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Intraindividual reaction time variability predicts prospective memory failures in older adults

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Abstract

This study investigated the relationship between intraindividual variability (IIV) in reaction time and prospective memory errors in older adults using data from the Zurich Longitudinal Study of Cognitive Aging (n=336 individuals aged 66-81 years). The results indicated that increased IIV measured from independent tasks was associated with a greater proportion of prospective memory errors. These significant findings were not influenced by age and did not vary according to prospective memory cue type. Variability is thought to reflect fluctuations in attentional and executive control and these attentional processes may also impact on prospective memory through failure to detect the target cue. The findings suggest, therefore, that measures of variability may have some potential in the identification of older persons who are more vulnerable to everyday errors such as prospective memory failures.

Keywords: Intraindividual variability; Prospective memory; Reaction time; Attention; Aging

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Ageing is typically accompanied by a decline in cognitive abilities, which may manifest as a slowing of responses or an increase in error rates. One error type that may have important implications for older adults is prospective memory failure. Prospective memory is defined as the ability to plan and remember to perform previously planned activities at a specific point in time (e.g., Ellis & Kvavilashvili, 2000; Kliegel, Mackinlay, & Jager, 2008). Tasks such as remembering to take one's medication after breakfast or remembering to switch off the stove after cooking, show that prospective memory can be regarded as an important prerequisite for autonomy and independence in everyday life (see, Cockburn & Smith, 1994; Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2012). Conceptually, prospective memory requires at least two distinct components, a retrospective and a prospective one (Einstein & Mcdaniel, 1990; Kliegel, Altgassen, Hering, & Rose, 2011). The retrospective component requires the recollection of the intended action (i.e., remembering what has to be done) and the recognition of the prospective memory target cue (i.e., remembering when it has to be done). This retrospective component is hypothesized to be related to episodic memory and represents the link to other traditionally studied memory processes (McDaniel, Glisky, Rubin, Guynn, & Routhieaux, 1999). The prospective component involves the self-initiated retrieval of the intention (i.e., remembering that it has to be done) at the appropriate moment (Einstein, Holland, Mcdaniel, & Guynn, 1992; Smith & Bayen, 2004). This component is thought to be supported by controlled attention and executive function. This includes attention switching between the ongoing and the prospective task to monitor for the prospective memory cue and inhibition of the ongoing activity when the appropriate moment has arrived to actually execute the delayed intention (Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013). The present study was motivated by an interest in the cognitive processes that may influence error outcomes in older adults. One variable with considerable potential to elucidate the attention processes involved in these types of errors is intraindividual variability.

Intraindividual variability (IIV) refers to an individual's fluctuation in cognitive performance over time. This can be measured using a single task on multiple occasions, across a battery of tasks, or, more commonly, by the trial-by-trial variation in reaction time (RT) on a single cognitive task. One proposal is that RT variability reflects fluctuations in attentional or executive control (Bunce, MacDonald, & Hultsch, 2004; Bunce, Warr, & Cochrane, 1993; West, Murphy, Armilio, Craik, & Stuss, 2002). Under this proposal, the extent to which an individual is focused on a task is reflected in RTs of differing durations, with greater fluctuation in RT indicating less task focus. RT variability may therefore be a simple measure of attentional or executive control, with greater fluctuations manifesting as an increase in IIV.

As noted, we were interested in the broader question of the link between variability and errors in older age. Previous research has shown a link between IIV and errors on tasks relating to everyday functioning including associations with simulated driving (Bunce, Young, Blane, & Khugputh, 2012) and flight performance (Kennedy et al., 2013), everyday problem solving (Burton, Strauss, Hultsch, & Hunter, 2009) and falls (Graveson, Bauermeister, McKeown, & Bunce, 2015). A relationship between IIV and errors may be particularly important in the context of prospective memory where successful performance involves multiple cognitive processes that rely on episodic memory and executive functioning. Therefore, more lapses in executive or attentional control (indexed by greater variability) might be expected to manifest as a greater propensity for prospective errors. Two previous studies have investigated this. The first in young adults found no association between prospective memory performance and IIV as quantified by the ex-Gaussian tau parameter (Loft, Bowden, Ball, & Brewer, 2014). Instead, individual differences in the mu parameter were positively related to prospective remembering, indicating a slowing of responses was beneficial to successful memory performance. By contrast, in a sample aged 18 to 90 years, higher IIV costs were associated with a greater number of prospective memory errors on a non-focal task (Ihle, Ghisletta, & Kliegel, 2016). It may be that cue monitoring is beneficial to prospective memory when it can be continuously applied, whereas lapses in attention may disrupt this monitoring and thereby impair prospective remembering. Age-related changes in attention may therefore underlie the contrasting results.

