

Age-Related Deficits in Guided Search Using Cues

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The ability of young and older adults to engage in guided conjunction search was tested in 2 experiments. In the cued condition, a picture of the target was presented before the search. In the noncued condition, there was no picture of the target. In Experiment 1, the cue was presented for 200 ms; the magnitude of the cuing effect (noncued response time – cued response time) was greater for the young than for the older observers. In Experiment 2 (older observers only), the cue duration was doubled, and older observers had a larger magnitude of cuing effect than found in Experiment 1 but not as large as what would be expected under generalized slowing. The results indicated that older observers had difficulty with interpreting the cue and setting search parameters when the target varied across trials.

Keywords: aging, visual search, guided search

In a visual search for a target among distractors, randomly choosing locations to search will eventually result in detection of the target, but top-down control over the search can improve efficiency. Wolfe's model of guided search, which is implemented as a simulation in Wolfe (1994), is a computational account of the way in which a parallel stage of feature extraction can interact with a serial stage of feature analysis to expedite search. More commonly, guided search is discussed in a less computationally explicit manner. For instance, in a conjunction search (Treisman & Gelade, 1980), searching for a red circle among red-square and green-circle distractors can be accomplished by searching for a circle among red items or for a red item among circles, depending on which dimension it is easier to segregate the display. Egeth, Virzi, and Garbart (1984) tested the ability of observers to selectively search the relevant subset and found that when the number of distractors sharing color with the target was fixed, detection response time (RT) was constant as a function of overall display size (i.e., the RT set-size slope was 0). When a fixed-size subset of distractors shared the same shape as the target, the RT set-size slope was greater than 0 but lower than was found for a standard conjunction search. These results indicated that observers were confining their searches to a relevant subset, which could be defined on the basis of color or shape.

Age-group differences in guided search were first examined by Plude and Doussard-Roosevelt (1989), who used a similar task to that of Egeth et al. (1984). In their guided-search condition (standard conjunction and feature searches were also conducted), two distractors always shared the same color as the target. Plude and Doussard-Roosevelt found that the age groups were equivalent in RT set-size slopes for the guided condition, although older adults

were slower overall than the younger adults. Both age groups manifested a slight positive RT set-size slope, which indicated that they were mostly successful in confining search to the relevant subset (see also Madden, Gottlob, & Allen, 1999). In a series of aging studies, Scialfa and colleagues directly measured the ability to confine search to the relevant subset by monitoring eye movements. Scialfa, Jenkins, Hamaluk, and Skaloud (2000) used a conjunction search task in which the target was a white line slanting left and the distractors were black lines slanting left and white lines slanting right. They computed a selection factor, which was the proportion of fixations landing on white objects in the display (they had found that observers tended to segregate by color rather than orientation). Scialfa et al. (2000) found that observers fixated white objects on 75%–90% of fixations and that this proportion did not differ across age groups, which indicated that older adults were just as effective in confining search as the young adults (see also Ho & Scialfa, 2002).

Another important process that Scialfa and colleagues examined in the above studies is the learning of guidance over successive sessions under conditions of consistent mapping (i.e., target and distractor identities were fixed). In Scialfa et al. (2000), the target and distractors remained the same for four (Experiment 1) or seven (Experiment 2) learning sessions, during which response time for target-absent and target-present trials decreased in the form of a power function, with the rates of learning comparable across age groups. In a *reversal* session run after the learning sessions, the target and one of the distractors switched identities. Scialfa et al. (2000) found a disruption effect (increased RT compared with learning trials) that was equivalent across age groups; this indicated that observers in both age groups had automatized the guidance of search in the learning trials. In Ho and Scialfa (2002), 16 sessions of conjunction search were run, which allowed them to include three reversal sessions. The key finding here was that a relatively large disruption effect was found for the first reversal session, but the disruption effect was small or nonexistent (with no important age-group effects) for the second and third reversal sessions. The results from Ho and Scialfa (2002) indicated that after the first reversal, observers had learned a general, flexible rule for guided search. Dennis, Scialfa, and Ho (2004) found a

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similar pattern along with a lack of age-group differences in multiple reversal sessions for a conjunction search. All of these studies provided evidence that young and older adults had equivalent capacities for learning and applying general rules for guided search.

