Effects of Environmental Support and Strategy Training on Older Adults' Use of Context

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IN PRESS, PSYCHOLOGY AND AGING

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Abstract

Age-related cognitive differences may be due, in part, to difficulties using task-relevant context in a proactive manner. Two studies evaluated different methods for increasing older adults' use of context in the AX-CPT task, which evaluates components of context processing. The results suggested that (a) age-differences in the use of context are not due to reduced access to cue information, (b) directed strategy training made older adults' context processing performance more like that of younger adults, and (c) similar performance changes could be observed with less directed instruction and extended practice. These results suggest that age-related differences in context processing can be ameliorated by directed strategy training or extended practice.

Effects of Environmental Support and Strategy Training

on Older Adults' Use of Context

Age-related impairment in several cognitive domains has been a topic of intense research interest for a number of decades. One theoretical explanation for age differences in cognitive performance suggests that normal aging is associated with impaired function of the prefrontal cortex (PFC). Support for this theory is provided by the observation that cognitive deficits in older adults resemble deficits observed in patients with frontal lobe damage (Moscovitch & Wincour, 1995). Furthermore, PFC-mediated cognitive processes appear to decline earlier than other cognitive processes (West, 1996).

Braver and colleagues (2005) proposed that age-related deficits in many cognitive abilities may be related to changes in cognitive control. Cognitive control is required in many demanding task situations such as the ability to hold two tasks in mind simultaneously (Verhaeghen & Cerella, 2002), inhibit an inappropriate but salient response (Spieler, Balota, & Faust, 1996; West, 1996), maintain and manipulate information in working memory (Salthouse, 1990), and overcome the tendency to neglect task-relevant goals (West, Murphy, Armillo, Craik, & Stuss, 2002). Furthermore, previous work postulates that one important aspect of cognitive control is the ability to update, maintain, and monitor internal goals or context representations (Cohen, 2002). Context has been defined as "task-relevant information that is internally represented in such a form that it can bias processing in the pathways responsible for task performance" (Braver et al., 2001, p. 747). Context processing supports attention, on-line maintenance, and inhibition. Context processing is similar to task set maintenance in that both processes involve keeping goal relevant information online in order to effectively complete a task. Nevertheless, context refers to several types of representations in addition to task instructions (e.g., the results of processing a prior stimulus) that can also bias subsequent behavior. Thus, task set maintenance is one form of context processing that facilitates overt behavior (Braver & Barch, 2002).

Theoretical and computational models of context processing posit that this particular aspect of cognitive control is supported by dopamine function in the PFC, and both functional imaging and pharmacological studies provide support for this hypothesis (Barch & Braver, in press; Braver et al., 2001; Braver, Cohen, & Barch, 2002). It has been proposed that dopamine projections to the PFC serve as a gating mechanism responsible for determining which context representations are accessed and stored in the PFC. Through reward learning, the dopamine system adapts by opening the gating mechanism to access context information necessary for task goals and closing the gating mechanism to protect from interference (Braver & Cohen, 2000). Thus, age-related impairment in the function of the dopamine projections to the PFC may result in age-related changes in context processing (Braver & Barch, 2002). The goal of the current studies was to investigate the component abilities contributing to age-related differences in context processing and possible means for rehabilitating these abilities in older adults.

One of the main tasks used to study context processing is a variant of the classic AX-Continuous Performance Test (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956) modified to specifically measure context processing (Servan-Schreiber, Cohen, & Steingard, 1996). Consecutive pairs of letters appear on a computer screen individually. The first letter of each pair is called the cue; the second letter is the probe. Participants are told to make a target response for an X (probe) that follows an A (cue) and to make nontarget responses for any other cue-probe combination. Two aspects of this task make it sensitive to two specific components of contextual processing: context activation/updating and context maintenance.

First, the majority (70%) of trials are target trials on which an A is followed by an X. The remaining 30% of trials are split evenly between three types of nontarget trials: (a) AY trials in which a valid cue (A) is followed by an invalid probe (not X, referred to as Y), (b) BX trials in which an invalid cue (not A, referred to as B) is followed by a valid probe (X), and (c) BY trials in which an invalid cue (not A) is followed by an invalid probe (not X). The ability to use context is assessed by investigating patterns of performance on the two most challenging trial types, AY and BX. Because AX trials occur more often than any other trial type, participants are biased to make a target response when they see an X probe, even when A was not the cue letter (i.e., BX trials). In order to make a nontarget response to these BX trials, contextual information provided by the cue letter must be used to inhibit the tendency to make a target response. Another bias occurs when the cue letter is an A and the probe letter is a letter other than X (i.e., AY trials). Again, because 70% of trials are AX trials, individuals with strong context representations expect to see an X cue following an A and must overcome this invalid expectation in order to make a correct nontarget response on AY trials. Individuals with strong context processing abilities are more likely to make a target response (i.e., an error) on AY trials (Braver et al., 2001; Braver et al., 2005) or to be slow when they must make a nontarget response because extra time is needed to override the invalid expectancy.

A second aspect of context processing assessed by the AX-CPT task is the ability to maintain the context information provided by the cue during the time period between the appearance of the cue and the probe. This aspect of the AX-CPT task and is referred to as context maintenance, and may be one subcomponent of working memory, the system held to responsible for active short-term storage and processing of information (Baddeley, 2003). When context maintenance is intact, the degree to which one's contextual representation biases response to the probe letter over a long delay should not differ or should actually improve compared with a short delay. If context maintenance is impaired, however, context representations should lose strength over time, leading to fewer AY errors and more BX errors.

In previous studies older adults made fewer errors than young adults on AY trials, suggesting that the identity of the cue letter did not as strongly bias their response to the probe letter (Braver et al., 2001; Braver et al., 2005). Further, older adults had longer reaction times (RTs) than young adults on BX trials, suggesting that they experienced interference from the X probe letter on these trials (Braver et al., 2001; Braver et al., 2005). These results suggest that older adults are less sensitive to context information than young adults (Braver et al., 2005).

