Journal of Memory and Language 67 (2012) 1–16

Contents lists available at SciVerse ScienceDirect

Journal of Memory and Language

journal homepage: www.elsevier.com/locate/jml

Variation in cognitive failures: An individual differences investigation of everyday attention and memory failures

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ARTICLE INFO

Article history:
Received 23 September 2011
revision received 8 December 2011
Available online 20 January 2012

Keywords:
Cognitive failure
Individual difference
Intelligence

ABSTRACT

The present study examined individual differences in everyday cognitive failures assessed by diaries. A large sample of participants completed various cognitive ability measures in the laboratory. Furthermore, a subset of these participants also recorded everyday cognitive failures (attention, retrospective memory, and prospective memory failures) in a diary over the course of a week. Using latent variable techniques the results suggested that individual differences in cognitive abilities (i.e., working memory, attention control, retrospective memory, and prospective memory) were related to individual differences in everyday cognitive failures. Furthermore, everyday cognitive failures predicted SAT scores and partially accounted for the relation between cognitive abilities and SAT scores. These results provide important evidence for individual differences in everyday cognitive failures as well as important evidence for the ecological validity of laboratory cognitive ability measures.

Introduction

We owe our ability to effectively focus and sustain attention on a task, to retrieve information accurately from memory, and to carry out planned intentions in the future to a well functioning cognitive system. Without question, this system allows us to carry out the myriad of important and mundane tasks set before us daily. Despite the effectiveness of our overall cognitive system, sometimes we make mistakes resulting in generalized cognitive failures. For instance, have you ever caught yourself daydreaming during an important meeting? Have you ever forgotten the name of a person you were just introduced to? Have you ever forgotten to add an attachment to an email before sending it? Most people will answer yes to these questions, although the frequency of these cognitive failures likely varies across people. Thus, although we carry out many of our day-to-day tasks successfully, every once in awhile we experience a cognitive failure. Such failures have long been considered an important topic of research in a number of domains including cognitive psychology, cognitive aging, developmental psychology, clinical psychology, educational psychology, neuropsychology, and neuroimaging.

An important reason for examining cognitive failures is that not only does the frequency of such errors likely vary as a function of individual differences, neuropsychological disorders, and age, but these failures also have real world consequences. For example, students who are more likely to daydream or mind-wander during lectures may perform more poorly on tests than students who are less likely to mind wander. Furthermore, forgetting to carry out an intention, such as putting the landing gear down before landing, will also have obvious real world consequences (see Reason (1990) for a review). Thus, examining cognitive failures will not only allow for a better understanding of the underlying mechanisms that give rise to such errors but also allow for a better understanding of who is likely to commit such errors.

Everyday attention and memory failures

Broadly construed, cognitive failures refer to all of the possible different types of failures within the cognitive

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0749-596X/$ - see front matter
doi:10.1016/j.jml.2011.12.005

system (i.e., memorial, attentive, or otherwise) that could conceivably occur. These include lapses of attention, mind wandering, failures of memory, action failures, etc. (e.g., Broadbent, Cooper, FitzGerald, & Parkes, 1982). Theoretically, these errors can be conveniently grouped into three classes of failures: attention failures, retrospective memory failures, and prospective memory failures (see Heckhausen and Beckman (1990), Norman (1981), and Reason (1984a) for similar taxonomies of action slips). In the current study attention failures refer to situations in which attention could not be maintained and sustained on a task leading to a momentary lapse. Such failures could arise from distracting external stimuli (e.g., a loud noise) or from internal thoughts and distractions (e.g., daydreaming). Thus, these attentional lapses could arise from distractions, from mind wandering, or from absent-mindedness (similar to action slips). Retrospective memory failures refer to situations in which information cannot be properly retrieved from the memory system even though that information is likely stored. Retrospective memory failures could include failures over the short-term (e.g., forgetting the name of a person you were just introduced to), failures of autobiographical/personal memory (e.g., forgetting your email password), or failures of more fact-based semantic memory (e.g., forgetting the name of the person who was the President of the United States during the Civil War). Prospective memory failures refer to situations in which an individual forgets to carry out some intention in the future. For example forgetting to carry out an activity (e.g., forgetting to add an attachment to an email), forgetting to do something at a particular time (e.g., forgetting to go to a meeting at 10:15 am), and forgetting to attend an event (e.g., forgetting to go to your sister's wedding) would all be considered prospective memory failures. Clearly there are a number of different ways that the cognitive system can fail and some of these errors can be relatively harmless, whereas other errors could have life-threatening consequences. Understanding these cognitive failure as well as possible sub-classifications of failures is important in order to not only understand how the cognitive system operates, but it is also for determining who is likely to demonstrate these different failures and in what situations these failures are most likely. That is, an examination of cognitive failures should provide us with more information regarding the underlying cognitive systems that give rise to such errors (attentional and memorial systems) as well as giving some indication of how these systems and their resulting errors are interrelated.

An important method for examining everyday attention and memory failures is through diary studies. As the name suggests, in these studies individuals are required to carry a diary for some amount of time and record their attention and memory failures. These studies provide important information about the different types of cognitive failures as well as the relative frequencies with which these cognitive failures occur in everyday life. For example, Reason (1984a) had 63 undergraduates record their action slips in the course of a week. Reason found that many of attentional failures occurred because participants were either preoccupied by internal thoughts or distracted by external stimuli. Furthermore, Reason found that most of these errors occurred during the late afternoon and early evening.

Crovitz and Daniel (1984) had 47 participants record their memory failures. Crovitz and Daniel found that the most frequently occurring memory error was a retrospective memory error (forgetting someone's name) followed by a prospective memory (forgetting to make a phone call). Likewise, Terry (1988) examining memory failures in 50 individuals found that prospective memory errors were the most common followed by retrospective memory failures. These results suggest that diary studies provide important information on everyday attention and memory failures. However, little work has examined the relation between cognitive failures assessed with diaries and performance on laboratory tasks. Thus, it is not known whether everyday attention and memory failures reflect breakdowns in the same cognitive mechanisms assessed via laboratory tasks and it is not known whether variations in performance on laboratory tasks will be able to predict who is likely to experience everyday attention and memory failures.

Individual differences in working memory capacity and cognitive control

Theoretically, cognitive failures likely result from general failures in cognitive control. Cognitive control refers to the ability to guide processing and behavior in the service of task goals and this ability is a fundamental aspect of the cognitive system that is thought to be important for a number of higher-level functions. Important components of cognitive control include actively maintaining task goals, selectively and dynamically updating task goals, detecting and monitoring conflict, and making adequate control adjustments in the presence of conflict (Cohen, Aston-Jones, & Gilzenrat, 2004). These components are thought to influence processing in a wide range of tasks and situations. As such, the ability to effectively utilize cognitive control and various executive functions (such as updating, switching and inhibition; Miyake et al., 2000) should be an important determinant of an individual's performance in such situations. Early work by Norman (1981) and Reason (1984a, 1984b) suggested that cognitive failures arise, in part, due to failures of cognitive control. For example, when attention is disengaged from the current task and focused on other external distracting stimuli or internal thoughts (e.g., daydreaming), cognitive failures are likely to occur. Along this line, Reason (1984b) suggested that "susceptibility to cognitive failures appears to be determined by some *general* control factor that exerts its influence over all aspects of mental function" (p. 115). Theoretically the absence of cognitive control can lead to an increase in the frequency of cognitive failures and this general lack of cognitive control leads to overall increases in all different types of failures rather than specific failures being due to failures of specific processing components (i.e., retrospective memory failures as a result of failures in retrospective memory processes). This notion of failures being due to general vs. specific factors will be examined more thoroughly later.

Recently, Engle, Kane and colleagues (Engle & Kane, 2004; Kane, Conway, Hambrick, & Engle, 2007) have suggested that individual differences in working memory capacity (WMC) are reflective of overall differences in general cognitive control abilities that are needed in a host of low-level and high-level cognitive tasks. Evidence for this view comes from a number of studies that have shown that individual differences in WMC are related to individual differences in attention control (e.g., Kane, Bleckley, Conway, & Engle, 2001; Unsworth & Spillers, 2010). Specifically, prior research has shown that measures of WMC are most pronounced in situations where task goals have to be maintained, particularly in the presence of internal and external distraction as in tasks like the antisaccade, Stroop, flankers, and various vigilance tasks (e.g., Kane et al., 2001; Unsworth & Spillers, 2010). Likewise, recent research has suggested that WMC is related to retrospective memory in terms of both encoding and retrieval operations such that individuals high in WMC are better able to encode information and better able to deal with interference at retrieval than individuals low in WMC (e.g., Unsworth, Brewer, & Spillers, 2009; Unsworth & Spillers, 2010). Finally, recent work has suggested that WMC is also related to prospective memory in that individuals high in WMC are better able to maintain and carry out planned intentions than low WMC individuals (e.g., Brewer, Knight, Marsh, & Unsworth, 2010). Overall, the results from prior studies suggest that high WMC individuals have greater cognitive control abilities than low WMC individuals, and that low WMC individuals are more likely to experience periodic cognitive failures than high WMC individuals in a number of domains. The current research addresses the degree to which these laboratory investigations of cognitive control and attention and memory abilities translates to cognitive failures in individuals day-to-day lives.

