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Consistency of attentional control as an important cognitive trait: A latent variable analysis

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ABSTRACT

The present study examined the extent to which consistency in attention control is an important individual difference characteristic related to other cognitive abilities. Experiment 1 demonstrated that intra-individual variability (IIV) on attention control tasks and lexical decision tasks were separate factors with IIV in the attention control factor relating to working memory capacity, fluid intelligence, and long-term memory. Experiment 2 replicated these results and further demonstrated that IIV in attention control predicted everyday cognitive failures (in particular everyday attentional failures). Experiment 3 demonstrated that IIV in attention control was related to subjective reports of mind-wandering but not external distraction, suggesting that fluctuations in attention control are linked to an individual's propensity to mind-wander. Finally, Experiment 3 demonstrated that individual differences in attention control and IIV in attention control are largely the same. These results suggest that the ability to consistently allocate attention control is an important cognitive trait.

Researchers have long been interested in mean level differences between individuals on a variety of tests and tasks. For instance, early research on psychometric intelligence was concerned primarily with finding differences between individuals on basic knowledge and reasoning tests. Likewise, in the experimental domain, much research has focused on examining how individuals differ in speed and accuracy on a number of memory and attention tasks. In each case the dependent variable of interest is a given individual's mean level of performance on the task. Recently, renewed interest has been focused on examining the importance of consistency (or intra-individual variability) in responding on a variety of tasks (e.g., Der & Deary, 2006; Dykiert, Der, Starr, & Deary, 2012; Fiske & Rice, 1955; Hultsch, Strauss, Hunter, & MacDonald, 2008; MacDonald, Nyberg, & Bäckman, 2006; Salthouse, 2007; Stuss, Murphy, Binns, & Alexander, 2003). The focus of this research has been on the amount a given individual varies around their own mean level of performance and how much variability a given individual demonstrates relative to other individuals. Thus, here the main dependent variable of interest is not the mean level of performance, but rather indices of variability (such as individual standard deviation and coefficient of variation).

Much of the work that has been done on intra-individual variability (IIV) has relied on reaction time (RT) tasks. Assume that not only do individuals differ in their mean RT, but individuals also differ in the amount of variability around their mean. That is, Individual A may respond more rapidly on average than Individual B, and there may also be differences in the amount of variability that Individual A demonstrates relative to Individual B. Additionally, it is possible that two individuals will have the same mean RT values, but one individual may have more overall variability (at both the upper and lower ends of the distribution) than the other. Thus, the amount of dispersion an individual demonstrates in their RT distributions can provide some indication of how efficiently aspects of their cognitive system are operating. In particular, the current study focuses on inconsistency, or fluctuations in RT that occur over short intervals (i.e., trial-to-trial variability).

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Prior work examining IIV in different populations has provided evidence consistent with these notions by demonstrating that older adults are more variable than younger adults, frontal patients are more variable than matched controls depending on lesion location, patients with various forms of traumatic brain injury are more variable than normal participants, both Alzheimer's and Parkinson's patients are more variable than normal elderly adults, schizophrenic patients are more variable than control participants, and individuals with attention deficit hyperactivity disorder are more variable than control participants, to name a few (e.g., Der & Deary, 2006; Duchek et al., 2009; Dykiert et al., 2012; Jackson, Balota, Duchek, & Head, 2012; Leth-Steensen, Elbaz King, & Douglas, 2000; MacDonald et al., 2006; Salthouse, 2007; Stuss et al., 2003; Tse, Balota, Yap, Duchek, & McCabe, 2010). Furthermore, a great deal of work examining the relation between RT and measures of intelligence has suggested that IIV in RT is moderately correlated with an individual's level of intelligence (see Jensen, 1992, 1998, 2006 for reviews). Thus, it seems clear that a number of groups who are thought to differ in basic cognitive functioning not only differ on average levels of performance, but also differ in the amount of IIV that they demonstrate. This suggests that this variability may provide an index of the amount of noise or fluctuations in the system which may be associated with mean levels of performance (Li, Lindenberger, & Sikstrom, 2001). That is, these fluctuations provide information about the efficiency of the cognitive system overall as well as determining, in part, mean levels of performance. As such, this points to the need to better examine IIV across tasks and examine the extent to which IIV is related to other cognitive and abilities.

Several researchers have suggested that increases in IIV are related to fluctuations in attention control which can lead to lapses of attention (Duchek et al., 2009; Jackson et al., 2012; Jensen, 1992; Unsworth, Redick, Lakey, & Young, 2010; West, 2001; West, Murphy, Armilio, Craik, & Stuss, 2002) or to overall goal neglect (De Jong, Berendsen, & Cools, 1999). In these views it is assumed that it is difficult to maintain attention on a task goal and therefore sustain attention on the task at hand when internal and external interference and distraction are high (Engle & Kane, 2004). In these situations when attention is tightly focused on the task goal performance will be both fast and accurate. However, if attention is not tightly focused on the task goal, lapses of attention can occur which will lead to overall slower responses or to very fast errors that are guided by prepotent tendencies (Unsworth, Schrock, & Engle, 2004). Evidence consistent with these views is the finding that low ability participants (i.e., low working memory, low fluid intelligence) demonstrate a large number of slow responses and an increase in the number of cases found in the tail of the upper end of the distribution which leads to an increase in overall variability compared to high ability participants (e.g., McVay & Kane, 2012; Schmiedek, Oberauer, Wilhelm, Süß, & Wittmann, 2007; Unsworth, Redick, Spillers, & Brewer, 2012; Unsworth, Redick, et al., 2010). This suggests that fluctuations in the efficiency of attention control processes may be an important reason for individual differences in cognitive abilities. Some individuals (high ability individuals) have more efficient attention control processes that allow them to consistently maintain attention on a demanding task than other individuals (low ability individuals) who cannot adequately maintain attention on tasks, but rather experience more fluctuations or lapses of attention leading to performance decrements. This suggests that it is not the overall amount of attention control that matters, but rather how efficiently and consistently one can allocate attention control processes to maintain optimal levels of performance.

Collectively prior work suggests that consistency in attention control might be an important cognitive trait that is linked to a number of other cognitive abilities. However this has not been fully evaluated in prior studies as most prior work has examined IIV in single tasks, has not examined how IIV is related across tasks, and has not examined how IIV is related to other important cognitive abilities such as working memory capacity and fluid intelligence. Thus, a number of outstanding questions remain in determining whether consistency in attention control is an important cognitive trait.

The aim of the present study was to better examine the notion that consistency in attention control is a reliable and valid cognitive trait linked to cognitive abilities in and out of the laboratory. Therefore, four main questions were addressed. First, is there a general consistency factor or does the type of task matter? Specifically, if IIV partially reflects fluctuations in attention control then IIV across a variety of attention control tasks should correlate and form a factor. Additionally, IIV is found in other RT tasks, such as simple and choice RT tasks. Is IIV in these non-attention demanding RT tasks the same as IIV found in attention control tasks? If IIV represents a general trait then IIV across multiple different measures should all correlate and load on the same general factor. But, if IIV in attention control tasks is different from IIV on other tasks then two factors should be found, one for the attention control measures and one for the non-attention RT tasks.

Second, is IIV related to other cognitive abilities such as working memory capacity, fluid intelligence, long-term memory, etc.? If IIV is an important cognitive trait then individual differences in IIV should be related to individual differences in other cognitive abilities. Furthermore, and in relation to the first question, if there are two separate IIV factors, then it is possible that IIV in attention control is related to other cognitive abilities, but IIV in non-attention demanding RT tasks is not related to other cognitive abilities over and above that of attention control. That is, only fluctuations in attention control are related to broad cognitive abilities.

Third, does consistency (or inconsistency) predict real world cognitive failures? If IIV represents fluctuations in attention control then these fluctuations should not only be related to performance on basic laboratory measures, but these fluctuations should predict who is likely to experience cognitive failures in the real world. In particular, IIV measured in the laboratory should predict real world attentional failures.

Finally, if IIV represents fluctuations or lapses in attention then it is important to understand what underlies these fluctuations. In particular, it is possible that lapses of attention are partially due to individuals experiencing off-task thoughts such as mind-wandering about topics unrelated to the experiment (e.g., daydreaming about an upcoming vacation) or being distracted by external information present during the experiment (e.g., a flickering overhead light or a cold room). Thus, IIV might reflect fluctuations in attention whereby participants shift their focus from the experiment inward to more personally pressing concerns (mind-wandering) or to other external information that is distracting (external distraction).

To address these questions data from three prior studies were reanalyzed (i.e. Unsworth, Brewer, & Spillers, 2012; Unsworth & McMillan, 2014; Unsworth & Spillers, 2010). In each study a large number of participants performed multiple measures of attention control and in order to examine IIV we computed the coefficient of variation (CV; *SD*/*M*) for correct RTs for each task and each participant (e.g., Duchek et al., 2009; Flehmig, Steinborn, Langner, Scholz, & Westhoff, 2007; Jackson et al., 2012; Kelly, Uddin, Biswal, Castellanos, & Milham, 2008; Rabbitt, Osman, Moore, & Stollery, 2001; Segalowitz, Poulsen, & Segalowitz, 1999; Stuss et al., 2003). Participants also performed multiple measures of other cognitive ability constructs (e.g., working memory capacity, fluid intelligence, long-term memory) to examine whether IIV in attention control is related to these other cognitive abilities. Latent variable techniques were used to examine the pattern of relations among the different constructs. 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 would not be due to unreliability or idiosyncratic task effects. Therefore, multiple measures of each cognitive construct were used to create latent variables. By examining a large number of participants and a large and diverse number of measures we should be able to better characterize the nature of individual differences in IIV in attention control and its relation to other important cognitive abilities.

1. Experiment 1

In order to examine the nature of IIV and its relation to a number of cognitive abilities, data from Unsworth and Spillers (2010) were reanalyzed. Specifically, Experiment 1 examined whether IIV in attention control tasks and non-attention demanding RT tasks (here lexical decision tasks thought to primarily rely on lexical and semantic processing) reflects the same or different constructs and whether IIV is related to broader cognitive abilities such as working memory capacity (WMC), fluid intelligence (gF), verbal fluency, and long-term memory (LTM). Participants performed multiple measures of each construct and latent variable analyses were used to examine the questions of interest.