There are three main methods to investigate IIV in the context of prospective memory. First, RTs from the prospective memory responses can be used. A disadvantage of this approach, however, is that there are typically too few trials to obtain a robust variability measure. Second, variability can be computed using RTs from the ongoing task (e.g., Ihle et al., 2016; Loft et al., 2014). Although there is merit to this approach, variability associated with the embedded prospective memory trials might overlap or be confounded with underlying variability associated with individual differences in attentional or executive control. To avoid this potential overlap, a third approach is to use IIV measures generated from independent tasks. The present study extends the literature in the third area. We investigated IIV and prospective memory relationships in community-dwelling individuals aged 66-81 with IIV generated from multiple tasks that provided trial-by-trial RTs, and prospective memory errors obtained from separate tasks within the broader cognitive test battery. Although we might expect similar results using variability derived from the ongoing task and those that come from independent measures, our broader research question was whether separate IIV measures identified individuals who were more likely to make prospective memory errors. Based on previous research linking IIV and errors using other tasks, our first expectation was that greater variability would be associated with an increased proportion of errors. We were also interested in the effect of age on this relationship.

Previous research in older individuals has shown that prospective memory errors (Zeintl, Kliegel, & Hofer, 2007) and variability (e.g., Hultsch, MacDonald, & Dixon, 2002) both increase with older age. We, therefore, expected the IIV-error association to grow stronger with greater age.

Finally, we compared the relationship between variability and different prospective memory cues. The tasks used in the present analysis were selected to provide a comprehensive representation of the prospective memory construct (Zeintl et al., 2007). These tasks varied on a number of dimensions including whether (1) the target cue could be regarded as being more or less the focus of attention, (2) the task absorption (level of engagement with the ongoing task) and (3) the clarity of the association between the cue and intended action. Tasks that have high absorption and cues that are outside of the focus of attention have higher monitoring demands than those with low absorption and cues within the focus of attention. Additionally, the clarity of the cue-action association may influence how easy it is to perform the correct response. In the present study, we were interested in whether there was a differential IIV-error relationship for different tasks. Several models, including the multiprocess framework (McDaniel & Einstein, 2000) and others (e.g., Smith & Bayen, 2004), suggest that the need for attentional control varies depending on cue type or ongoing task difficulty. Following up on these predictions, and considering that IIV is thought to reflect fluctuations in attentional control, we anticipated that the IIV-error relationship would vary across tasks with a stronger relationship with errors on tasks that have a higher monitoring demand.

Method

Participants

Data from 336 participants (154 Female) aged 66-81 (*M*=74.4, *SD*=4.4) were taken from Wave 2 of the Zurich Longitudinal Study on Cognitive Aging (Zimprich et al., 2008). At baseline, 364 participants born between 1925 and 1940 were recruited from the community in Zurich. Participants were excluded from the study if they scored lower than 24 on the Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975) at either wave. Data from the baseline demographic variables have previously been reported (Zimprich et al., 2008).

Measures

Prospective memory.

Three prospective memory tasks were included in the test battery. Participants were given instructions for all tasks at the start of the testing session and were asked to repeat them to ensure they understood. For all tasks, failure to complete the intended action was classified as a prospective memory error. *Red pencil task (Dobbs & Rule, 1987):* Whenever the experimenter mentioned the words “red pencil” participants were supposed to repeat them. This happened three times during the testing session. *Token task:* Whenever the examiner started the instruction of a new task with, “The next task involves digits”, participants had to take a token out of the drawer and place it on the desktop. This occurred four times during the testing session. *Background change task:* This task was modified from a previous background pattern task (Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). During the test session, the background of the computer screen changed from light grey to yellow on three occasions. Participants were required to press a designated key when this happened. The task demands varied along a number of dimensions, which are summarized in Table 1. The background change task had relatively high monitoring demands and this task can be considered non-focal within the multiprocess framework (McDaniel & Einstein, 2000). Overall, the red pencil and token tasks had lower monitoring demands as the cue appeared in the focus of attention and there was low task absorption at the time of the cue. In addition, participants did not have to monitor for cues throughout the session (e.g., the cue would not appear during a cognitive task).