The results of these previous studies might also reflect differences in the type of cognitive control strategy used by young and older adults. Braver, Gray, and Burgess (in press) proposed two distinct types of cognitive control that can be used in tasks such as the AX-CPT: proactive and reactive. Proactive control on the AX-CPT task involves activating and using contextual information provided by the cue to prepare to respond to the upcoming probe in advance of its onset (i.e., when the cue letter is A, expect X and prepare to make target response). A person using a proactive approach on the AX-CPT would pay attention to the cue letter as it appears and prepare for the target. For instance, if the cue was an A, he or she would prepare for an X target by priming a target response. Such a strategy would lead to more AY errors because preparing a target response when an A cue appears would lead to an increased execution of such responses when the probe appears, regardless of its identity. Using a proactive approach when the cue is a letter other than A involves attending to the cue and preparing to make a nontarget response before the probe appears, allowing one to make the correct nontarget response on BX trials. Hence, a proactive approach leads to increased AY errors but decreased BX errors. In previous studies young adults showed this pattern, suggesting that they used a proactive approach on the task (Braver et al., 2001; Braver et al., 2005). Proposing that a proactive approach on the AX-CPT task is a good strategy seems paradoxical at first because it leads to an increase in AY errors, and errors usually do not reflect efficient or effective processing. Proactive control is, however, an effective and efficient approach to the AX-CPT task because it enhances performance on AX trials, which are the most frequently occurring trial type.

In contrast, reactive control on the AX-CPT task involves minimal activation of the cue information at the time of cue presentation (i.e., expectancies for an X target are not developed following an A cue) but requires reactivation of the cue information when the probe appears and a target or nontarget response must be made (i.e., if the probe is X, recall if the cue was an A). A person using a reactive approach would not prepare to make a target response immediately following presentation of the A cue. Thus, these people would be less likely to make AY errors, but there might be an increase in BX interference because they also do not prepare to make a nontarget response following the appearance of a non-A cue. The appearance of the X probe on BX trials causes interference due to its dominant association with a target response, which is reflected in disproportionate slowing of responses, but potentially only a minimal increase in errors (if context reactivation can occur prior to response generation). The results of previous studies suggest that older adults use a reactive form of cognitive control on the AX-CPT task (Braver et al., 2001; Braver et al., 2005).

There are several possible explanations for the age-related differences observed on the AX-CPT task. One account may be related to age-related deficits in working memory as older adults sometimes show impaired working memory abilities relative to young adults (Braver et al., 2005; Hultsch, Hertzog, Small, McDonald-Miszczak, & Dixon, 1992; Salthouse, 1990).

Specifically, age differences in performance may be due to age-related deficits in the ability to maintain access to cue information across a delay. Thus, in the AX-CPT, older adults may differ from young adults in the ability to maintain access to the task-relevant information conveyed by the contextual cue despite an intact ability to process the cue information initially. This process of maintaining access to context over a delay may be a subcomponent of working memory. Older adults show improved performance in other task domains when context maintenance demands are decreased. For example, Craik and Anderson (1999, p. 607) pointed out that "older people's performance can certainly benefit (sometimes differentially) from context reinstatement and environmental support when previous events must be brought to bear on the task." Thus, older adults' inability to maintain access to contextual cue information is one potential explanation of the age differences observed on the AX-CPT. This hypothesis was examined in Study 1.

Another possible explanation for age-related differences in context processing is that older adults may approach the task with a reactive instead of a proactive form of cognitive control. Such a hypothesis is consistent with prior work showing that older adults often fail to adopt beneficial strategies in other cognitive domains (such as episodic memory) spontaneously, although they can use such strategies when given environmental support to do so (Naveh-Benjamin, Craik, & Ben-Shaul, 2002). This hypothesis was examined in Study 2.

Study 1

In this study we wanted to determine if old adults' performance on the AX-CPT task could be changed when we manipulated accessibility of the cue information over the delay period. We tested this by manipulating the duration of the cue presentation. Furthermore, by varying the length of the delay interval we also examined whether cue accessibility would have stronger effects when context maintenance demands were greatest (i.e., long delay interval).

Method

Participants. The participants in this study were 24 older adults aged 68 to 87 years (*M* = 74.88) and 24 younger adults aged 18 to 24 years (*M* = 19.92) who were recruited from the Washington University Aging and Development volunteer pool. Three young adults were excluded because they were remarkably distracted or sleepy during the testing session. There were an equal number of men and women in each age group. The older group was more educated (*M* = 15.04 years, *SD* = 2.69) than the young adult group (*M* = 13.75 years, *SD* = 1.45), t (46) = 2.07, $p < .05$, who were current undergraduate students who had not yet completed their education. There were 20 Caucasian, 2 African American, and 2 Asian young adults and 23 Caucasian and 1 African American older adults.

After providing written informed consent young adults were screened for depression, and older adults were screened for depression and cognitive impairment. Depression was measured with the short Geriatric Depression Scale (GDS, Sheikh & Yesavage, 1986); participants who scored 7 or greater were excluded. Cognitive impairment was assessed with the Blessed Orientation-Memory-Concentration Test (Katzman et al., 1983) with a cut-off score of 6 or more. No participants were excluded on the basis of either screening measure. Each participant received $10.

Tasks and apparatus. Participants performed four conditions of the AX-CPT task on an Apple Macintosh computer with PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). In each condition letters appeared individually in a continuous manner on the computer screen. Each trial consisted of the presentation of a cue followed by the presentation of a probe.

Participants were instructed to respond by pushing the *target* button when an X probe appeared after an A cue. They were instructed to push the *nontarget* button for all other letters (e.g., all cues and any probes that were not Xs that followed an A). The nontarget cue and probe letters were all other letters of the alphabet except K and Y, which were excluded because of their visual similarity to X. Target trials (AX) occurred 70% of the time, and each of the three nontarget trial types (AY, BX, and BY) appeared 10% of the time.

Each participant performed both standard and low maintenance conditions at each of two cue-probe delays (1000 ms vs. 5000 ms) for a total of four blocks of 100 trials each. In the standard maintenance condition participants viewed the cue letter for 750 ms, followed by an unfilled delay period of either 1000 ms (short delay) or 5000 ms (long delay), after which the probe letter appeared for 750 ms. In the low maintenance condition the cue letter remained visually present throughout the duration of the delay (either 1700 or 5700 ms.). At the end of the delay period the cue was replaced by the probe letter following a very brief 50 ms ISI. The ITI for both the standard and low maintenance task condition was 1000 ms in the long delay condition and 5000 ms in the short delay condition.