1.1. Method

1.1.1. Participants

A total of 181 participants (60% female) were recruited from the subject-pool at the University of Georgia. Participants were between the ages of 18 and 35 ($M = 18.74$, $SD = 1.06$) and received course credit for their participation. Each participant was tested individually in two laboratory sessions lasting approximately 2 h each.

1.1.2. Materials and procedure

After signing informed consent, all participants completed operation span, symmetry span, reading span, delayed free recall with unrelated words, picture source recognition, lexical decision task 1, animal fluency, and number series in Session 1. In Session 2, all participants completed a continuous distractor free recall task, delayed free recall with semantically related words, antisaccade, arrow flanker, psychomotor vigilance, Stroop, lexical decision task 2, F letter fluency, verbal analogies and Raven Advanced Progressive Matrices. All tasks were administered in the order listed above.

1.1.3. Tasks

1.1.3.1. Working memory capacity (WMC) tasks

1.1.3.1.1. 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, & 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.

1.1.3.1.2. 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. There were three trials of each list-length with list-length ranging from 2 to 5 for a total possible of 42 (see Unsworth, Redick, Heitz, Broadway, & Engle, 2009). The same scoring procedure as Ospan was used.

1.1.3.1.3. 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. There were three trials of each list-length with list-length ranging from 3 to 7 for a total possible of 75 (see Unsworth et al., 2009). The same scoring procedure as Ospan was used.

1.1.3.2. Attention control (AC) tasks

1.1.3.2.1. Antisaccade. In this task (Kane, Bleckley, Conway, & Engle, 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 the target stimulus (a B, P, or R) onscreen for 100 ms. This was followed by masking stimuli (an H for 50 ms and an 8 which remained onscreen until a response was given). The participants' task was to identify the target letter by pressing a key for B, P, or R (the keys 1, 2, or 3) 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, 15 trials of the prosaccade condition, and 60 trials of the antisaccade condition. The dependent variable was the coefficient of variation for correct RTs.

1.1.3.2.2. 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 50 neutral trials the arrow was flanked by two horizontal lines on each side. On 50 congruent trials the arrow was flanked by two arrows pointing in the same direction as the target arrow on each side. Finally, on 50 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 coefficient of variation for correct RTs.

1.1.3.2.3. Stroop. Participants were presented with a color word (red, green, or blue) presented in one of three different font colors (red, green, or blue). The participants' task was to indicate the font color via key press (red = 1, green = 2, and blue = 3). Participants were told to press the corresponding key as quickly and accurately as possible. Participants received 15 trials of response mapping practice, and 6 trials of practice with the real task. Participants then received 75 total real trials. Of these trials 67% were congruent such that the word and font color matched (i.e., red printed in red) and the other 33% were incongruent (i.e., red printed in green). The dependent variable was the coefficient of variation for correct RTs.

1.1.3.2.4. 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 the 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 the 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 coefficient of variation for correct RTs.

1.1.3.3. Lexical decision tasks. Participants performed two lexical decision tasks on two separate days. Participants were told that they were going to be deciding whether the 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. The dependent variable was the coefficient of variation for correct RTs.

1.1.3.4. Long-term memory (LTM) tasks

1.1.3.4.1. Delayed free recall unrelated words. Participants were given 6 lists of 10 words each. All words were common nouns that were presented for 1 s each. After list presentation, participants engaged in a 16 s distractor task before recall: participants saw 8 three-digit numbers appear for 2 s each, and were required to write the digits in ascending order. After the distractor task 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.

1.1.3.4.2. Delayed free recall semantically related words. Participants received 6 lists of 10 words each broken down into two blocks (three lists per block). All words in each block came from the same semantic category (e.g., professions and fruits). The first three lists allowed for proactive interference to accrue and the first list in the next block allowed for a release from proactive interference. Following the last word in a list participants were required to count backwards by three's as quickly and accurately as possible from a three digit number onscreen for 15 s and to write the numbers down as they go. After the distractor task 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.

1.1.3.4.3. 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 the proportion of correct items.

1.1.3.4.4. Continuous distractor free recall. Participants were given 3 lists of 10 words each. All words were common nouns that were presented for 2.5 s each. Before and after each item presentation, participants were required to arrange four separate three digit numbers (presented for 2 s each) in descending order on a sheet of paper. After list presentation, participants engaged in an additional 30 s distractor activity (e.g., 15 three digit numbers instead of four) before recall. After the distractor task 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.

1.1.3.5. Verbal fluency

1.1.3.5.1. Animal fluency. In the animal fluency task, participants were given 1 min to type as many exemplars from the category of animals as possible. The dependent variable was the total number of unique instances retrieved.

1.1.3.5.2. Letter fluency. In the letter fluency task, participants were given 1 min to type as many words that began with the letter F as possible. The dependent variable was the total number of unique instances retrieved.

1.1.3.6. Fluid intelligence (gF) tasks

1.1.3.6.1. Raven Advanced Progressive Matrices. The Raven is a measure of abstract reasoning (Raven, Raven, & Court, 1998). The test consists of 36 items presented in ascending order of difficulty (i.e. easiest–hardest). Each item consists of a display of 3 × 3 matrices of geometric patterns with the bottom right pattern missing. The task for the participant is to select among eight alternatives, the one that correctly completes the overall series of patterns. Participants had 10 min to complete the 18 odd-numbered items. A participant's score was the total number of correct solutions. Participants received two practice problems.

1.1.3.6.2. Number series. In this task participants saw a series of numbers and were required to determine what the next number in the series should be (Thurstone, 1962). That is, the series follows some unstated rule which participants are required to figure out in order to determine which the next number in the series should be. Participants selected their answer out of five possible numbers that were presented. Following five practice items, participants had 4.5 min to complete 15 test items. A participant's score was the total number of items solved correctly.

1.1.3.6.3. Verbal analogies. In this task participants read an incomplete analogy and were required to select the one word out of five possible words that best completed the analogy. After one practice item, participants had 5 min to complete 18 test items. These items were originally selected from the Air Force Officer Qualifying Test (AFOQT; Berger, Gupta, Berger, & Skinner, 1990), and we used the same subset of items used in Kane et al. (2004). A participant's score was the total number of items solved correctly.

1.2. Results

1.2.1. Descriptive statistics

Descriptive statistics for all of 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, 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 all measures.

Measure	*M*	*SD*	Skew	Kurtosis	Reliability
Ospan	59.54	12.49	−1.71	1.97	.80
Symspan	29.95	7.60	−.95	.71	.76
Rspan	57.33	13.17	−1.13	1.48	.78
DFRU	31.71	9.04	.29	.67	.82
DFRS	36.85	6.17	−.22	.48	.75
PicSour	.77	.14	−1.25	2.18	.80
CDT	11.65	3.63	−.39	−.38	.63
Animal	19.21	4.97	−.15	.77	–
Letter	19.36	5.16	−.58	1.97	–
Raven	10.79	2.49	−.09	−.20	.70
NS	9.46	2.41	.22	−.17	.67
Analogy	10.97	2.77	.06	−.67	.63
AntiCV	.48	.21	1.57	2.71	.62
FlankerCV	.25	.06	.17	−.36	.83
StroopCV	.36	.14	3.75	11.43	.73
PVTCV	.28	.21	3.74	18.17	.81
LDT1CV	.50	.15	.72	−.07	.60
LDT2CV	.46	.17	1.23	2.16	.62

Note. Ospan = operation span; Symspan = symmetry span; Rspan = reading span; DFRU = delayed free recall unrelated words; DFRS = delayed free recall semantically related words; PicSour = picture source recognition; CDT = continual distractor free recall; Animal = animal verbal fluency; Letter = letter verbal fluency; Raven = Raven Advanced Progressive Matrices; NS = number series; Analogy = verbal analogies; AntiCV = antisaccade; FlankerCV = arrow flankers; StroopCV = Stroop; PVTCV = psychomotor vigilance task; LDT = lexical decision task; CV = coefficient of variation.

1.2.2. Confirmatory factor analyses

Next, confirmatory factor analysis was used to better examine the relations among IIV from the different tasks. Specifically, it was tested whether IIV from attention control and the lexical decision tasks was best conceptualized as a single unitary factor, or whether there were sufficient differences between IIVs from the different types of tasks to suggest two separate, yet correlated factors. To examine this two models were specified. In the first model IIVs from all tasks were specified to load onto a single factor. The fit of the model was poor, χ^2 (9) = 43.70, $p < .01$, RMSEA = .15, SRMR = .09, NNFI = .79, CFI = .82. Shown in Fig. 1a is the resulting model. As can be seen IIV from all tasks loaded significantly and onto the single factor, although some of the loadings were quite weak.

In the second model it was specified that IIV from the attention control tasks loaded onto one factor and IIV from the lexical decision tasks loaded onto a second factor. The fit of the model was acceptable, $\chi^2(8)$ = 16.63, $p < .05$, RMSEA = .08, SRMR = .06, NNFI = .91, CFI = .95. Shown in Fig. 1b is the resulting model. As can be seen, IIV from the attention control tasks loaded significantly on the IIV attention control factor, while IIV from the lexical decision tasks loaded significantly onto the IIV lexical decision factor. Furthermore, the IIV attention control and IIV lexical decision factors were moderately correlated (r = .33), suggesting that the two types of IIV were similar, but clearly not the same. In fact, the fit of the two factor IIV model was significantly better than the unitary IIV model, $\Delta\ \chi^2(1)$ = 27.07, $p < .01$. Thus, the two factor model was retained as the preferred model.

The next set of analyses was done in order to examine the extent to which cognitive abilities such as WMC, LTM, verbal fluency, and gF were related to the different IIV factors. Confirmatory factor analysis was used to examine a measurement model of all of the measures and to determine how each of the putative factors were related to one another. Specifically, two IIV factors were specified one for attention control and one for lexical decision based on the prior analyses. Additionally, a WMC factor was specified based on the three WMC measures, an LTM factor was specified based on the four LTM measures, a

Table 2
Correlations among all measures for Experiment 1.

