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Remembering to Prepare: The Benefits (and Costs) of High Working Memory Capacity

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The dual mechanisms of control framework postulates that cognitive control can operate in 2 distinct modes: a "proactive" preparatory mode and a "reactive" wait-and-see mode. Importantly, the 2 modes are associated with both costs and benefits in cognitive performance. Here we explore this framework, in terms of its relationship with working memory capacity (WMC). We hypothesize that high-WMC individuals are more likely to utilize proactive control yielding not only benefits, but also specific costs to performance. Across 2 separate, large-sample experiments, healthy young adults performed different variants of the AX-Continuous Performance Test context processing task, a well-established probe of proactive and reactive cognitive control. In 2 experiments, WMC predicted both improvements and relative impairments in task performance in a manner that was consistent with usage of proactive control. These findings suggest that individuals differ in the degree to which they utilize proactive control based on WMC.

Keywords: working memory capacity, cognitive control, dual mechanisms of control, individual differences

Executive functions, such as cognitive control and working memory abilities, are central to many everyday activities (P. Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Cahn-Weiner, Boyle, & Malloy, 2002; Isquith, Gioia, & Espy, 2004). For example, working memory capacity (WMC) has been found to predict performance in a wide variety of cognitive domains including reasoning (Kyllonen & Christal, 1990), reading comprehension (Daneman & Carpenter, 1980), and fluid intelligence (Engle, Kane, & Tuholski, 1999). Similarly, cognitive control abilities have been shown to be related to theory of mind performance in preschool children (Carlson, Moses, & Claxton, 2004). In addition, a key component of cognitive control, interference resolution, has been shown to mediate the relation between WMC and fluid intelligence (G. Burgess, Gray, Conway, & Braver, 2011). However, there is still relatively little known about the subcomponents of cognitive control that can be explained by WMC. Specifically, the work presented here aims to investigate the extent to which WMC might modulate cognitive control in terms of the way that contextual information is strategically deployed in a proactive, or preparatory, manner.

The AX-Continuous Performance Test (AX-CPT) has previously been utilized to study cognitive control. In this task, contextual contingencies are built into the task such that specific cues indicate the appropriate response to be made to a subsequent stimulus. Specifically, the stimulus "X" is only a target when it follows an "A" cue ("AX" trial type). In contrast, an X stimulus following any non-A cue warrants a nontarget response (termed "BX," indicating a non-A–X stimulus sequence). Similarly, an A cue prior to any non-X stimulus warrants a nontarget response ("AY," indicating an A–non-X sequence). Lastly, there are trials in which neither A nor X are present, and these trials also warrant a nontarget response (i.e., "BY" trials, indicating a non-A–non-X sequence). In other words, it is only the context provided by the cue that determines whether or not a target response to the X is appropriate. Thus, the task probes the processing and utilization of contextual cues in terms of how they lead to expectancies and response biases to upcoming stimuli (see Braver et al., 2001, for an extended discussion of this task).

Previous work utilizing this paradigm has shown that there are two primary control strategies that one can adopt within the AX-CPT (Braver, 2012). A *proactive strategy* is characterized by preparing a response to the probe (X or Y) based on information gleaned from the cue (A or B). Utilization of a proactive strategy on this task will lead to high accuracy for AX and BX trials, but may lead to increased interference on AY trials (e.g., lower accuracy or slower RTs), given the increased difficultly in overriding the prepared target response. An alternative strategy has been termed *reactive control*. This strategy involves a sort of "wait-and-

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see" mentality; participants wait to prepare a response until the probe is presented (X or Y) and then think back to the context set up by the cue (A or B) to determine the correct response. Here, participants are expected to perform Y-probe trials relatively successfully, but may exhibit poorer performance on AX and BX trials because sometimes the cue context will be incorrectly (or slowly) retrieved.

A more familiar example may help solidify the main properties of the proactive versus reactive control distinction. Imagine that you are driving your vehicle at a high rate of speed when you notice that a car appears ready to pull out from a side street into your lane of traffic. In order to avoid an accident, you could engage in proactive control by preparing to swerve into the other lane based on the expectation that the car will in fact turn in front of you. Alternatively, you could just mentally note that the car is about to pull out without actually translating that into an avoidant maneuver. In this case, even if you have not prepared to swerve in advance, it may still be possible to use reactive control to switch lanes at the last second. However, it is likely that there is more of a chance of an accident in this latter case, as you would need to react very quickly to avoid hitting the turning car. Other variables may influence the likelihood of engaging in proactive or reactive control in this situation. For example, if you are driving a motorcycle, the consequences for not using predictive information from the driving environment could be more hazardous. In addition, you may have driven on this stretch of road previously and had an accident or near-accident in a similar situation. Accessing this previous event history may bias you to engage in proactive control mode to ensure that an error (an accident) does not occur (see Braver, 2012, for another outside-of-the-lab example of proactive and reactive control).

Healthy young adults with intact executive functioning generally exhibit a proactive control strategy in the AX-CPT (Braver, Cohen & Barch, 2007; Paxton, Barch, Storandt & Braver, 2006). Conversely, previous research has demonstrated that those with reduced executive functioning ability, such as children (Chatham, Frank & Munakata, 2009; Lorsbach & Reimer, 2008), older adults (Braver et al., 2001; Paxton et al., 2006), and people with schizophrenia (Barch, Carter, MacDonald, Braver, & Cohen, 2003; Dias, Butler, Hoptman & Javitt, 2011) generally exhibit a reactive strategy in response to this task.

In general, high WMC has been widely associated with other positive cognitive outcomes (cf. Unsworth & Engle, 2007, Table 4). However, there is some evidence that even within healthy young adults, individual differences in WMC may account for differences in the use of proactive and reactive control; these differences may not only lead to performance benefits, but also performance costs. For example, compared to low-WMC individuals, participants with high WMC (a) showed more forgetting of items from a "forget" list in a directed forgetting task (Delaney & Sahakyan, 2007), (b) were more likely to miss hearing their name in the unattended channel of a dichotic listening task (Conway, Cowan, & Bunting, 2001), (c) exhibited a significantly smaller facilitation effect on the Stroop task (Kane & Engle, 2003, Experiment 1), and (d) performed worse on a surprise memory test for the neutral word stimuli from a previously completed Stroop task (Shipstead & Broadway, 2013). Interestingly, even in school-age children, this pattern of costs associated with high WMC has been observed. With respect to math achievement, students with high WMC tend to rely on WM-intensive solution strategies. However, when these students also exhibit high levels of math anxiety, these strategies become less effective (Ramirez, Gunderson, Levine, & Beilock, 2013; see also Beilock, 2008, for theoretical grounding of this account). Taken together, these results are largely consistent with the idea that individual differences in WMC might predispose some participants to use the proactive mode and others the reactive control mode. For example, within the context of the Stroop task (Kane & Engle, 2003), if high-WMC individuals are actively using a proactive strategy and keeping the task instruction in mind in advance of each trial, this is expected to result in selectively slowed performance on congruent trials relative to low-WMC individuals who appear to not engage in such preparation and instead quickly read the word when it appears onscreen.

More germane to the current work, Redick and Engle (2011) administered the AX-CPT and found that young adults with low WMC made more AX and BX errors compared to high-WMC individuals. In addition, low-WMC participants were slower than high-WMC participants to respond on AX, BX, and BY trials. Importantly, high- and low-WMC participants did not differ in AY response times (RTs), indicating that high-WMC participants were disproportionately slowed by the unexpected nontarget stimulus (Redick & Engle, 2011). Additional work in this vein (Redick, 2014) tested a number of permutations of the traditional AX-CPT and found increased error rates (although no RT differences), specifically on AX and BX trials for low- versus high-WMC participants. These results support the interpretation that low-WMC individuals are less likely than high-WMC individuals to maintain the cue information across time, leading to an increased error rate when an X stimulus is presented (Redick, 2014).