For the most part, these individual differences studies have examined variation in cognitive control with laboratory tasks and have not examined how individual differences in WMC and cognitive control are related to everyday attention and memory failures. However, one study in particular has examined the relation between individual differences in WMC and cognitive failures in the real world (Kane et al., 2007). In this study, Kane et al. had 124 participants perform a battery of WMC tasks in the laboratory and then participants were required to carry personal digit assistants (PDAs) around for 1 week. During that time the PDA would signal the participant to fill out a questionnaire regarding whether they had experienced any mind-wandering (e.g., Mason et al., 2007; Smallwood & Schooler, 2006) at the time of the signal, thereby providing information on everyday attention failures. Kane et al. found that individual differences in mind wandering were strongly related with measures of WMC, especially during challenging tasks. Specifically, during challenging tasks low WMC individuals reported more mind-wandering than high WMC individuals. This study provides important initial evidence that individual differences in cognitive control as assessed with laboratory tasks are related to everyday attention failures in some contexts.

Given the strong theoretical link between individual differences in cognitive control and everyday attention and memory failures, the results from Kane et al. (2007) are exactly what one would expect to see. Those individuals who are better at attention control should demonstrate less mind wandering (and fewer lapses) than those individuals who are poorer at attention control. Indeed, in discussing potential reasons for individual differences in cognitive failures Reason and Mycielska (1982) suggested that "the liability to minor cognitive failures may not necessarily depend primarily upon the quantity of the sparse attentional resource, but upon the facility with which individuals dispose of this commodity from moment to moment. In other words, people may vary in the effectiveness with which they deploy their attentional reserve in response to the current demands of the situation" (p. 230). Thus, individual differences in attention control should predict who is likely to experience frequent cognitive failures. Although the results of Kane et al. (2007) suggest this might be the case, it should be noted that Kane et al. only examined individual differences in WMC and mind-wandering and did not examine the other cognitive failures or other cognitive abilities (such as attention control, retrospective memory, or prospective memory). Clearly more work is needed to examine the potential linkages between cognitive control in the laboratory and cognitive failures in everyday life.

A further reason to explore individual differences in everyday cognitive failures is because laboratory assessments of WMC have long been shown to predict performance on scholastic ability measures such as the SAT (Engle, Tuholski, Laughlin, & Conway, 1999) which can be seen as a proxy for general intelligence (Frey & Detterman, 2004). The fact that individual differences in cognitive control (as assessed by WMC) are related to individual differences in scholastic abilities and intelligence has long been taken as evidence for the general importance of cognitive control and much research has been devoted to examining the reasons for this relation. However, as yet, no research has directly examined the extent to which everyday cognitive failures are important predictors of scholastic abilities and general intelligence and the extent to which everyday cognitive failures account for the relation between cognitive abilities assessed in the laboratory and formal intellectual tasks such as the SAT. Theoretically, those individuals with poor cognitive control capabilities should be more likely to experience lapses of attention (e.g., mind-wandering during test taking) and memory (e.g., momentarily forgetting the definition of the word "diatribe") which could impact their scores on formal intellectual tasks. If this is the case, then individual differences in everyday cognitive failures should be related to performance on scholastic and intellectual tasks such as the SATs.

The present study

The goal of the present study was to better examine individual differences in cognitive failures. In particular, three main questions were examined. First, do people who differ in cognitive abilities differ in the extent to which they experience real-world cognitive failures? Specifically, do measures of attention control, WMC, retrospective memory, and prospective memory predict everyday cognitive failures? Intuitively and theoretically one would expect that attention and memory processes assessed in the laboratory would predict attention and memory failures in everyday life, but, little work has directly examined these issues. Thus, it is unclear whether individual differences in cognitive abilities and cognitive control more specifically will predict cognitive failures in everyday life. Indeed, as noted by Reason and Mycielska (1982) "laboratory tests do not always prove to be good predictors of a person's performance in the outside world. The attempt to bridge this gulf between the highly specific and easily manipulable laboratory task and the uncontrollable and myriad concerns of actual day-to-day living remains one of psychology's most difficult challenges. Both modes of inquiry are necessary and important; but reconciling their findings is not easy" (p. 233). We agree with Reason and Mycielska that attempting to bridge laboratory studies of cognition with ecologically valid studies of everyday attention and memory failures is an important endeavor and one that will help us to not only understand the potential mechanisms that give rise to various cognitive failures, but also allow us to predict who is likely to experience frequent cognitive failures in everyday life.

Furthermore, most prior studies of everyday cognitive failures have specifically examined attention failures (e.g., lapses of attention and slips of action) or memory failures (retrospective and prospective failures), but little work has been done to examine the extent to which different types of cognitive failures are related to one another. Thus, it unclear whether individual differences in cognitive failures represent a global issue or whether various cognitive failures (attention failures, retrospective memory failures, and prospective memory failures) represent distinct constructs. Intuitively it seems plausible that individual differences in cognitive failures represent a broad construct such that a person with poor cognitive control is likely to experience many cognitive failures across the various different sub-categories of errors. Indeed, Reason and Mycielska (1982) suggested that individual differences in cognitive failures were due to a general problem and were not localized to specific domains (i.e., attention, memory, etc.). Thus, based on this theory one would expect that a single factor represents all cognitive failures. It also seems plausible that individual differences in cognitive failures are relatively distinct such that a person who experiences many lapses of attention does not necessarily experience many retrospective memory failures, thus suggesting that various cognitive failures are distinct. That is, to the extent that attention control, retrospective memory, and prospective memory are relatively distinct (but related) constructs, one would expect some relations between the different types of cognitive failures that arise from each, but that these failures would be directly tied to the underlying construct rather than to a general factor. Therefore, the second main question addressed in the current study was to what extent are different types of cognitive failures (e.g., attention failures, retrospective memory failures, and prospective memory failures) related and to what extent do they represent general or specific constructs?

Finally, the third main question addressed in the current study was to what extent are everyday cognitive failures related to scholastic abilities and intelligence as indicated by SAT scores? Specifically, prior research has found that individual differences in cognitive abilities assessed in the laboratory (such as WMC) strongly predict SAT scores (e.g., Engle et al., 1999), but prior research has not addressed the extent to which everyday attention and memory failures predict variation in SAT scores. Theoretically, individuals with lower cognitive control abilities who also experience more cognitive failures should also have lower scholastic abilities as a lapse of attention or being distracted while taking a test could potentially lead to a lower than normal score. If this is the case then individual differences in everyday cognitive failures should be related to scholastic abilities as measured by the SATs.

To address these questions we a tested a large number of participants ($N = 165$) on several laboratory tasks thought to measure WMC, attention control, retrospective memory, and prospective memory. A subset of participants ($N = 100$) also agreed to carry diaries for a week in which they recorded cognitive failures (attention, retrospective memory, and prospective memory failures) they experienced each day. Finally, we obtained verbal and quantitative SAT scores for each participant via self-report.

The current study goes significantly beyond prior work by examining a large number of participants on a number of different laboratory measures of cognitive abilities as well as diary self-reports of a number of different types of cognitive failures. We used a latent variable approach to examine the relations between the laboratory cognitive measures and the various everyday cognitive failures measures. In order to derive latent variables for the constructs of interest, multiple indicators of each cognitive construct were used. This was done in order to ensure that any lack of a relation found between laboratory cognitive measures and everyday cognitive failures would not be due to unreliability or idiosyncratic task effects. Therefore, multiple measures of each cognitive construct were used to create latent variables of WMC, attention control, retrospective memory, and prospective memory and examine the relation between these latent variables with the self-report measures. By examining a large number of participants and a large and diverse number of measures we should be able to better characterize individual differences in everyday cognitive failures and address our three questions of primary interest.

Method

Participants

A total of 165 participants (68% female) were recruited from the subject-pool at the University of Georgia. Participants were between the ages of 18 and 35 ($M = 19.24$, $SD = 1.51$) and received course credit for their participation. Each participant was tested individually in a laboratory session lasting approximately 2 h. Of these 165 participants, 100 agreed to carry diaries for a week in which they recorded cognitive failures.

Materials and procedure

After signing informed consent, all participants completed operation span, symmetry span, reading span, free recall, antisaccade, low association cue–target PM, paired associates recall, arrow flankers, non-focal PM. All tasks were administered in the order listed above. Following the task, participants who were willing to participate in the diary portion of the study were given explicit and elaborate instruction on the diaries.