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Ospan	–																	
2. Symspan	0.46	–																
3. Rspan	0.64	0.42	–															
4. Raven	0.20	0.21	0.19	–														
5. NS	0.19	0.20	0.23	0.30	–													
6. Analogy	0.25	0.18	0.37	0.32	0.40	–												
7. DFR	0.20	0.23	0.26	0.13	0.12	0.11	–											
8. BP	0.29	0.23	0.31	0.11	0.09	0.07	0.34	–										
9. PicSour	0.21	0.21	0.30	0.37	0.17	0.21	0.33	0.27	–									
10. CDT	0.29	0.21	0.32	0.14	0.18	0.12	0.41	0.33	0.22	–								
11.Animal	0.13	0.16	0.18	0.04	0.24	0.12	0.01	0.15	0.14	0.12	–							
12. Letter	0.16	0.25	0.21	0.06	0.17	0.03	−0.01	0.29	0.13	0.07	0.37	–						
13. PVTCV	0.00	−0.11	−0.09	−0.04	−0.11	−0.05	−0.06	−0.10	−0.02	−0.08	−0.13	−0.01	–					
14. AntiCV	−0.02	−0.07	−0.06	−0.18	−0.21	−0.05	−0.11	−0.22	−0.19	−0.17	−0.01	−0.04	0.25	–				
15. FlankerCV	−0.15	−0.14	−0.19	−0.14	−0.08	−0.11	−0.16	−0.05	−0.07	−0.20	0.03	0.01	0.20	0.33	–			
16. StroopCV	−0.15	−0.14	−0.23	−0.08	−0.12	−0.17	−0.18	−0.19	−0.20	−0.16	0.03	−0.01	0.16	0.33	0.57	–		
17. LDT1 CV	0.14	0.06	0.10	−0.11	−0.01	0.07	0.04	0.05	−0.14	0.06	−0.05	−0.15	0.13	0.19	0.07	0.06	–	
18. LDT2 CV	0.04	−0.02	0.02	−0.07	−0.10	0.00	−0.03	−0.08	−0.11	−0.08	0.00	−0.15	0.10	0.31	0.24	0.17	0.39	–

Note. Ospan = operation span; Symspan = symmetry span; Rspan = reading span; DFRU = delayed free recall unrelated words; DFRS = delayed free recall semantically related words; PicSour = picture source recognition; CDT = continual distractor free recall; Animal = animal verbal fluency; Letter = letter verbal fluency; Raven = Raven Advanced Progressive Matrices; NS = number series; Analogy = verbal analogies; PVTCV = psychomotor vigilance task; AntiCV = antisaccade; FlankerCV = arrow flankers; StroopCV = Stroop; LDT = lexical decision task; CV = coefficient of variation.

verbal fluency factor was specified based on the two verbal fluency measures, and a gF factor was specified based on the three gF measures. All of the factors were allowed to correlate with one another. 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, $\chi^2(120) = 141.92, p > .08$, RMSEA = .03, SRMR = .06, NNFI = .96, CFI = .97, suggesting that the specified model provided a good description to the underlying pattern of data. The factor loadings for each task and the interfactor correlations are shown in Fig. 2. As can be seen, each of the measures loaded moderately and significantly on their respective factors. An examination of the interfactor correlations suggested that the attention control IIV factor was significantly and moderately related to the WMC, LTM, and gF factors, but not to the verbal fluency factor. The lexical decision IIV factor, however, was only significantly related to the verbal fluency factor. Thus, IIV in attention control demonstrated significantly relations with a number of cognitive abilities, whereas IIV during lexical decision tasks did not correlate with these same cognitive abilities suggesting differences between the two types of IIV.

Although the current results suggest a strong link between IIV in attention control and cognitive abilities, an important alternative to examine is whether mean differences in RT actually account for these relations. That is, the mean and coefficient of variation will tend to be correlated with higher means being associated with higher coefficients of variation. Indeed, in the current data there was a positive correlation between the mean and coefficient of variation ($r = .55$). Thus, it is possible that differences in mean RT, rather than variability per se account for the relations observed here. To examine this, factor composites for mean RT and IIV were formed and separate regressions were analyzed predicting working memory capacity, LTM, and gF.[1] Examining the relations with the

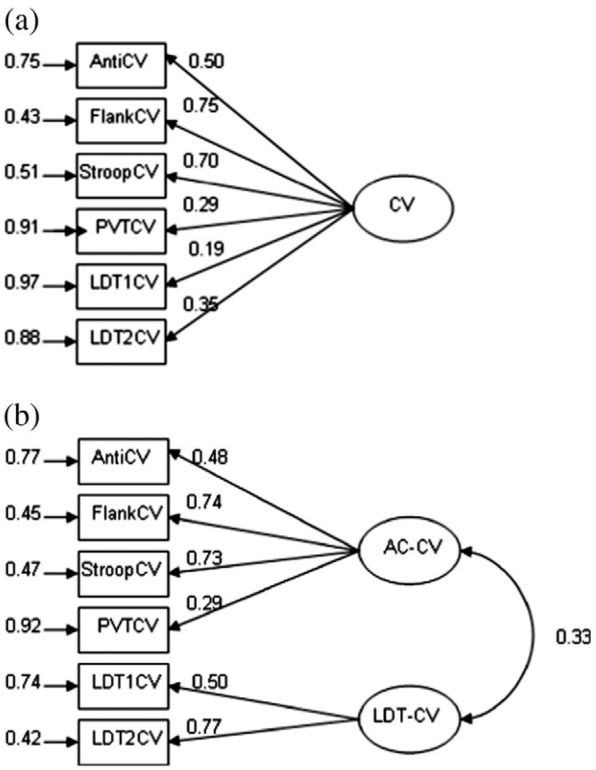

Fig. 1. a) Confirmatory factor analysis for unitary coefficient of variation model; (b) confirmatory factor analysis for separate attention control and lexical decision coefficient of variation factors.

[1] Note, initially these analyses were attempted by forming latent factors for IIV and mean RT and examining whether they accounted for unique variance in cognitive abilities via structural equation modeling. Unfortunately the models failed to converge on an acceptable solution after 1000 iterations even when allowing several of the error variances between IIV and mean RT from the same task to correlate. Thus, factor composites and regression analyses were used.

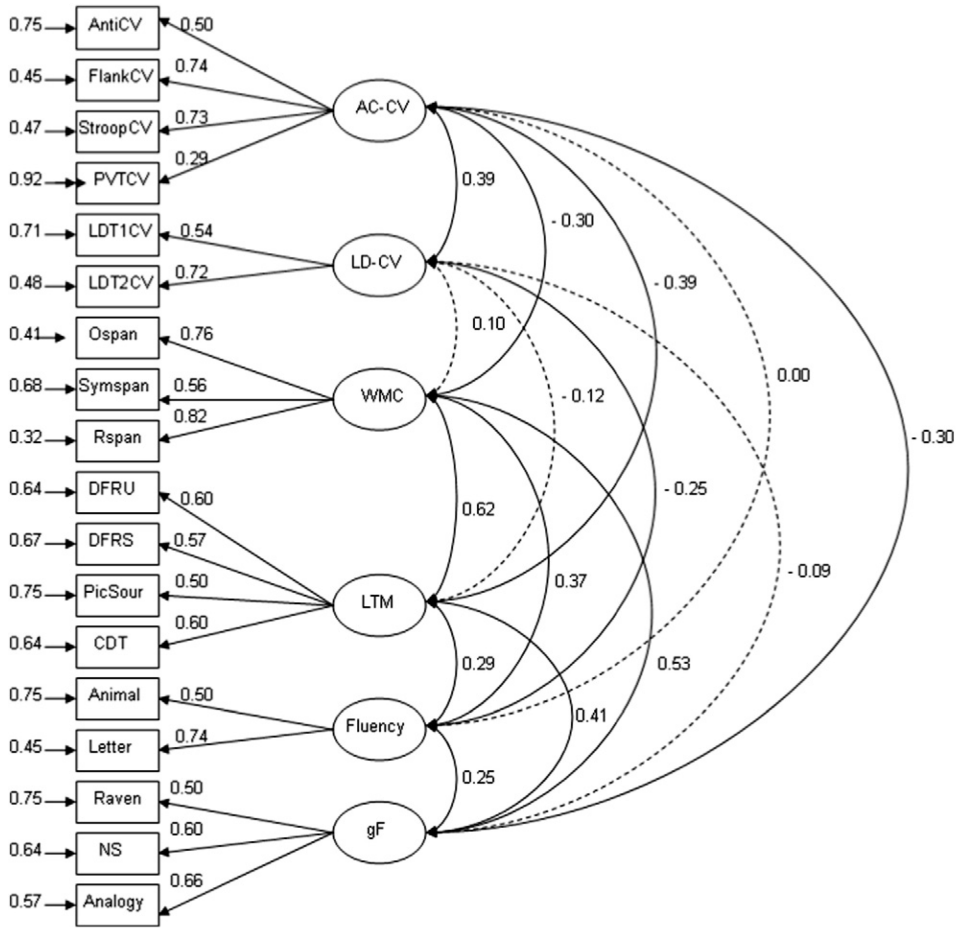

Fig. 2. Model for attention control coefficient of variation (AC-CV), lexical decision coefficient of variation (LD-CV), working memory capacity (WMC), long-term memory (LTM), verbal fluency (Fluency), and fluid intelligence (gF). Solid lines are significant at the $p < .05$ level and dotted lines are not significant at the $p < .05$ level.

WMC, the results suggested that IIV predicted unique variance in WMC ($\beta = -.21$, $p < .05$), but mean RT did not ($\beta = -.08$, $p > .26$). Similar results were found when examining LTM in which IIV predicted unique variance ($\beta = -.32$, $p < .05$), but mean RT did not ($\beta = -.06$, $p > .48$) and gF with IIV accounting for unique variance ($\beta = -.19$, $p < .05$), but mean RT did not ($\beta = -.11$, $p > .24$). Thus, IIV accounted for variance in cognitive abilities over and above that accounted for by mean RT.

1.3. Discussion

The results from Experiment 1 demonstrated that IIV from multiple measures were correlated and formed two separate factors with one factor consisting of IIV from the attention control measures and the other factor consisting of IIV from the lexical decision tasks. Thus, there is not a single unitary IIV factor, but rather IIV across different measures is likely picking up some of the same variance and some variance that is specific only to certain types of tasks. Examining the relations between these two factors with other cognitive abilities suggested that IIV from the attention control tasks was related to WMC, LTM, and gF (but not verbal fluency), whereas IIV from the lexical decision tasks was only related to verbal fluency. Furthermore, when taking mean RT into account, IIV still accounted for unique variance in cognitive abilities. These results suggest that consistency (or inconsistency) in attention control is a reliable and important cognitive trait that is related to other cognitive abilities. Individuals who demonstrate only minor fluctuations in attention control tend to have higher working memory capacities, greater long-term memory abilities, and higher fluid intelligence than individuals who demonstrate much more fluctuations in attention control.