The current research differs from, and extends Redick (2014) and Redick and Engle (2011) in several ways: (a) we manipulated the AX-CPT trial-type frequencies in a novel manner (see below for specific manipulations); (b) we utilized cue-based and probe-based signal detection indices of sensitivity and response bias; and (c) instead of using an extreme-groups approach (i.e., top 25% and bottom 25% of WMC), here we evaluate individual differences in WMC as a continuous variable (see Conway et al., 2005, for a discussion of the strengths and weaknesses of both approaches). The manipulation of trial-type frequencies is similar to the approach taken in a previous set of experiments investigating individual differences in WMC and their relation to Stroop interference (Kane & Engle, 2003). In addition, a new trial type is introduced in Experiment 2 to isolate preparatory processes. Specifically, the current investigation was aimed at investigating whether individuals with better cognitive control (as indexed by WMC) preferentially adopt a proactive strategy to respond quickly but accurately when presented with information that allows advance preparation. We predicted that such a strategy would reveal clear benefits in task performance on most trial types, but also relative costs on other trial types, demonstrating theoretical specificity (as opposed to a pattern of generally superior performance).

Experiment 1

On the AX-CPT, if a participant takes a *proactive* approach to the task, participants would prepare their response to the probe (X or non-X) based on the cue information (A or non-A). Under a proactive strategy, errors and/or slow RTs are predicted to be most pronounced for AY trials. Moreover, a strong target response bias is expected following an A cue. Conversely, participants engaging in a *reactive* strategy would be expected to make a greater number of errors and/or display the slowest RTs on BX trials, where the X probe sets up the condition for the participant to think back to the cue stimulus (and sometimes get it wrong). Previous research indicates that higher WMC is also associated with better accuracy on AX trials (Redick, 2014; Redick & Engle, 2011). This may also be due to the disadvantages of a reactive strategy adopted by low-WMC individuals, since a wait-and-see approach would lead to generally greater uncertainty when retrieving the appropriate context and response following presentation of an X probe. This form of context retrieval uncertainty should also be associated with a reduced ability to discriminate between AX and BX trials (i.e., in terms of signal detection measures). To summarize, a proactive strategy is predicted to improve AX and BX performance but impair AY performance, while a reactive strategy should yield the opposite performance pattern.

In the version of the AX-CPT used in Experiment 1, AX trials occur at a rate of ~40%, AY trials at a rate of ~10%, BX trials at rate of ~10%, and BY trials at a rate of ~40%. This trial type frequency differs from the traditional AX-CPT-70 (Braver et al., 2001; Redick, 2014; Redick & Engle, 2011) by decreasing AX trials by 30% and increasing BY frequency by 30%. The frequency manipulation presented here was meant to accentuate differences in performance related to WMC specifically on AY trials in order to more definitively distinguish between proactive and reactive control as it relates to WMC. This manipulation has beneficial consequences for understanding proactive and reactive control within the AX-CPT. First, the frequency of the A- and B-cue types is equated (50/50 here vs. 80/20 in the traditional version), allowing us to control potential sources of variance related to the novelty/infrequency of both the B cue and the context for a nontarget response. As suggested by Chiew and Braver (2013), in the traditional AX-CPT, B cues occur less frequently than A cues, and so subjects may differentially process A and B cues because of differences in novelty and not because of the expected response to the subsequent probe. Not only does the current version equate the overall frequency of A and B cues, but the manipulation served to equate the cue validities; A cues predict one type of probe on 80% of the trials (X probe), and B cues predict one type of probe on 80% of the trials (Y probe).

A second advantage of the new design is that the frequency manipulation equates the overall likelihood of an X probe and non-X probe (i.e., 50% of trials in this version of the AX-CPT contain an X probe and the other 50% of trials contain a Y probe), placing relatively greater emphasis on using cue information to guide performance. In the traditional AX-CPT-70, one fairly effective strategy would be to make "target" responses to all X probes, regardless of cue information, given that AX trials are so much more likely than BX trials. In this way, individuals engaged in this strategy could ignore the cue information and still exhibit high levels of overall accuracy (except on the rare BX trials). The frequency manipulations employed here served to control for (minimize) these alternative explanations/strategies based on stimulus frequencies while retaining the critical features of the AX-CPT. Specifically, just like the traditional AX-CPT-70, in this design, the A cue creates a strong expectancy of an upcoming target response that is violated on AY trials, whereas the B cue is perfectly predictive of a subsequent nontarget response, and X probes are only rarely associated with a nontarget response.

To further examine performance on the critical AX, AY, and BX trials, we created two signal detection performance indices. First, the *A-cue index* was calculated by comparing AX hit rates and AY false alarm rates and was intended to capture the degree to which individuals differentially prepared target responses based on the A cue. If an individual is using proactive control based on the A cue, that individual should exhibit higher AX hit rates and higher AY false alarm rates compared to an individual using reactive control. This would translate into individuals using proactive control showing a target response bias on A-cue trials. Second, the *X-probe index* was calculated by comparing AX hit rates and BX false alarm rates and was intended to capture the degree to which individuals correctly incorporated the appropriate context when responding to X probes. If an individual is using proactive control, that individual should exhibit somewhat higher AX hit rates and especially lower BX false alarm rates compared to an individual using reactive control. This would translate into individuals using reactive control showing decreased sensitivity (d') and a response bias toward target responses in the presence of X probes compared to individuals using proactive control.[1]

The hypothesized pattern of findings would provide further evidence that high-WMC participants adopt a more proactive approach than those with lower estimates of WMC. Importantly, prior work (Redick, 2014; Redick & Engle, 2011) generally supported the proposed findings with respect to individuals with low WMC showing a disadvantage on AX and BX trials relative to individuals with high WMC (although Redick, 2014, showed no RT differences between high- and low-WMC individuals). However, these investigations (Redick, 2014; Redick & Engle, 2011) failed to provide strong confirmation of the hypothesized disadvantage on AY trials specifically for individuals with high WMC. Thus, the key goal of the current experiment was to examine WMC differences in a large sample of healthy young adults, using the trial type frequency manipulations as well as specific signal detection indices of performance to investigate proactive and reactive control.

Method

Participants. One hundred five participants took part in this experiment. Participants were an average of 21.33 (5.30 *SD*) years of age and 26.61% male (demographic data missing for 4 participants). Seven additional participants completed the study, but two participants' data were excluded from analysis due to overall low accuracy on the AX-CPT[2] and five participants' data were not collected in full due to computer error. Participants were recruited

[1] Previous AX-CPT studies have examined d'-*context* (e.g., Cohen, Barch, Carter & Servan-Schreiber, 1999), which is equivalent to the X-probe index of d'. In addition, while this article was under review, Stawarczyk, Majerus, Catale, and D'Argembeau (2014) reported 2 d' indices similar to those used here. However, we are not aware of previous AX-CPT work examining response bias measures of signal detection indices similar to what we are proposing here.

[2] The criterion for inclusion in the sample was for each subject to provide data for each of eight cells (accuracy and RTs for each of the four trial types). Particularly in the case of trial types with a small number of trials, participants sometimes did not produce any accurate trials from which to pull RTs. Thus, these participants were excluded from the sample.

from Temple University's psychology department subject pool and were compensated with course credit for their participation. All procedures and materials were reviewed and approved by Temple University's Institutional Review board.

Materials and procedure. Participants completed three tasks: two WMC tasks (see Figure 1) and the AX-CPT (see Figure 2). Order of task presentation was randomized across participants.

WMC. WMC was measured using two automated span tasks: operation and symmetry span (Redick et al., 2012; Unsworth, Heitz, Schrock, & Engle, 2005). Complex working memory span tasks like operation and symmetry span involve both a processing component during which decisions about one type of stimuli are made, as well as a storage component, during which another stimulus is encoded for later recall. After alternating processing and storage a number of times, storage stimuli are recalled in order of presentation.