(Insert Table 1 here)

Reaction time tasks.

Participants completed a broad cognitive test battery that included three working memory tasks (operation span, reading span, and counting span) and three processing speed tasks (digit letters, number comparison, and identical pictures). The working memory span measures required participants to hold information in memory, whilst concurrently completing an ongoing task that provided trial-by-trial RTs. These RTs were used to generate variability metrics. *Operation decision:* RTs were taken from the operation span task (Turner & Engle, 1989). Twenty-eight simple math problems and solutions were displayed successively on a computer screen. Participants had to decide whether the answer was correct or incorrect and respond by pressing a designated key. *Reading decision:* This formed part of the reading span task (Daneman & Carpenter, 1980). Participants were shown 28 short sentences on the computer screen. They had to decide whether the sentence described a situation that could normally occur and respond by pressing a designated key. *Counting:* RTs were taken from the counting span task (Engle, Tuholski, Laughlin, & Conway, 1999). Targets (dark blue circles) and distractors (dark blue squares, light blue circles) were presented on the computer screen. Participants had to count the targets and report their answer by pressing the correct number on the keyboard. Across 28 trials, the number of targets varied from 3-9 items, whilst distractors varied from 1-5 items. *Digit letters*: A table was displayed on the computer screen in which five letters were paired with the numbers 1 to 5. Participants were provided with a letter and had to respond by pressing by the corresponding number on the keyboard. This task was self-paced, and participants had 90 *s* to complete as many trials as possible out of a maximum of 75 trials. *Number comparison:* This task used 60 items from the Number Comparison Task (Ekstrom, French, Harman, & Derman, 1976). Two numbers (ranging from 3-13 digits) were presented on the computer screen. Using designated keyboard keys, participants had to respond whether the numbers were the same or different. The task was self-paced and lasted for 90*s*. *Identical pictures:* 60 items from the Identical Pictures Test (Ekstrom et al., 1976) were used in this measure. On each trial, participants were presented with a reference picture and five other images on the computer screen. They had to select which of the options matched the reference picture and respond by pressing the corresponding number on the keyboard. The task was self-paced, and lasted for 90*s*.

Data processing

Prior to calculating RT variability metrics, errors trials and unusually fast (<750 ms) or slow (≥ 3 SDs beyond the individual mean RT) RTs were removed. Across all tasks, this resulted in the removal of 7.6% of trials. We used the coefficient of variation (CV = individual SD/individual mean RT) as a measure of IIV as this adjusts for differences in variability that may be related to individual mean-level performance. Previous research has indicated that there are similar relationships with cognitive decline for the CV and other IIV measures (Lovden, Li, Shing, & Lindenberger, 2007). The CV was calculated for each RT task separately.

Results

Descriptive statistics for the RT variability and prospective memory measures are displayed in Table 2. The majority (99%) of participants made at least one error on the prospective memory tasks, with 33 participants (10%) failing to complete any of the tasks.

For the RT tasks, the mean proportion of errors was ≤0.15 and the group average mean RT ranged from 3017-7367 ms. For the prospective memory tasks, the group mean proportion of errors ranged from .38 to .67. Across task intercorrelations for CV, mean RT, prospective memory errors, and the study covariates are presented in Table 3. There was a strong association between errors on the red pencil and token tasks (*r*=.51), whilst these tasks had a medium correlation with the background change task (*r*=.30 and *r*=.38, respectively).