2. Experiment 2

Experiment 1 demonstrated that IIV in attention control and lexical decision tasks are not necessarily the same with IIV in attention control being related to a number of cognitive abilities and IIV in lexical decision not being related to those same abilities. The purpose of Experiment 2 was to replicate and extend these effects. Specifically, Experiment 2 examined whether IIV in attention control and lexical decision tasks would be best conceptualized as two factors and whether IIV in attention control, but not IIV in lexical decision, would be related to cognitive abilities. Furthermore, Experiment 2 examined the extent to which IIV in attention control would predict real world cognitive failures. As noted previously, if IIV represents fluctuations in attention control then these fluctuations should not only be related to performance on basic laboratory measures, but these fluctuations should predict who is likely to experience cognitive failures in the real world. To examine these issues, data from Unsworth, Brewer, et al. (2012) were reanalyzed. In this study a large number of participants performed multiple laboratory measures of attention control, WMC, LTM, prospective memory, and participants carried a diary for a week in which they logged their everyday cognitive failures.

2.1. Method

2.1.1. 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.

2.1.2. Materials and procedure

After signing informed consent, all participants completed operation span, symmetry span, reading span, free recall, antisaccade, low association cue–target prospective memory, paired associates recall, arrow flankers, and non-focal prospective memory. 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.

2.1.3. Laboratory tasks

2.1.3.1. Working memory capacity (WMC) tasks

2.1.3.1.1. Operation span (Ospan). Same as Experiment 1.

2.1.3.1.2. Symmetry span (Symspan). Same as Experiment 1.

2.1.3.1.3. Reading span (Rspan). Same as Experiment 1.

2.1.3.2. Attention control (AC) tasks

2.1.3.2.1. Antisaccade. Same as Experiment 1 except that participants performed 40 antisaccade trials. The dependent variable was the coefficient of variation for correct RTs.

2.1.3.2.2. Arrow flankers. Same as Experiment 1 except that participants performed 30 trials of each trial type. The dependent variable was the coefficient of variation for correct RTs.

2.1.3.2.3. Psychomotor vigilance task (PVT). Same as Experiment 1. The dependent variable was the coefficient of variation for correct RTs.

2.1.3.3. Long-term memory (LTM) tasks

2.1.3.3.1. 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.

2.1.3.3.2. Paired associates recall. Same as Experiment 1.

2.1.3.3.3. Picture source-recognition. Same as Experiment 1.

2.1.3.4. Prospective memory (PM) tasks

2.1.3.4.1. 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 for prospective memory was the proportion of correct responses entered in this fashion. For the lexical decision IIV the dependent variable was the coefficient of variation for correct RTs.

2.1.3.4.2. 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 for prospective memory was the proportion of correct responses entered in this fashion. For the lexical decision IIV the dependent variable was the coefficient of variation for correct RTs.

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

2.1.4. Diary

Participants were given a booklet and asked to keep a diary of their attention, retrospective, and prospective memory failures over the course of one 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 roommate's 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., daydreaming 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 a 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 a meeting or an appointment at a predefined time (i.e., forgetting to be at the doctor's office at exactly 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 sub-classification 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.

2.2. Results

2.2.1. Descriptive statistics

Descriptive statistics for all of the measures are shown in Table 3. 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. Correlations, shown in Table 4, 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.

2.2.2. Confirmatory factor analyses

Similar to Experiment 1, confirmatory factor analysis was next used to better examine the data. Specifically, a model was specified in which IIV from the attention control tasks loaded on one factor and IIV from the lexical decision tasks loaded on another factor. Factors were also specified for WMC, LTM, prospective memory, and SAT. All factors were allowed to correlate. The fit of the model was acceptable, χ^2 (75) = 146.60, $p < .01$, RMSEA = .08, SRMR = .07, NNFI = .87, CFI = .90. The factor loadings for each task and the interfactor correlations are shown in Fig. 3. As can be seen, each of the measures loaded strongly and significantly on their respective factors. Consistent with Experiment 1, the attention control IIV and lexical decision IIV factors were correlated (r = .26), but clearly separate factors. Additionally, consistent with Experiment 1, the attention control IIV factor was significantly related to WMC and LTM, but not significantly related to prospective memory or SAT scores. Additionally, the lexical decision IIV factor was only significantly related to the IIV attention control factor. These results replicate Experiment 1 in

Table 3
Descriptive statistics for laboratory tasks and diary responses.

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
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	–
QSAT	613.15	74.37	−.30	−.86	–
AntiCV	.47	.25	2.78	11.41	.60
FlankerCV	.26	.08	3.63	18.62	.81
PVTCV	.36	.29	2.98	10.84	.84
LDT1CV	.55	.20	2.01	6.40	.63
LDT2CV	.52	.25	2.78	11.41	.61
Total failures	22.90	13.44	1.61	3.54	–
AttnTot	9.34	5.47	.81	.14	–
AttnD	4.19	3.02	1.08	.63	–
AttnM	2.19	2.08	1.75	4.67	–
AttnW	2.77	2.14	.74	−.14	–
RetroTot	6.74	4.68	1.53	3.23	–
RetS	2.76	2.19	1.35	2.29	–
RetP	1.91	1.99	1.72	4.08	–
RetF	1.79	1.88	1.43	2.21	–
ProTot	6.13	4.88	.70	−.19	–
ProA	3.36	3.16	1.14	1.12	–
ProT	1.29	1.70	1.56	2.03	–
ProE	1.26	1.51	1.19	.65	–

Note. Ospan = operation span; Rspan = reading span; Symspan = symmetry span; 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; AntiCV = antisaccade; FlankerCV = arrow flankers; PVTCV = psychomotor vigilance task; CV = coefficient of variation; 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.

Table 4
Correlations among all measures for Experiment 2.

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1. Ospan	–																											
2. Rspan	0.62	–																										
3. Symspan	0.46	0.56	–																									
4. PicSour	0.20	0.23	0.34	–																								
5. Recall	0.21	0.27	0.23	0.34	–																							
6. PA	0.12	0.20	0.37	0.33	0.45	–																						
7. LCTpm	0.09	0.27	0.21	0.20	0.33	0.27	–																					
8. NFpm	0.10	0.25	0.23	0.16	0.16	0.07	0.37	–																				
9. VSAT	0.26	0.21	0.27	0.16	0.12	0.23	0.05	0.02	–																			
10. QSAT	0.39	0.30	0.44	0.19	0.08	0.13	0.17	0.07	0.44	–																		
11. PVTCV	−0.12	−0.24	−0.18	−0.47	−0.26	−0.14	−0.17	−0.17	−0.05	−0.08	–																	
12. AntiCV	−0.22	−0.32	−0.25	−0.32	−0.14	0.05	0.04	−0.18	−0.10	−0.16	0.44	–																
13. FlankCV	−0.11	−0.30	−0.17	−0.36	−0.14	−0.19	−0.14	−0.06	0.02	0.01	0.31	0.43	–															
14. LDT1CV	0.04	0.01	−0.02	−0.03	−0.02	0.17	0.14	0.00	−0.05	−0.05	0.13	0.11	0.12	–														
15. LDT2CV	0.05	−0.05	−0.01	−0.13	−0.10	0.06	0.14	0.00	−0.04	−0.09	0.22	0.21	0.14	0.81	–													
16. Total Fail	−0.06	−0.10	−0.13	−0.20	−0.19	−0.18	−0.12	0.02	−0.26	−0.13	0.19	0.13	0.02	−0.11	−0.08	–												
17. Attn Total	−0.14	−0.24	−0.33	−0.30	−0.14	−0.27	−0.20	0.00	−0.27	−0.18	0.43	0.14	0.11	−0.04	0.02	0.66	–											
18. RetroTotal	−0.01	−0.11	−0.09	−0.14	−0.14	−0.19	−0.08	−0.01	−0.23	−0.09	0.08	0.14	−0.05	−0.08	−0.07	0.87	0.49	–										
19. Pro Total	0.05	−0.01	−0.06	−0.16	−0.14	0.02	−0.06	−0.04	−0.07	0.03	0.08	0.14	0.07	−0.07	−0.10	0.72	0.30	0.51	–									
20. AttnD	−0.12	−0.21	−0.36	−0.28	−0.15	−0.19	−0.16	0.15	−0.32	−0.19	0.33	0.14	0.07	−0.05	−0.02	0.61	0.78	0.44	0.27	–								
21. AttnM	−0.03	−0.04	−0.07	−0.20	−0.19	−0.27	−0.27	−0.05	−0.13	−0.12	0.23	0.03	−0.16	−0.03	0.03	0.56	0.57	0.51	0.25	0.33	–							
22. AttnW	−0.19	−0.20	−0.20	−0.14	−0.07	−0.22	−0.08	−0.04	−0.26	−0.12	0.20	0.05	0.11	−0.07	−0.02	0.62	0.71	0.50	0.31	0.44	0.28	–						
23. RetS	−0.12	−0.21	−0.09	−0.12	−0.18	−0.21	−0.07	−0.02	−0.24	−0.09	0.05	−0.01	−0.09	−0.09	−0.12	0.59	0.37	0.72	0.33	0.39	0.29	0.35	–					
24. RetP	−0.01	−0.09	−0.06	−0.11	−0.03	−0.11	−0.03	−0.04	−0.21	−0.16	0.16	0.25	0.05	−0.03	0.03	0.70	0.34	0.79	0.29	0.33	0.45	0.33	0.39	–				
25. RetF	0.07	−0.01	−0.08	−0.05	−0.07	−0.14	−0.09	0.03	−0.12	0.01	−0.03	0.06	−0.09	−0.06	−0.08	0.67	0.39	0.73	0.52	0.29	0.39	0.50	0.29	0.37	–			
26. ProA	0.15	0.16	0.03	−0.13	−0.09	0.05	−0.04	0.02	0.01	0.15	0.00	0.00	0.05	0.05	−0.02	0.48	0.12	0.32	0.84	0.15	0.07	0.15	0.29	0.08	0.31	–		
27. ProT	−0.13	−0.27	−0.14	−0.15	−0.20	−0.17	−0.15	−0.10	−0.21	−0.12	0.16	0.24	0.18	−0.16	−0.09	0.68	0.45	0.56	0.55	0.37	0.31	0.42	0.32	0.48	0.45	0.14	–	
28. ProE	−0.06	−0.12	−0.11	−0.06	−0.03	0.10	0.05	−0.05	−0.02	−0.15	0.04	0.22	−0.05	−0.14	−0.15	0.42	0.14	0.32	0.64	0.09	0.27	0.16	0.06	0.21	0.44	0.28	0.33	–

Note. Ospan = operation span; Rspan = reading span; Symspan = symmetry span; 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; AntiCV = antisaccade; FlankerCV = arrow flankers; PVTCV = psychomotor vigilance task; CV = coefficient of variation; 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.

suggesting that IIV is not a unitary factor and that IIV in attention control is related to a number of cognitive abilities, but IIV in non-attention demanding RT tasks like lexical decision is not.