Laboratory tasks

Working memory capacity (WMC) tasks
Operation span (Ospan). Participants solved a series of math operations while trying to remember a set of unrelated letters (F, H, J, K, L, N, P, Q, R, S, T, Y). Participants were required to solve a math 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. Three trials of each list-length (3–7) were presented for a total possible of 75. The order of list-length varied randomly. At recall, letters from the current set were recalled in the correct order by clicking on the appropriate letters (see Unsworth, Heitz, Schrock, and Engle (2005) for more details). Participants received three sets (of list-length two) of practice. For all of the span measures, items were scored if the item was correct and in the correct position. The score was the proportion of correct items in the correct position.

Symmetry span (Symspan). In this task participants were required to recall 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 in the preceding displays, in the order they appeared by clicking on the cells of an empty matrix (see Unsworth, Redick, Heitz, Broadway, and Engle (2009) for more details). There were three trials of each list-length with list-length ranging from 2 to 5 for a total possible of 42. The same scoring procedure as Ospan was used.

Reading span (Rspan). Participants were required to read sentences while trying to remember the same set of unrelated letters as Ospan. For this task, participants read a sentence and determined whether the sentence made sense or not (e.g. "The prosecutor's dish was lost because it was not based on fact. ?"). Half of the sentences made sense while the other half did not. Nonsense sentences were made by simply changing one word (e.g. "dish" from "case") from an otherwise normal sentence. Participants were required to read the sentence and to indicate whether it made sense or not. After participants gave their response they were presented with a letter for 1 s. At recall, letters from the current set were recalled in the correct order by clicking on the appropriate letters (see Unsworth et al. (2009) for more details). There were three trials of each list-length with list-length ranging from 3 to 7 for a total possible of 75. The same scoring procedure as Ospan was used.

Attention control (AC) tasks
Antisaccade. In this task (Kane et al., 2001) participants were instructed to stare at a fixation point which was onscreen for a variable amount of time (200–2200 ms). A flashing white "=" was then flashed either to the left or right of fixation (11.33° of visual angle) for 100 ms. This was followed by a 50 ms blank screen and a second appearance of the cue for 100 ms making it appear as though the cue (=) flashed onscreen. Following another 50 ms blankscreen the target stimulus (a B, P, or R) appeared onscreen for 100 ms followed by masking stimuli (an H for 50 ms and an 8 which remained onscreen until a response was given). All stimuli were presented in Courier New with a 12 point font. The participants' task was to identify the target letter by pressing a key for B, P, or R (keys 1, 2, or 3 on the number keypad) as quickly and accurately as possible. In the prosaccade condition the flashing cue (=) and the target appeared in the same location. In the antisaccade condition the target appeared in the opposite location as the flashing cue. Participants received, in order, 10 practice trials to learn the response mapping, 10 trials of the prosaccade condition, and 40 trials of the antisaccade condition.

Arrow flankers. Participants were presented with a fixation point for 400 ms. This was followed by an arrow directly above the fixation point for 1700 ms. The participants' task was to indicate the direction the arrow was pointing (pressing the F for left pointing arrows and pressing J for right pointing arrows) as quickly and accurately as possible. On 30 neutral trials the arrow was flanked by two horizontal lines on each side. On 30 congruent trials the arrow was flanked by two arrows pointing in the same direction as the target arrow on each side. Finally, on 30 incongruent trials the target arrow was flanked by two arrows pointing in the opposite direction as the target arrow on each side. All trial types were randomly intermixed. The dependent variable was the reaction time difference between incongruent and congruent trials.

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 pressing the spacebar the RT was left on screen for 1 s to provide feedback to the participants. Interstimulus intervals were randomly distributed and ranged from 1 to 10 s. 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).

Retrospective memory (RM) tasks

Free recall. Participants were given 2 lists of 10 words each. All words were common nouns that were presented for 1.5 s each. After the list presentation participants saw ???, which indicated that they should type as many words as they could remember from the current list in any order they wished. Participants had 45 s for recall. A participant's score was the total number of items recalled correctly.

Paired associates recall. Participants were given 3 lists of 10 word pairs each. All words were common nouns and the word pairs were presented vertically for 2 s each. Participants were told that the cue would always be the word on top and the target would be on bottom. After the presentation of the last word participants saw the cue word and ??? in place of the target word. Participants were instructed to type in the target word from the current list that matched cue. Cues were randomly mixed so that the corresponding target words were not recalled in the same order as they were presented. Participants had 5 s to type in the corresponding word. A participant's score was proportion correct.

Picture source-recognition. Participants were presented with a picture (30 total pictures) in one of four different quadrants onscreen for 1 s. Participants were explicitly instructed to pay attention to both the picture as well as the quadrant it was located in. At test participants were presented with 30 old and 30 new pictures individually in the center of the screen. Participants indicated if the picture was new or old and, if old, what quadrant it was presented in via key press. Participants had 5 s to press the appropriate key to enter their response. A participant's score was proportion correct.

Prospective memory (PM) tasks

Low association cue–target PM. Participants were told that they were going to be deciding whether strings of letters were valid English words or not (i.e., Lexical Decision Task; LDT). Following the LDT instructions, all participants were presented with 105 letter strings of which 52 were valid English words and 53 were pronounceable nonwords. These letter strings were presented one at a time in the center of the screen. Participants were allowed to make their response by pressing one of two keys on the keyboard (F and J). After making each response, participants were presented with a "waiting" message at which point they pressed the spacebar to initiate the next trial. In addition to completing the LDT, participants were told that we were interested in their ability to remember to perform an action in the future. Participants were instructed to type a target word during the "waiting" message after classifying any one of four cue words during the LDT. The four cue–target pairs were SPAGHETTI–STEEPLE, THREAD–SAUCE, CHURCH–PENCIL, and ERASER–NEEDLE. For example, when participants encountered the word SPAGHETTI in the LDT they made a word response and then typed STEEPLE during the waiting message before initiating the next LDT trial with a spacebar press. All participants learned all four cue–target pairs to 100% criterion before completing a brief (2 min) paper and pencil distractor task and then beginning the LDT. Cue trials always occurred on the 25th, 50th, 75th, and 100th trials of the LDT. The dependent measure was the proportion of correct responses entered in this fashion.

Nonfocal PM. The general parameters of this task were identical to the low association cue–target PM task described previously. Participants completed a LDT task with the intention to make a special response (slash key) if they ever classified a word with the syllable TOR in it. Cue trials always occurred on the 25th, 50th, 75th, and 100th trials of the LDT. The dependent measure was the proportion of cues detected.

SAT

In addition to the above measures we also obtained each individuals' SAT scores (both quantitative and verbal scores) via self-report.

Diary

Participants were given a booklet and asked to keep a diary of their attention, retrospective, and prospective memory failures over the course of 1 week. Participants were told to indicate their various failures by writing a brief description of the failure and recording when it occurred (Morning, Noon, or Evening). Participants were encouraged to document the failures as soon as they happened or soon after they happened. Additionally, participants were instructed to classify each failure according the following basic scheme.

Attention failure – A failure of focusing mental effort that results in poor performance on any task.

1. Distraction – When task-irrelevant information captures your attention, thus keeping you from focusing on your task (i.e., your roommates cell phone keeps ringing).
2. Absent mindedness – When you forget to pay attention to an important component of a task (i.e., leaving your drink on top of your car).
3. Mind wandering – When you find yourself lost in thoughts which are totally unrelated to a task (i.e., day dreaming in class).
4. Other.

Retrospective memory failure – A failure of retrieving information from memory.

1. Short-term – When you are trying to remember something over a brief period of time and you forget it (i.e., forgetting the name of newly introduced person).
2. Personal – When you cannot remember information personal to you (i.e., forgetting names, where you left your keys, a message you were told, or event from your past).
3. Fact-based – When you cannot remember factual information for quizzes, tests, or trivia (i.e., forgetting the president's name during the Civil War).
4. Other.

Prospective memory failure – A failure of remembering to do something in the future.

1. Activity – When you fail to remember to do something *after* completing a different activity (i.e., forgetting to attach a document when you finish writing an email).
2. Time – When you fail to go to meeting or appointment at a predefined time (i.e., forgetting to be at the doctor's office exactly at 10:15).
3. Event – When you fail to attend an event, or when you fail to remember to do something tied to an environmental event (i.e., forgetting to go to your friend's birthday party).
4. Other.

Each failure was classified as an attention failure, a retrospective memory failure, or a prospective memory failure. Each error was further classified based on the subclassification for each main type of error. All responses were checked by three raters to make sure that the descriptions of each error matched the classification provided by the participant. Inter-rater agreement was high (>95%), and disagreements were resolved. Participants were given detailed instructions about how to record responses in the diary and examples were provided to assist them.

Results

The results are divided into two primary sections. In the first section the relation among the laboratory tasks is examined for the full sample of participants. In the second section, results from the diaries are examined as well as the relations among the diary responses and the laboratory tasks.