The letters were presented in white 48-point uppercase bold Helvetica font on a black screen. Participants responded by pushing either the middle (nontarget) or left (target) button on a constructed button box that recorded the RT within 1ms. On all trials participants were given 1500 ms to respond to the cue or probe letter. Responses after 1500 ms elicited a "bloop" sound to motivate participants to increase speed and were not recorded.

Procedure. Participants were tested individually in a single session with rest periods between blocks of trials as desired. The four experimental conditions (standard/short delay, standard/long delay, low maintenance/short delay, low maintenance/long delay) were administered in a counter-balanced order across participants. The counter-balancing scheme involved computing all 24 possible orderings of the four conditions and assigning one person from each participant group (young vs. old) to each ordering. Verbal instructions and 10 to 20 practice trials preceded the first block. Participants were instructed to respond as quickly and accurately as possible to each letter presented.

Data analysis. Error rates (misses and false alarms) and median correct RTs served as the dependent measures. A z-score transformation was applied to the RTs across all correct trials for each participant to correct for individual differences (including general slowing with age) in RT (Faust, Balota, Spieler, & Ferraro, 1999) and to increase power (Bush, Hess, & Wolford, 1993). Specifically, for each participant a global mean RT and standard deviation was computed using all trials for that participant. Then the RT for each trial was normalized by subtracting the mean RT and dividing by the standard deviation. This procedure thus equates all participants in terms of global RT and RT variance (i.e., global RT = 0, standard deviation = 1 for each participant). The median z-transformed RTs for each experimental cell thus represent standardized deviations from the participants' global RT. If the assumption of sphericity was not met in any of the analyses of variance, the Huynh-Feldt correction was applied.

Results

Errors. Proportion of errors was examined in a mixed model analysis of variance where age group (young vs. old) was a between-subjects variable and maintenance condition (standard vs. low maintenance), delay (long vs. short), and trial type (AX, AY, BX, BY) were within-subjects variables. See Table 1 for means and standard deviations. Both the main effects of age,

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Insert Table 1 about here

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$F(1, 46) = 15.83$, partial $\eta^2 = .26$, and trial type, $F(1.94, 89.02) = 30.53$, partial $\eta^2 = .40$ were significant (ps < .0001). They were qualified by an Age X Trial Type interaction, $F(1.94, 89.02) = 12.40$, $p < .0001$, partial $\eta^2 = .21$. Older adults made fewer AY errors than young adults, $F(1, 47) = 22.53$, $p < .01$, partial $\eta^2 = .33$, but did not differ from younger adults on any of the other three trials types (all ps > .05). Age comparisons for each trial type in all four conditions of delay and maintenance are also shown in Table 1. This pattern of errors replicates previous studies using the AX-CPT task (Braver et al., 2001). In addition, planned contrasts indicated that young adults made more AY than BX errors, $F(1, 23) = 15.25$, $p < .01$, partial $\eta^2 = .40$, but older adults did not, $F(1, 23) = .01$, $p = .92$.

The absence of a significant main effect or interaction involving maintenance condition indicates that the maintenance condition (standard vs. low maintenance) did not influence accuracy rates and did not alter the performance of older adults. Additionally, the main effect of delay was not significant, nor were any of its interactions.

RTs. Table 2 shows RT values of each age group for each trial, delay, and maintenance conditions. The z-score-transformed RTs were examined in a mixed model analysis of variance

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Insert Table 2 about here

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analogous to that used to examine error rates. The main effect of delay was significant, $F(1, 46) = 23.33$, $p < .0001$, partial $\eta^2 = .34$; participants responded faster with the short delay ($M = -0.07$) than they did with the long delay ($M = 0.16$). The delay factor did not show any further interactions with age or trial-type. The main effect of trial type, $F(1.57, 72.01) = 60.51$, $p <$

.0001, partial $\eta^2 = .57$, was also significant, but it was qualified by an Age X Trial Type interaction, $F(1.57, 72.02) = 3.68$, $p < .05$, partial $\eta^2 = .07$. Older adults ($M = 0.33$) had longer z-transformed RTs on BX trials than young adults ($M = -0.15$), $F(1, 46) = 4.92$, $p < .05$, partial $\eta^2 = .09$. Age differences were not found for any of the other three trial types. Examination of the z-transformed RTs for AY trials collapsed across delay and maintenance conditions revealed a trend for faster responding among older adults (*Ms* = .86 vs. .72 for young and old, respectively). This pattern of RTs replicates previous studies comparing younger and older adults on the AX-CPT task (Braver et al., 2001; Braver et al., 2005).

The only other significant effect was the Age X Maintenance condition interaction, $F(1, 46) = 6.04$, $p < .05$, partial $\eta^2 = .12$. Older adults had significantly longer z-transformed RTs ($M = 0.19$) than younger adults ($M = -0.01$) in the low maintenance condition, $F(1, 46) = 9.8$, $p < .01$, partial $\eta^2 = .18$, but not the standard condition, $F(1, 46) = .06$, $p = .80$, (*M*s = -0.00 vs. 0.02 for old and young, respectively). Increased RTs by the older adults in the low maintenance is counter to the hypothesis that their performance would improve in the low maintenance condition. Thus, when the task was made easier by reducing the need to maintain cue accessibility over the delay, older adults were slower, not faster.

Discussion

Consistent with the results of previous studies (Braver et al., 2001; Braver et al., 2005) older adults made fewer AY errors and had longer RTs on BX trials than young adults in the standard condition of the AX-CPT task. They continued to show this pattern, however, when the cue information remained accessible throughout the delay. These results are not consistent with the idea that older adults' impaired performance on the AX-CPT is due to an inability to maintain cue information across a delay. Nevertheless, the results of this study do not rule out the possibility that age-related deficits in other aspects of working memory may impact AX-CPT performance in older adults. For example, the manipulation in the current study very specifically examined the influence of cue accessibility across the delay. There are other ways to manipulate working memory load such as dual task paradigms, interference effects, delay length manipulations, or providing other types of environmental support that might reveal a clearer role of working memory impairments in AX-CPT performance.

Nevertheless, at first blush this finding seems to contradict our original hypothesis that older adults may not use context in the same way as young adults because of difficulties with the active maintenance of context information. There are two possible interpretations of the results, however. First, in previous work, age differences in the active maintenance of context were largely in the oldest subset of older adults consisting of individuals older than 75 (Braver et al., 2005). Therefore, it could be that only the oldest individuals have difficulties with maintaining context information. In the current study the sample size was not large enough and the age distribution was not balanced enough to conduct analyses examining age effects within the older adult group.