Specifically, operation span involves solving simple math problems (processing) alternating with the presentation of letters to be remembered (storage). Once the span for a given trial is reached, participants are asked to recall the letter stimuli in the order that they were seen. Set sizes ranged from three to seven, with three exposures to each set size, for a total of 75 math problems and 75 letters (Unsworth et al., 2005). Following a similar design, symmetry span involves making symmetry decisions about black-and-white grids (processing) and remembering spatial locations in a 16-square matrix, with the to-be-remembered location colored in red (storage). Again, when the span is reached for a given trial, participants must recall the spatial locations in the order that they were seen. Set sizes ranged from two to five, with three exposures to each set size, resulting in a total of 42 symmetry judgments and 42 to-be-remembered locations (Unsworth, Redick, Heitz, Broadway & Engle, 2009). These two tasks have previously been used to estimate WMC in association with AX-CPT performance (Redick & Engle, 2011).

AX-CPT-40. The AX-CPT is a widely used task thought to tap cognitive control processes and context processing abilities (Braver et al., 2001). Participants must respond to every stimulus. Participants are instructed to make a nontarget response to all stimuli unless the letter X follows presentation of the letter A. The AX combination requires a target response.

The AX-CPT contains four different trial types: AX, AY, BX, and BY. Participants responded to both cue and probe stimuli. Only when A was followed by the presence of an X (i.e., an AX trial) were participants instructed to press the 1 key to indicate that the target sequence had been detected. For all other stimuli, participants were instructed to respond by pressing the 2 key.[3] AY trials consist of seeing an A cue followed by a non-X probe. BX trials present a non-A cue, but a subsequent X probe. Last, BY trials present a combination of stimuli that were never associated with a target response.

All cue letters were presented in white font on a black background and all probe letters were presented in blue font on a black background. Each cue was displayed for 1,000 ms and each probe displayed for 500 ms with a 5,000-ms interstimulus interval (ISI) and a 1,000 ms intertrial interval. A 5,000-ms ISI was chosen for consistency with the long ISIs utilized in Braver et al. (2005) and Redick and Engle (2011). Braver et al. (2001) used an ISI of 4,900 ms, and Redick (2014) used an ISI of 4,500 ms. During both the ISI and the intertribal interval fixation crosses were displayed for the duration. Participants were continuously alerted to their performance via an auditory cue (i.e., a "ding" for a correct answer, a "buzz" for an incorrect answer, and a "knock" sound if they failed to respond within a 1,500-ms window, which is the same response deadline as used in Braver, Satpute, Rush, Racine, & Barch, 2005).

In the particular version of the AX-CPT used in Experiment 1, 144 total trials were performed, with the following trial-type frequencies: AX = 58 trials (40.3%), BX = 14 trials (9.7%), AY = 14 trials (9.7%), BY = 58 trials (40.3%). Trial-type frequencies and ISI were modified from the AX-CPT paradigm available for download via the Cognitive Neuroscience Test Reliability and Clinical applications for Schizophrenia Consortium (http://cntracs.ucdavis.edu/task).

Statistical analyses. Participants' WMC was estimated by combining operation and symmetry span performance. Participants' partial scores (i.e., a scoring system that gives credit for correctly recalling to-be-remembered items in the correct position regardless of performance on the whole trial) were combined and then divided by the maximum possible partial score to create a proportion. Similar results to those reported below were obtained by using the more stringent absolute scoring as a predictor (i.e., only giving credit for correctly recalled items in the correct position for the entire trial) and for combining scores from the WM tasks differently (i.e., creating proportions for each task first and averaging those proportions second). Combined partial scores are reported based on previous research suggesting that partial scoring may be more sensitive to individual differences (Redick et al., 2012).

To analyze the relationship between WMC and AX-CPT performance, we used three approaches. First, hierarchical regression was employed, with performance on BY trials entered as the first step and then WMC as the second step. This method was employed for both accuracy (BY accuracy entered on first step) and RT analyses (BY RT entered on first step). Importantly, any nonspecific effects of processing speed (RT) or overall error rates (accuracy) are taken into account in the first step of the regression in order to determine if any additional variance is specifically explained by WMC (see Braver et al., 2001, for the same statistical procedure). RTs were analyzed on correct trials only.

One drawback to the hierarchical regression method is that performances on all trial types are not considered simultaneously, which prevents us from interpreting WMC × Trial Type interactions. Because we wanted to retain data collected from subjects across the full range of WMC scores, we conducted ANCOVAs with trial type as a within-subjects factor and WMC as a continuous covariate (see Hutchison, 2007, and Poole & Kane, 2009, for similar approaches). For visual presentation of the ANCOVA results, we used a tertile split to create low-, medium-, and high-WMC groups to facilitate comprehension.

Finally, A-cue and X-probe signal detection indices of sensitivity (d') and bias (C; Stanislaw & Todorov, 1999) were calculated to specifically examine responses based on A cues (AX and AY trials) and X probes (AX and BX), respectively. Hit and false alarm rates equal to 0 or 1 were adjusted by .01.

[3] Participants were not given strict finger–key mapping instructions on the AX-CPT in this or the following experiment.

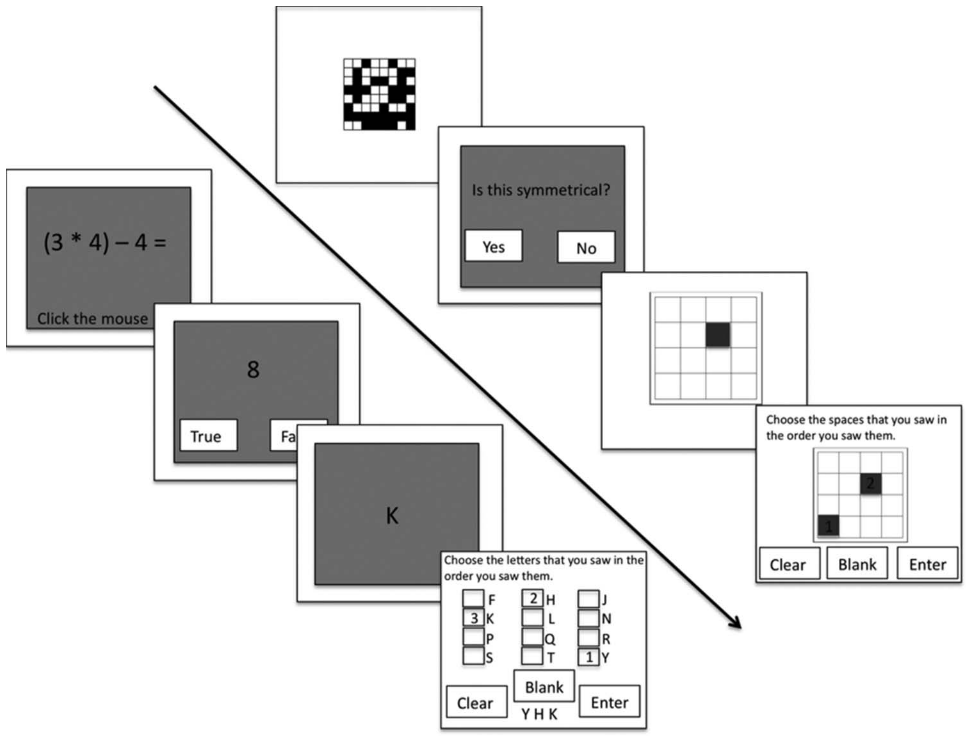

Figure 1. Illustration of the complex working memory span tasks (operation and symmetry span). Data from these two tasks were combined to create a composite working memory capacity variable.

Results

Hierarchical regressions. Scores for the operation span (M = 54.98, SD = 12.26) and symmetry span (M = 25.97, SD = 7.90) tasks were found to be similar to normative data reported in Redick et al. (2012). See Appendix for correlations between WMC and AX-CPT trial types for both RTs and accuracy. See Table 1 for descriptive statistics, Cronbach's alpha, and R^2 change values for the AX-CPT. Beginning with AX trials, participants with higher WMC exhibited higher accuracy than individuals with low WMC after controlling for BY accuracy, $\beta = .23$, $t(102) = 2.91$, $p = .004$. However, RTs on AX trials did not differ as a function of WMC after controlling for BY RTs, $\beta = .00$, $t(102) = -0.01$, $p = .996$.