Laboratory tasks

First we examined the relations among the laboratory measures of WMC, AC, RM, PM, and SAT. Descriptive statistics for the measures are shown in Table 1. As can be seen in Table 1, the measures had generally acceptable values of internal consistency and most of the measures were approximately normally distributed with values of skewness and kurtosis under the generally accepted values (i.e., skewness <2 and kurtosis <4; see Kline, 1998). Correlations among the laboratory tasks, shown in Table 2, were weak to moderate in magnitude with measures of the same construct generally correlating stronger with one another than with measures of other constructs, indicating both convergent and discriminant validity within the data.

Table 1
Descriptive statistics and reliability estimates for laboratory tasks.

Measure	*M*	*SD*	Skew	Kurtosis	Reliability
Ospan	61.04	11.47	−1.32	1.71	.81
Rspan	57.42	14.15	−1.18	1.49	.77
Symspan	29.77	7.28	−.88	.89	.79
Anti	.52	.14	.05	−.85	.70
Flanker	116.17	61.13	.75	.79	NA
PVT	667.07	451.62	2.04	3.89	.96
PicSour	.69	.20	−1.11	.84	.86
Recall	6.78	1.71	−.12	−.09	.63
PA	.47	.25	.29	−.77	.72
LCTpm	.43	.39	.23	−1.49	.72
NFpm	.76	.33	−1.27	.42	.86
VSAT	602.91	62.40	−.22	1.90	NA
QSAT	613.15	74.37	−.30	−.86	NA

Note: Ospan = operation span; Rspan = reading span; Symspan = symmetry span; Anti = antisaccade; Flanker = arrow flankers; PVT = psychomotor vigilance task; PicSour = picture source recognition; Recall = free recall; PA = paired associates recall; LCTpm = low association cue–target PM; NFpm = nonfocal PM; VSAT = verbal SAT; QSAT = quantitative SAT.

Next, we used confirmatory factor analysis (CFA) to examine a measurement model of all of the laboratory tasks and the SAT measures to determine how each of the putative factors were related to one another. Separate factors were formed for WMC, AC, RM, PM, and SAT. All of the factors were allowed to correlate. Thus, this model tests the extent to which different measures can be grouped into separate yet correlated factors, and examines the latent correlations among the factors. The fit of the model was acceptable, $\chi^2(55) = 94.47$, $p < .01$, RMSEA = .07, SRMR = .06, NNFI = .93, CFI = .95, suggesting that the specified model provided a good description to the underlying pattern of data. Shown in Fig. 1 is the resulting model.

As can be seen each of the tasks loaded significantly on their respective constructs and all of the latent constructs were moderately correlated with one another. Specifically, WMC was related to AC and RM consistent with prior research (e.g., Unsworth & Spillers, 2010), additionally WMC was related to both PM (e.g., Brewer et al., 2010) and SAT scores (e.g., Engle et al., 1999). Attention control (AC) was moderately related to RM and PM, but had a much weaker relation with SAT scores. Finally, both RM and PM were related to one another and both demonstrated similar relations with SAT scores. These results replicate and extend prior research by demonstrating that all of these cognitive constructs are moderately related to one another and predict performance on the SAT. Thus, all of the laboratory tasks were related to one another and latent factors could be constructed from the underlying data.

Diaries

The above results suggested that the cognitive ability measures were related to one another. To more fully examine the questions of primary interest, we now turn to the results from the diaries. For each individual's diary we counted the total number of reported failures as well as the total number of attention failures (further broken down into three types), the total number of retrospective memory failures (further broken down into three types), and the total number of prospective memory failures (further broken down into three types). Shown in Table 3 are the results. As can be seen, there was a total of 2290 failures reported across all participants. Of these 934 were attention failures, 674 were retrospective memory failures, and 613 were prospective memory failures. Thus, there were more attention failures, both t's > 5.8, both p's < .001, than either of the two types of memory failures, which did not differ significantly, $t(99) = 1.39$, $p > .16$. Breaking down each of the failures we see that the

Table 2
Correlations for the laboratory tasks and questionnaires.

		1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Ospan	–												
2.	Rspan	0.62	–											
3.	Symspan	0.46	0.56	–										
4.	Anti	0.24	0.33	0.41	–									
5.	Flanker	−0.13	−0.24	−0.22	−0.23	–								
6.	PVT	−0.29	−0.22	−0.25	−0.40	0.21	–							
7.	Picsour	0.20	0.23	0.34	0.37	−0.20	−0.38	–						
8.	Recall	0.21	0.27	0.23	0.14	−0.15	−0.24	0.34	–					
9.	PA	0.12	0.20	0.37	0.24	−0.05	−0.12	0.33	0.45	–				
10	LCTpm	0.09	0.27	0.21	0.31	−0.22	−0.16	0.20	0.33	0.27	–			
11	NFpm	0.10	0.25	0.23	0.27	−0.14	−0.15	0.16	0.16	0.07	0.37	–		
12	VSAT	0.26	0.21	0.27	0.15	−0.07	−0.06	0.16	0.12	0.23	0.05	0.02	–	
13	QSAT	0.39	0.30	0.44	0.16	−0.16	−0.10	0.19	0.08	0.13	0.17	0.07	0.44	–

Note: Ospan = operation span; Rspan = reading span; Symspan = symmetry span; Anti = antisaccade; Flanker = arrow flankers; PVT = psychomotor vigilance task; PicSour = picture source recognition; Recall = free recall; PA = paired associates recall; LCTpm = low association cue–target PM; NFpm = nonfocal PM; VSAT = verbal SAT; QSAT = quantitative SAT. Correlations > .15 are significant at the $p < .05$ level.

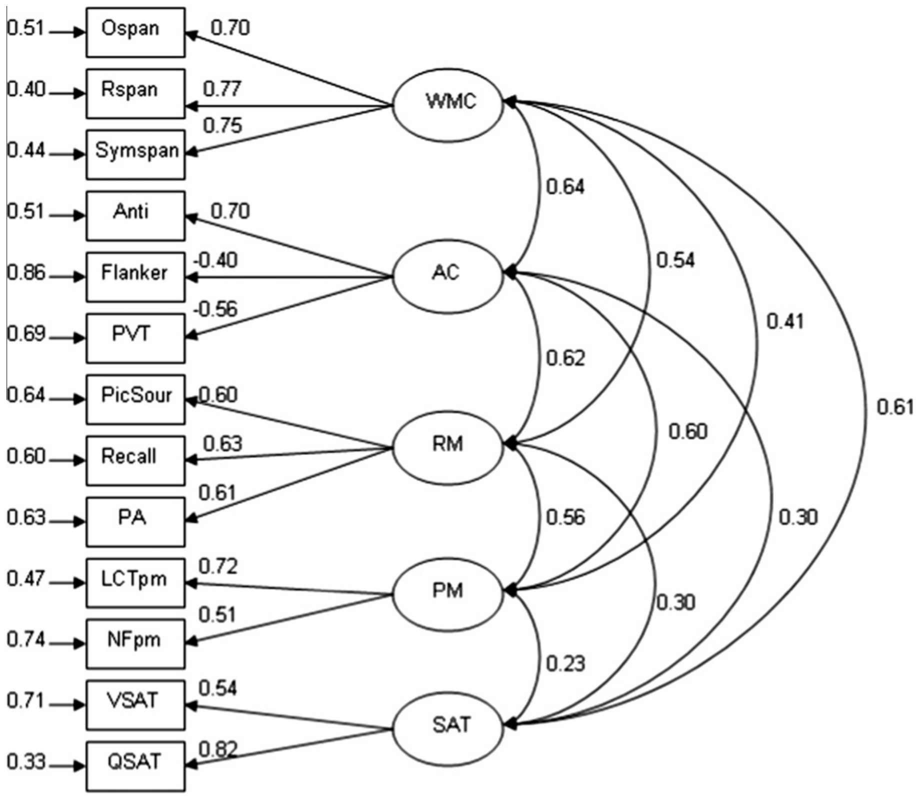

Fig. 1. Model for working memory capacity (WMC), attention control (AC), retrospective memory (RM), prospective memory (PM), and SAT. Paths connecting latent variables (circles) to each other represent the correlations between the constructs, the numbers from the latent variables to the manifest variables (squares) represent the loadings of each task onto the latent variable, and numbers appearing next to each manifest variable represent error variance associated with each task. All loadings and paths are significant at the $p < .05$ level.

majority of attention failures were failures due to distractions, followed by mind-wandering failures, and then absent-minded failures (all three types were significantly different from one another, all p's < .05). In terms of retrospective memory failures there were more short-term memory failures, both t's > 3.49, both p's < .001, than either personal or fact-based memory errors which did not differ from one another, $t(99) = .57$, $p > .57$. In terms of prospective memory failures there were more activity-based memory failures, both t's > 6.17, both p's < .001, than either time-based or event-based memory errors which did not differ from one another, $t(99) = .16$, $p > .87$. Thus, overall a large number of cognitive failures were reported and there were clear differences not only

Table 3
Descriptive statistics for the diary responses.