A second interpretation of the results is that the low maintenance manipulation did not affect the kind of active maintenance impairment present in older adults. In particular, there may be an important distinction between the ability to maintain perceptual or identity information about the cue (e.g., Is the cue a C or an F?) and the ability to actively maintain the contextual information provided by the cue (e.g., Was the cue from the A or "not-A" category? What does the cue predict about the upcoming probe?). The low maintenance condition may have made it easier for older adults to maintain perceptual or identity information about the cue but may not have affected their ability to represent and maintain the contextual information provided by the cue. If this latter interpretation is correct, then further investigation of the way that information is accessed and stored across short periods of time could provide insight about age-related differences in storage and interpretation of goal-relevant information in working memory.

This alternative explanation regarding AX-CPT age differences may specifically relate to the type of cognitive control strategy used by the two age groups. As described in the introduction, the dominant control strategy used by young adults appears to be a proactive approach that involves preparation of responses to an upcoming probe in advance of its onset (Braver et al., in press). In contrast, older adults may rely on a reactive strategy in which they reassess or reactivate the relevant cue information or context after the onset of a probe if it is ambiguous (i.e., on BX trials). The X probe is ambiguous because, when it appears, the identity of the cue letter is needed to determine whether a target or nontarget response is correct. Thus, a reactive approach would lead to few errors on AY trials that are negatively affected by an expectancy-based preparation strategy but increased response latencies for BX trials. This is the pattern observed in older adults in Study 1.

A reduction in the proactive use of context on the AX-CPT could stem from either a reduction in the spontaneous use of an effective strategy or difficulty in the application of the strategy. Previous research has demonstrated that, when compared with younger adults, older adults are less accurate in monitoring strategies (Brigham & Pressley, 1988), are less able to maintain an effective strategy (West & Baylis, 1998), and use less efficient strategies (Hybertson, Perdue, & Hybertson, 1982; Touron & Hertzog, 2004). If age differences on the AX-CPT task reflect age differences in the spontaneous use of a proactive control strategy, then it may be possible to train older adults to use such a strategy. Under such conditions we would predict that the older adults would then perform more like young adults. In contrast, if older adults have deficits in the application of effective strategies even when provided with training to do so, their performance would not change. With this goal in mind, we conducted a second study to investigate the effects of strategy training.

Study 2

The AX-CPT task is constructed with an asymmetry in frequency of target trials that leads to the pattern of performance observed in young adults (i.e., increased errors and slowing on AY trials but fast and accurate BX responses). The fact that older adults did not show this pattern of performance in previous studies suggests they may be slower than young adults to develop expectancies based on experience with the differential frequencies of trial types. Alternatively, it is possible that older adults may develop expectancies about the differential frequency of trial types at the same rate as young adults but still use different response strategies than young adults. The second study was conducted to determine if older adults would use context similarly to young adults after receiving explicit information about the frequency of each trial type and training in proactive strategies to use the cue information.

Participants were assigned to the training condition or one of two control conditions. The two control conditions were designed to control for several aspects of the training procedure other than the strategy training that might influence performance on this task. First, the instruction control condition was as similar to the training condition as possible except it did not include strategy training or information about the differential frequency of target trials. Specifically, both the training and instruction control condition included re-instruction regarding task rules, implied demands due to awareness that an aspect of the procedure was being manipulated, increased interaction and nonspecific encouragement during the practice blocks, and extended practice. Second, we included another control condition that only involved additional practice with the task, under the hypothesis that extended practice might be sufficient to allow enhanced learning of the expectancy bias produced by the greater frequency of the AX trials.

Method

Participants. Older adults were recruited from the Washington University Aging and Development volunteer pool into the training group (n = 33, age range 65 to 87 years, M = 75.55), the instruction control group (n = 36, age range 65 to 88 years, M = 75.33), or the practice control group (n = 36, age range 66 to 89 years, M = 75.56). The three groups did not differ in years of education, $F(2, 103) = .29$, $p = .74$, M = 14.83, SD = 2.47. All participants were Caucasian except for 1 African American and 1 American Indian participant in the practice control group. Participants were screened for depression and cognitive dysfunction in the same way as in Study 1 and received $10 for participation. One participant in the strategy training condition made 100% errors on the BX trials in the baseline block, and 6 participants in the instruction control group had 90% or more errors on BX trials at baseline, which suggests that they did not understand the directions for the task at the beginning of the session. Statistical analyses reported here were conducted without these latter 7 participants; the same pattern of results was obtained when the analyses were repeated including them.

Tasks and apparatus. The standard version of the AX-CPT with the long delay described in Study 1 was used as the basic task for Study 2. Participants viewed a cue letter for 750 ms followed by an unfilled delay of 5000 ms, and then they saw the probe letter for 750 ms; the ITI was 1000 ms for all trials. The standard directions differed slightly from those used in Study 1. The response buttons were referred to as red for the target button and yellow for the nontarget button (which corresponded to their color) in an effort to simplify the instructions.

Participants also completed a forward digit span task on an Apple Macintosh computer with PsyScope software. They repeated series of 2 to 11 auditorily presented digits in the same order. The experimenter entered the participant's responses. One point was given for each correct digit recalled in the correct order. Data were not available for 5 participants because of computer malfunction.

Procedure. Participants in all three conditions were tested individually in a single session. The procedure was the same for all conditions until the end of the baseline block; they were given standard instructions for the AX-CPT task followed by 10 to 20 practice trials and a baseline block of 100 trials. After completion of the baseline block participants in the *training group* were asked to estimate the proportion of trials. After providing these estimates, they were explicitly told that 70% of the trials in the task were an A cue followed by an X probe and would require a red response. They were also told that the investigators were interested in whether people would perform differently if given instructions about strategies to use in the task. Then they were told to first pay attention to the cue letter and decide if it was an A or not. If it was an A, they were encouraged to prepare to see an X and push the red button. If the letter was not A, they were encouraged to prepare to push the yellow button regardless of what letter appeared as the probe. They were trained to verbally categorize (i.e., say "A" or "not A") and attend to the cue at the time that it appeared in three blocks of 10 training trials. The experimenter verbally categorized the cue letters on the first of these three blocks; the participant categorized the cues on the second block while the experimenter completed the task; then the participant categorized the cues while completing the task on the third block.