(Insert Table 2 here)

(Insert Table 3 here)

A composite measure that combined errors on the three prospective memory tasks was computed using Principal Components Analysis. Inspection of the scree plot and the eigenvalues for each component suggested that the tasks loaded onto a single factor that explained 60% of the variance. The factor scores were saved and used in the subsequent analyses. Using a composite measure extended the range of possible scores on the prospective memory measure, and provided a comprehensive prospective memory construct that encompassed tasks that varied on a number of dimensions. In the first analyses, a series of regression models were run in which the composite error measure was regressed onto each RT variability metric in turn (see Table 4, Model 1). Years in education and sex were entered at Step 1, with the RT measure included in Step 2. Due to the number of regression models, we applied a Bonferroni correction (p=.008). The results indicated that prospective memory errors were associated with variability on the operation decision, reading decision, digit letters, and number comparison tasks. On all of these tasks, greater variability was associated with increased error rates (βs>.157, ps<.003). In contrast, variability on the counting task and identical pictures did not significantly predict prospective memory performance.

(Insert Table 4 here)

To investigate the influence of age, a second series of regression analyses were run in which we additionally adjusted for age at Step 1 (see Table 4, Model 2). The results indicated that age was positively associated with prospective memory error rates. However, after adjusting for age, the relationship between IIV and errors remained statistically significant for the operation decision, reading decision, digit letters, and number comparison RT tasks. We compared ΔR^2 for Step 2 (the addition of the IIV measure) with and without age added at Step 1. The inclusion of age attenuated the association between IIV and prospective memory errors by between 12 and 36%. This represents a relatively modest degree of attenuation, with reductions over 40% considered important and over 60% considered critical (Salthouse, 1992). We further investigated the influence of age by rerunning the regressions and introducing an Age x RT variability interaction term. In all cases, these interaction terms were nonsignificant.

The final analyses investigated the relationship between variability and errors on the individual prospective memory tasks rather than the composite measure reported above. Here, we were interested in whether the relationship between IIV and errors varied according to whether the prospective memory cue depended less on strategic monitoring (red pencil and token tasks) or a more on strategic monitoring (background change). Due to the restricted range of potential scores on the separate prospective memory tasks, we used multivariate logistic regression for these analyses. We compared participants making a high (100%) or medium (50-75%) number of errors to the reference group of participants who made zero or one errors (0-33%). It is clear in Table 5 that similar results were obtained across the prospective memory tasks. IIV on the operation decision and digit letter tasks was associated with errors on all three tasks. The reading decision and digit letter tasks predicted errors on two of the three prospective memory tasks, but importantly this did not differ according to cue type.

(Insert Table 5 here)

Discussion

This study is the first to investigate the relationship between prospective memory failures and RT variability obtained from separate cognitive tasks in older adults. The main finding was that greater variability was associated with more prospective memory errors. Secondly, although older age was associated with an increase in error rates, age had only a modest influence on the relationship between IIV and errors. Finally, significant relationships were identified across multiple RT tasks with differing cognitive demands, but were unrelated to the type of prospective memory task.

The results broadly supported our expectation that greater IIV would be associated with increased prospective memory error rates. Behaviorally, it has been proposed that IIV reflects fluctuations in executive or attentional control (Bunce et al., 2004; Bunce et al., 1993; West et al., 2002). Correspondingly, prospective memory involves multiple processes including planning, monitoring, and inhibition/switching, which demand cognitive resources including executive functioning (Kliegel et al., 2011; Kliegel, Martin, McDaniel, & Einstein, 2002). The relationship between IIV and prospective memory errors may therefore stem from this shared association with executive or attentional processes. Fluctuations in attentional control may be reflected in RTs of differing duration with more consistent responding (i.e., lower IIV) indicating greater focus. Attentional fluctuation may also impact on prospective memory through failure of executive processes (e.g., monitoring) leading to a failure to detect a target. The present results converge with our recent finding that IIV was associated with visual search errors, and particularly errors of omission, a result that strengthened with older age (Haynes, Bauermeister, & Bunce, 2016). These results both suggest that older adults who are more variable are more likely to fail to detect a target, whether this is a prospective memory cue or a visual search target. Similarly, the findings are consistent with research identifying relationships in older adults between IIV and errors on other tasks that may relate to everyday functioning (Bunce et al., 2012; Burton et al., 2009; Papenberg et al., 2011).

