths and correlations between latent variables were significant at $p < .05$. $N = 201$. $\chi^2(115) = 256.25$, CFI = 0.90, RMSEA = 0.08, SRMR = 0.07, where CFI = Comparative Fit Index, RMSEA = Root Mean Squared Error of Approximation, SRMR = Standardized Root Mean Square Residual.

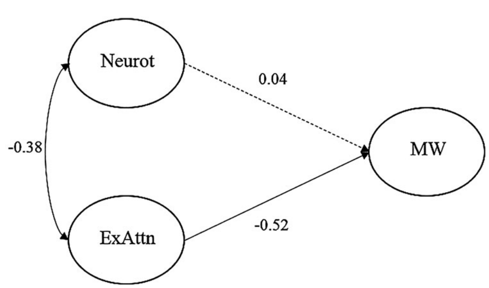


**Figure 3.** Structural equation model predicting mind-wandering (MW) with neuroticism (Neurot) and executive attention (ExAttn). Solid lines represent significant paths and correlations at $p < .05$, and dotted lines are not significant at $p < .05$. $N = 201$. $\chi^2(115) = 256.25$, CFI = 0.90, RMSEA = 0.08, SRMR = 0.07, where CFI = Comparative Fit Index, RMSEA = Root Mean Squared Error of Approximation, SRMR = Standardized Root Mean Square Residual.

executive control tend to mind-wander more, and individuals with relatively good executive control are able to resist mind-wandering.

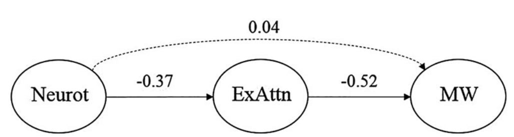


**Figure 4.** Structural equation model in which executive attention (ExAttn) mediates the relationship between neuroticism (Neurot) and mind-wandering (MW). The indirect path between neuroticism and mind-wandering is significant ($\beta = -0.19$, $p < .001$).$N = 201$. $\chi^2(115) = 256.25$, CFI = 0.90, RMSEA = 0.08, SRMR = 0.07, where CFI = Comparative Fit Index, RMSEA = Root Mean Squared Error of Approximation, SRMR = Standardized Root Mean Square Residual.