Then participants were trained to use the cue to influence how they prepared for the probe. They were reminded that when the cue was an A it was very likely that an X would follow; therefore, they should begin to prepare for a red response. Participants were told to say "if X, red" when they saw an A as the cue and "yellow" when they saw a cue that was not an A. The experimenter said these phrases for 10 trials while the person completed the task; then the participant said the phrases while the experimenter completed the task for 10 trials. Finally, the participant completed three 10-trial blocks saying these phrases while completing the task. If the participant did not say the phrase out loud on a trial, the examiner did. Following training participants completed another block of 100 trials (posttest) followed by still another block of 100 trials (final block). They were reminded of the strategy cues between the posttest and final block. After the final block, participants estimated whether their performance changed from the baseline to the final block.

The *instruction control condition* was designed to be as similar as possible to the training condition without including information about the differential frequency of trial types or strategy training. Thus, the instruction control condition had no specific strategy training, but included many other elements common to the training condition such as re-familiarization with task rules during practice, awareness that an aspect of the study was being manipulated, practice with shorter 10-trial blocks, and interaction with the experimenter during the practice trials. After the baseline block of 100 trials they were reinstructed with standard task instructions and told that they would be practicing with shorter blocks to determine if that affected performance. Then they completed six practice blocks of 10 trials each without any reminders between blocks but receiving nonspecific encouragement that they were doing well. (There were six practice blocks rather than eight as in the training condition because two blocks of 10 trials in the training condition were performed by the experimenter.) After a posttest and final block, each with 100 trials, participants estimated whether their performance changed from the baseline to the final block and the proportion of the various types of trials. A second control condition, *practice control,* was included to determine the effect of additional task practice by itself on AX-CPT performance, without any other instruction or differential treatment. Participants in the practice control condition received a pretest block of 100 trials, an additional block of 100 trials with no reinstruction or reminders, and then a posttest block of 100 trials (again with no reinstruction or reminder). They were then asked for their estimates of the change in their performance and the proportion of the various types of trials.

Data analysis. Data were analyzed using error rates (misses and false alarms) and median correct RTs as dependent measures for each condition. As described in the introduction, performance on AY and BX trials are the most sensitive indicators of the proactive use of context. Thus, to simplify the analysis of training effects, only the AY and BX conditions were examined. For completeness, data regarding the other two AX-CPT trial types (AX, BY) are reported in Appendix A.

Results

Comparison of error rates from baseline to posttest. The proportion of errors for the three groups is shown in Table 3. Error rates were examined in a mixed model analysis of

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Insert Table 3 about here

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variance where group (training, instruction control, practice control) was a between-subjects independent variable and block (baseline vs. posttest) and trial type (AY vs. BX) were within-subjects independent variables. The Block X Trial Type interaction, $F(1,102) = 30.81$, $p <$ 0001, partial $\eta^2 = .23$, was significant. The Group X Block X Trial Type interaction was not,

$F(2, 102) = 0.05$, $p = .95$. The absence of a significant main effect or interaction involving group indicates that the change in error rates from pretest to posttest did not differ significantly across group (training, instruction control, practice control). In all three groups there were increased AY errors and decreased BX errors at posttest as illustrated in Figure 1. Planned contrasts examined the Block X Trial Type effect separately for the training group, $F(1,32) = 13.79$, $p <$ 01, partial $\eta^2 = .30$, the instruction control group, $F(1, 35) = 9.31$, $p < .01$, partial $\eta^2 = .21$, and the practice control group, $F(1, 35) = 8.16$, $p < .01$, partial $\eta^2 = .19$. Moreover, simple effects tests suggested that BX errors significantly decreased in the training group and the instruction control group, and were trend-level in the practice control group. Conversely, AY errors significantly increased in the training group and the practice control group, and were trend-level in the instruction control group. The effect sizes from pretest to posttest for each of the three groups are included in Table 3.

Insert Figure 1 about here.

Comparison of RTs from baseline to posttest. RTs for the three groups are shown in the Table 4. They were examined in a mixed model analysis of variance analogous to that used to

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Insert Table 4 about here.

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examine errors rates. A main effect of trial type, $F(1, 102) = 14.61$, $p < .0001$, partial $\eta^2 = .13$, and a Block X Trial Type interaction, $F(1, 102) = 5.61$, $p < 05$, partial $\eta^2 = .05$, were uncovered. Again the Group X Block X Trial Type interaction was not significant, $F(2, 102) = 0.03$, $p = .97$. The Block X Trial Type interaction reflected the general trend for BX RTs to decrease in the posttest block and for AY RTs to increase slightly. The lack of a significant interaction with Group suggests that the RT effects were consistent across groups. The Block x Trial Type effect was small in each individual group, as none of the simple effects of block on BX or AY RTs in any of the groups were significant (all *p*s > .10). Moreover, the RT results suggest that the accuracy effects do not reflect a speed-accuracy trade-off because, on AY trials, RTs did not decrease as errors increased, and on BX trials, RTs did not increase as errors decreased.

Additional analyses. The training and instruction control groups completed an additional block of 100 trials after the posttest block (see Table 3). To determine if increased error rates on AY trials and decreased error rates on BX trials were maintained from the posttest block to the final block, we conducted an analysis of variance where group (training vs. instruction control) was a between-subjects variable and block (posttest vs. final) and trial type (AY vs. BX) were within-subjects variables. There was a main effect of trial type, $F(1, 67) = 27.93$, $p < .0001$, partial $\eta^2 = .29$, but no other significant effects. The absence of a significant effect for block indicates that error rates did not change from the posttest to the final block. The absence of a group effect indicates that this pattern was consistent across the two groups.

RTs for posttest and final blocks were also compared (see Table 4). There was a main effect of trial type, $F(1, 67) = 17.10$, $p < .0001$, partial $\eta^2 = .20$; and a Block X Trial Type interaction, $F(1, 67) = 5.87$, $p < .05$, partial $\eta^2 = .08$. Comparison of posttest and final blocks within AY and BX trials revealed a further reduction in RTs on BX trials, $F(1, 32) = 9.76$, $p <$

.01, partial $\eta^2 = .23$, from the posttest ($M = 589$) to the final block ($M = 557$) but no change on AY trials from posttest ($M = 670$) to final block ($M = 677$). The absence of an interaction with group suggests that the effect was consistent across the two groups.