The influence of age on the relationship between IIV and errors was investigated as previous research suggests that older age is associated with an increase in both variability (Bielak, Cherbuin, Bunce, & Anstey, 2014; Hultsch et al., 2002) and prospective memory failures (Zeintl et al., 2007), even within the narrow age range of the present cohort. When adjusting for age however, there was only a modest attenuation of the initial significant results, suggesting the relationship between IIV and errors was independent of any concurrent age-IIV or age-error associations. Additionally, there were no significant Age x Variability interactions. Although it is possible that differential IIV-error relationships exist between younger- and older-adult samples, the present results suggest the relationship does not vary as a function of age within the present age range (66-81 years). It should, however, be noted that this study had a relatively restricted age range, and this may have limited our ability to detect age effects on the relationship between IIV and prospective memory.

Our final analyses investigated whether the IIV-error relationship varied according to prospective memory cue. Available models of prospective memory suggest that not all tasks require the same amount of cognitive control but that the level of controlled attention involved varies according to task characteristics such as focus of attention or ongoing task difficulty. Thus, we anticipated that there would be a stronger relationship between IIV and errors for tasks with higher monitoring demands (e.g., where the background change task was non-focal and had higher task absorption). Contrary to expectations however, similar results were found for all tasks, with IIV-error relationships of a similar magnitude throughout. This contrasts with previous findings in which IIV was only associated with prospective remembering on a non-focal task (Ihle et al., 2016). Although it is likely that the background change task required more strategic monitoring, all of the tasks placed some demands on executive control. Participants had to periodically switch between the ongoing battery of cognitive tasks and the prospective memory intention held in mind, and they also had to inhibit the normal action (i.e., what they were currently doing) after detecting the cue word. This may explain the relationship between IIV and errors on the token and red pencil tasks and suggest that more variable older individuals may be prone to making errors in multiple contexts of varying executive demands. Future studies will have to address these questions in using more fine-grained manipulations of prospective memory task types that allow, for example, clearly distinguished focal and non-focal cues.

Although significant relationships were evident between IIV and prospective memory errors, these associations were identified only for four of the six RT tasks. Errors were not associated with IIV on the counting and identical pictures tasks. Inspection of the group mean error rates and mean-RTs suggests that these two tasks did not differ in terms of difficulty, as performance fell within the range of the other tasks. In the counting task, the number of targets and distractors varied from trial to trial. This could have lengthened the RT for certain trails, adding noise to the IIV measure and potentially reducing its predictive utility. However, it is unclear why the identical pictures task was a poor predictor of errors, especially as this measure was predictive of cognitive decline in previous research (Lovden et al., 2007). Further work is needed to investigate what factors differentiate RT tasks, and how these relate to attentional or executive control.

The present study possesses a number of strengths. For example, it is the first to investigate the relationship between IIV and prospective memory errors in older adults, there was a relatively large sample size, and the broad cognitive test battery allowed us to use multiple RT and prospective memory measures. However, there are some limitations that we should consider. First, the individual prospective memory tasks had a narrow range of responses as it was only possible to score between zero and three or four. It is possible that this prevented detection of differences in the association with IIV for the separate prospective memory tasks. In addition, the principal components analysis indicated that these tasks loaded onto a single factor. They may, therefore, have been too similar to be able to detect differential relationships with IIV. Second, this study did not have simple or choice RT tasks available, as are commonly used in variability studies (e.g., Hultsch, MacDonald, Hunter, Levy-Bencheton, & Strauss, 2000). Although there is little consensus as to which RT tasks are best for this type of analysis, those used in the present study were all relatively complex. The working memory tasks included other factors that may influence RTs to a variable degree across trials, which may have reduced their predictive utility. However, despite this, we were still able to identify significant relationships between IIV and errors for the majority of the RT tasks. Nonetheless, future research should consider the more basic psychomotor RT tasks in relation to prospective memory.

In conclusion, this study has shown that greater RT variability predicts more prospective memory failures in older adults. This relationship may stem from fluctuations in attentional control that impact on prospective memory through failure to detect the target cue, and impact on measures of IIV by influencing RT duration on a trial-by-trial basis. It is important that older adults maintain prospective memory performance in order to support independent living, as failures can have potentially harmful consequences and impact on both health and social engagement. Failures in prospective memory, as opposed to retrospective memory, therefore, have important implications for everyday functioning. The present findings suggest that IIV measures may have some potential in helping to identify older persons who are more vulnerable to everyday errors, including prospective memory failures.