In all of the above studies, target identity was constant across trials (consistently mapped) within a session. This meant that a particular search strategy could be practiced and refined during that session. Recently, two (nonaging) studies were published in which target identity could vary across blocks or within a block (variably mapped), requiring observers to adopt an even more general strategy for guided search. Scialfa, McPhee, and Ho (2004) used a type of variable mapping in which reversals occurred across blocks or within a block. When a target-distractor reversal occurred only at the beginning of each block, observers could execute efficient guided search. When reversals occurred randomly within a block (and each trial was preceded by a preview of the target), observers could still execute efficient guided search. When reversals occurred within a block and targets were not previewed, however, search was impaired relative to the other conditions. These results indicated that observers could use efficient guided search under conditions of variable mapping, as long as target identity was known before each trial.

Another guided-search study, which directly investigated the use of target cues, was conducted by Wolfe, Horowitz, Kenner, Hyle, and Vasan (2004), who used multiple target identities (not reversals per se). Wolfe et al. (2004) examined the systematic variation of timing parameters, as well as performance in two different control conditions (no cue and fixed target, establishing ceiling and floor for search RT). In their guided-search conditions, target identity varied across trials, but a target-identity cue (preview) was presented before target-display onset. Target-identity cues were of two types: a verbal description of the target (word cue) or a visual example of the target (picture cue). Both types of cues facilitated visual search compared with the no-cue control condition, but picture cues were more effective than word cues. A 50-ms picture cue, presented immediately before the onset of the target display, reduced RT close to the level observed in the fixed-target control condition. Maximal (asymptotic) cuing was produced by a 200-ms interval between cue and target onsets (stimulus onset asynchrony; SOA). This speed of cuing indicated that observers were able to encode the target and implement unique search settings in a very short period of time (50–200 ms).

On the basis of the aging work of Scialfa and colleagues (2004) cited above, it has been established that older adults are not impaired relative to young adults under conditions of target-distractor reversal. This indicates that older adults are capable of using flexible guidance in conjunction search when targets are consistent within a block. In addition, the work by Scialfa et al. and Wolfe et al. (2004) indicates that young observers are capable of conducting guided search when target identity is unique to each trial, as long as they can set guidance parameters “on the fly” in response to target-identity cues. It is not known, however, whether there are age-group differences in this capability. Accordingly, the procedure of Wolfe et al. (2004) was chosen to investigate possible age-group differences in the ability to use target-identity cues to effect guidance. A picture cue (copy of the target) was presented before onset of the search display in a conjunction search; we used a 200-ms cue duration instead of the 50 ms that Wolfe et al. used

in order to maximize cue-encoding time. In previous research using masked stimuli, it was found that older adults could identify two letters with an exposure duration of 80 ms (Cerella, Poon, & Fozard, 1982), so it was expected that a 200-ms unmasked cue could be perceived adequately by the older adults.

Wolfe et al. (2004) found that guidance reduced both overall RT and RT set-size slopes compared with the noncued control condition for both target-present and target-absent trials. In the current experiments, the magnitude of the cuing effect (reduction of RT and RT set-size slope) was examined as a function of age group. It was expected that the overall RT of the older adults would be increased because of generalized cognitive slowing, but it was not clear whether the magnitude of the cuing effect would be increased or decreased relative to that of the young group. Under generalized slowing, if effects of guidance were equivalent across age groups, then the magnitude of the cuing effect would be larger in the older group (Cerella, Poon, & Williams, 1980). In addition, the cue-target SOA was manipulated to examine age-group differences in the time course of cuing. As stated above, Wolfe et al. found that the cuing effect was asymptotic (maximal) by 200-ms SOA; results consistent with generalized slowing would show a relative delay in the growth of guidance for the older adults.