As described in the methods, participants in all three groups provided estimates of the frequency of each trial type. The accurate proportion of each trial type was subtracted from each estimate. These deviation values were squared to remove the influence of directionality and averaged across the four types of trials. The error of the estimations made by each person was defined as the square root of this average. It was, by and large, small for all three groups (M = 7.79, 9.0, and 8.25 for training, instruction control, and practice control groups, respectively), $F(2, 104) = 0.50$, $p = .61$, even though the training group provided these estimates after the baseline block and before strategy training and the two control groups provided estimates after the posttest. Examination of the mean estimates for each trial type also indicated that all three groups were relatively accurate in estimating the frequency of each trial type: training group *Ms* = 68.06, 13.98, 9.24, and 8.44 for AX, AY, BX, and BY, respectively; instruction control *Ms* = 64.11, 14.36, 11.40, and 9.85 for AX, AY, BX, and BY, respectively; and practice control *Ms* = 73.42, 11.26, 8.79, and 5.81 for AX, AY, BX, and BY, respectively

To evaluate whether there were preexisting group differences that might have confounded the results, the three groups were compared on the digit span test and for baseline performance on the AX-CPT task. The number of items on the digit span test that were correctly recalled did not differ across groups, $F(2, 104) = .20$, $p = .82$, $M = 60.56$, $SD = 10.83$, demonstrating that participants in the three groups did not differ in short-term storage ability. The three groups also did not differ in errors or RTs on AY or BX trials at baseline (all ps > .48).

When the three groups were compared on estimates of the degree to which their performance improved as a result of practice or training there was a significant difference, $F(2, 101) = 3.33$, $p < .05$. The training group reported greater improvement ($M = 3.73$) than did the instruction control group ($M = 3.14$), $t(64) = 2.48$, $p < .05$, and there was a trend level difference in mean estimates of the training and practice control groups (3.73 vs. 3.31), $t(64) = 1.89$, $p = .06$.

General Discussion

On the basis of the results of Study 1 it is clear that age differences in performance on the AX-CPT task cannot be attributed to older adults' inability to maintain access to cue information over the delay. Even when the cue information remained available on the screen, their pattern of errors and RTs indicated they were not using the cue information to bias their responses in the same way as young adults. Therefore we tested the hypothesis that older adults may not use the same strategy as younger adults by attempting to manipulate the cognitive control strategy used by older adults in Study 2. Older adults showed more AY errors and fewer BX errors after strategy training and receiving information about the differential frequency of target trials. Indeed, their error rates approached those of young adults in the standard task/long delay condition from Study 1. They also reduced their error rates and RTs on BX trials. These results provide evidence that the performance of older adults on the AX-CPT task can be modified to be more similar to that of younger adults. When the performances of the training and control groups were compared, however, we found that all three groups showed increased AY errors and, decreased BX errors and RTs from baseline to posttest.

It is highly encouraging that older adults' performance could be modified to be more similar to that of younger adults, but a critical question arises about the mechanism responsible for this change in performance. All three manipulations involved more extensive practice than standard administration of the AX-CPT. Given that no significant difference among the three conditions was observed, the most parsimonious explanation is that added practice is a critical way to increase proactive use of context by older adults. This finding is consistent with results from previous studies showing that older adults are slower to learn in a variety of domains (see Kausler, 1994, for a review). Of note, the older adults in Study 1 performed like the older adults before training in Study 2, despite the fact that participants completed 400 consecutive trials in Study 1. Given the effects of simple practice discovered in Study 2, one might have thought that the overall performance in Study 1 would have benefited from the practice afforded by the large number of trials. Participants in Study 1, however, actually performed four different conditions of the AX-CPT, and it is possible that practice effects are reduced when the surface structure of the task changes. In addition, the counterbalancing schedule used in Study 1 precluded an unconfounded assessment of practice effects, which is part of the reason we choose to examine practice directly in Study 2.

If extended practice results in older adults performing more like young adults, then we are driven to ask what specifically is learned with additional practice. One possibility is that older adults do not recognize the differential frequency of the target trials as quickly as do younger adults and therefore cannot use this information to influence their approach to the task as quickly as younger adults. As such, one might hypothesize that extended practice allowed older adults to detect the frequency distribution of trial types and to use this information to bias their behavior. The older adults in the training condition in Study 2, however, were very accurate in their estimates of the frequency of the different trials types after the initial baseline block of trials and before being explicitly informed about the trial type distributions. Indeed, their estimates were as accurate as those of the two control groups, who made their estimates after more trials. Thus, extended practice was clearly not necessary for older adults to learn the trial type distribution on the AX-CPT.

Even if older adults can detect the frequency of trial types as quickly as young adults, they still may not use this information to bias their task performance. Other studies suggest that knowledge about a task is separate from and does not always affect performance on the task. For instance, Munakata and Yerys (2001) demonstrated that young children possessed knowledge about rules for completing a card-sorting task but were often unable to translate this knowledge into action. In another study older adults were able to report rules for a category-learning task accurately although their performance was not consistent with correct rule use on more challenging trials that involved novel items, high working memory demands, and inhibitory abilities (Racine, Barch, Braver, & Noelle, in press). These results might reflect what Duncan and colleagues (1996) refer to as goal neglect: "disregard of a task requirement even though it has been understood" (p. 265). Also, it may be that verbally reporting the frequency of trial types is a simpler task than integrating this knowledge into one's approach to the task, especially when much of one's attention is focused on completing a cognitively demanding task such as the AX-CPT.

It is also possible that older adults are impaired at spontaneously and/or quickly learning to use a proactive strategy in applicable cognitive situations. This hypothesis is consistent with a growing body of work suggesting that older adults often fail to spontaneously apply effective strategies in a variety of cognitive domains (Dunlosky & Hertzog, 2001; Kausler, 1994; Touron & Hertzog, 2004) but can apply these strategies when given support to do so (Saczynski, Margrett, & Willis, 2004; Saczynski, Willis, & Schaie, 2002). There has been some evidence that age-related deficits in skill acquisition could reflect associative learning deficits, rather than strategy use, but even in this domain the role of strategy use cannot be ruled out (Touran, Hoyer, & Cerella, 2004). In part, older adults may not be able to use strategies effectively because doing so is too cognitively demanding (Guttentag, 1985). It also may be that older adults have difficulty applying strategies while performing a challenging task that demands their attentional resources. The directed training provided in the Study 2 training condition might have effectively "jumpstarted" strategy use in older adults. Some support for this idea can be seen in the slightly larger effect size on AY trials observed in the training group. Likewise, the self-report measures given at the end of the session indicated that the participants in the training group estimated their performance improvements to be greater than the two other control groups. Of course, this latter effect may also have reflected demand characteristics, as the training condition involved the strongest degree of experimenter intervention.