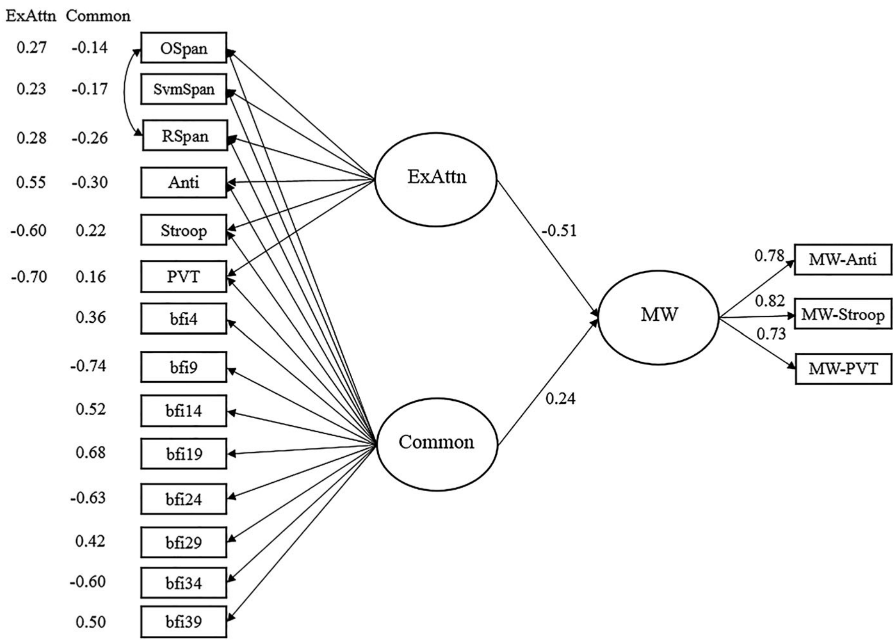


**Figure 5.** Structural equation model in which common variance among measures of neuroticism and executive attention and unique variance in executive attention both significantly predicted mind-wandering. Residual variance in operation span (OSpan) and reading span (RSpan) were allowed to correlate. The common and executive attention (ExAttn) latent variables were not allowed to correlate, but were both entered as predictors of mind-wandering (MW) in the model. SymSpan = symmetry span; Anti = accuracy on antisaccade task; Stroop = reaction times to incongruent Stroop trials; PVT = slowest 20% of response times on psychomotor vigilance task; bfi = Big Five Inventory items. Numbers in the columns on the left are the loadings of each item onto the latent variables. All loadings and paths were significant. $N = 201$. $\chi^2(110) = 247.75$, CFI = 0.90, RMSEA = 0.08, SRMR = 0.07, where CFI = Comparative Fit Index, RMSEA = Root Mean Squared Error of Approximation, SRMR = Standardized Root Mean Square Residual.

## General discussion

Because mind-wandering has been identified in such a wide array of important areas of human functioning including cognition, emotion, and psychopathology, it is important we gain a more complete understanding of mind-wandering, both of its causes and of its effects. The present study attempted to tie together various areas of research that have studied mind-wandering, how and why it occurs, and what effects it has on cognitive and emotional functioning. To test the Control Failure × Concerns model of mind-wandering (McVay & Kane, 2010) from an individual differences perspective, the present study investigated the relationships among neuroticism, executive attention, and mind-wandering. A large sample of participants allowed for an individual differences approach to these constructs at the latent level. Structural equation models revealed two distinct sources of mind-wandering. The first source was shared variance among neuroticism and executive attention. This source is probably due to a group of participants who endorsed high levels of neuroticism, showed deficits in performance on the executive attention (i.e., working memory capacity and attention control) tasks, and mind-wandered more frequently. However, there was also a source of variance in mind-wandering that was uniquely accounted for by executive attention. This common variance between mind-wandering and executive attention, independent of neuroticism, is probably driven by a subset of individuals who have poor executive control and thus show frequent mind-wandering (and others who have good executive control and do not mind-wander much), but do not endorse neurotic personality traits.

In general our results are consistent with the Control Failures × Concerns account of mind-wandering (McVay & Kane, 2010). In this model, mind-wandering is determined both by failures of executive control and by the prevalence of salient personal concerns. For some individuals, mind-wandering is a product of their natural tendency to entertain personal concerns and related deficits in the ability to maintain task focus. Theoretically, the fact that they cannot consistently maintain their attention on the task because of their personal concerns leads to decreased cognitive performance. But for other individuals, while personal concerns may not be weighing heavily on their minds, their attention nevertheless continually shifts to task-irrelevant thoughts, and their performance likewise suffers.

There are several possible reasons for why neuroticism is positively related to propensities to mind-wander and negatively related to executive control. By definition, neurotic individuals tend toward an over-concern with personal worries, they have a tendency to be anxious, and they are more likely to carry a negative mood. From previous investigations of mind-wandering and mood (e.g., Killingsworth & Gilbert, 2010; Poerio et al., 2013; Smallwood, Fitzgerald, et al., 2009), we know that negative moods are associated with mind-wandering. Poerio et al. (2013) suggest that sadness predicts later mind-wandering (but not vice versa). If neurotic individuals are more likely to be in negative moods, negative moods result in more mind-wandering, and mind-wandering results in reduced cognitive performance, the observed results are entirely plausible. Mason, Brown, Mar, and Smallwood (2013) suggest a more nuanced relationship between mood and mind-wandering, suggesting that there are several possible mediating variables, including task characteristics, life events, and individual dispositions. Among the dispositions that Mason et al. mention is neuroticism, so the current results may help us to understand the mood to mind-wandering relationship, as well. Perkins et al. (2015) argue that self-generated thoughts are actually the cause of neuroticism. In this theory, individual differences in brain circuits that regulate self-generated thoughts, executive control, and emotion regulation interact in such a way that some individuals are simply more prone to entertaining thoughts that are irrelevant to the current context. Future research should focus on both state and trait aspects of worry, anxiety, and mood to better understand situations in which the mood–cognition relationship is especially strong and in what situations individuals with certain traits are most likely to mind-wander and experience impaired cognitive performance. For example, a negative mood induction may strengthen the relationship between neuroticism, mind-wandering, and executive control as the mood induction serves to make neurotic traits more manifest.

