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Age-Related Differences in Perceptual Learning

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The present study investigated age-related differences in perceptual learning. We assessed performance and learning on a semantic category visual search task. We investigated whether prepractice was beneficial for general learning and for automatic attention response development. In terms of general learning, prepractice was beneficial, especially for older adults; however, prepractice did not benefit automatic attention response development. The implications of these results for training purposes are discussed.

INTRODUCTION

Learning is a lifelong endeavor. Consequently, it is critical for trainers to understand how best to train adults of all ages. In the present-day work environment, new technologies and improvements in existing technologies necessitate employee training and retraining. Knowledge of basic training principles derived from the laboratory will be indispensable for the development of training programs in real-world environments.

The purpose of the current research was to assess the benefits of prepractice for the development of a perceptual skill. We compared skill acquisition for young and older adults to determine if the characteristics of their performance were similar after consistent practice.

Age Differences in Perceptual Learning

The development of a perceptual skill involves learning to associate a particular perceptual stimulus with the appropriate response. For example, hearing one's own name results in an orienting response to the source. Similarly, seeing a stop sign results in the driver's moving to stop the vehicle. More complex perceptual skills include responses made by firefighters to a particular type of fire, instructions given to pilots by air traffic controllers on the basis of a display of information, and so on.

Shiffrin and Schneider (1977; Schneider & Shiffrin, 1977) and many others (see Shiffrin, 1988, for a review) have demonstrated the importance of consistent practice for the development of stimulus-response relationships. Consistent practice involves the invariant association of particular stimuli (or sets of stimuli) with particular responses. After extensive consistent practice on perceptual tasks, individuals can develop an automatic attention response (AAR) to the trained stimulus; that is, well-learned responses to stimuli need not be mediated by attention but occur immediately, unconsciously, and even involuntarily in the presence of the eliciting stimulus.

The literature on perceptual learning for older

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adults suggests that although they do improve with extensive consistent practice, older adults do not develop new AARs (e.g., Fisk & Rogers, 1991; Rogers, 1992; Rogers, Fisk, & Hertzog, 1994). One focus of the present research was to provide an optimum training environment for AAR development. The question was whether older adults might then successfully develop an AAR.

There are two components of perceptual learning on which we focus here. First is what we will call *general learning*. An individual must first learn the general requirements of the task. We will illustrate with the perceptual task used in the present research: a semantic category visual search task. The participant is presented with a category (e.g., color) followed by two to four category exemplars (e.g., red, yellow) on a computer screen. The task is to determine quickly and accurately which of the words is a member of the given category (i.e., the target item). Thus general learning on this task requires learning where to look on the computer screen, understanding the sequence of events occurring in the task, learning the layout of the buttons to press on the keyboard, interpreting the feedback provided after each trial, and developing a strategy for scanning the words on the computer screen. Thus for a relatively simple task, there is a lot to be learned.

The second component of learning on this task is the development of an AAR. After extensive consistent practice (such that particular words are always targets and are responded to, whereas other words are always distractors and are ignored), target items automatically attract attention by appearing to "pop out" of the display (e.g., Shiffrin & Dumais, 1981). AAR development is assessed using a reversal manipulation whereby the roles of targets and distractors are reversed: Trained target words that were always attended to become distractors, which must be ignored. It is analogous to having your name changed and trying not to respond when someone calls out your old name. The degree of disruption at reversal provides an index of the strength of AAR development.

Both young and older adults show significant improvements in performance with practice on category search tasks (e.g., Fisk & Rogers, 1991). However, older adults show less evidence of AAR development in comparison with younger adults. In the present experiment we wanted to separate the two components of learning in an effort to simplify the task while also emphasizing the consistencies that can lead to AAR development. We provided young and older adults with an entire session (960 trials) of prepractice on the category search task. The logic was that this prepractice would enable participants to learn all the general components of the task and hence to develop a general search skill. We then provided 3840 trials of consistent practice on a new search task. At this point participants had only to learn the relationship between the stimulus items and the particular responses (i.e., the consistent mapping). We provided prepractice rather than simply providing overtraining on the same stimuli for the following reason.

Evidence from studies by Rogers and Fisk (1988) and Clark and Rogers (1994) suggest that older adults may develop an inefficient strategy that is then difficult to alter. If, while learning the mechanics of the task, the older adults are utilizing a less-efficient strategy, they might never develop an AAR, even with extensive practice. With our design, during practice on the new task, participants would have the chance to focus on the task consistencies (and perhaps develop an AAR).