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Table 1: Summary of the prospective memory tasks

	Red pencil	Token	Background change
Focus of attention: was the cue included in the information the participant was currently attending to?	Yes	Yes	No
Association between cue and intended action	High	Low	Low
Task absorption: level of engagement at the time of the cue	Low	Low	High

Table 2: Summary statistics for reaction time and prospective memory variables

	Mean RT (ms)	SD (ms)	CV	Proportion errors
Reaction time				
Operation decision	7367 (3147)	2500 (1773)	0.32 (0.09)	.06 (.07)
Reading decision	5962 (1521)	1537(746)	0.25 (0.08)	.01 (.03)
Counting	6469 (1712)	1939 (773)	0.30 (0.08)	.06 (.06)
Digit letters	3017 (927)	723 (488)	0.23 (0.08)	.05 (.05) [1]
Number comparison	4732 (1243)	2220 (1069)	0.45 (0.11)	.15 (.09) [1]
Identical pictures	4846 (1410)	1479 (766)	0.30 (0.09)	.10 (.07) [1]
Prospective memory				
Red pencil				.41 (.44)
Background change				.67 (.30)
Token				.38 (.40)

Notes: Values are for the group mean (standard deviation). RT= reaction time; SD= standard deviation; CV= coefficient of variation (individual SD/individual mean RT); Mean-RT, SD, and CV were generated from correct trials only. [1]Accuracy was calculated as the proportion correct for the items completed in 90 *s*.

Table 3: Across task intercorrelations for measures of CV and mean RT

Task	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Operation decision	-	.55***	.58***	.71***	.49***	.60***	.21***	.20***	.18**	-.23***	.05	.171**
2. Reading decision	.29***	-	.64***	.45***	.31***	.46***	.10	.09	.07	-.07	-.15**	.09
3. Counting	.10	.41***	-	63***	.50***	.53***	.14*	.13*	.16**	-.06	-.11*	.19***
4. Digit letters	.22***	.10	.08	-	.63***	.73***	.24***	.23***	.22***	-.20***	-.01	.31**
5.Number comparison	.09	.18**	.00	.12*	-	.54***	.25***	.22***	.16**	-.08	-.05	.25***
6. Identical pictures	.13*	.04	.07	.06	<.01	-	.15**	.12*	.08	-.15**	-.09	.24***
7. Red pencil	.19***	.04	.03	.20***	.15**	.09	-					
8. Token	.17**	.16**	.07	.19***	.16**	.06	.51***	-				
9. Background change	.15**	.13*	.02	.20***	.08	.01	.30***	.38***	-			
10. Education	-.07	.07	-.09	-.15**	.05	-.00	-.15**	-.16**	-.15**	-		
11. Sex	.05	-.02	.08	.09	-.07	-.03	.12*	.07	.11*	-.31**	-	
12. Age	.05	.02	-.05	.16**	.10	.09	.24**	.30***	.29**	-.14**	-.02	-

Notes: For the RT measures, intercorrelations involving the CV are displayed below the diagonal while values above the diagonal are for mean RT; CV = coefficient of variation; RT = reaction time.
$^{*}p \leq .05$, $^{**}p \leq .01$, $^{***}p \leq .001$.

Table 4: Results for the analyses regressing the composite prospective memory error score on the variability measures

	Model 1			Model 2		
	ΔR^2	Beta (SE)	β	ΔR^2	Beta (SE)	β
	.045			.158		
Sex		0.14 (0.11)	.070		0.19 (0.11)	.092
Years in education		-0.06 (0.02)	-.179**		-0.04 (0.02)	-.122*
Age					0.08 (0.01)	.341**
Variability measures						
Operation decision	.041	2.36 (0.61)	.204***	.036	2.19 (0.57)	.190***
Reading decision	.025	1.90 (0.64)	.157**	.022	1.78 (0.60)	.147**
Counting	.001	0.46 (0.69)	.036	.003	0.73 (0.64)	.057
Digit letters	.050	2.96 (0.69)	.226***	.032	2.38 (0.66)	.182***
Number comparison	.034	1.75 (0.50)	.185***	.022	1.42 (0.48)	.150**
Identical pictures	.005	0.82 (0.62)	.071	.002	0.49 (0.58)	.043