Measure	*M*	*SD*	Sum	Range
Total failures	22.90	13.44	2290	73
AttnTot	9.34	5.47	934	31
AttnD	4.19	3.02	419	13
AttnM	2.19	2.08	219	12
AttnW	2.77	2.14	277	8
RetroTot	6.74	4.68	674	26
RetS	2.76	2.19	276	11
RetP	1.91	1.99	191	10
RetF	1.79	1.88	179	9
ProTot	6.13	4.88	613	20
ProA	3.36	3.16	336	14
ProT	1.29	1.70	129	7
ProE	1.26	1.51	126	6

Note: Total failures = the total number of all types of failures; AttnTot = total number of all types of attention failures; AttnD = total number of distraction attention failures; AttnM = total number of absent-minded attention failures; AttnW = total number of mind-wandering attention failures; RetroTot = total number of all types of retrospective memory failures; RetS = total number of short-term retrospective memory failures; RetP = total number of personal retrospective memory failures; RetF = total number of fact-based retrospective memory failures; ProTot = total number of prospective memory failures; ProA = total number of activity-based prospective memory failures; ProT = total number of time-based prospective memory failures; ProE = total number of event-based prospective memory failures.

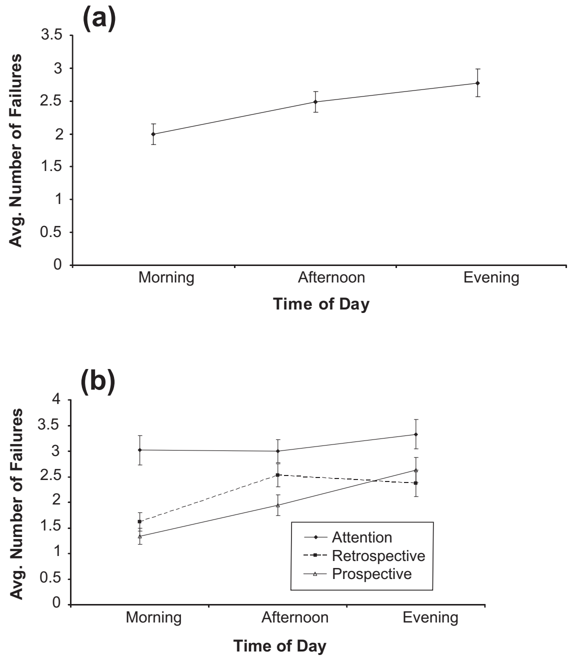

Fig. 2. (a) Number of cognitive failures as a function of time of day. (b) Number of cognitive failures as a function of type of failure and time of day. Note error bars reflect one standard error of the mean.

between the main different types of failures, but also between the various sub-types.

We next examined attention, retrospective, and prospective memory failures as a function of time of day. Recall that participants not only indicated the type of error they experienced, but also the time of day (morning, afternoon, or evening) that that the error occurred. To examine this we conducted a 3 (type of failure: attention, retrospective, or prospective) $\times$ 3 (time of day: morning, afternoon, or evening) repeated measures ANOVA. The ANOVA suggested that there was a main effect of type, $F(2,198) = 28.19$, $MSE = 3.98$, $p < .01$, partial $\eta^2 = .22$, with attention failures being more frequent than either type of memory error as seen previously. Additionally, there was a main effect of time of day, $F(2,198) = 9.78$, $MSE = 4.82$, $p < .01$, partial $\eta^2 = .09$. As shown in Fig. 2a, failures became more frequent as the day progressed generally consistent with prior research (Reason, 1984a). Importantly, these two factors interacted, $F(4,396) = 28.19$, $MSE = 3.09$, $p < .01$, partial $\eta^2 = .03$, suggesting that the time of day effects differed for the different types of failures. Specifically, as shown in Fig. 2b, the number of attention failures did not change as a function of time of day, whereas retrospective memory failures increased from morning to afternoon and plateaued, and prospective memory failures increased throughout the day. These time of day effects could be partially due to the fact that the participants were students who likely have more classes in the afternoon and study more in the afternoon than in the morning resulting in more failures as the day progresses. Furthermore, these time of day effects could be due to differences in circadian rhythms which are linked to individuals differences in cognitive abilities (e.g., Hasher, Goldstein, & May, 2005). Future work is needed to better examine these time of day effects.

The above results suggest that not only were there differences in the number of different types of errors and differences in the number of errors as a function of time of day, but the different types of failures changed differentially throughout the day. Next we wanted to better examine individual differences in these self-reported cognitive failures. As shown in Table 3 there seemed to be substantial variation for each of the different types of failures. The question of course, is whether this variation is systematic in the sense that individuals who report many failures of one type also experience many other types of failures and whether these reported failures are related to individual differences in cognitive abilities assessed in the lab. To address this, we first examined the correlations among the different types of attention and memory failures reported in the diaries. Shown in Table 4 are the correlations among the different types of failures from the diaries. For the most part all of the different types of failures were significantly and positively related to one another. This pattern occurred for the overall frequency of the different types of errors as well as with the various sub-types. For instance, the total number of attention failures was positively related to both the total number of retrospective memory failures ($r = .65$) and the total number of prospective memory failures ($r = .44$) and two types of memory failures were related ($r = .58$). Similar patterns emerge when examining the sub-types of failures. For example, all of the attention failure were related to one another and were related to the subtypes of retrospective and prospective memory failures. The same trends occur for both the retrospective and prospective memory which were not only related within a sub-type but also related to the other sub-types. These

Table 4
Correlations for the diary responses.

		1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Total	–												
2.	AttnTot	0.80	–											
3.	RetroTot	0.88	0.65	–										
4.	ProTot	0.76	0.44	0.58	–									
5.	AttnD	0.66	0.84	0.51	0.36	–								
6.	AttnM	0.53	0.64	0.49	0.25	0.29	–							
7.	AttnW	0.59	0.71	0.44	0.33	0.43	0.24	–						
8.	RetroS	0.65	0.53	0.76	0.41	0.54	0.27	0.31	–					
9.	Retro P	0.63	0.43	0.73	0.27	0.26	0.47	0.28	0.33	–				
10	Retro F	0.67	0.52	0.73	0.54	0.32	0.41	0.48	0.33	0.40	–			
11	ProA	0.49	0.20	0.31	0.81	0.18	0.06	0.21	0.29	0.06	0.32	–		
12	ProT	0.72	0.53	0.64	0.59	0.47	0.32	0.37	0.46	0.44	0.49	0.15	–	
13	ProE	0.46	0.28	0.38	0.65	0.15	0.29	0.18	0.11	0.26	0.49	0.31	0.34	–

Note: Total = the total number of all types of failures; AttnTot = total number of all types of attention failures; AttnD = total number of distraction attention failures; AttnM = total number of absent-minded attention failures; AttnW = total number of mind-wandering attention failures; RetroTot = total number of all types of retrospective memory failures; RetS = total number of short-term retrospective memory failures; RetP = total number of personal retrospective memory failures; RetF = total number of fact-based retrospective memory failures; ProTot = total number of prospective memory failures; ProA = total number of activity-based prospective memory failures; ProT = total number of time-based prospective memory failures; ProE = total number of event-based prospective memory failures. Correlations > .20 are significant at the $p < .05$ level.

results provide important evidence for the generality of cognitive failures. At the same time because the different failures were only moderately correlated with one another, the current results also suggest some specificity with slight differences among the different types of failures.

Are the self-reported cognitive failures from the diaries related to the cognitive ability factors assessed with the laboratory tasks? To examine this we used the same latent variables derived from the cognitive tasks used earlier and then correlated those latent variables with the different cognitive failures. First, we examined the relation between the cognitive latent factors and the total number of failures participants reported. Specifically, we specified a model with the five latent factors used previously (WMC, AC, RM, PM, and SAT) and as well as the total number of failures as a manifest variable. The fit was acceptable, $\chi^2(63) = 63.46$, $p > .46$, RMSEA = .01, SRMR = .06, NNFI = .99, CFI = 1.0. Shown in Table 5 are the correlations between the latent factors and the total number of cognitive failures (avg. correlation = −.26). As can be seen, the total number of failures was moderately negatively related to the AC, RM, and SAT factors, and only weakly (and not significantly) related to the WMC and PM factors. Thus, those participants who performed poorly on the AC and RM tasks and scored poorly on the SATs also tended to report more failures overall.

Table 5
Correlations between diary responses and latent cognitive ability factors.

Measure	Latent factor				
	WMC	AC	RM	PM	SAT
Total failures	−.17	−.27*	−.31*	−.19	−.35*
AttnTot	−.29*	−.46*	−.34*	−.25*	−.38*
RetroTot	−.14	−.14	−.29*	−.13	−.33*
ProTot	−.07	−.20*	−.17	−.11	−.15

WMC = working memory capacity; AC = attention control; RM = retrospective memory; PM = prospective memory; AttnTot = total number of attention failures; RetroTot = total number of retrospective memory failures; ProTot = total number of prospective memory failures.
* $p < .05$.