If the older adults were successful at developing an AAR in the current study, we would have information about the benefits of prepractice that would be relevant to the development of training programs. If they were unsuccessful, we would have to conclude that aging affects the mechanisms of AAR development and consider this fact when training older adults on new perceptual tasks.

METHOD

Participants. Twenty-four young adults (mean age 20.92 years, SD = 2.41, range 19–29) and 24 older adults (mean age 72.12 years, SD = 4.44, range 65–80) participated in the experiment; each age group consisted of 19 women and 5 men. The young adults were college students enrolled in an introductory psychology course who received course credit for their participation. The older adults were healthy community-dwelling individuals who received monetary compensation ($5.00/h) for their participation as well as reimbursement for parking expenses.

All participants were screened for psychotropic drug use; those taking more than two medications that affect attention were excluded (Giambra & Quilter, 1988). Both the young and older adults had corrected or uncorrected binocular visual acuity of at least 20/40, both near and far. Older adults had received significantly more formal education than the young adults: The mean number of years of education was 15.42 for the older adults (SD = 2.43) and 13.08 for the young adults (SD = 1.21); $t(46) = 4.21$, $p < .001$.

Participants rated their health on a scale from 1 (*excellent*) to 5 (*poor*). Both the young and the older adults rated their health between good and excellent (older adults: M = 1.67, SD = 0.76; young adults: M = 1.75, SD = 0.61); no significant difference was found between them. All participants were administered the Extended Range Vocabulary Test (Ekstrom, French, Harman, & Derman, 1976) and the digit-symbol substitution of the Wechsler Adult Intelligence Scale (Wechsler, 1981). The young adults performed significantly better than the older adults on the digit-symbol substitution test (older adults: M = 45.75, SD = 11.23; young adults: M = 73.96, SD = 12.98), $t(46) = 8.05$, $p < .001$, whereas the older adults performed significantly better on the vocabulary test (older adults: M = 15.54, SD = 4.76; young adults: M = 9.21, SD = 3.89), $t(46) = 5.05$, $p < .001$.

Design. Age (young or older) was a quasi-experimental variable. Prepractice was manipulated between subjects. In each age group, 12 participants were assigned to the prepractice group and 12 were assigned to the control group, which did not receive prepractice.

Display set was either two, three, or four and was manipulated within subjects. Within each block of 48 trials were 16 trials of each display size, randomly permuted. When display set size was less than four, a placeholder was used. The same placeholder (!+@%*&), equivalent in length to the longest word, was used consistently throughout the experiment. Placeholders were required to maintain the appearance of the display (i.e., a total of four items in the display) while varying the semantic load across display sizes (Fisher, Duffy, Young, & Pollatsek, 1988). Based on an average viewing distance of 45 cm from the screen, the visual angle of the height of the display set was approximately 1.90° and the length of the display set was 4.79°.

Practice was also a within-subject variable. The prepractice group completed 960 trials (20 blocks of 48 trials) on the prepractice task in a single 1-h session. The prepractice and control groups each completed 3840 trials (80 blocks of 48 trials) on the criterion task; these trials were completed in 1-h sessions on each of four consecutive days.

AAR development was assessed with a reversal task in which the roles of targets and distractor items were reversed. The prepractice group completed 240 reversal trials immediately following the prepractice task. Both groups completed 240 trials of reversal trials immediately following the last block of practice on the criterion task. (The sequence of trials for each group is presented in Table 1.)

The primary dependent variable was reaction time (RT, measured in milliseconds). Accuracy data were also collected to ensure that participants followed instructions to maintain a 95% rate.

Stimuli. Memory set items were the unrelated semantic categories of birds, body parts, clothing, countries, earth formations, fruit, and musical instruments (Collen, Wickens, & Daniele, 1975). The targets and distractors were exemplars that are high associates of each category (Battig & Montague, 1969). Each category set contained eight words between four and six letters in length. Three categories (animals, body parts, and colors) were assigned as criterion

TABLE 1

Number of Trials in Experimental Procedure and Sample Category Assignment

	Phase			
Group	Prepractice	Prepractice Reversal	Criterion	Criterion Reversal
		Number of Trials		
Prepractice	960	240	3840	240
Control	—	—	3840	240
		Sample Category Assignment		
Target category	body parts	fruits	earth formation	clothing
Distractor category	fruits	body parts	clothing	earth formation

target categories. (These three categories were chosen in order to collect data to be used for another experiment replicating that of Schneider and Fisk, 1984.) The remaining categories were assigned as prepractice targets, prepractice distractors, and criterion distractors. Category assignment was counterbalanced across participants within an age group and replicated across age groups (see Table 1 for an example).