Similar to Experiment 1 the extent to which the relations between IIV and cognitive abilities were due to shared variance with mean RT was examined given a strong relation between IIV and mean RT ($r = .44$). To examine this, factor composites for mean RT and IIV were formed and separate regressions were analyzed predicting WMC and LTM. Examining the relations with the WMC, the results suggested that IIV predicted unique variance in WMC ($\beta = -.28$, $p < .05$), and so did mean RT ($\beta = -.20$, $p < .05$). Examining LTM suggested that IIV predicted unique variance ($\beta = -.20$, $p < .05$), but mean RT did not ($\beta = -.14$, $p > .09$). Thus, IIV accounted for variance in cognitive abilities over and above that accounted for by mean RT.

Next, the extent to which IIV would predict everyday cognitive failures was examined by adding in the diary responses to the model. Specifically, in the first model the total number of cognitive failures across all types of failures was added into the model shown in Fig. 4 and was allowed to correlate with all of the latent factors. The fit of the model was acceptable, χ^2 (84) = 154.75, $p < .01$, RMSEA = .07, SRMR = .07, NNFI = .87, CFI = .90. As shown in Table 5, the attention control IIV factor correlated with the total number of cognitive failures, but the lexical decision IIV factor did not. In the next model the different types of errors were broken down into categories, one for the total number of attention failures, one for the total number of retrospective memory failures, and one for the total number of prospective memory failures. Each type of cognitive failure was added into the model and each was allowed to correlate with one another and with the laboratory latent factors. The fit of the model was acceptable, χ^2 (102) = 208.99, $p < .01$, RMSEA = .08, SRMR = .07, NNFI = .85, CFI = .89. As shown in Table 5, the attention control IIV factor only correlated with the total number of attention failures, and the lexical decision IIV factor did not correlate with any of the different types of failures. In the final set of models each subtype of failure was examined. Specifically, first a model examining the subtypes of attention failures (i.e., distraction, absent-mindedness, and mind-wandering) was specified. The fit of the model was acceptable, χ^2 (102) = 213.24, $p < .01$, RMSEA = .07, SRMR = .07, NNFI = .85, CFI = .89. As shown in Table 5, both distraction and mind-wandering were related to the attention control IIV factor, but none of the attention subtypes were related to the lexical decision IIV factor. Next a model examining the subtypes of retrospective memory failures (i.e., short-term memory, personal memory, fact-based) was specified. The fit of the model was acceptable, χ^2 (102) = 174.67, $p < .01$, RMSEA = .07, SRMR = .07, NNFI = .87, CFI = .90. As shown in Table 5, personal retrospective memory failures were related to the attention control IIV factor, but none of the attention subtypes were related to the lexical decision IIV factor. Finally, a model examining the subtypes of prospective memory failures (i.e., activity-based, time-based,

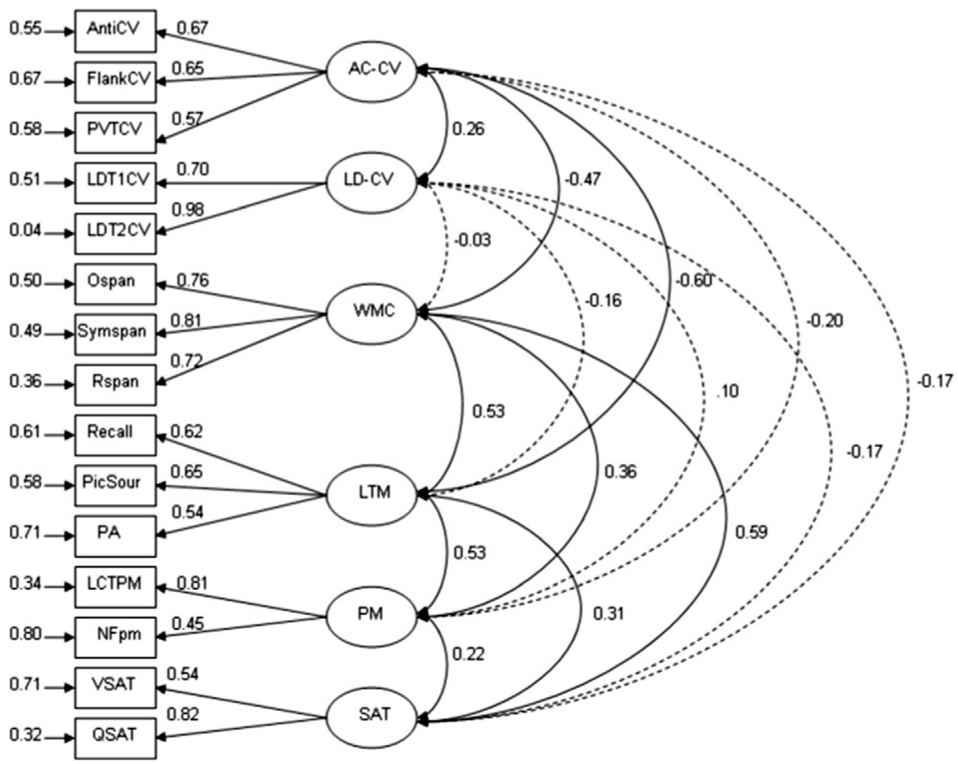

Fig. 3. Model for attention control coefficient of variation (AC-CV), lexical decision coefficient of variation (LD-CV), working memory capacity (WMC), long-term memory (LTM), prospective memory (PM), and SAT. Solid lines are significant at the $p < .05$ level and dotted lines are not significant at the $p < .05$ level.

event-based) was specified. The fit of the model was acceptable, χ^2 (102) = 191.10, $p < .01$, RMSEA = .07, SRMR = .07, NNFI = .85, CFI = .89. As shown in Table 5, time-based prospective memory failures were related to the attention control IIV factor, but none of the attention subtypes were related to the lexical decision IIV factor. Overall, these results demonstrate that IIV in attention control is related to a number of different types of everyday cognitive failures, but IIV in non-attention demanding lexical decision tasks is not.

2.3. Discussion

Experiment 2 broadly replicated Experiment 1 in demonstrating that IIV in attention control is related across tasks and that a latent IIV attention control factor is related to other important cognitive abilities, whereas IIV found in non-attention demanding RT tasks such as lexical decision tasks is generally not related to other cognitive abilities. Furthermore, examining relations with everyday cognitive failures suggested that attention control IIV is related to a number of real world cognitive failures, and in particular related to everyday attentional failures. These results suggest that IIV in attention control is an important cognitive trait that is related not only to other cognitive abilities indexed with laboratory tasks, but also related to real-world cognitive failures.

3. Experiment 3

The purpose of Experiment 3 was to better examine individual differences in IIV in attention control. In particular, as noted previously, if IIV represents fluctuations or lapses in attention then it is important to understand what underlies these fluctuations. It is possible that fluctuations in attention are partially due to individuals experiencing mind-wandering or being distracted by external information present during the experiment. Indeed, some prior research has suggested a link between RT variability and mind-wandering (Bastian & Sackur, 2013; Cheyne, Solman, Carriere, & Smilek, 2009; McVay & Kane, 2009; Seli, Cheyne, & Smilek, 2013). Therefore, to examine this, data from Unsworth and McMillan (2014) were reanalyzed. In this study a large number of participants performed multiple laboratory measures of attention control, WMC, and gF. Importantly, during the attention control measures participants were periodically presented with thought probes that asked if they were on-task, if they were experiencing task-related interference, if they were distracted by external stimuli, or if they were mind-wandering. Thus, with this technique it is possible to examine the extent to which individual differences in mind-wandering and/or external distraction influence IIV in attention control.

3.1. Method

3.1.1. Participants

A total of 252 participants (64% female) were recruited from the subject-pool at the University of Oregon. Data from 11 participants were dropped because the participants failed to complete two or more tasks. The remaining 241 participants were between the ages of 18 and 35 (M = 19.59, SD = 1.61) and received course credit for their participation. Each participant was tested in groups of 1–6 in a laboratory session lasting approximately 2 h.

3.1.2. Materials and procedure

After signing informed consent, all participants completed operation span, symmetry span, reading span, Ravens Advanced Progressive Matrices, number series, letter sets, the Sustained Attention to Response Task, antisaccade, flankers, Stroop, and the psychomotor vigilance task. All tasks were administered in the order listed above. Following the tasks participants filled out a battery of questionnaires that were part of a different aspect of a larger project.

3.1.3. 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 or how long it is taking
3. I am distracted by information present in the room (sights and sounds)
4. I am zoning out/my mind is wandering.
5. Other.

These thought probes were based on those used by Stawarczyk, Majerus, Maj, Van der Linden, and D'Argembeau (2011). During the instructions participants were given specific instructions regarding the different categories. Response three was classified as external distraction and response four was classified as mind-wandering. Response one was considered as on-task thoughts, while response two was considered as task-related interference.