Notes: Model 1 controlled for sex and years in education. Model 2 additionally controlled for age. Variability measured as the coefficient of variation (individual *SD*/individual mean RT).
$^{*}p \leq .05$, $^{**}p \leq .01$, $^{***}p \leq .001$.

Table 5: Results for the multinomial logistic analyses regressing errors on the variability measures run separately for each prospective memory task.

		Red pencil		Token		Background change	
	Error group	Beta (SE)	OR (% CI)	Beta (SE)	OR (% CI)	Beta (SE)	OR (% CI)
Operation decision	Low (ref)	-	-	-	-	-	-
	Medium	0.56 (0.20)	1.68 (1.13-2.49)**	0.41 (0.14)	1.50 (1.14-1.99)**	0.29 (0.15)	1.33 (0.99-1.76)
	High	0.35 (0.13)	1.42 (1.11-1.82)**	0.29 (0.14)	1.34 (1.02-1.76)*	0.37 (0.14)	1.44 (1.11-1.88)**
Reading decision	Low (ref)	-	-	-	-	-	-
	Medium	0.27 (0.19)	1.31 (0.89-1.91)	0.32 (0.15)	1.37 (1.04-1.83)*	0.09 (0.16)	1.09 (0.80-1.48)
	High	0.05 (0.13)	1.05 (0.82 -1.91)	0.40 (0.14)	1.49 (1.14-1.95)**	0.37 (0.13)	1.45 (1.12-1.87)**
Counting	Low (ref)	-	-	-	-	-	-
	Medium	0.01 (0.22)	1.01 (0.66-1.56)	0.09 (0.14)	1.09 (0.82-1.45)	0.09 (0.15)	1.10 (0.82-1.46)
	High	0.02 0.12)	1.02 (0.80-1.29)	0.13 0.14)	1.14 (0.88-1.49)	0.06 0.13)	1.06 (0.82-1.36)
Digit letters	Low (ref)	-	-	-	-	-	-
	Medium	0.87 (0.20)	2.39 (1.61-3.53)**	0.08 (0.17)	1.09 (0.78-1.51)	0.22 (0.19)	1.24 (0.86-1.79)
	High	0.46 (0.14)	1.58 (1.19-2.11)**	0.4 (0.14)	1.56 (1.18-2.06)**	0.52 (0.16)	1.69 (1.22-2.32)**
Number comparison	Low (ref)	-	-	-	-	-	-
	Medium	0.25 (0.21)	1.28 (0.86-1.92)	0.20 (0.15)	1.23 (0.92-1.64)	0.08 (0.15)	1.08 (0.80-1.45)
	High	0.30 (0.12)	1.35 (1.06-1.71)*	0.42 (0.14)	1.51 (1.16-1.98)**	0.20 (0.13)	1.22 (0.95-1.58)
Identical pictures	Low (ref)	-	-	-	-	-	-
	Medium	0.18 (0.21)	1.20 (0.79-1.82)	0.26 (0.14)	1.29 (0.99-1.69)	-0.23 (0.16)	0.79 (0.58-1.08)
	High	0.19 (0.12)	1.21 (0.95-1.52)	0.09 (0.14)	1.09 (0.83-1.44)	0.02 (0.27)	1.02 (0.80-1.30)
Sample size	**Low (ref)**		**208**		**196**		**127**
	Medium		**24**		**67**		**78**
	High		**124**		**73**		**131**

Note: SE=Standard error; OR=Odds ratio; CI=Confidence interval. Errors were catagorised as low (<33%: reference category), medium (50-75% errors) or high (100% errors) Variability measured as the coefficient of variation (individual *SD*/individual mean RT) converted to *z*-scores to ease interpretation of the ORs. All Models controlled for sex and years in education. $^{*}p \leq .05$, $^{**}p \leq .01$