To examine these relations more fully, we next specified a structural equation model (SEM) in which the main cognitive ability factors (WMC, AC, RM, and PM) each predicted the total number of cognitive failures. In the specified SEM each of the four cognitive ability factors were allowed to correlate with one another based on the previous confirmatory factor analysis, and all were allowed to predict the total number of everyday cognitive failures. This model examines the extent to which each of the cognitive ability factors accounts for unique or shared variance in predicting the total number of cognitive failures. The fit was acceptable, $\chi^2(45) = 50.98$, $p > .25$, RMSEA = .04, SRMR = .07, NNFI = .97, CFI = .98. As shown in Fig. 3, only RM predicted unique variance in the total number of cognitive failures (labeled TotalFail). The relation between AC and the total number of cognitive failures dropped below significance once the other cognitive ability factors were taken into account. This suggests that much of the variance shared between RM and the total number of cognitive failures is unique, whereas the variance between AC and the total number of cognitive failures is shared with the other cognitive ability factors.

Next, we examined the relations between the latent cognitive factors and the total number of attention, retrospective memory, and prospective memory failures. The fit of this model was acceptable, $\chi^2(79) = 86.95$, $p > .25$, RMSEA = .03, SRMR = .06, NNFI = .97, CFI = .98. As seen in Table 5 the total number of attention failures was significantly related to all of the cognitive latent factors. As would be expected, the strongest correlation seemed to be between the total number of attention failures and the AC latent variable suggesting that participants who demonstrated poor attention control in the laboratory typically experienced more everyday attention failures. Looking at the total number of retrospective memory failures, the only significant correlations were between the failures and the RM and SAT latent variables. As expected, partici-

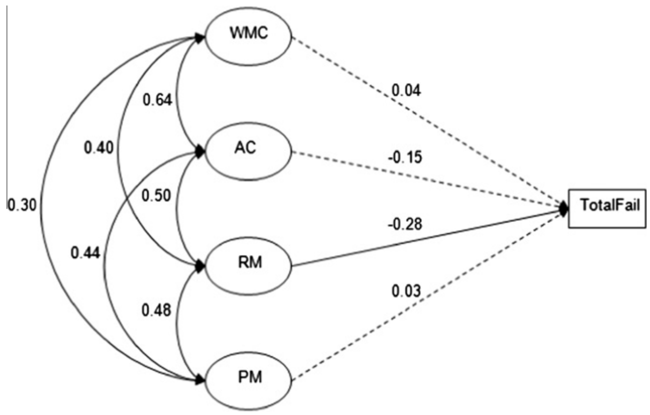

Fig. 3. Structural equation model predicting the total number of cognitive failures with WMC, AC, RM, and PM. Single-headed arrows connecting latent variables (circles) to the manifest variable (rectangle) represent standardized path coefficients indicating the unique contribution of the latent variable. Double headed arrows connecting the latent factors represent the correlations among the factors. Solid lines are significant at the $p < .05$ level and dotted lines are not significant at the $p < .05$ level.

pants who performed poorly on the RM tasks in the laboratory also reported more everyday retrospective memory failures. Finally, an examination of Table 5 suggests that the total number of prospective memory failures was only significantly related to AC. Overall these results suggest that self-reports of everyday cognitive failures as assessed by diaries are related to performance on laboratory cognitive tasks (avg. correlation = −.23).

To examine these relations more fully, we next specified a SEM in which the main cognitive ability factors (WMC, AC, RM, and PM) each predicted the total number of attention failures, retrospective memory failures, and prospective memory failures. In the specified SEM each of the four cognitive ability factors were allowed to correlate with one another based on the previous confirmatory factor analysis, and all were allowed to predict the total number of each of the everyday cognitive failures. This model examines the extent to which each of the cognitive ability factors accounts for unique or shared variance in predicting the different types of cognitive failures. The fit was acceptable, $\chi^2(59) = 74.63$, $p > .08$, RMSEA = .05, SRMR = .07, NNFI = .93, CFI = .96. As shown in Fig. 4, only two of the specified paths were significant. Specifically, AC significantly predicted the total number of attention failures and RM significantly predicted the total number of retrospective memory failures. Thus, there was unique variance shared between AC and everyday attention failures and between RM and everyday retrospective memory failures. These results provide important evidence for the domain-specificity of cognitive failures.

Given the relations between the cognitive ability factors and the diary failures, one question is whether individual differences in susceptibility to the everyday attention and memory failures would mediate the relations between the cognitive ability factors and SAT. That is, the prior analyses demonstrated a relation between the AC and RM latent factors with SAT, and the current analyses suggest a relation between the total number of attention and retrospective memory failures and SAT. Is it possible that these everyday attention and memory failures partially account for the relation between the cognitive ability factors and performance on the SATs? To examine this we tested two structural equation models. In the first model we specified that the AC latent variable predicted both the total number of attention failures (AttTot) and SAT, and the total number of attention failures predicted SAT. If the total number of attention failures fully accounts for the shared relation between AC and SAT, then the path between AC and SAT should be non-significant. If, however, the total number of attention failures only partially accounts for the relation between AC and SAT, then both paths to SAT should be significant. Shown in Fig. 5 is the resulting model. The fit of the model was acceptable, $\chi^2(7) = 4.71$, $p > .69$, RMSEA = .00, SRMR = .04, NNFI = 1.0, CFI = 1.0. As can been seen, AC significantly predicts the total number of attention failures, and both AC and the total number of attention failures predict SAT. The indirect path from AC to SAT was significant (indirect effect = .13, $p < .05$) suggesting that attention failures partially mediated the relation between AC and SAT. Thus, everyday failures of attention partially account for the relation between attention control and SAT scores.

In the second structural equation model we examined the same hypothesis, but now for the RM latent factor and for the total number of retrospective memory failures. Specifically, we specified a model in which the RM latent variable predicted both the total number of retrospective memory failures (RetroTot) and SAT, and the total number of retrospective memory failures predicted SAT. The fit of the model was acceptable, $\chi^2(7) = 3.62$, $p > .82$, RMSEA = .00, SRMR = .03, NNFI = 1.0, CFI = 1.0. Shown in Fig. 6 is the resulting model. As can been seen, RM significantly predicted the total number of retrospective memory failures, and both RM and the total number of retrospective memory failures predicted SAT. The indirect path from RM to SAT was significant (indirect effect = .10, $p < .05$) suggesting that retrospective memory failures partially mediated the relation between RM and SAT. Similar to the above analyses, everyday failures of retrospective memory partially accounted for the relation between retrospective memory and SAT scores. Thus, both everyday attention and retrospective memory failures partially mediated the relation between the cognitive ability factors and SAT. This provides important evidence that not only do

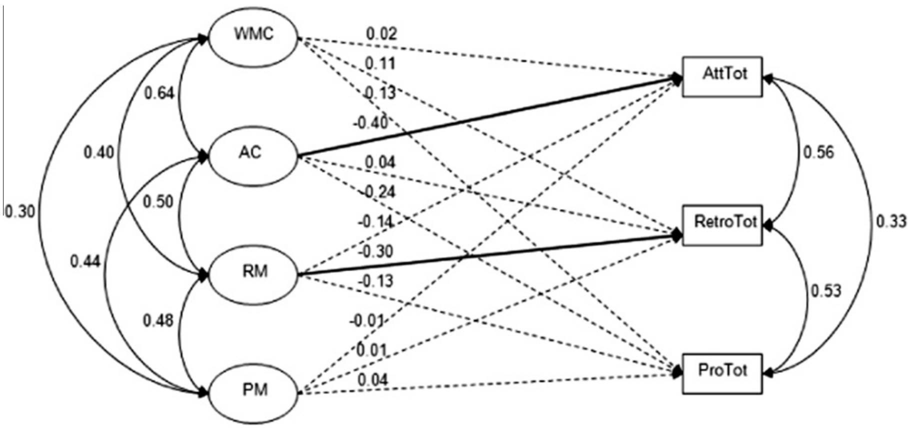

Fig. 4. Structural equation model predicting the total number of attention failures, total number of retrospective memory failures, and total number of prospective memory failures with WMC, AC, RM, and PM. Single-headed arrows connecting latent variables (circles) to the manifest variable (rectangle) represent standardized path coefficients indicating the unique contribution of the latent variable. Double headed arrows connecting the latent factors represent the correlations among the factors. Double headed arrows connecting the manifest variables represent the residual correlations among the tasks. Solid lines are significant at the $p < .05$ level and dotted lines are not significant at the $p < .05$ level.

Fig. 5. Structural equation model for attention control (AC), total number of attention failures (AttTot) and SAT. All loadings and paths are significant at the $p < .05$ level.