Another possible explanation is that the challenging nature of the tasks actually induced test anxiety among some participants, and this effect was especially present among the individuals who scored highly on the neuroticism scale. This anxiety could have led to more negative self-appraisals, and these self-appraisals manifested themselves as mind-wandering. These participants' focus of attention could have been frequently drawn away from task goals and inward to self-appraisal, which in turn hurt their performance. It is also possible that this effect snowballed across the session. Participants saw scores after each list on the complex span tasks and were probably able to infer their performance from their accuracy and response times. This feedback, both explicit and implicit, may have reinforced anxious feelings about their task performance. Indeed, Moutafi, Furnham, and Tsaousis (2006) found a negative correlation between neuroticism and fluid intelligence. But once they accounted for test anxiety, the partial correlation between neuroticism and intelligence was no longer significant. Levels of "induced anxiety" also mediated the relationship between neuroticism and intelligence. So it is certainly possible that test anxiety may be accounting for the observed relationships in the present study. However, this would also suggest a positive relationship between neuroticism and task-related interference reports ("I am thinking about my performance on the task"), and there was no such relationship in the current sample. But one way to test this possibility is to alter the feedback structure of the tasks, making feedback more or less salient and perhaps affecting the neuroticism–mind-wandering–cognition relationships. If by removing all feedback from the task we observe a reduction in the magnitude of the relationships, or if by making feedback more salient or by providing false feedback we strengthen the relationships, this would provide evidence that testing anxiety is partially accounting for the relationship between these constructs.

A third possibility is that there is fundamental relation between neurotic personalities and deficient attention control abilities. These deficiencies are reflected in two ways: (a) an inability to disengage from negative thoughts, personal concerns, and worries; and (b) a more generally deficient attention control system (Eysenck et al., 2007). As a result, they tend to entertain negative thoughts, and these thoughts frequently intrude during the completion of tasks, especially those that require cognitive control. In the present study, both personality variables and individual differences in working memory capacity predicted mind-wandering rates and attention control abilities. This explanation is also consistent with the neuroimaging observations of Forster et al. (2015), who propose a model in which task-unrelated mind-wandering is jointly and independently produced by the tendency to generate self-relevant thoughts and deficient attention control. Similarly, these results may assist the study of mind-wandering (e.g., rumination) in the context of clinical depression. Default mode network dominance over task positive networks (presumably due to mind-wandering) has been connected to major depressive symptoms such as depressive rumination.

Although neuroticism is a personality trait, and it is not necessarily the case that neurotic individuals will be depressed or anxious in a clinically significant way, neuroticism is a predictor of depression and depression proneness (e.g., Saklofske, Kelly, & Lanzen, 1995). Therefore, the current results could be applicable to the neuroscientific study of depression, as well. A way to test this explanation is by giving the content of the memoranda or task content emotional valence. For example, we used a classic Stroop colour–word task, but an emotional Stroop task (Watts, McKenna, Sharrock, & Tresize, 1986) may have different effects, especially for highly neurotic individuals. If tasks that carry a level of emotional arousal strengthen the neuroticism–mind-wandering–cognition relationships, that would be evidence for this account. We should note, however, that neuroticism, anxiety, worry, and depression are distinct psychological constructs, and, although they are related, it is not necessarily the case that they will all show similar relationships to the ones observed in the present study. Future research should attempt to clarify the specific relationships among similar yet related constructs (e.g., anxiety) with executive control and mind-wandering.

As is the case with any study, the present investigation has several limitations. First, the present study uses a rather brief (eight-item) measure of neuroticism. A longer, more detailed measure that is designed to specifically measure neuroticism, or perhaps multiple measures with convergent validity, may be more appropriate for future studies on the relation between neuroticism, mind-wandering, and executive control. Second, the mind-wandering construct was drawn from rates of mind-wandering during the attention control tasks. In the future, these measurements can be combined with other indices of mind-wandering (e.g., diaries, experience sampling) to corroborate the findings of mind-wandering in the lab. Third, the present study does not measure other closely related aspects of neuroticism such as negative affect, mood, anxiety, and worry, nor does it ask participants to report any recent life events that may impact their cognitive performance and ability to resist mind-wandering beyond their personality traits. For example, if an individual recently experienced a personal crisis or has a stressful upcoming event in the near future, they may be more prone to mind-wandering about such an important personal event, which could be totally independent of their stable personality traits. Future work should measure both state (i.e., temporally specific) factors and trait factors that can contribute to the relationship between emotion and cognition. Finally, the tasks inherently carry a level of explicit and implicit feedback that may be unintentionally inducing test anxiety. This procedure-induced test anxiety could be affecting task performance, especially for those individuals high in neuroticism and thus more predisposed to experiencing anxious thoughts and feelings.