With respect to BX trials, accuracy increased as WMC increased after controlling for BY accuracy, $\beta = .33$, $t(102) = 3.55$, $p = .001$, but for RTs, WMC added no additional predictive validity above and beyond BY RTs, $\beta = .07$, $t(102) = 1.19$, $p = .238$.

Performance on AY trials revealed a pattern of performance consistent with our prediction that high-WMC individuals adopted a more proactive strategy than low-WMC individuals. While there was no difference in AY accuracy as a function of WMC after controlling for BY performance, $\beta = -.05$, $t(102) = -0.54$, $p = .594$, critically, RTs on AY trials were *slower* for participants with higher WMC after controlling for RTs on BY trials, $\beta = .24$, $t(102) = 3.00$, $p = .003$ (see Figure 3).

ANCOVA. Inspection of Figure 4[4] shows that low-WMC individuals were clearly less accurate than high-WMC individuals on AX and BX trials and were slower to correctly respond than high-WMC individuals on AX, BX, and BY trials. For the accuracy ANCOVA, significant main effects of trial type, $F(3, 309) = 15.15$, $p < .001$, and WMC, $F(1, 103) = 26.41$, $p < .001$, were

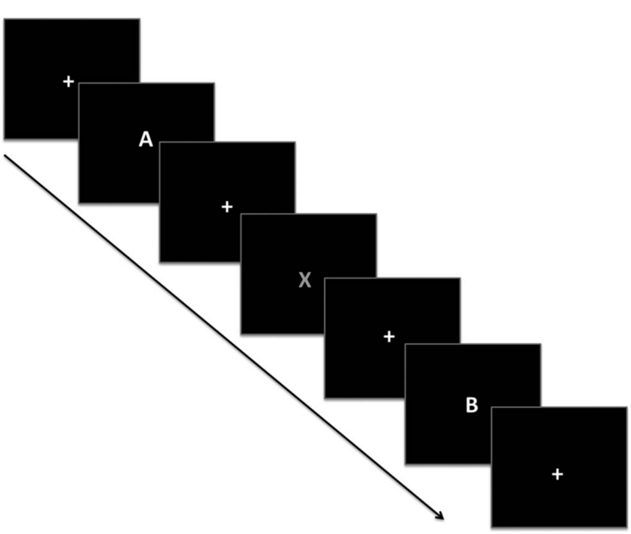

Figure 2. Illustration of the AX-Continuous Performance Test (AX trial). Task format and timing was the same throughout all three experiments.

[4] As a reminder, Figure 4 is for illustrative purposes only. The reported analyses consider the full range of WMC.

Table 1
Means, Standard Deviations, R^2 Change Values, and Cronbach's α for Experiment 1

	AX	AY	BX	BY
Accuracy				
Mean (*SD*)	.86 (.13)	.90 (.10)	.88 (.16)	.98 (.04)
Cronbach's α	.897	.371	.770	.790
R^2 change	.047**	.002	.097**	—
Reaction time				
Mean (*SD*)	479.33 (73.03)	553.91 (58.02)	480.94 (105.21)	439.76 (62.41)
Split-half	.72	.54	.57	.80
R^2 change	<.001	.052**	.005	—

Note. Accuracy data represent probe accuracy, presented as proportions. Reaction time (RT) data represents accurate RTs for probes. R^2 change values represent variance accounted for by working memory capacity after entering BY performance (accuracy or RT) into the model.
** $p < .01$. Cronbach's α values are reported for accuracy; split-half reliabilities are reported for RTs on correct trials only.

qualified by the critical WMC × Trial Type interaction, $F(3, 309) = 9.19$, $p < .001$. For the correct RT ANCOVA, the main effect of trial type was not significant, $F(3, 309) = 0.80$, $p = .495$, whereas the main effect of WMC, $F(3, 309) = 6.55$, $p = .012$, and WMC × Trial Type interaction, $F(3, 309) = 5.45$, $p < .001$, were significant.

Signal detection. In order to more fully characterize the relation between strategic approach and WMC, A-cue and X-probe signal detection indices were calculated. Comparison of A-based trials (AX vs. AY trials) revealed that increases in WMC were related to a more liberal A-cue response bias, $R^2 = .08$, $F(1, 103) = 8.35$, $p = .005$; $\beta = -.27$. This liberal A-cue bias was

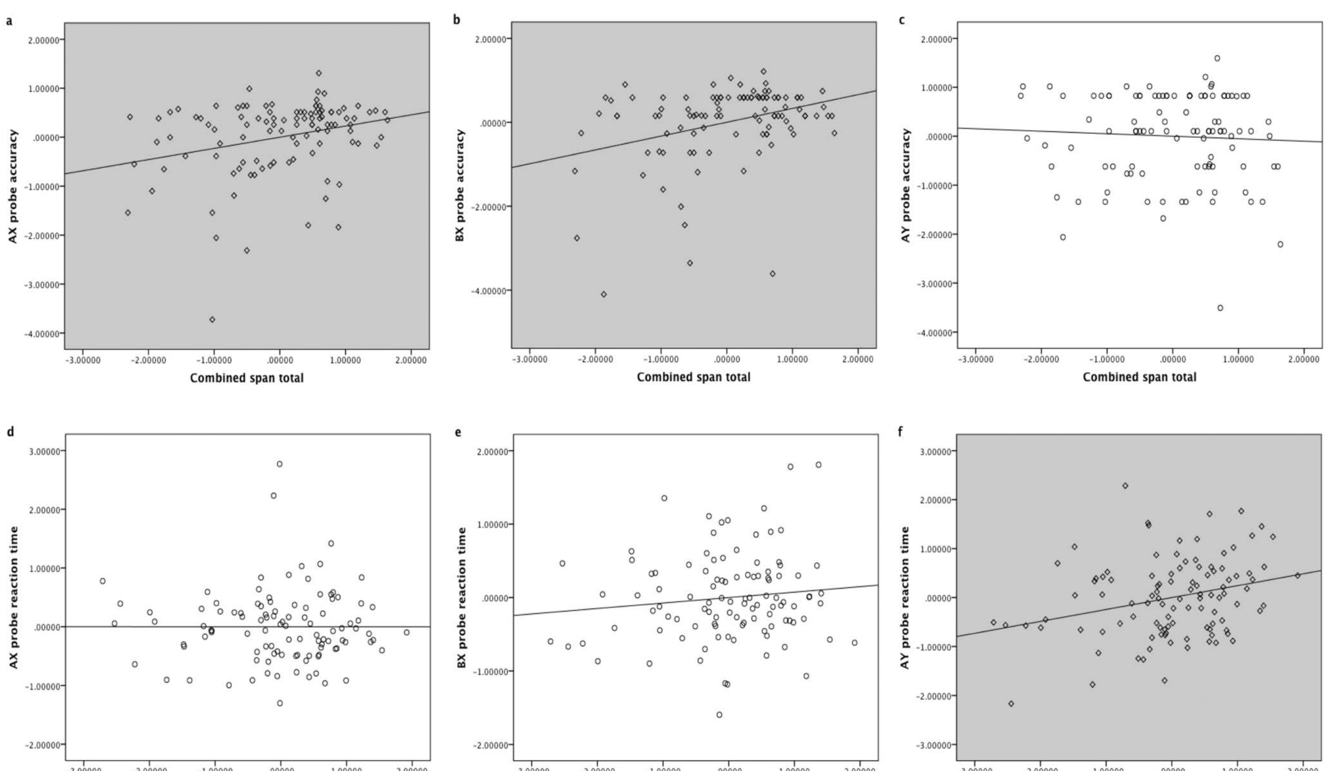

Figure 3. Experiment 1 data. All data represent *z* scores. Plots show the relation between AX-Continuous Performance Test constructs of interest and combined working memory capacity (WMC) estimates partialing out the variance associated with BY performance. Charts with gray backgrounds and diamond-shaped markers represent a significantly more variance accounted for by WMC above and beyond BY performance, whereas charts with white background and circle markers represent a nonsignificant portion of the variance accounted for by WMC above and beyond performance on BY trials.