Procedure. The prepractice task was a consistently mapped semantic category visual search task. One category served as the target set (i.e., the exemplars of the category were always to be responded to when they appeared in the display), and a different category served as the distractor set (i.e., exemplars of the category were always to be ignored when they appeared in the display). In the prepractice reversal task, the prepractice targets became distractors and the prepractice distractors became targets.

The criterion task consisted of a new consistently mapped semantic category visual search task. It was virtually identical to the prepractice task (e.g., trial procedure, response keys); however, a new category was assigned as the target category and another new category was assigned as the distractor category. In the criterion reversal task, the criterion targets became distractors and criterion distractors became targets.

An individual trial consisted of the following sequence of events. The participant was presented with the memory set of one category label (e.g., colors). He or she was instructed to press the space bar to initiate the trial. After the space bar press, a focus cross was presented for 500 ms in the center of the screen, where the display set was to appear. Immediately following the focus cross the display set appeared. The display set consisted of four stimuli (words or placeholders) arranged in a rectangle. The task was to determine the location of the target word (i.e., lower left, lower right, upper left, upper right) and press the appropriate key (labeled LL, LR, UL, UR); a target word was present on every trial. Each of the eight exemplars served as a target a total of six times, and their presentation was permuted. The target location was also permuted across trials. The display set remained on the screen for a maximum of 6000 ms. If the participants did not respond within the allotted time, the trial was considered an error.

Following each response, the participant received performance feedback. After a correct trial, RT was displayed in hundredths of a second. After an incorrect trial an error tone was sounded. After each block of trials the participant's average RT was displayed along with his or her percentage accuracy for that block. Participants were instructed to maintain an accuracy level of 95% and to respond as quickly as possible. If accuracy fell below 93% in a block, a message was displayed instructing the participant to respond more carefully. If accuracy was above 97% in a block, a message was displayed instructing the participant to respond faster.

Participants were prompted to take a break after every block to rest their eyes.

Equipment. IBM PS/2 microcomputers were used to present the stimuli and collect responses. The computers were programmed with Psychological Software Tools' Microcomputer Experimental Language (Schneider, 1988). The stimuli were presented on IBM PS/2 color monitors with an approximate luminance of 55 cd/m^2. The numeric keypad was labeled so that the 1, 2, 4, and 5 keys represented LL (lower left), LR (lower right), UL (upper left), and UR (upper right), respectively. All participants were tested at individual partitioned workstations and monitored by a research assistant. During all sessions pink noise was played at approximately 55 dB to mask background noises.

Results

The accuracy data are discussed at the end of this section. Only correct-trial RTs and trials in which the RT was between 100 and 4000 ms were included. The data were grouped into sets of five blocks (240 trials) for stability. The analyses were conducted on comparison slopes and intercepts. Comparison slopes represent the increase in RT per unit increase in display size and were calculated for each individual participant by a regression of RT on display size. In some search and detection tasks, slopes that are near zero represent a parallel search and, hence, automatic processing. However, in the present task, slopes typically remain high because of the need for eye movements (e.g., to bring stimuli into foveal view), which may impose a mechanical limit on search speed. Thus in the present case there might be a minimum time necessary to read the words because it is difficult to take in the entire display in a single fixation (see Rogers, Fisk, & Hertzog, 1994; Shiffrin, 1988).

AAR development was therefore operationally defined as the amount of disruption in performance that occurred when the roles of the consistently mapped targets and distractors were reversed. Reversal data are presented in the form of disruption scores, which were calculated as follows: [(reversal RT − final RT)/final RT] × 100. This formula provides a relative disruption score that controls for baseline differences between participants and between groups of participants. A disruption score was calculated separately for each participant and for each display size prior to being averaged. Thus automaticity (i.e., the development of an AAR) is indexed in the present task by the percentage of disruption at reversal. The intercepts represent the task components that are independent of display size, such as where to look in the display, how to respond, and other basic components of the task.

Prepractice results. The purpose of the prepractice task was to allow participants to learn the mechanics of the task prior to performing the criterion task. We expected to see significant improvements in intercepts, which represent the nonsearch components of the task. These data are presented in Figure 1 for the four sets of prepractice trials.