Thus, we conclude that training and extended practice are both effective mechanisms for increasing proactive use of context information. Still, the training and practice manipulations may not influence performance in an identical way and might not produce the same effects over varying periods of time or with different tasks. Hence, a question arises as to whether practice and directed training influence the same cognitive processes and whether they change behavior at the same rate. One way to address this issue would be to conduct studies specifically designed to investigate the rate at which practice and training change performance. Such studies could provide better information as to whether one of these manipulations is more efficient than the other. It is also possible that brain-imaging techniques such as functional magnetic resonance imaging (fMRI) could be used to gain insight about the underlying neural mechanisms that mediate context processing and how it differs in young and old adults. For example, previous work suggests that lateral PFC is not engaged as effectively during cognitive task performance in older adults compared with young adults (for review see Buckner, 2004). Lateral PFC has been found to be linked to context maintenance in previous AX-CPT studies with young adults (Barch et al., 1997; Barch et al., 2001; Braver & Bongiolatti, 2002; Braver & Cohen, 2001; MacDonald & Carter, 2003; MacDonald, Cohen, Stenger, & Carter, 2000). Thus it seems plausible that increased practice or direct strategy training may have its effect on behavioral performance by increasing the context-related activation of lateral PFC. Although the practice manipulations produced an equivalent effect on behavioral performance, it may be the case that extended practice may exert a behavioral effect via a different neural mechanism than changes in lateral PFC activity.

Older adults often encounter situations in their daily lives for which it would be beneficial to use context information proactively or, in other words, use information that was previously presented to influence a response to environmental stimuli. For instance, older adults must use context information effectively to be cognitively flexible to changing goals or demands, such as changing a habitual driving route to incorporate a trip to a new place. After finding that older adults can improve their use of context information on the AX-CPT task with practice, an important next step might be to determine whether practice and additional experience can modify performance on other challenging, "real-world" tasks. For instance, in a study investigating older adults' ability to perform simulated customer service responsibilities by email, the oldest group of adults benefited the most from practice, suggesting that practice may play a significant role in allowing older adults to become more adept with challenging technological systems such as computers (Sharit et al., 2004).

The results of these studies provide support for the theory that older adults show significant differences in context processing and do not approach the task in the same way as young adults. In addition to replicating the pattern of performance observed in previous studies, Study 1 provided evidence that the difference in performance observed among young and older adults cannot be attributed to older adults' inability to remember context information over a delay; their performance was not different when the information remained available. Study 2 provided evidence that other types of manipulations such as directed strategy training and extended practice can change the way older adults use context. Future studies should be aimed at delineating the precise contribution of strategy training, nonspecific encouragement, and practice on context processing by older adults and determining the extent to which these findings can be generalized to other challenging cognitive situations.

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This research was supported by grant 5 T32 AG00030 from the National Institute on Aging and by grant 5 R01 MH06607803 from the National Institute of Health.

Portions of these results were presented at the annual meeting of the International Neuropsychological Society, St. Louis, MO, February, 2005, and the annual meeting of the American Psychological Association, Washington, DC, August, 2005.

The authors would like to thank Adrianne Casagrand and Timothy Heaven for assisting with data collection.

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Table 1

Comparison of Errors of Young and Old Adults for Standard and Low Maintenance Conditions Across the Four Trial Types and Two Delay Conditions in Study 1

	Short delay			Long delay		
Trial type	Young	Old	*F*(1, 47)	Young	Old	F(1, 47)
			Standard condition			
AX	.01 (.01)	.01 (.01)	2.53	.02 (.03)	.01 (.02)	.36
AY	.09 (.10)	.04 (.06)	5.12*	.11 (.14)	.02 (.05)	8.42**
BX	.02 (.05)	.01(.04)	.39	.04 (.09)	.03 (.07)	.13
BY	.00 (.02)	.00 (00)	--	.00 (00)	.00 (00)	--
			Low maintenance			
AX	.01 (.01)	.00 (.01)	3.44	.01 (.01)	.01 (.02)	.04
AY	.14 (.13)	.03 (.06)	13.81**	.13 (.15)	.03 (.06)	9.01**
BX	.06 (.07)	.01 (.10)	1.19	.04 (.05)	.04 (.08)	00
BY	.00 (.02)	.00 (00)	---	00 (00)	.00 (00)	--

Note. Entries are means; standard deviations are in parentheses. No *F* test was computed in conditions with no variance.

* $p < .05$. ** $p < .01$.

Table 2

Comparison of Reaction Times of Young and Old Adults for Standard and Low Maintenance Conditions Across the Four Trial Types and Two Delay Conditions in Study 1

	Short delay		Long delay	
Trial type	Young	Old	Young	Old
		Standard condition		
AX	394 (81)	522 (99)	405 (81)	554 (109)
AY	544 (93)	676 (82)	560 (86)	700 (120)
BX	420 (193)	607 (219)	423 (171)	674 (108)
BY	381 (103)	489 (92)	381 (82)	523 (108)
		Low maintenance		
AX	384 (77)	537 (109)	411 (95)	580 (123)
AY	546 (108)	698 (90)	584 (105)	732 (92)
BX	407 (179)	625 (197)	420 (187)	718 (264)
BY	368 (92)	502 (85)	381 (116)	583 (114)

Note. Entries are means; standard deviations are in parentheses. *F* tests for RT were computed using z-transformed RTs.

* $p < .05$.

Table 3

Errors for Two Trial Types at Baseline and Posttest in Training and Control Groups

Trial type	Training	Instruction control	Practice control
AY			
Baseline	.03 (.05)	.03 (.05)	.03 (.07)
Posttest	.08 (.11)	.08 (.11)	.07 (.08)
Partial η^2	.19*	.10	.14*
Final	.07 (.09)	.06 (.07)	
BX			
Baseline	.07 (.12)	.08 (.10)	.11 (.22)
Posttest	.02 (.05)	.03 (.06)	.06 (.21)
Partial η^2	.14*	.15*	.10
Final	.00 (.02)	.02 (.05)	

Note. Entries are means; standard deviations are in parentheses. Partial η^2 represents the effect size for the comparison between baseline and posttest values.