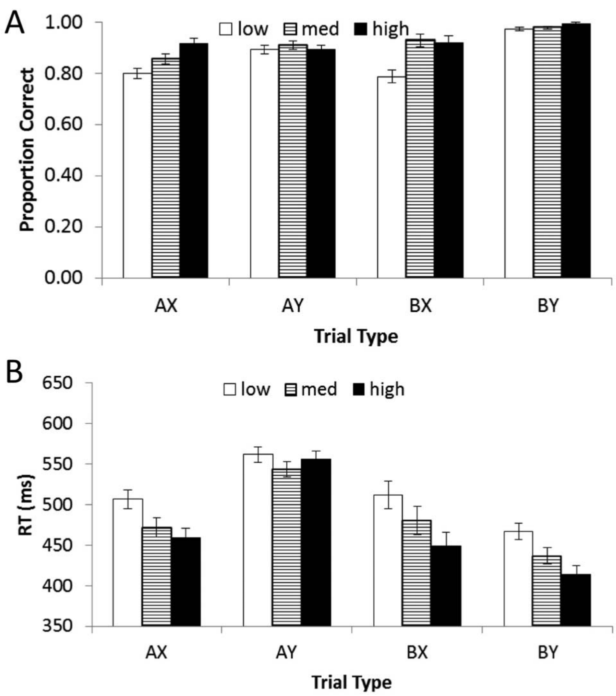

Figure 4. Experiment 1 data. AX-Continuous Performance Test performance (Panel A: accuracy; Panel B: mean reaction times [RTs]) as a function of working memory capacity group and trial type. Error bars reflect ±1 standard error of the mean.

coupled with increased sensitivity in the presence of an A cue for individuals with higher working memory capacity, $R^2 = .07$, $F(1, 103) = 7.82$, $p = .006$; $\beta = .27$. In short, individuals with higher working memory span exhibited a more liberal response bias on A-cue trials but were still able to disentangle target from nontarget contexts upon presentation of the probe (X or Y) and therefore did not suffer the overt "cost" of making an error by adopting a more liberal response bias in the presence of the A cue. Investigation of signal detection indices for X-based probes revealed that increases in WMC were related to increases in sensitivity, $R^2 = .22$, $F(1, 103) = 28.77$, $p < .001$; $\beta = .47$, but no change in X-probe response bias as a function of working memory span, $R^2 = .01$, $F(1, 103) = 1.25$, $p = .266$; $\beta = .11$.

Discussion

These data provide strong evidence for the proactive/high WMC, reactive/low WMC distinction. Importantly, manipulation of the trial type frequencies within the AX-CPT provided evidence that high-WMC individuals are utilizing a proactive, preparatory cue-based strategy given the longer latencies in particular on AY trials. This cost of higher WMC is similar to comparisons of young adults and older adults on the AX-CPT (e.g., Braver et al., 2001) where young adults are slowed relative to older adults on AY trials specifically. An additional piece of evidence speaking toward specific costs associated with high WMC comes from the signal detection analyses, where individuals with high WMC were found to exhibit a more liberal response bias in response to the A cue. This sort of bias does have a relative disadvantage on AY trials, where the tendency to make a target response can make performance more error prone or slower when a Y probe is presented. The selective AY impairment is exactly what is observed in individuals with high WMC, suggesting that the liberal response bias following A cues may be predisposing these individuals toward slower AY performance.

Findings from Experiment 1 indicate that high-WMC participants are proactively preparing a target response based on the A cue but must cancel that motor program and instead quickly execute a nontarget response on Y-based trials. Note that this is corroborated by the finding of increased sensitivity on A-cue trials for individuals with higher working memory capacities; although the response criterion adopted on A-cue trials by individuals with high-WMC was more liberal, increased sensitivity allowed them to avoid being "hurt" by this bias in the form of an overt error. On the other hand, low-WMC individuals do not appear to use the cue–probe interval to plan a response; thus, low-WMC participants are quicker to simply execute a nontarget response when the Y probe appears onscreen. Furthermore, the association between the lower end of the WMC spectrum and increased error rates on AX and BX trials lend support to the idea that individuals with lower WMC are engaging in a primarily probe-based reactive strategy.

There are, however, alternative explanations that might be offered for the pattern of results observed on the AX and BX trials. One of the most obvious and least taxing ways of approaching the AX-CPT might involve using information gleaned about the *frequency* of cue–probe pairings to guide probe-based responses. Experiment 2 was designed specifically to address this alternative hypothesis.

Experiment 2

The purpose of this experiment was to examine the possibility that the apparent association between low WMC and a reactive response mode might actually be driven by low-WMC participants' tendency to choose responses based on first-order frequencies rather than exhibiting a truly reactive profile. In other words, it could be the case that low-WMC participants are making "target" responses to BX trials simply because that is the response most frequently given when an X probe is presented (i.e., in Experiment 1, a target response should be made on 80% of X-probe trials; in other words, four out of five X-probe trials are AX targets). If so, this pattern of response is not indicative of a reactive strategy; rather it indicates utilization of a strategy based purely on statistical learning. In the version of the AX-CPT task used in Experiment 2, AX trials occurred at a rate of ~40%, BX, AY and BY trials occurred at a rate of ~10%. In addition, a novel trial type, CX, occurred ~30% of the time, and required a unique third type of response.

Importantly, C cues are only associated with one trial type, such that the C cue is 100% predictive of the X probe. That is, whenever the letter C appears, 100% of the time the next letter is X, and will always have a distinct button response mapped to it. Consequently, X probes are not strongly associated with a target response with this set of trial type frequencies (i.e., target responses should be made on only 50% of X-probe trials; 40% AX targets vs. 10% BX, and 30% CX nontargets). In contrast, this manipulation still maintains the predictive validity of contextual cues (i.e., A cues predict the correct response 80% of the time, while B and C cues predict the correct response 100% of the time).

As a result of this trial type manipulation, two divergent predictions can be made. If errors in low-WMC individuals on nontarget X-based trials are purely driven by the presence or absence of a dominant response tendency to the X probe, then in the current version the relationship between WMC and BX (and CX) performance should be eliminated. On the other hand, if CX and BX errors are selectively attributed to proactive control failures, then these errors should still be greater in low-WMC individuals compared to high-WMC participants.

Method

Participants. One hundred six participants participated in this experiment. Participants were an average of 20.56 (2.27 *SD*) years of age, and 55.14% were male (demographic data missing for six participants). Recruitment and compensation procedures were the same as Experiment 1. Three additional participants completed the study, but two subjects' data were excluded due to low overall accuracy on the AX-CPT and one subjects' data was not collected in full due to computer error.

Materials. WMC was measured using operation and symmetry span scores, as described above in Experiment 1. In Experiment 2, 144 total trials of the AX-CPT were again performed, with the following trial-type frequencies: AX = 58 trials (40.3%), BX = 15 trials (10.4%), AY = 14 trials (9.7%), BY = 14 trials (9.7%), and CX = 43 trials (29.9%). Again, participants responded to both cue and probe stimuli. Here, participants were instructed to press the 1 key when an AX trial appeared and the 3 key when a CX trial was presented; all other trial types warranted a response of 2. All other properties of the program are the same as Experiment 1. Importantly, AX, AY, and BX trial rates did not differ between Experiments 1 and 2.

Statistical analyses. First, as in Experiment 1, BY trial performance was entered into the hierarchical regression for all analyses except for the analysis regarding CX RTs (see Footnote 5). Next, WMC was entered as a predictor. In addition, ANCOVA and signal detection measures were again calculated and analyzed as in Experiment 1.