The young adults were significantly faster than the older adults, $F(1, 22) = 299.89$, $p < .001$, $MSE = 136\,793.38$, and there was a significant effect of practice set, $F(3, 66) = 33.54$, $p < .001$, $MSE = 7584.67$. Moreover, there was a significant Age × Practice Set interaction, $F(3, 66) = 5.92$, $p < .001$, $MSE = 7584.67$. Older adults showed significantly greater improvements in terms of intercepts than did the young adults. This finding is consistent with previous research (e.g., Rogers, Bertus, & Gilbert, 1994) and

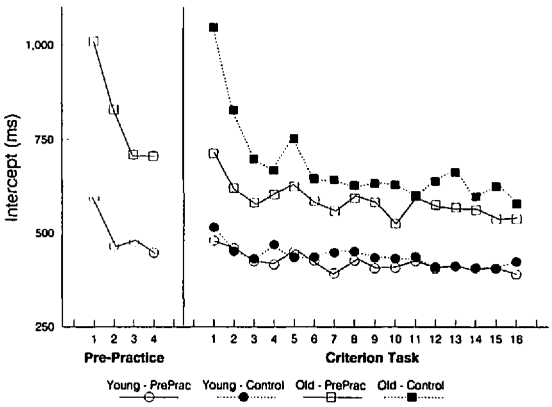

Figure 1. Intercepts for the prepractice and criterion tasks. Each point represents a practice set consisting of 240 trials.

suggests that the general learning requirements may have been greater for the older participants because of their inexperience with computers in general and with these types of tasks in particular.

The slope data are presented in Figure 2. As noted, the slopes are not very informative for this task. In fact, there were no significant effects of age or practice set, nor was there an interaction. We also had participants perform a reversal task at the end of the prepractice trials. These data are presented in the far left bars of Figure 3 (averaged across display sizes). The young adults were significantly more disrupted than the older adults, $F(1, 22) = 12.03, p < .002$, $MSE = 0.04$. In fact, only 1 of the 12 older participants was disrupted more than 25%. Thus whereas reversal greatly disrupted one of the older participants, it was not greatly disruptive for the majority of that age group. Even after only 960 trials with the prepractice stimuli, the young adults showed evidence of having developed an AAR, whereas the older adults did not.

Criterion task results. The slope data are presented in Figure 2. The only significant effect was for practice set, attributable to a general improvement across trials, $F(15, 660) = 8.01$, $p < .001$, $MSE = 476.23$. Again, the slope data are not particularly informative for this task. More informative are the intercept data and the reversal results.

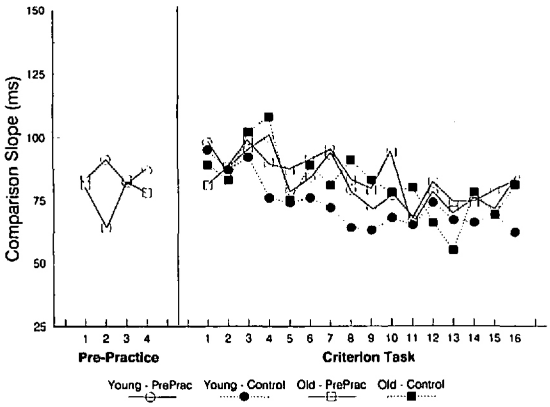

Figure 2. Comparison slope estimates for the prepractice and criterion tasks. Each point represents a practice set consisting of 240 trials.

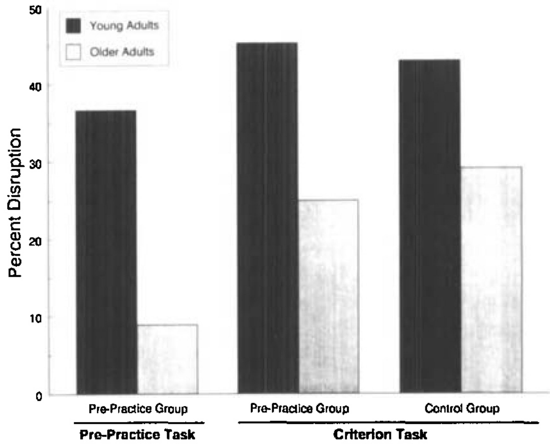

Figure 3. Reversal data presented in the form of disruption scores which were calculated as follows: ((Reversal RT − Final RT)/Final RT) * 100.