Experiment 1

Method

Observers

Fifteen older adults (mean age = 70.1, range 64–77 years) and 15 young adults (mean age = 21.4; range = 20–25 years), recruited from the community, participated. One young observer was removed (without replacement) for failure to follow instructions. The older adults were members of the Sanders–Brown Center on Aging subject registry at the University of Kentucky, and the young adults were university students. Older observers were paid \$10 per 1-hr session; younger observers received course credit. Observers passed a computer-administered color-blindness test, and minimum visual acuity, measured using letters at 4 feet (~1.22 m), was 4/8 (equivalent to 20/40). All observers had a minimum of 12 years of education. A computerized vocabulary test was administered; mean scores were 14.9 ($SE = 1.3$) and 15.9 ($SE = 1.1$) for older and younger participants, respectively, $F(1, 22) = 1.15$, $p > .05$. A computerized version of the digit-symbol test was also administered; mean RTs were 1.41 s ($SE = 0.09$) and 0.86 s ($SE = 0.05$) for older and younger participants, respectively, $F(1, 23) = 24.7$, $p < .01$. (Because of experimenter error, some of the values for vocabulary and digit symbol were missing.)

Apparatus

The stimulus displays were controlled by a Pentium 4 computer connected to a 19" monitor running at 120 Hz and with a screen resolution of 800×600 . The observer was seated such that the eye-to-screen distance was approximately 80 cm. The room had dim natural lighting. Stimulus displays were programmed in E-Prime (Psychology Software Tools, Pittsburgh, PA). Responses were collected on the PC keyboard.

Stimuli and Procedure

The task was a conjunction search in which the target changed from trial to trial. All stimulus items were bars of length 0.5° varying along three dimensions: color (red, green), thickness (0.1° or 0.3° ; i.e., thin or thick),

and orientation (vertical, horizontal). There were eight possible targets constructed by factorial combination of the three dimensions. Distractors were always divided into two equal classes with two dimensions differing. A single target, if present, differed from each distractor class by a single dimension. For instance, if the distractors were green thick horizontal bars and red thin horizontal bars, the target would be a green thin horizontal bar or a red thick horizontal bar; if the distractors were red thick vertical bars and red thin horizontal bars, the target would be a red thick horizontal bar or a red thin vertical bar. There were three display sizes used (6, 12, and 18 items total). Luminance of the stimuli was 30 to 69 cd/m^2 , and background luminance was 3.4 cd/m^2 . Figure 1 shows a typical display.

The instruction was to search for a unique item, which would take the place of one of the distractors on half the trials. Cued and noncued trials were run in separate blocks (three each, randomly ordered) of 48 trials. Targets were chosen randomly within blocks such that each of the eight targets was shown 18 times over the session. SOA and set size were determined pseudorandomly such that all factor combinations were equally probable (because the full canonical set of 480 trials would not fit into a single session). A fixation cross (1000-ms duration) was presented first, followed by a $.5^\circ$ white square (noncued trial) or the target (cued trial) presented at fixation for 200 ms. The cue was followed by the search display with an SOA of 200, 350, 500, 650, or 800 ms. The stimulus display was terminated by the manual response, with the z key mapped to "target absent" and with the m key mapped to "target present". Observers completed two sessions, each of which consisted of 6 blocks of 48 trials each. There were 30 practice trials at the beginning of each session.

Results

We used a repeated-measures design using the generalized linear mixed model, as implemented in PROC MIXED (Littell, Milliken, Stroup, & Wolfinger, 1996). A mixed model was used because it allowed the modeling of the within-subject variance parameters along with between-subjects differences in means. The models implemented in PROC MIXED are evaluated using likelihood functions instead of sums-of-squares as in an analysis of variance. In PROC MIXED, generalized F ratios are calculated using (restricted) maximum likelihood estimates of variance components and generalized least-squares estimates of treatment differences (Littell et al., 1996). In these results, least-square means

are presented with standard errors in parentheses. All multiple comparisons were adjusted using the Sidak correction.