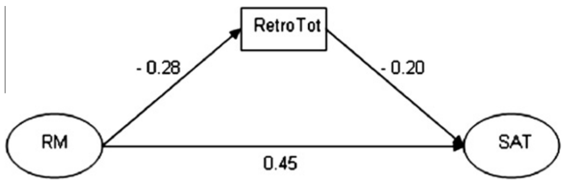

Fig. 6. Structural equation model for retrospective memory (RM) total number of retrospective memory failures (RetroTot) and SAT. All loadings and paths are significant at the $p < .05$ level.

laboratory measures predict real-world cognitive failures, but these cognitive failures partially account for the relation between the laboratory measures and measures of intellectual functioning like the SATs.[1] Note, similar analyses were not conducted for the PM latent factor and everyday prospective memory failures given that the total number of everyday prospective memory failures was not correlated to either the PM latent factor or SAT scores.

To examine these relations more fully, we next examined the relation between the various sub-types of failures with the cognitive latent variables. In these analyses we examined each sub-type of each main type of failure (i.e., attention, retrospective memory, prospective memory) separately. First, we examined the three sub-types of attention failures that were classified and their relation with the cognitive latent factors. The fit of this model was acceptable, $\chi^2(79) = 87.54$, $p > .23$, RMSEA = .03, SRMR = .06, NNFI = .95, CFI = .97. As seen in Table 6 the attention failures due to distractions (labeled AttnD) were negatively correlated with WMC, AC, RM, and SAT. Thus, individual differences in susceptibility to everyday distractions were related to individual differences in WMC, AC, RM, and SAT scores. These results are consistent with prior research suggesting that WMC and AC are needed in order to deal with distraction and this ability to deal with distraction is part of the reason that WMC and AC are related to intelligence (e.g., Engle & Kane, 2004; Unsworth & Spillers, 2010). Likewise, as seen in Table 6, absent-minded attention failures (labeled AttnM) were negatively related to AC, RM, and PM. Thus, individual differences in everyday absent-mindedness were related to individual differences in overall attention control as well as overall individual differences in forgetfulness as indexed by RM and PM. Finally, as seen in Table 6, mind-wandering failures (labeled AttnW) were negatively related to WMC, AC, RM, and SAT. This suggests that individuals who report more everyday failures due to mind-wandering likely have poorer WMC, AC, and RM abilities and overall lower SAT scores. These results are consistent with prior research suggesting that individual differences in WMC are related to individual differences in mind-wandering (e.g., Kane et al., 2007) and lapses of attention (e.g., Unsworth, Redick, Lakey, & Young, 2010) which partially account for the relation between WMC and intelligence. Importantly, all three sub-types of attention failures were related to overall AC abilities,

[1] At the risk of being further redundant we also examined these notions with partial-correlation analyses. Specifically, the correlation between AC and SAT partialling out the total number of attention failures was significant, $pr = -.25$, $p < .05$, as was the correlation between the total number of attention failures and SAT partialling out AC, $pr = -.25$, $p < .05$. Likewise, the correlation between RM and SAT after partialling out the total number of retrospective memory failures was significant, $pr = -.45$, $p < .05$, as was the correlation between the total number of retrospective memory failures and SAT partialling out RM, $pr = -.23$, $p < .05$.

Table 6
Correlations between sub-types of diary responses and latent cognitive ability factors.

Measure	Latent factor				
	WMC	AC	RM	PM	SAT
AttnD	−.29*	−.34*	−.21*	−.18	−.36*
AttnM	−.05	−.36*	−.37*	−.26*	−.18
AttnW	−.25*	−.28*	−.20*	−.11	−.29*
RetS	−.24*	−.16	−.21*	.09	−.28*
RetP	−.04	−.18	−.22*	−.07	−.30*
RetF	.00	.06	−.20*	−.13	−.17
ProA	.14	−.09	−.06	−.07	.06
ProT	−.28*	−.26*	−.29*	−.20*	−.30*
ProE	−.13	−.20*	−.06	−.05	−.19

WMC = working memory capacity; AC = attention control; RM = retrospective memory; PM = prospective memory; AttnD = total number of distraction attention failures; AttnM = total number of absent-minded attention failures; AttnW = total number of mind-wandering attention failures; RetroTot = total number of all types of retrospective memory failures; RetS = total number of short-term retrospective memory failures; RetP = total number of personal retrospective memory failures; RetF = total number of fact-based retrospective memory failures; ProTot = total number of prospective memory failures; ProA = total number of activity-based prospective memory failures; ProT = total number of time-based prospective memory failures; ProE = total number of event-based prospective memory failures.
* $p < .05$.

providing some ecological validity for AC abilities assessed in the laboratory. Collectively these results suggest that there is substantial variation in everyday attention failures which are differently related to various cognitive abilities (especially attention control) assessed with cognitive tasks.

Next, we examined the three sub-types of retrospective memory failures that were classified and their relation with the cognitive latent factors. The fit of this model was acceptable, $\chi^2(79) = 77.89$, $p > .51$, RMSEA = .00, SRMR = .06, NNFI = 1.0, CFI = 1.0. As seen in Table 6 short-term retrospective memory failures (labeled RetroS) were related to WMC, RM, and SAT. As one would expect this is consistent with the notion that individual differences in WMC as assessed with working memory span tasks should be related to real-world failures of short-term memory. Furthermore, as one would expect retrospective short-term memory failures were related to overall RM abilities, and these failures were correlated with SAT scores. Examining retrospective memory failures associated with personal information suggested that these failures were only related to RM and SAT, consistent with the notion that RM measures assessed in the laboratory predict everyday memory failures associated with recollecting personal information. Finally, examining retrospective memory failures associated with factual information suggested that these failures were only related to RM, consistent with the notion that general RM abilities are needed to recall fact-based information from long-term memory. Collectively these results suggest that RM abilities indexed in the laboratory are significantly related to real-world retrospective memory failures.

Next, we examined the three sub-types of prospective memory failures that were classified and their relation with the cognitive latent factors. The fit of this model was acceptable, $\chi^2(79) = 79.29$, $p > .46$, RMSEA = .01, SRMR = .06, NNFI = .98, CFI = .99. As seen in Table 6 activity-based prospective memory failures were not significantly related to any of the cognitive latent variables. In contrast, time-based prospective memory failures were related to all of the cognitive latent variables. Thus, real-world problems associated with remembering to carry out an intention at a specific time seems to be related not only to PM abilities, but also to WMC, AC, RM, and SAT scores. Specifically, individuals who likely experience many time-based prospective memory failures are also likely to score poorly on a number of cognitive tasks assessed in the laboratory. Finally, as seen in Table 6, event-based prospective memory failures were only significantly related to AC. Interestingly, PM abilities assessed in the laboratory were only related to one type of prospective memory failure. This is consistent with prior research that has suggested that laboratory-based prospective memory tasks may not have the best ecological validity in terms of predicting real-world prospective memory failures (Phillips, Henry, & Martin, 2008).

General discussion

The current study investigated individual differences in everyday cognitive failures. A large number of participants performed various laboratory measures thought to represent working memory capacity (WMC), attention control (AC), retrospective memory (RM), and prospective memory (PM). In addition, a sub-sample of participants reported cognitive failures (attention, retrospective, and prospective failures) in a diary over the course of 1 week. The use of diaries resulted in the reporting of over 2200 cognitive failures (of all different types) that occurred throughout week. With this data, three primary questions were addressed. These were (1) To what extent do laboratory cognitive ability tasks predict individual differences in everyday cognitive failures? (2) To what extent are different types of cognitive failures (e.g., attention failures, retrospective memory failures, and prospective memory failures) related? (3) To what extent are everyday cognitive failures related to scholastic abilities and general intelligence as indicated by SAT scores? The current results provide important answers to these questions.

With respect to the first question, the current results suggested that cognitive ability tasks used in the laboratory did successfully predict individual differences in everyday cognitive failures. Thus, variation in different cognitive abilities assessed in the laboratory predicted variation in cognitive failures. There was also evidence of convergent validity with those cognitive ability tasks thought to measure a particular construct being related to cognitive failures of the same construct. For example, the total number of attention failures correlated −.46 with attention control. Furthermore, structural equation modeling suggested that AC abilities accounted for unique variance in attention failures and RM abilities accounted for unique variance in retrospective memory failures. These results provide important ecological validity to the cognitive ability tasks used the laboratory and suggest that individual differences in cognitive abilities predict individual differences in everyday attention and memory failures. These results are very much in line with theories of individual differences in cognitive control that suggest that individuals low in cognitive control (i.e., low in WMC and AC) are more likely to experience lapses of attention (e.g., Unsworth et al., 2010) and mind-wandering (e.g., Kane et al., 2007) than individuals high in cognitive control and these differences should be especially pronounced under conditions of high distraction (e.g., Engle & Kane, 2004). Furthermore, the current results suggest that individuals low in cognitive control and general memory abilities are also more likely to experience more memory failures than individuals high in cognitive control and general memory abilities. Thus, the current results suggest that variation in cognitive abilities assessed in the laboratory do indeed predict individual differences in everyday attention and memory failures. As such, the current result provide important empirical evidence for cognitive control theories of individual differences and provide evidence for the ecological validity of laboratory measures of cognition.