The degree to which prepractice provided an initial benefit to criterion task performance was determined by comparing the intercepts of the prepractice group with those of the control group for the initial set of criterion task trials (i.e., the first 240 trials). There was significant main effect of age, $F(1, 44) = 50.52$, $p > .001$, $MSE = 34\,735.40$; and group, $F(1, 44) = 11.81$, $p < .001$, $MSE = 34\,735.40$. In addition, there was a significant interaction between age and group, $F(1, 44) = 50.52$, $p < .001$, $MSE = 34\,735.40$.

As is clear from Figure 1, the initial benefits were greatest for the older adults. In fact, follow-up analyses for the older adults' data revealed that even at the end of practice (Set 16), the group that had received prepractice had significantly lower intercepts than did the control group, $F(1,34) = 4.16$, $p < .049$, $MSE = 10\,100.06$.

The patterns of initial benefit revealed that both the young and older adults who received prepractice on the category search task showed positive transfer to a similar search task with new stimuli. However, the benefit was largest and longest-lasting for the older adults. Thus older adults who have had the benefit of general learning of the search task revealed superior performance relative to a control group that was performing the search task for the first time; in addition, the older adults' superior performance was maintained even after 3840 trials. The question remains as to whether the prepractice group was also better able to develop an AAR.

The reversal data are presented in Figure 3. A benefit of prepractice on AAR development would have been revealed by a significant difference in disruption between the two groups. However, there was no difference between the prepractice and control groups in the amount of disruption ($p < .84$), nor was there a significant Age × Group interaction ($p < .50$). Thus there does not appear to be a benefit of prepractice for AAR development, even for the old adults, who showed a substantial benefit of prepractice in intercepts. There was a significant age difference in disruption, $F(1, 44) = 13.57$, $p < .001$, $MSE = 0.03$, because the young adults were disrupted more, overall, than were the older adults (44% vs. 27%). This finding suggests that the young adults developed a stronger AAR than did the older adults. In fact, only 8 of the 24 older participants were disrupted more than 25%. Thus, whereas eight of the older participants were greatly disrupted in the reversal condition, the majority of older participants were not.

Accuracy. The accuracy data are presented in Table 2 for the prepractice, criterion, and reversal tasks. Participants followed accuracy instructions and maintained an average accuracy of between 93% and 97% for all of the tasks.

Discussion

Even with prepractice, older adults showed significantly less evidence of AAR development relative to younger adults. Thus, as has been previously suggested, there appears to be some age-related deficit in the ability to acquire new automatic processes in perceptual learning tasks (e.g., Fisk & Rogers, 1991; Rogers, 1992).

However, an important finding was that prepractice was beneficial, especially for the older adults. The older adults who had some previous exposure to the task of interest outperformed the control group even after 3840 trials of practice. For the young adults, though there was some initial benefit of prepractice, that benefit dissipated quickly as the control group caught up (see Figure 1). Thus from a training perspective, a brief amount of prepractice or exposure to the general task has long-lasting benefits for older adults.

IMPLICATIONS FOR TRAINING

The fact that older adults learn a more general search skill rather than an AAR has both costs and benefits. The cost is that the task remains attention demanding for them. This is particularly problematic in situations that require them to perform two tasks simultaneously (Rogers, Bertus, & Gilbert, 1994). The benefit is that when the roles of the stimuli are changed but the task remains the same, older adults are less disrupted than are young adults. In some situations an AAR is disruptive. In the present experiment, it occurred when the roles of the targets and distractors were reversed. The previously well learned AAR disrupted the young adults to a

TABLE 2

Mean Accuracy Rates for Prepractice, Prepractice Reversal, Criterion, and Criterion Reversal Tasks

	Task			
Age, Group	Prepractice	Prepractice Reversal	Criterion	Criterion Reversal
Young adults				
Prepractice	95%	94%	95%	95%
Control	—	—	95%	94%
Older adults				
Prepractice	95%	94%	95%	95%
Control	—	—	95%	95%

greater degree. Thus in situations that require flexibility in response to changing stimuli, older adults may have a benefit.

The important point from a training perspective is that the trainer should be aware of the capabilities and limitations of older adults. In a perceptual learning task, older adults require time to learn the general components of the task. The present data, along with previously reported results (e.g., Rogers, Fisk, & Hertzog, 1994), show that older adults improve tremendously during the first several hundred trials. Moreover, having prepractice on the mechanisms of the task enabled the participants to perform better with the actual stimuli. Thus although the older adult prepractice group did not develop an AAR, they did outperform the older adult group that did not receive prepractice.

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