3.1.3.1. Working memory capacity (WMC) tasks

3.1.3.1.1. Operation span (Ospan). Same as Experiment 1.

3.1.3.1.2. Symmetry span (Symspan). Same as Experiment 1.

3.1.3.1.3. Reading span (Rspan). Same as Experiment 1.

3.1.3.2. Attention control (AC) tasks

3.1.3.2.1. Sustained Attention to Response Task (SART). Participants completed a version of a Sustained Attention to Response Task (SART) with semantic stimuli adapted from McVay and Kane (2009, 2012). The SART is a go/no-go task where subjects must respond quickly with a key press to all presented stimuli except infrequent (11%) target trials. In this version of SART, word stimuli were presented in Courier New font size 18 for 300 ms followed by a 900 ms mask. Most of the stimuli (non-targets) were members of one category (animals) and infrequent targets were members of a different category (foods). The SART had 470 trials, 50 of which were targets. The dependent variable was the coefficient of variation for correct RTs. Thought probes followed 60% of target trials.

3.1.3.2.2. Antisaccade. Same as Experiment 1 except that participants performed 40 antisaccade trials. The dependent

Table 5
Correlations between diary responses and intra-individual variability factors.

Measure	Latent factor	
	AC-CV	LD-CV
Total failures	.20*	−.06
AttnTot	.44*	.04
AttnD	.31*	.00
AttnM	.09	.04
AttnW	.20*	.01
RetroTot	.11	−.04
RetS	−.01	−.09
RetP	.26*	.05
RetF	−.01	−.05
ProTot	.14	−.08
ProA	.02	−.03
ProT	.31*	−.07
ProE	.15	−.14

Note. AC = attention control; LD = lexical decision; CV = coefficient of variation; 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.
* $p < .05$.

Table 6
Descriptive statistics for all measures.

Measure	M	SD	Skew	Kurtosis	Reliability
Ospan	55.33	12.89	−1.33	1.94	.77
Symspan	29.24	7.38	−.87	1.03	.71
Rspan	50.74	13.62	−.81	.91	.82
Raven	8.08	2.97	−.20	−.35	.70
LS	9.15	2.78	.23	−.31	.64
NS	8.61	2.45	.05	.05	.70
AntiCV	.55	.29	1.73	4.20	.65
FlankerCV	.25	.09	1.89	8.05	.78
SARTCV	.40	.10	.60	.36	.74
StroopCV	.37	.10	2.32	9.54	.70
PVTCV	.36	.32	3.55	17.13	.85
AntiED	.08	.14	2.39	6.56	–
FlankerED	.07	.12	2.23	6.45	–
SARTED	.10	.11	1.73	4.52	–
StroopED	.07	.08	2.50	7.56	–
PVTED	.14	.15	1.44	2.04	–
AntiMW	.20	.25	1.63	2.11	–
FlankerMW	.24	.24	.97	.24	–
SARTMW	.21	.17	1.05	1.37	–
StroopMW	.13	.17	1.86	3.64	–
PVTMW	.27	.27	.94	.68	–

Note. Ospan = operation span; Rspan = reading span; Symspan = symmetry span; Raven = Raven Advanced Progressive Matrices; LS = letter sets; NS = number series; Anti = antisaccade; Flanker = arrow flankers; SART acc = accuracy on Sustained Attention to Response Task; SART sd = standard deviation of response time on the Sustained Attention to Response Task; Stroop = color word Stroop task; PVT = psychomotor vigilance task; CV = coefficient of variation; ED = external distraction; MW = mind-wandering.

variable was the coefficient of variation for correct RTs. Thought probes followed 16% of antisaccade trials.

3.1.3.2.3. Arrow flankers. Same as Experiment 1 except that participants performed 30 trials of each trial type. The dependent variable was the coefficient of variation for correct RTs. Thought probes followed 40% of incongruent trials.

3.1.3.2.4. Stroop. Same as Experiment 1 except that participants performed 135 total trials. The dependent variable was the coefficient of variation for correct RTs. Thought probes followed 44% of incongruent trials.

3.1.3.2.5. Psychomotor vigilance task (PVT). Same as Experiment 1. The dependent variable was the coefficient of variation for correct RTs. Thought probes followed 20% of trials.

3.1.3.3. Fluid intelligence (gF) tasks

3.1.3.3.1. Raven Advanced Progressive Matrices. Same as Experiment 1.

3.1.3.3.2. Number series. Same as Experiment 1.

3.1.3.3.3. Letter sets. In this task participants saw five sets of four letters, and participants were required to induce a rule that applies to the composition and ordering of four of the five letter sets (Ekstrom, French, Harman, & Dermen, 1976). Participants are then required to indicate the set that violates the rule. Following two examples participants had 5 min to complete 20 test items. A participant's score was the total number of items solved correctly.

3.2. Results

3.2.1. Descriptive statistics

Descriptive statistics for all of the measures are shown in Table 6. 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. Correlations, shown in Table 7, 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.

3.2.2. Confirmatory factor analyses

Similar to the prior experiments, confirmatory factor analysis was next used to better examine the data. Specifically, a model was specified in which IIV from the attention control tasks loaded on one factor, the WMC measures loaded onto a WMC factor, the gF measures loaded onto a gF factor, the external distraction responses loaded onto an external distraction factor, and the mind-wandering responses loaded onto a mind-wandering factor. All factors were allowed to correlate. The fit of the model was acceptable, χ^2 (179) = 372.67, $p < .01$, RMSEA = .07, SRMR = .07, NNFI = .88, CFI = .90. The factor loadings for each task and the interfactor correlations are shown in Fig. 4. As can be seen, each of the measures loaded strongly and significantly on their respective factors. Consistent with the prior experiments the attention control IIV factor was significantly related to cognitive abilities including WMC and gF. More importantly, the attention control IIV factor was significantly related to mind-wandering but not external distraction. These results suggest that fluctuations in attention control (at least in these tasks performed in the laboratory) are related to an individual's propensity to mind-wander during these tasks, but is not related to susceptibility to external distraction.

The next analysis examined the relation between IIV in attention control and a more standard attention control latent

Table 7
Correlations among all measures for Experiment 3.

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1. Ospan	–																										
2. Symspan	0.48	–																									
3. Rspan	0.56	0.45	–																								
4. Raven	0.22	0.31	0.22	–																							
5. LS	0.26	0.35	0.32	0.24	–																						
6. NS	0.23	0.30	0.19	0.32	0.35	–																					
7. Anti	0.26	0.29	0.24	0.21	0.30	0.24	–																				
8. Flanker	−0.08	−0.26	−0.08	−0.14	−0.17	−0.13	−0.17	–																			
9. SART sd	−0.15	−0.19	−0.21	−0.15	−0.26	−0.19	−0.21	0.16	–																		
10. SART acc	0.14	0.06	0.17	0.08	0.17	0.23	0.24	−0.07	−0.23	–																	
11. Stroop	−0.20	−0.25	−0.19	−0.07	−0.13	−0.17	−0.18	0.22	0.12	−0.03	–																
12. PVT	−0.15	−0.12	−0.24	−0.14	−0.22	−0.10	−0.23	0.13	0.20	−0.15	0.13	–															
13. aMW	−0.15	−0.26	−0.22	−0.15	−0.18	−0.20	−0.29	0.14	0.16	−0.15	0.07	0.15	–														
14. fMW	−0.17	−0.21	−0.06	−0.03	−0.13	−0.06	−0.12	0.01	0.06	−0.13	−0.01	0.18	0.36	–													
15. sMW	−0.10	−0.22	−0.29	−0.17	−0.23	−0.12	−0.22	0.22	0.25	−0.20	0.04	0.30	0.45	0.33	–												
16. stMW	−0.17	−0.05	-0.12	−0.08	-0.02	−0.02	-0.03	−0.02	0.11	−0.12	−0.06	0.31	0.32	0.65	0.39	–											
17. pMW	−0.12	−0.12	−0.17	−0.01	−0.10	−0.14	−0.12	0.23	0.15	−0.13	0.05	0.40	0.27	0.40	0.36	0.50	–										
18. aED	−0.10	−0.03	0.05	0.04	0.06	−0.07	−0.02	−0.02	0.00	−0.03	−0.04	0.03	0.01	0.13	0.09	0.11	0.02	–									
19. fED	−0.13	0.01	−0.02	−0.14	−0.09	−0.14	−0.08	−0.02	0.07	−0.07	0.08	0.06	0.06	0.05	0.05	0.12	0.06	0.16	–								
20. sED	−0.20	−0.17	−0.24	−0.20	−0.16	−0.23	−0.14	−0.04	0.11	−0.11	0.04	0.14	0.12	0.05	0.05	0.11	0.29	0.13	0.20	–							
21. stED	−0.21	−0.17	−0.15	−0.12	−0.17	−0.16	−0.04	0.05	0.09	−0.10	0.06	0.25	0.31	0.21	0.18	0.32	0.22	−0.01	0.36	0.38	–						
22. pED	−0.12	−0.24	−0.09	−0.20	−0.13	−0.18	0.00	0.01	0.05	0.01	−0.01	0.07	0.13	0.20	0.06	0.11	0.06	0.10	0.24	0.17	0.26	–					
23. AntiCV	−0.19	−0.15	−0.16	−0.13	−0.14	−0.17	−0.22	0.14	0.19	−0.16	0.08	0.10	0.29	−0.05	0.14	0.01	0.06	0.03	−0.04	0.16	0.11	0.04	–				
24. FlankCV	−0.11	−0.29	−0.27	−0.29	−0.30	−0.22	−0.28	0.32	0.34	−0.15	0.16	0.47	0.30	0.22	0.25	0.13	0.14	−0.08	−0.02	0.03	0.00	0.07	0.23	–			
25. SARTCV	−0.13	−0.23	−0.21	−0.16	−0.15	−0.16	−0.29	0.09	0.31	−0.35	0.11	0.28	0.20	0.13	0.20	0.07	0.14	−0.03	0.06	0.14	0.08	0.08	0.18	0.19	–		
26. StroopCV	−0.06	−0.04	−0.07	−0.21	−0.02	−0.21	−0.04	−0.01	0.14	−0.16	0.22	0.23	0.23	0.16	0.07	0.20	0.12	−0.04	0.10	0.05	0.06	0.13	0.08	0.27	0.21	–	
27. PVTCV	−0.09	−0.04	−0.14	−0.22	−0.21	−0.11	−0.14	0.03	0.24	−0.16	0.10	0.65	0.07	0.07	0.14	0.17	0.18	−0.01	0.06	0.01	0.01	−0.05	0.18	0.40	0.13	0.28	–

Note. Ospan = operation span; Rspan = reading span; Symspan = symmetry span; Raven = Raven Advanced Progressive Matrices; LS = letter sets; NS = number series; Anti = antisaccade; Flanker = arrow flankers; SART acc = accuracy on Sustained Attention to Response Task; SART sd = standard deviation of response time on the Sustained Attention to Response Task; Stroop = color word Stroop task; PVT = psychomotor vigilance task; CV = coefficient of variation; ED = external distraction; MW = mind-wandering.