We should also note that a previous investigation by one of the authors (Unsworth et al., 2009) found a null correlation between neuroticism and one measure of working memory (operation span) and neuroticism and attention control/inhibition. There are several possible reasons for the discrepancies in these findings. The first is that the personality measurement in Unsworth et al. (2009) was the 280-item Revised NEO Personality Inventory (Costa & McCrae, 1992), and the present study used a 44-item Big Five Inventory. Although the measures of neuroticism in the two measures are moderately to highly correlated, they are not identical (Rammstedt & John, 2007). So it is possible that the subtle differences in these two measures can explain the discrepant findings. We acknowledged earlier that one element of the present study is the use of only one measure of neuroticism, so it is possible that these measures may be tapping slightly different aspects of neuroticism that have different relationships with mind-wandering and executive control. Another possibility is a difference in procedure. In Unsworth et al.'s (2009) study, participants completed laboratory measures of working memory, vigilance, fluid intelligence, fluency, and response inhibition in one laboratory session and completed a battery of personality questionnaires in a separate session. In the current study, participants completed the Big Five Inventory immediately following the working memory and attention control measures. It is possible that the procedure, especially considering the discussion of possible testing anxiety mentioned earlier, may have altered which neuroticism items individuals tended to endorse. Follow-up research should investigate this possibility, as well as use multiple measures in an attempt to measure neuroticism with perhaps more convergent validity. Finally, there could simply be differences in samples between the two studies.

Even with these limitations, the present study makes several novel findings in the field of mind-wandering and human cognition. Tests of the Control Failure × Concerns model of mind-wandering have largely focused on individual differences in executive control and their relationships to mind-wandering rates. The personal concerns piece has received considerably less attention, especially from an individual differences perspective. Recent experimental evidence (e.g., Banks et al., 2015; McVay & Kane, 2013) has suggested that priming personal concerns, and perhaps especially negative ones, leads to more mind-wandering, and this effect seems to be particularly pronounced among individuals with high stress reactivity. Because of the large sample and the ability to use structural equation modelling to partial common and unique variance among executive control, neuroticism, and mind-wandering, we were able to further delineate sources of mind-wandering. Therefore, we have given further credence and clarification to the Control Failure × Concerns model of mind-wandering and opened doors for future research.

## Conclusion

Mind-wandering relates to a variety of important areas of human functioning, including basic cognition, higher order cognition, daily success, happiness, and even certain types of psychopathology. Therefore, a more complete understanding of mind-wandering will aid our ability to understand how and when it occurs, when it is detrimental and when it may help, and how it can inform models of human cognition and emotion. We set out to test the Control Failure × Concerns model of mind-wandering by measuring individual differences in neuroticism, which should measure an individual's tendency to entertain personal concerns, or similarly the relative salience of personal concern to individuals. By finding relationships among neuroticism, executive control, and mind-wandering, the present study brings new converging evidence for the Control Failure × Concerns model and hopefully opens the door to future areas of research. These results can inform neuroscientific investigations of constructs like psychopathology, deficient attention control, mind-wandering, and the relationships among them, tying together the fields of clinical psychology, cognitive psychology, affective neuroscience, and cognitive neuroscience to give us a more complete understanding of the human cognitive and emotional systems, as well as the complex ways in which they interact.

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# Appendix

**Table A1.** Items measuring neuroticism on the 44-item Big Five Inventory.

| Item | Prompt |
|---|---|
| bfi4 | "I see myself as someone who is depressed, blue." |
| bfi9 | "I see myself as someone who is relaxed, handles stress well." |
| bfi14 | "I see myself as someone who can be tense." |
| bfi19 | "I see myself as someone who worries a lot." |
| bfi24 | "I see myself as someone who is emotionally stable, not easily upset." |
| bfi29 | "I see myself as someone who can be moody." |
| bfi34 | "I see myself as someone who remains calm in tense situations." |
| bfi39 | "I see myself as someone who gets nervous easily." |

Note: Participants rated these items on a 5-point scale with 1 = "disagree strongly" and 5 = "agree strongly". bfi = Big Five Inventory.