There were five factors overall: age group (young, older), guidance (cued, noncued), target presence (absent, present), cue-target SOA (200, 350, 500, 650, 800), and set size (6, 12, 18). Only Session 2 was analyzed to maximize the effects of any practice gains. Because of the complexity of the design, analyses are reported using different subsets of factors (main effects first, followed by interactions of particular interest). The details of the results are below, but the main findings will be summarized here. There were no age-group effects on accuracy. For correct RT collapsed over target-present and target-absent conditions, as well as for correct RT for target-present and target-absent trials separately, there were Age Group \times Guidance interactions, with young adults showing a larger guidance effect than older adults. Individual analyses showed that almost all of the young adults showed effects of guidance but that very few of the older adults did.

Accuracy

Errors consisted of misses on target-present trials and false alarms on target-absent trials (see Figure 2). There were no interactions involving age group. Main effects of age group, SOA, guidance, target presence, and set size were also analyzed. There was no effect of age group, $F(1, 27) = 0.26, p > .6$, and no effect of SOA, $F(4, 108) = 1.95, p > .1$. There was a main effect of target presence, $F(1, 27) = 134.92, p < .001$, with miss rate ($M = .10, SE = .01$) measuring higher than false alarm rate ($M = .04, SE = .01$). There was a main effect of set size, $F(2, 54) = 15.95, p < .001$, with error rates of $.05 (SE = .01)$, $.06 (SE = .01)$, and $.09 (SE = .01)$ for set sizes of 6, 12, and 18 items, respectively. A follow-up analysis revealed that all pairwise differences between set sizes were significant except for that between 6 and 12 items, $t(54) > 3.34, p < .01$.

RT

Next, RT on correct responses was analyzed (see Figure 3). Responses faster than 200 ms and slower than 8000 ms were removed; this accounted for less than 2% of responses. For some measures, RT set-size slopes (and, if appropriate, y-intercepts) are reported.

Main effects. First, main effects of age group, SOA, guidance (cued, noncued), target presence, and set size were analyzed. There was a main effect of age group, $F(1, 27) = 37.52, p < .001$, with young observer RT ($M = 1,210 \text{ ms}, SE = 173$) measuring less than older observer RT ($M = 2,680 \text{ ms}, SE = 167$). There was no effect of SOA, $F(4, 108) = 0.01, p > .99$. Visual inspections of the data plotted by SOA indicated almost completely flat functions with respect to SOA. There was an effect of guidance, $F(1, 27) = 133.79, p < .001$, with cued trials ($M = 1,805 \text{ ms}, SE = 120$) measuring lower in RT than noncued trials ($M = 2,085 \text{ ms}, SE = 120$). There was also an effect of target presence, $F(1, 27) = 869.60, p < .001$, with participants in target trials ($M = 1,675 \text{ ms}, SE = 120$) performing faster than nontarget trials ($M = 2,215 \text{ ms}, SE = 120$). Finally, there was an effect of set size, $F(2, 54) = 469.60, p < .001$, with RTs of 1,584, 1,983, and 2,268 ms ($SE = 121$) for set sizes of 6, 12, and 18 items, respectively.

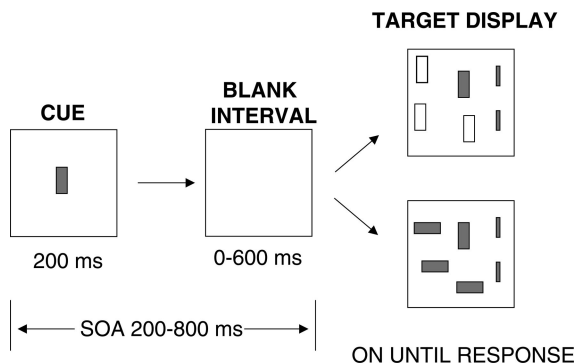


Figure 1. Order of events for both experiments. Timing is for Experiment 1. Cue is a picture cue (cue condition) or a white square (noncued condition). The target display (6, 12, or 18 items) had distractors segregated into two sets. On 50% of trials (target-present trials), one distractor was replaced with the target. Two sample target-present displays are shown (blank = red, filled in = green). SOA = stimulus onset asynchrony.