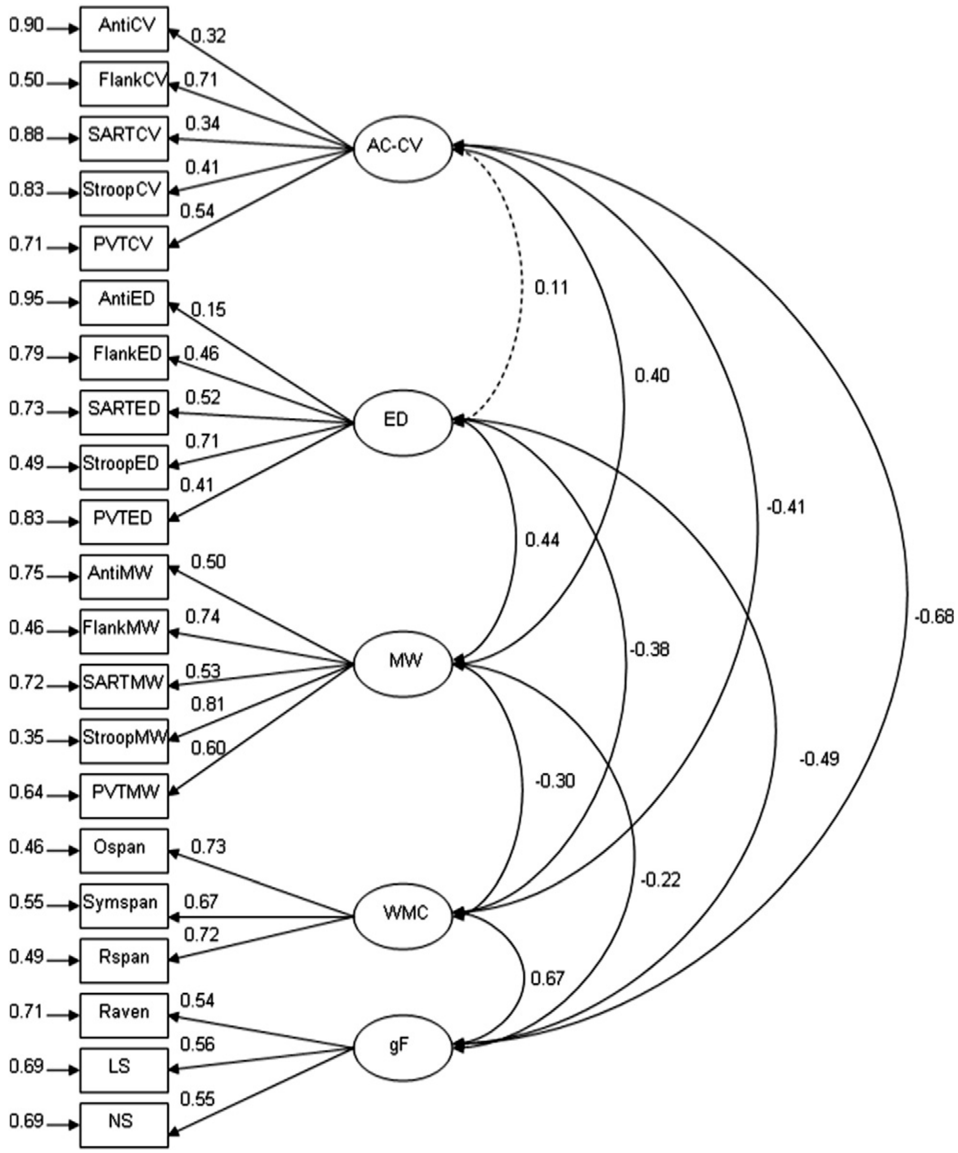

Fig. 4. Model for attention control coefficient of variation (AC-CV), external distraction (ED), mind-wandering (MW), working memory capacity (WMC), and fluid intelligence (gF). Solid lines are significant at the $p < .05$ level and dotted lines are not significant at the $p < .05$ level.

variable. That is, given that there were five attention control measures it is possible to examine how IIV in attention control from some tasks would relate to attention control in other tasks not composed of IIV measures. To examine this, an attention control IIV factor was formed based on the coefficient of variation for the SART and for the psychomotor vigilance task given that the primary measures for these tasks are RT. The attention control factor was then formed based on accuracy in the antisaccade task, the flanker effect in the flanker task (reaction time difference between incongruent and congruent trials), and the Stroop effect in the Stroop task (reaction time difference between incongruent and congruent trials). Thus, the attention control IIV factor is based on independent measures of IIV and the attention control factor is composed of either accuracy measures or RT difference measures. These factors were combined in a model with the WMC, gF, external distraction, and mind-wandering factors from the prior model. The fit of the model was acceptable, $\chi^2\,(174) = 336.62$, $p < .01$, RMSEA = .06, SRMR = .07, NNFI = .88, CFI = .90. The factor loadings for each task and the interfactor correlations are shown in Fig. 5. As can be seen, the IIV attention control and attention control factors were similarly related to the other constructs, and most importantly these two factors were highly correlated ($r = -.93$). In fact, comparing a two-factor model to a one-factor model demonstrated that the one-factor model fit just as well as the two-factor model, $\Delta\ \chi^2(1) = 0.28$, $p > .59$, suggesting that the two factors were not distinguishable. Thus, a latent factor composed of measures of IIV in two attention control tasks was indistinguishable from an attention control latent factor composed of more standard measures of attention

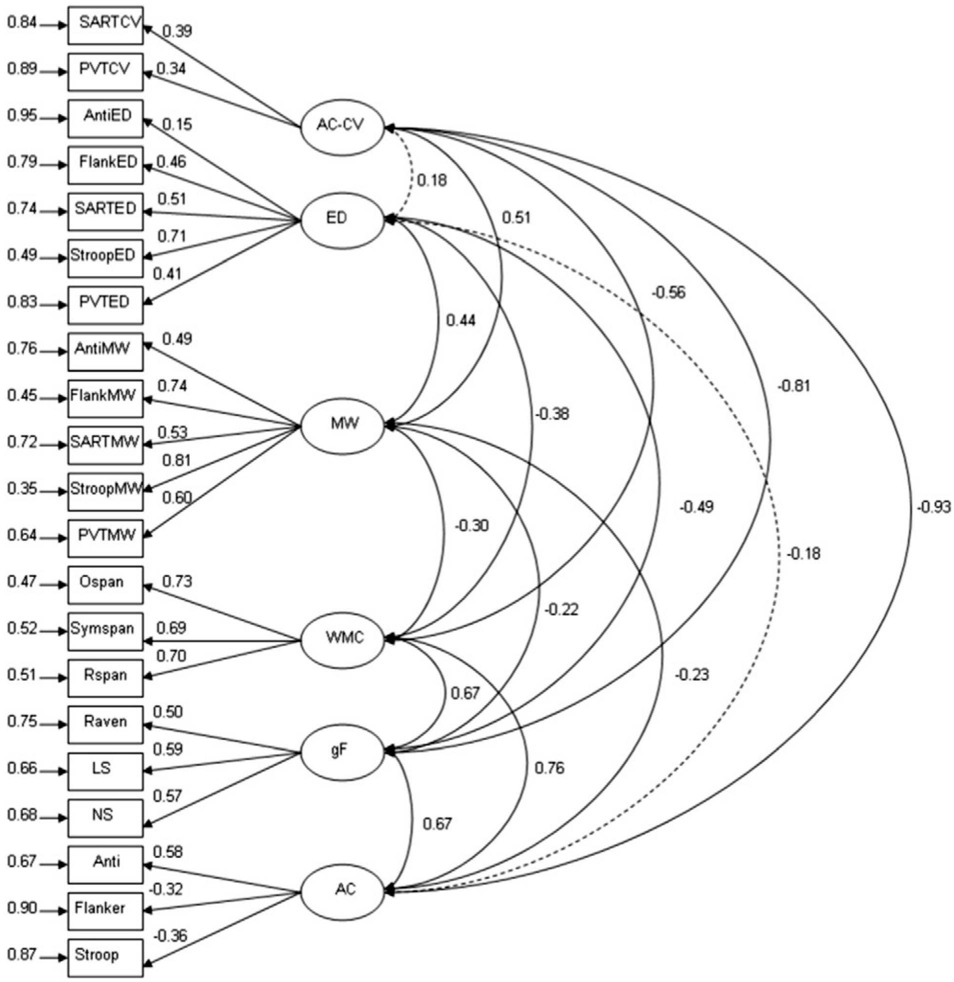

Fig. 5. Model for attention control coefficient of variation (AC-CV), external distraction (ED), mind-wandering (MW), working memory capacity (WMC), fluid intelligence (gF), and attention control (AC). Solid lines are significant at the $p < .05$ level and dotted lines are not significant at the $p < .05$ level.

control. These results suggest that prior work which has examined individual differences in attention control may have actually been measuring individual differences in fluctuations in attention control.

Similar to the prior experiments the extent to which the relations between IIV and cognitive abilities were due to shared variance with mean RT was examined. Again there was a strong relation between IIV and mean RT ($r = .55$). To examine whether IIV accounted for variance over and above that accounted for by mean RT factor composites for mean RT and IIV were formed and separate regressions were analyzed predicting WMC, gF, and mind-wandering rates. Examining the relations with the WMC, the results suggested that IIV predicted unique variance in WMC ($\beta = -.20$, $p < .05$), and so did mean RT ($\beta = -.16$, $p < .05$). Examining gF suggested that IIV predicted unique variance ($\beta = -.28$, $p < .05$), and so did mean RT ($\beta = -.17$, $p < .05$). Finally, examining mind-wandering suggested that IIV predicted unique variance in mind-wandering ($\beta = -.29$, $p < .05$), but mean RT did not ($\beta = .01$, $p > .87$). Examining gF suggested that IIV predicted unique variance ($\beta = -.28$, $p < .05$), and so did mean RT ($\beta = -.17$, $p < .05$). Thus, similar to the prior experiments IIV accounted for variance in cognitive abilities over and above that accounted for by mean RT.