Results

Hierarchical regressions. Again, scores for the operation span ($M = 52.19$, $SD = 16.46$) and symmetry span ($M = 26.51$, $SD = 8.20$) tasks were found to be similar to normative scores reported previously (Redick et al., 2012). See Appendix for correlations between WMC and AX-CPT trial types (accuracy and RTs). Table 2 displays descriptive statistics, Cronbach's alpha, and R^2 change values for Experiment 2. Confirming our Experiment 1 findings in AX trials, participants with higher WMC exhibited better AX accuracy after controlling for BY performance, $\beta = .32$, $t(103) = 3.85$, $p < .001$ (see Figure 5). Again, as in Experiment 1, AX RTs did not differ as a function of WMC after controlling for BY RTs, $\beta = .13$, $t(103) = 1.65$, $p = .101$.

With respect to BX trials, accuracy again increased in step with increases in WMC after controlling for BY accuracy, $\beta = .15$, $t(103) = 2.07$, $p = .041$. WMC added no additional predictive validity for BX RTs after controlling for BY RTs, $\beta = .01$, $t(103) = 0.12$, $p = .906$.

AY trial performance also followed the pattern of results from Experiment 1. Again, there was no relationship with AY accuracy as a function of WMC after controlling for BY performance, $\beta = -.02$, $t(103) = -0.20$, $p = .844$. The RT results on AY trials are consistent with Experiment 1 findings (that is to say, higher WMC is associated with longer AY response latencies), although in this design the effect only reached trend levels, $\beta = .14$, $t(103) = 1.70$, $p = .092$.

CX trials were analyzed to adjudicate between two possible explanations for the data presented in Experiment 1. Namely, the question remained whether low-WMC individuals were truly engaging in a reactive strategy or if they were simply responding to statistical regularities present in the task. For the former, WMC should be positively correlated with CX performance; for the latter, a negative (or nonsignificant) correlation should be present. Increased accuracy on CX trials was associated with higher WMC estimates after controlling for BY

Table 2
Means, Standard Deviations, R^2 Change Values, and Cronbach's α for Experiment 2

	AX	AY	BX	BY	CX
Accuracy					
Mean (*SD*)	.85 (.14)	.84 (.14)	.85 (.19)	.97 (.07)	.88 (.16)
Cronbach's α	.897	.571	.829	.621	.924
R^2 change	.095**	<.001	.021*	—	.060
Reaction time					
Mean (*SD*)	485.08 (66.40)	592.41 (64.24)	470.95 (110.43)	483.46 (98.47)	454.91 (60.66)
Split-half	.69	.67	.67[b]	.70	.69[a]
R^2 change	.015	.017^	<.001	—	<.001

Note. Accuracy data represent probe accuracy, presented as proportions. Reaction time (RT) data represents accurate RTs for probes. R^2 change values represent variance accounted for by working memory capacity after entering BY performance (accuracy or RT) into the model, except for CX RTs, where suppression among the variables was evident when BY RTs were controlled for in the first step of the model. Cronbach's α values are reported for accuracy; split-half reliabilities are reported for RTs on correct trials only.
[a] CX split half represents 105 (*n* – 1; subjects could not be included in calculation of split-half reliability because of high error rate). [b] BX split-half represents 104 subjects (*n* – 2).
^ $p < .10$. * $p < .05$. ** $p < .01$.

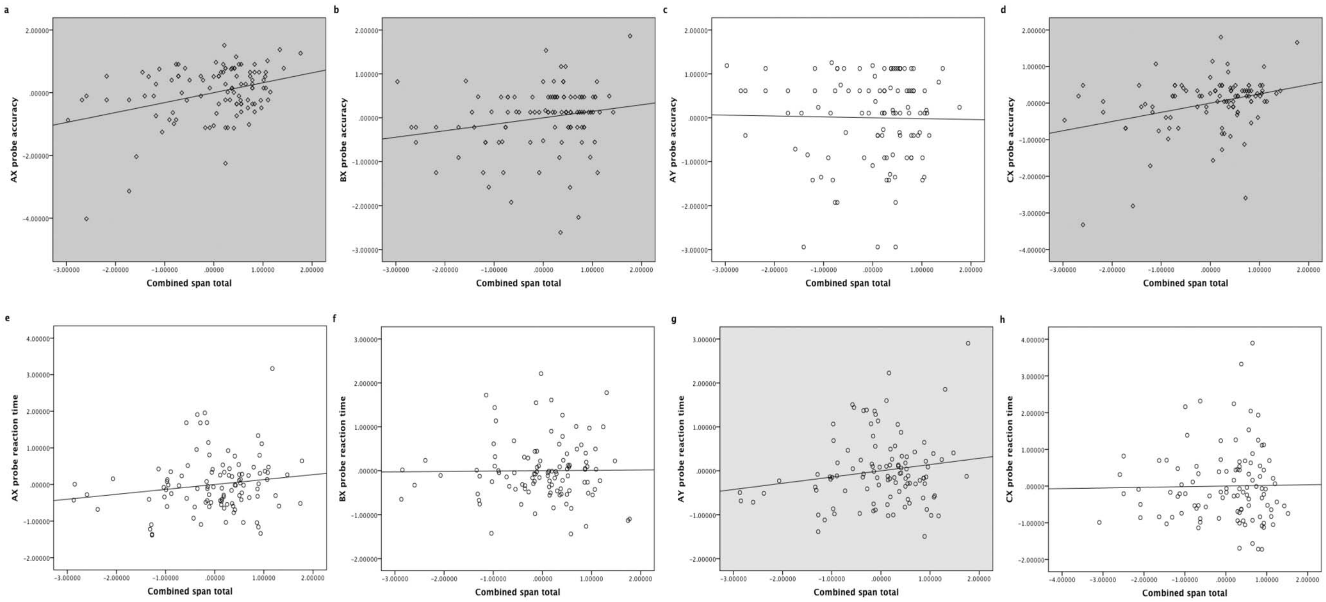

Figure 5. Experiment 2 data. All data represent *z* scores. Plots show the relation between AX-Continuous Performance Test constructs of interest and combined working memory capacity (WMC) estimates partialing out the variance associated with BY performance (save Panel h, where suppression among variables was observed when partialing out BY performance). Charts with dark gray backgrounds and diamond-shaped markers represent a significantly more variance accounted for by WMC, whereas charts with white background and circle markers represent a nonsignificant portion of the variance accounted for by WMC. The chart representing the marginally significant finding between WMC and AY response times has a light gray background and circle markers.

accuracy, $\beta = .25$, $t(103) = 3.50$, $p = .001$. There was no relationship identified between WMC and CX RTs, $\beta = .02$, $t(104) = .18$, $p = .858$.[5]

ANCOVA. Inspection of Figure 6 shows that low-WMC individuals were clearly less accurate than high-WMC individuals on AX, BX, and CX trials, and were slower to correctly respond than high-WMC individuals on AX, BX, and BY trials. For the accuracy ANCOVA, significant main effects of trial type, $F(4, 416) = 9.45$, $p < .001$, and WMC, $F(1, 104) = 16.09$, $p < .001$, were qualified by the critical WMC x trial type interaction, $F(4, 416) = 6.48$, $p < .001$. For the correct RT ANCOVA, significant main effects of trial type, $F(4, 416) = 16.74$, $p < .001$, and WMC, $F(1, 104) = 8.86$, $p = .004$, were qualified by a significant WMC $\times$ Trial Type interaction, $F(4, 416) = 12.53$, $p < .001$.

Signal detection. The utilization of a more liberal response bias on A-cue trials was again found to be related to increases in WMC, $R^2 = .08$, $F(1, 104) = 9.02$, $p = .003$; $\beta = -.28$. Similar to the pattern described in Experiment 1, this more liberal A-cue response bias was coupled with increased sensitivity on A-cue trials for individuals with higher working memory spans, $R^2 = .04$, $F(1, 104) = 4.02$, $p = .048$; $\beta = .19$. Turning to the X-probe indices, increases in WMC were associated with increases in sensitivity (d') to the probe, $R^2 = .15$, $F(1, 104) = 18.66$, $p < .001$; $\beta = .39$, but no association between working memory span and response bias on X-probe trials was detected, $R^2 = .01$, $F(1, 104) = 1.19$, $p = .28$; $\beta = .11$. These findings are consistent with signal detection analyses reported in Experiment 1.