At the same time it is clear that more work is needed to better link specific cognitive processes studied in the laboratory with specific cognitive failures found in everyday life. For example, although the results suggest that AC abilities predict everyday attention failures, it is not clear what aspect of AC are important for this relation. That is, current research suggests that goal maintenance is important in terms of actively maintaining task goals in the face of distraction (e.g., Engle & Kane, 2004). Likewise, current inhibitory control views suggest that inhibition is needed to suppress internal and external distraction (e.g., Hasher, Lustig, & Zacks, 2007). Future work is needed to better understand if everyday attention failures are a result of failures in goal maintenance, failures in inhibitory control, or some combination of both. Furthermore, although the current results suggest that RM abilities predictive everyday retrospective memory failures, it is unclear whether these failures of retrospective memory arise due to problems in encoding abilities, retrieval abilities, or both. Prior laboratory research has suggested that individual differences in WMC and RM are due to differences both encoding and retrieval abilities. Thus, future work is needed to better examine how encoding and retrieval abilities account for shared and/or unique variance in everyday retrospective memory failures. Additionally, the fact that everyday prospective memory failures were poorly predicted by laboratory PM tasks (as well as the other laboratory measures) suggests the possibility that many everyday prospective memory tasks can be accomplished via relatively automatic processing rather than more effortful processing (Einstein & McDaniel, 2008; McDaniel & Einstein, 2000). That is, the current laboratory PM tasks used tend to index relatively effortful processing (as indicated by the fact that they are related to WMC and AC abilities) yet these tasks did not predict everyday prospective memory tasks. This suggests the possibility that the fulfilling of intentions in everyday life might occur via relatively automatic processes whereby multiple perceptual, temporal, and action-based cues aid substantially in reminding individuals of their intentions (Brewer, Ball, Knight, Dewitt, & Marsh, in press; Brewer et al., 2011). More work is needed to better examine the processes needed for everyday prospective memory tasks.

In terms of the second question of whether different types of cognitive failures are related, the results suggest that the different types of cognitive failures assessed with the diaries were related, but were clearly separate. Specifically, although the total number of attention, retrospective memory, and prospective memory failures were all related (avg. correlation = .56), the different types of cognitive failures demonstrated different time of day effects, and were differentially related to the cognitive ability factors. Furthermore, the various classifications of sub-types of failures also demonstrated differential relations with each other and with the cognitive ability factors. Thus, there seemed to be evidence for general cognitive failure problems such that participants who demonstrated many attention failures also demonstrated many retrospective memory and prospective memory failures. At the same time, there was also evidence for specificity of each main type (as well as each sub-type) of cognitive failures indicating that some individuals have fairly specific issues relating to one type (or sub-type) of cognitive failures. Collectively these results suggest that cognitive failures have both general and specific components and suggest that there are important individual differences in each. Future work is needed to better examine these general and specific components and how they relate to laboratory measures.

With respect to our final question of whether cognitive failures are related to scholastic ability and general intelligence, the results suggest that everyday cognitive failure are related to scholastic abilities and general intelligence as indexed by SAT scores. In fact, the cognitive failures-SAT correlations were some of the strongest and most consistent across the various types of failures. In particular, not only were the total number of cognitive failures related to SAT scores ($r = -.35$), but so were the total number of attention failures ($r = -.38$) and the total number of retrospective memory failures ($r = -.33$). Furthermore, individual differences in everyday attention and retrospective memory failures partially accounted for the relation between the cognitive ability measures (AC and RM) and SAT scores. Thus, those individuals who demonstrate greater attention control and memory abilities in the laboratory tend to experience fewer attention and memory failures in real-life, and tended to score higher on the SATs than individuals who demonstrate poor attention control and memory abilities in the laboratory. This provides not only important ecological validity for the laboratory measures, but also provides important evidence for cognitive control theories of individual differences (e.g., Engle & Kane, 2004; Unsworth & Engle, 2007) by suggesting that attention control abilities are needed in scholastic aptitude tests such as the SAT in order to focus and sustain attention on the task at hand and to prevent attentional capture. These attention control abilities are very important in situations where there is a lot of external (e.g., people coughing and making noise) and internal distractions (e.g., ruminating and worrying about how one is doing). Thus, with tests like the SAT where participants typically take the test in a large room with many other students there is likely quite a bit of external distraction present. Furthermore, given that these tests are widely used, in part, to determine college admissions there also likely quite a bit of internal rumination and distraction. In order to perform well one must try to block both types of distraction and focus on the test itself. Furthermore, the ability to successfully learn and later retrieve factual information from long-term memory will also dictate performance on these types of scholastic ability tests. Thus, individual differences in the susceptibility to everyday attention and memory failures will likely influence one's ability to perform well on scholastic measures such as the SAT. Given that similar abilities are likely needed in other academic test-taking situations (i.e., taking a test in a large introductory psychology class) similar results should also be found when directly examining performance in such situations.

In addition to examining our three questions of primary interest, a detailed examination of the diary responses suggested a number of important findings. As noted above, in the current study participants reported over 2200 total cognitive failures. Within the current classification scheme, participants classified these failures as attention failures, retrospective memory failures, or prospective memory failures. Of these three types of failures, attention failures were the most frequently reported with over 900 total attention failures reported. Breaking each type of failure down into various sub-types suggested that the most frequently occurring failures were attention failures due to distraction (e.g., being distracted by people talking during class), followed by activity-based prospective memory failures (e.g., forgot to stop by a professor's office after class), and then followed by attention failures due to mind-wandering (e.g., daydreaming during class and missed part of the lecture) and short-term retrospective memory failures (e.g., forgot a phone number a friend just told me). Clearly individuals experience many different types of cognitive failures throughout the week and our analyses of time of day effects further suggest that failures likely occur at different times during the day.

These results combined with prior diary studies (e.g., Crovitz & Daniel, 1984; Reason, 1984a; Terry, 1988) provide important information about the various types of everyday cognitive failures that occur, their relative frequencies, when they are likely to occur, as well as who is likely to experience them most frequently. As such these results go beyond prior work by examining different types of cognitive failures rather than focusing on only one type of failure. That is, prior diary studies typically only focused on either attention failures (or action slips) or memory failures (both retrospective and prospective). In the current study we examined both types of errors for a large number of participants in order to better gauge the relative frequencies of these different types of errors. Of course it should be noted that despite the obvious strengths of using diary methods to assess everyday cognitive failures, there are also clear limitations with these types of studies. For example, given that diary methods require both prospective and retrospective memory it clear that not all failures will be reported and not failures will be reported entirely accurately. However, despite these limitations diary methods are particularly useful (especially when combined with laboratory measures and individual differences analyses) in obtaining more naturalistic data. As noted by Reason and Lucas (1984) diaries "serve a valuable function as wide-gauge trawl nets, picking up the more salient types of lapse" (p. 56).

Furthermore, we examined individual differences in different types of cognitive failures via latent variable techniques to ensure that the relations between individual differences in cognitive abilities and individual differences in everyday cognitive failures were relatively stable and free from idiosyncratic task effects which could obscure the true relations. Thus, the current results provide important evidence for current theories of individual differences in cognitive control and suggest that there is a direct link between performance obtained in the laboratory and susceptibility to everyday failures of cognition. Furthermore, these results have important implications for other areas that have long been interested in cognitive failures including educational psychology, clinical psychology, cognitive aging, developmental psychology, and neuropsychology. In particular, the current results suggest promising means by which to identify those individuals who are likely to experience frequent cognitive failures and which cognitive mechanisms might underlie those cognitive failures. This future line of research is especially important given that the current study relied exclusively on undergraduate participants and more work is needed to generalize the results to broader samples of participants. Understanding who is likely to experience frequent cognitive failures and understanding which of the various cognitive mechanisms lie at the heart of those cognitive failures is an important goal for future research. The current study is a step in this direction.

Conclusions

In a novel combination of laboratory assessments of individual differences in cognitive abilities and diary methods examining cognitive failures the current study demonstrated that individual differences objectively measured in the laboratory predicted everyday cognitive failures. Furthermore individual differences in cognitive failures were found to predict scholastic abilities and general intelligence as measured by SAT scores. These results provide important ecological validity to laboratory assessments of individual differences and suggest a promising avenue of future research in terms of examining the link between individual differences in cognitive control and susceptibility to everyday cognitive failures. As such, the results from the current study are an important piece in bridging the gap between laboratory tasks and everyday cognition.

Acknowledgment

Thanks to Tom Redick for helpful comments on a previous version of the article.

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