3.3. Discussion

Experiment 3 demonstrated that IIV in attention control is not only related to broader cognitive abilities, but is also related to subjective reports of mind-wandering during attention control tasks. This suggests that fluctuations in attention control during laboratory attention tasks are linked to individual differences in susceptibility to mind-wandering. Those individuals who mind-wander frequently also demonstrate more variable responding than individuals who mind-wander less frequently. Thus, IIV in attention control may be due to periodic lapses of attention whereby a participant's attention is focused internally to current thoughts and concerns. Although the current results demonstrated that IIV in attention control was linked to mind-wandering reports, it was not linked to reports of external distraction. Thus, at least within the current data, fluctuations in attention were not related to individual differences in susceptibility to distraction. Finally, the results from Experiment 3 demonstrated that a more standard attention control latent factor (composed of antisaccade, flanker, and Stroop tasks) was strongly related to the IIV attention control factor (composed of the SART and the psychomotor vigilance task) suggesting that a key underlying factor may be individual differences in the consistency of attention control. That is, individuals do not necessarily differ in the overall amount of attention control that can be applied, but rather differences arise in the consistency with which control is applied. Thus, low ability individuals experience more trial-by-trial fluctuations in attention control than high ability individuals which can impact overall mean levels of performance.

4. General discussion

In the current study data from three prior latent variable studies were reanalyzed to better examine the notion that consistency in attention control is an important cognitive trait. Experiment 1 demonstrated that IIV on attention control tasks and IIV on lexical decision tasks were best accounted for as separate factors with the IIV attention control factor being related to cognitive abilities including working memory capacity, fluid intelligence, and long-term memory. Experiment 2 replicated these results demonstrating differences between IIV on attention control and non-attention demanding lexical decision tasks and extended these results by demonstrating that IIV in attention control predicted a number of everyday cognitive failures (in particular everyday attentional failures). Experiment 3 demonstrated that IIV in attention control was related to subjective reports of mind-wandering but not external distraction, suggesting that fluctuations in attention control are linked to individual differences in the propensity to mind-wander. Finally, Experiment 3 demonstrated that individual differences in attention control and IIV in attention control are largely the same.

Overall these results demonstrate that consistency of attention control is an important cognitive trait that is related to a number of cognitive abilities, predicts real-world everyday cognitive failure, and is linked to lapses of attention due to mind-wandering. These results go significantly beyond prior work by demonstrating that IIV is not a single unitary factor, but that IIV in attention control seems to be particularly important. Furthermore, by using multiple measures of IIV the current results suggest that IIV in attention control is a stable trait that is found across a number of different attention control measures and is related to a number of other important cognitive abilities.

The present results provide support for the notion that variability in RT during attention control tasks is an important index of an individual's ability to consistently maintain and sustain attention on a task which is related to other important executive and fluid abilities. As noted previously this ability is likely related to executive deficits seen in a number of populations (e.g., Hultsch et al., 2008; Karalunas, Geurts, Konrad, Bender, & Nigg, 2014; Leth-Steensen et al., 2000; Stuss et al., 2003). From a theoretical standpoint, the current results suggest that it is not necessarily overall mean level differences in attention control that matter, but rather differences in how consistently one can utilize attention control. That is, low attention control individuals can perform just as well as high attention control individuals some of the time, but they are more inconsistent in their ability to engage attention control which leads to more lapses of attention. This increase in fluctuations of attention control may be related to fluctuations in arousal or alertness that are related to norepinephrine neuromodulation (Aston-Jones & Cohen, 2005) or to motivation and reward processing linked to dopamine neuromodulation (Li et al., 2001; MacDonald, Li, & Backman, 2009). Importantly IIV in attention control seems to be an important cognitive trait that is linked to a number of cognitive abilities and to real world cognitive failures.

4.1. Relations to the mean and slowest reaction times

As noted in each experiment, although the current results suggest a strong link between IIV in attention control and cognitive abilities, an important alternative to examine is whether mean differences in RT actually account for these relations. That is, the mean and coefficient of variation will tend to be correlated with higher means being associated with higher coefficients of variation. Thus, it is possible that differences in mean RT, rather than variability per se account for the relations observed here. However, in each experiment IIV accounted for unique variance in cognitive abilities over and above that accounted for by mean RT. Thus, although differences in mean RT are related to IIV, and mean differences in RT tend to be related to other cognitive abilities, these differences in mean RT do not fully account for the relation between IIV in attention control and other cognitive abilities.

In addition to examining whether differences in mean RT account for the relation between IIV in attention control and other cognitive abilities, it is important to examine the extent to which variability in the slowest RTs account for the relation. A good deal of prior research has shown that the slowest RTs tend to correlate the highest with various cognitive abilities (i.e., the worst performance rule; Coyle, 2003; Larson & Alderton, 1990; Schmiedek et al., 2007; Tse et al., 2010; Unsworth, Redick, et al., 2010). Given that there is a lower limit on RT, it is highly likely that increases in IIV are due to increases in the slow tail of the RT distribution. Indeed, in each experiment there was a positive correlation between IIV and the slowest 20% of trials (Experiment 1 $r = .78$, Experiment 2 $r = .45$, Experiment 3 $r = .77$). Thus, much of the differences in variability are due to increases in the slow tail of the distribution. However, despite the strong linkage between increased IIV and increased slow responses, it is important to note that not all situations in which IIV increases lead only to increases in the slow tail of the distribution. For example, in go/no-go tasks like the SART variability in the fastest RT can be just as important as variability in the slowest RTs. Specifically, McVay and Kane (2012) computed RT quintiles for the SART and found that the fastest 20% of trials was positively correlated with working memory capacity and negatively correlated with mind-wandering, whereas the slowest 20% of trials was negatively correlated with working memory capacity and positively correlated with mind-wandering. Thus, low ability individuals were faster on the fastest trials and slower on the slowest trials compared to high ability individuals. These fast responses have been linked with inattention and premature responding (Cheyne et al., 2009). Similar results were found when examining the results from Experiment 3 in which the fastest 20% of trials were positively correlated with both working memory capacity ($r = .16$) and gF ($r = .15$), but were negatively correlated with mind-wandering ($r = -.14$).

Table 8
Descriptive statistics and omnibus ANOVA results for each group defined by the cluster analysis and overall performance collapsed across groups.

Measure	Group 1	Group 2	Group 3	Group 4	Overall	F	η^2
Fast	−.41 (.27)	.11 (.27)	.87 (.49)	−.87 (.85)	.00 (.68)	114.37	.61
Slow	−.84 (.29)	−.04 (.38)	.73 (.49)	.87 (.75)	.00 (.77)	150.62	.68
CoV	−.59 (.43)	−.04 (.59)	.21 (.44)	1.19 (1.11)	.00 (.77)	55.10	.43
WMC	.27 (.80)	.09 (.81)	−.17 (.89)	−.23 (.88)	.00 (.84)	3.55	.05
gF	.31 (.69)	.05 (.71)	−.10 (.75)	−.37 (.76)	.00 (.75)	6.27	.08

Note. Fast = factor scores for fastest 20% of trials across all attention tasks; Slow = factor scores for slowest 20% of trials across all attention tasks; CoV = factor scores for coefficient of variation across all attention tasks; WMC = factor scores for working memory capacity measures; gF = factor scores for fluid intelligence measures. Numbers in parentheses are standard deviations.

The slowest 20% of trials, however, were negatively correlated with both working memory capacity ($r = -.16$) and gF ($r = -.29$), but were positively correlated with mind-wandering ($r = .20$). Furthermore, in each attention control task the coefficient of variation negatively correlates with the fastest trials and positively correlates with the slowest trials suggesting that variability in both fast and slow responses jointly contributed.

It is also possible that the relations with the fastest trials might be due to a subset of individuals who are more prone to premature responding. To examine this factor scores were computed for the fastest and slowest 20% of trials across all of the attention tasks and these scores were submitted to a cluster analysis. The cluster analysis suggested the presence of four groups of individuals consisting of 64, 88, 41, and 27 participants each. Note 21 participants were excluded from this analysis because they did not have enough correct trials in the fastest or slowest bins mostly due to low accuracy on the antisaccade task. As can be seen in Table 6, Group 1 tended to have fast RTs overall, Group 2 had average RTs overall, Group 3 had slow RTs overall, and importantly Group 4 had very fast fast RTs and very slow slow RTs. Thus, this group demonstrated very fast responding on some trials, and very slow responding on other trials. Additionally, as seen in Table 8 these groups also tended to differ in cognitive abilities with Group 1 being high ability, Group 2 being average ability, and Groups 3 and 4 being low ability. Importantly, although Groups 3 and 4 were low ability and had the largest amount of IIV, they differed in the nature of that IIV with Group 3's IIV being located in the slow tail of the distribution and Group 4's IIV being located in both tails of the distribution. Collectively these results suggest that variability in the fastest responses may be just as important as variability in the slowest responses. Importantly this may depend on the particular tasks that are being examined, with nearly all tasks showing relations between the slowest trials and cognitive abilities, and only some tasks showing relations between the fastest trials and cognitive abilities (here positive relations). Furthermore, this may not only be due to the type of task that is being assessed, but may also be due to differences between individuals, with a subset of individuals responding both very fast and very slow. Thus, IIV can (and typically does) manifest itself as increases in the slow tail of the distribution, but increases in IIV can also be seen in increases in fast responses linked to premature responding.

4.2. Conclusions and future directions

Overall, the current work suggests that variation in fluctuations of attention control are related to a number of important cognitive constructs which are needed in a number of real-world situations. Future research is needed to examine the many potential varieties of IIV and how these different types of IIV are related to one another and to cognitive abilities. Furthermore, future work is needed to better understand the nature of these fluctuations in attention control to determine their ultimate cause and to identify potential means of reducing these fluctuations in both the laboratory and real-world situations. The current work (along with previous research) suggests a promising field of inquiry examining how fluctuations in attention control determine overall levels of task performance across individuals and how these fluctuations are related to other important processes.

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