Discussion

The results presented in Experiment 2 are highly consistent with the Experiment 1 findings. Namely, high-WMC participants exhibited accuracy advantages for AX and BX trials. These advantages in high-WMC participants were coupled with disadvantages in terms of a trend toward slower RTs on AY trials. Signal detection findings replicated the pattern of data presented in Experiment 1; higher WMC was associated with on X- increased sensitivity on X-probe trials and both a more liberal response bias and increased sensitivity on A-cue trials.

One goal of Experiment 2 was to determine whether low-WMC individuals' AX-CPT performance was more accurately characterized as being driven primarily by reactive control or stimulus-response frequencies. If BX errors in low-WMC individuals are driven primarily by a target-response bias, we would expect that this version of the AX-CPT, with the addition of the CX trial type to balance out the frequency of X probes that do not receive a target response, should eliminate the low-WMC performance decrement on BX trials. Likewise, a strategy based on stimulus-response frequencies should result in improved or equivalent performance on CX trials for low-WMC individuals. Instead, in Experiment 2, lower WMC was still associated with both lower BX and CX accuracy. Thus, we interpret these findings as offering additional support for the reactive framework as a good description

[5] Controlling for BY performance in the first step of the regression resulted in suppression among the variables. Therefore, this analysis was conducted and reported without first controlling for BY RTs.

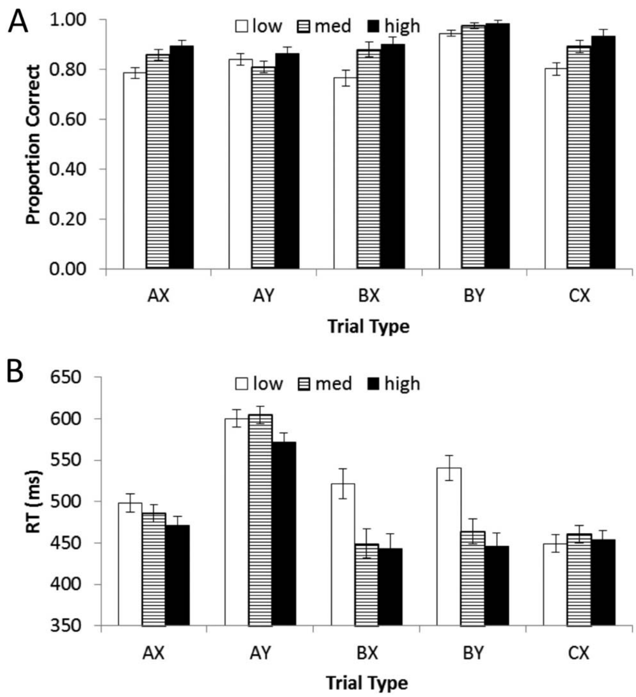

Figure 6. Experiment 2 data. AX-Continuous Performance Test performance (Panel A: accuracy; Panel B: mean reaction times [RTs]) as a function of working memory capacity group and trial type. Error bars reflect ±1 standard error of the mean.

of the performance profiles exhibited by individuals with low WMC.

Nonetheless, it is possible that low-WMC individuals are exhibiting a variable approach to the AX-CPT, which sometimes includes performance consistent with the reactive mode. It is plausible that participants with low WMC can be proactive for a certain amount of time, but have difficulty sustaining that approach as long as high-WMC individuals do. Individuals with low WMC may experience more lapses of attention (Unsworth, Redick, Lakey, & Young, 2010) that lead to the use of the reactive mode on at least some trials, resulting in higher error rates than high-WMC individuals.

General Discussion

Together, these data build upon evidence presented in Redick (2014) and Redick and Engle (2011) relating WMC and strategy choice on the AX-CPT. These data extend the findings presented in Redick (2014) in two important ways: examination of WMC in a continuous, rather than extreme-groups, fashion and the strong evidence of high WMC being related to a proactive approach (i.e., slowed RTs on AY trials and a more liberal target response bias specifically associated with higher WMC). That is, although the accuracy data in Redick (2014) were consistent with high-WMC individuals more often using proactive control, the data were not conclusive in demonstrating costs as well as benefits of this strategy.

Experiment 1 revealed convincing evidence that high-WMC individuals are more inclined to adopt a proactive approach to the AX-CPT. This interpretation was supported by both the longer latencies for AY trials in high-WMC participants, as well as the signal detection data (high-WMC participants exhibited a more liberal A-based response bias and were more sensitive to both the probe context in the presence of an A and the cue context in the presence of an X compared to low-WMC participants).

In Experiment 2, we introduced a fifth trial type (CX) to determine if low-WMC participants performed in a manner consistent with reactive control to X probes, to eliminate a possible alternative explanation for the AX and BX results in Experiment 1. Indeed, we provided evidence that low-WMC individuals do exhibit behavioral markers of a reactive response style. Further, the positive association between AX accuracy and WMC observed in both versions of the AX-CPT administered here, in addition to the same relationship observed in Redick (2014) and Redick and Engle (2011), speaks to the relatively better fit of the reactive profile to participants with lower WMC than the frequency-matching hypothesis. That is, AX error commission indicates the participant has not chosen the prepotent or more-frequent target response, and instead selected the competing nontarget response, inconsistent with a response tendency influenced solely by overall response probabilities. However, low-WMC individuals may be more difficult to characterize than high-WMC individuals in terms of a dichotomous, either/or proactive-reactive framework.

Similarly, there is evidence, particularly stemming from B-cue trials, that high-WMC individuals exhibit some degree of reactivity. If high-WMC participants always prepared a nontarget response based on the presence of the B cue, they should not only be more accurate on BX trials but also respond as quickly as they do for BY trials. Instead, the null finding for the regression analyses on BX RTs suggest that all participants benefitted equally from the presence of the Y probe on BY regardless of capacity. Thus, high-WMC individuals may not have been able to wholly avoid being "captured" by the X probe, even on B-based trials.

Importantly, the signal detection measures across two experiments revealed striking consistency. In general, higher WMC was associated with both an increased sensitivity to both the relevant dimension of the A cue as well as the X probe. In addition, higher WMC was associated with a more liberal target response bias *only* when an A cue was present. Together these data provide strong evidence that across a number of different iterations of the trial types within the AX-CPT paradigm, individuals with high WMC approach the task proactively, whereas individuals with lower WMC tend to approach the task in a more reactive mode.

There are important implications for these results in terms of real-world functioning. Individuals with high WMC may be able to activate and maintain a goal in service of ongoing cognition (namely, response selection) more readily than those with lower WMC. This might suggest that individuals with low WMC and less well-developed proactive control systems would derive more benefit from external goal support, such as incentives, than individuals with high WMC. Individuals falling into the purview of the latter category might wish to seek out external supports, such as friends, family or even smartphone apps, to increase the likelihood of being reminded of the goal at the critical moment of response selection when one response might be more consistent with the overarching goal than the other. It is important to note that the examples used here might lead one to the belief that proactive control is necessarily *better* than reactive control. Both control frameworks play important roles in the actions we choose to engage in throughout our daily lives. The interaction of and ability to engage in both response styles, when appropriate, is indicative of intact everyday functioning. Successful or well-functioning individuals are able to balance goal pursuit with environmental demands; others with compromised WM systems (e.g., older adults; individuals with schizophrenia) may be less able to utilize the appropriate control mode when necessary.