* $p < .05$

Table 4

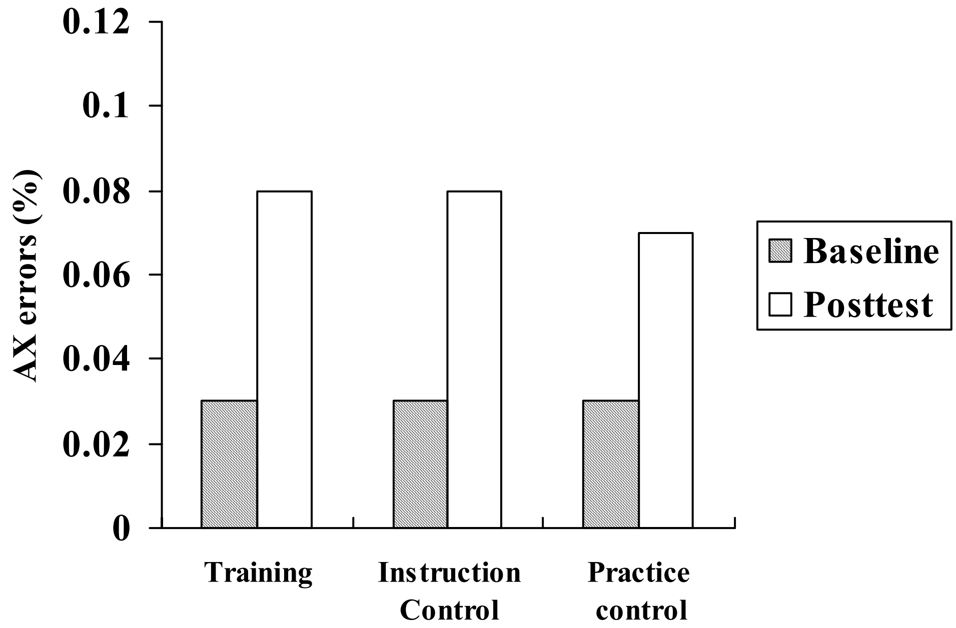
Median RTs for Two Trial Types at Baseline and Posttest in Training and Control

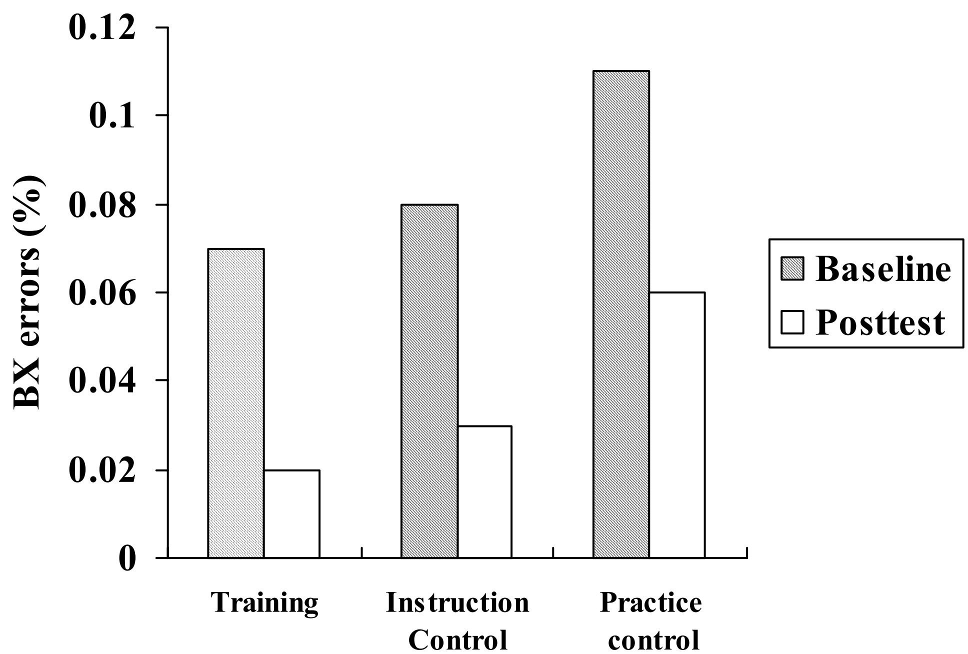
Trial type	Training	Instruction control	Practice control
AY			
Baseline	675 (112)	648 (94)	692 (104)
Posttest	694 (111)	649 (110)	693 (92)
Final	694 (99)	661 (100)	
BX			
Baseline	624 (215)	621 (233)	597 (294)
Posttest	605 (244)	574 (202)	556 (188)
Final	547 (185)	567 (213)	

Note. Entries are means; standard deviations are in parentheses.

Figure Caption

Figure 1. Upper panel: Percentage of errors on AY trials for participants in the training, instruction control, and practice control groups at baseline and posttest. Lower panel: Percentage of errors on BX trials for participants in the training, instruction control, and practice control groups at baseline and posttest.


0.12
0.1
0.08
0.06
0.04
0.02
0
AX errors (%)
Training
Instruction Control
Practice control
Baseline
Posttest


0.12
0.1
0.08
0.06
0.04
0.02
0
BX errors (%)
Training
Instruction Control
Practice control
Baseline
Posttest

Appendix A

Proportion of Errors and Mean Reaction Times at Baseline and Posttest in AX and BY Trial Types for Training and Control Groups

Trail type	Training	Instruction control	Practice control
		Errors	
AX			
Baseline	.02 (.03)	.05 (.14)	.03 (.07)
Posttest	.01 (.02)	.04 (.12)	.03 (.06)
Final	.02 (.03)	.06 (.16)	
BY			
Baseline	.00 (.00)	.00 (.00)	.01 (.04)
Posttest	.00 (.00)	.00 (.02)	.00 (.00)
Final	.00 (.00)	.00 (.00)	
		Median RTs	
AX			
Baseline	523 (71)	534 (99)	564 (88)
Posttest	507 (912)	507 (109)	517 (84)
Final	499 (64)	500 (94)	
BY			
Baseline	526 (106)	533 (122)	575 (104)
Posttest	494 (111)	502 (107)	513 (103)
Final	484 (101)	489 (120)	

Note. Entries are means; standard deviations are in parentheses.