Limitations and Future Directions

Generally, reliability levels were found to be in the acceptable range. Importantly, even when Cronbach's alpha levels were found to be relatively low, strong correlations with other variables (such as other AX-CPT trial types) were observed. For example, in Experiment 1, split-half reliability for BX RTs was .57, yet BX RT correlations with the other three trial types range from $r = .60$ to .80, indicating that there is systematic variance present even in the face of lower internal consistency. We can only speculate about why AY trials in particular exhibit lower Cronbach's alpha. First, there were 14 AY trials in Experiment 1, compared to 58 AX and BY trials in Experiment 1; there were 14 AY trials in Experiment 2, compared to 58 AX and 43 CX trials in Experiment 2. With fewer observations for AY versus these other trial types, it is not particularly surprising that that the AY Cronbach's alpha values were lower. It is also important to consider what Cronbach's alpha reflects in this context—the degree to which the trials are measuring the same ability/process across each of the 14 instances, for each subject. If one assumes that subjects might take different paths to achieve the same answer on AY trials, then Cronbach's alpha will reflect that variability. For example, on correct trials, subjects may prepare a target response based on the A cue, but then stop that prepared response and then execute a nontarget response within the time limit provided; other times, subjects may not prepare a response based on the A cue, but would still arrive at a nontarget response based the Y probe information. If this variability is present not only between-subjects but also within-subjects, then the Cronbach's alpha values for AY trials would be expected to be lower.

In addition, one finding that warrants some discussion is how to best characterize BY trials within the AX-CPT. Because previous work has used the BY trials as the baseline condition, especially to control for potential global differences in RTs (e.g., Braver et al., 2001), and because some previous work has shown main effects of WMC in mean RTs on cognitive tasks (e.g., Unsworth & Engle, 2005; Redick & Engle, 2006), we wanted to examine effects on the AX-CPT after controlling for potential baseline RT differences. However, as discussed elsewhere (Redick, 2014), proactive control could be expected to lead to faster RTs on BY trials because the subject would have prepared a nontarget response based on the B cue. Treating BY RTs as indicators of proactive control is consistent with the results in both E1 and E2 that high-WMC individuals were faster than low-WMC individuals (Figures 4 and 6), and thus, our approach to first partial out the variance associated with BY RTs may have contributed to the lack of significant WMC relationships with AX and BX RTs in the regression analyses. Conversely, the finding of WMC associated with AY slowing specifically when controlling for BY trials (but not using the ANCOVA approach), indicates that on Y-probe (nontarget) trials individuals with high WMC exhibit greater interference selectively due to the A cue (rather than to the Y probe itself).

Because the current study adopted a relatively novel approach to studying the AX-CPT, there are a number of unanswered questions that remain. It remains to be seen if low-WMC individuals are a more heterogeneous group generally in terms of cognitive control modes compared to high-WMC individuals (and that there may be subtypes or subgroups comprising the lower tail of WMC; see Unsworth, 2009, for evidence of different memory profiles for low-WMC individuals). For example, one might imagine that low-WMC individuals are more likely to exhibit variable strategies within a single task or can engage in a proactive mode on some trials, but cannot sustain proactive control over the same timescale as individuals with high WMC. This might indicate that individuals with low-WMC do not hit on a successful strategy as readily as those with high WMC and thus spend more time "strategy searching" than higher-WMC participants, making performance of low-WMC individuals particularly difficult to characterize within a dichotomous proactive/reactive framework. Additional support for this notion comes from practice analyses presented in Redick (2009) whereby only low-WMC participants showed the "practice-related proactive shift" seen previously in older adults (Braver, Paxton, Locke, & Barch, 2009; Paxton et al., 2006). In short, do low-WMC individuals exhibit behavioral markers of a mixed proactive/reactive strategy, either at the group level (i.e., subgroups within "low WMC") or at the individual level? The answer to this question is essential in order to prescribe approaches to ameliorate the behavioral deficit on exhibited by those with low WMC in situations similar to those tapped by the AX-CPT (and might possibly extend to other tasks on which low-WMC participants exhibit a disadvantage as well).

A second issue that has not been sufficiently explored in the AX-CPT is the degree to which the task can be modified to both encourage, and make advantageous, a reactive control strategy. Various approaches to such a design have been employed in past studies, such as manipulating the predictive validity of contextual cues (Redick, 2014), inserting distractor stimuli during the cue–probe delay period (Braver et al., 2001; Dreisbach, 2006), and utilizing no-go trials and/or performance penalties (Braver et al., 2009; Chow, Gonthier, MacNamara, Conway & Braver, 2014). However, it is still not clear whether such manipulations actually enhance the utilization and advantages of reactive control, or instead merely discourage the utilization of proactive control. One strategy that seems potentially worthwhile is to utilize the item-specific manipulations that have begun to be explored in the Stroop and other cognitive control tasks (Bugg & Crump, 2012), in which certain probes (e.g., AY, BX) are accompanied by specific features or cues that indicate a heightened demand for control. This form of control would necessarily be reactive, since it would only be indicated at the time of probe presentation. In studies utilizing these types of item-specific control manipulations, performance benefits have been observed, suggesting the advantages of such reactive strategies (Bugg, 2014). However, these strategies seem to involve different mechanisms that may be differentially sensitive to WMC, as indicated by findings that (a) low-WMC individuals showed greater sensitivity to item-specific manipulations in the Stroop than do high-WMC individuals (Hutchison, 2011); and (b) older adults, who show declines in WMC, nevertheless show sparing of item-specific reactive control effects in both the Stroop and flanker tasks (Bugg, 2014). Together, this work suggests that further explorations of the relationship between WMC and item-specific reactive control manipulations in the AX-CPT might be fruitful.

A related open question is the extent to which strategy instruction might modify the relation between WMC and response mode. If low-WMC individuals were told to be proactive, could they maintain such a response style? Would high-WMC participants be able to avoid activating preparatory mechanisms in response to the presentation of an A cue? In addition, it would be interesting to explore the extent to which participants might persist in using a prescribed strategy even if it does not match with the cognitive control mode that is best for successful performance? Might high-WMC individuals “switch” to a productive strategy more readily than low-WMC individuals? These open questions may provide fruitful starting points for future experiments in this vein.

Conclusions

In general, the data presented here suggest that higher WMC is strongly related to the use of a proactive control mode; conversely, low-WMC individuals are more likely to exhibit a reactive control mode. The AY RT data in Experiments 1 and 2, as well as consistently finding a more liberal response bias following A cues, represent one of only a handful of demonstrations of the *costs* associated with higher WMC (Delaney & Sahakyan, 2007; Kane & Engle, 2003; Shipstead & Broadway, 2013). Much of the research on WMC has focused on the positive associations between this domain-general cognitive workspace and higher-order cognition (Engle et al., 1999; Kane, Conway, Hambrick, & Engle, 2007; Kane et al., 2004; Redick, Calvo, Gay, & Engle, 2011; Unsworth & Engle, 2007). In contrast, the current work demonstrates that while high WMC confers many advantages in terms of performance on a cognitive control task, these advantages may not be without some costs.

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(*Appendix follows*)

Appendix

WMC and AX-CPT Trial Type Correlations

Table A1
Correlation Matrix for Experiment 1 (N = 105)

Variable	WMC	AX	AY	BX	BY
WMC	—	−.27*	.01	−.21*	−.35*
AX	.41*	—	.45*	.66*	.78*
AY	.09	.36*	—	.56*	.60*
BX	.41*	.42*	.05	—	.80*
BY	.33*	.63*	.42*	.34*	—

Note. WMC = working memory capacity. Correlations below diagonal are for accuracy; correlations above diagonal are for correct mean reaction times.
* $p < .05$.

Table A2
Correlation Matrix for Experiment 2 (N = 106)

Variable	WMC	AX	AY	BX	BY	CX
WMC	—	−.16	−.15	−.30*	−.42*	.02
AX	.41*	—	.66*	.59*	.65*	.78*
AY	−.01	.15	—	.54*	.63*	.59*
BX	.29*	.49*	.09	—	.74*	.47*
BY	.22*	.49*	.07	.69*	—	.48*
CX	.38*	.80*	.09	.57*	.66*	—

Note. WMC = working memory capacity. Correlations below diagonal are for accuracy; correlations above diagonal are for correct mean reaction times.
* $p < .05$.

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