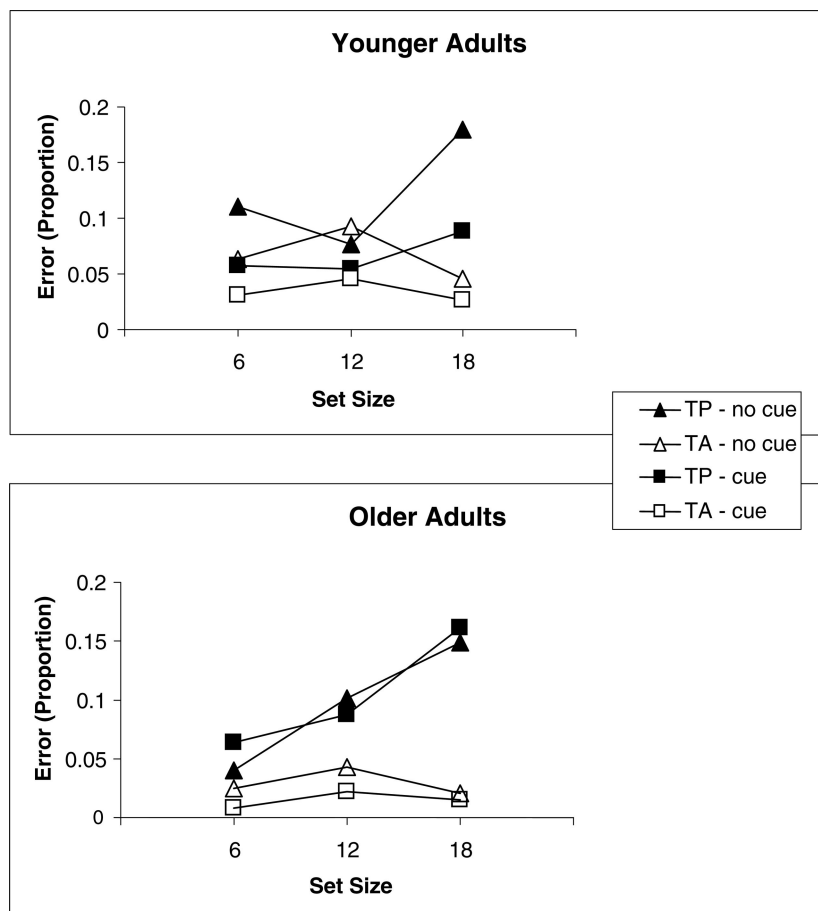


Figure 2. Error rates for younger adults (top) and older adults (bottom) in Experiment 1. Results are plotted for target-present (TP) and target-absent (TA) trials by cued and noncued conditions.

Interactions involving age group. There were three two-way interactions involving age group. First, there was an Age Group \times Target Presence interaction, $F(1, 27) = 220.93, p < .001$; young observers had RTs of 1,076 ms and 1,344 ms in target-present and target-absent conditions, respectively, and older observers had RTs of 2,273 ms and 3,086 ms in the same respective conditions. Second, there was an Age Group \times Guidance interaction, $F(1, 27) = 55.13, p < .001$. Young observers had RTs of 1,418 ms and 1,002 ms in the noncued and cued conditions, $F(1, 13) = 688.71, p < .001$, yielding a cuing effect of 416 ms, which was 34% of their mean RT. Older observers had RTs of 2,751 ms and 2,607 ms in the noncued and cued conditions, $F(1, 14) = 19.98, p < .001$; the cuing effect for older adults was 144 ms, which was 5% of their mean RT. Third, there was an Age Group \times Set Size interaction, $F(2, 54) = 137.09, p < .001$, with search rates (collapsed across target presence) of 27 ms/item and 88 ms/item for young and older observers, respectively.

Target-present trials. As follow-up analyses to the Age Group \times Target Presence interaction, target-present and target-absent trials were examined separately. For target-present trials, there were interactions of Age Group \times Set Size, $F(2, 54) = 25.26, p < .001$, and Age Group \times Guidance, $F(1, 27) = 19.52, p < .001$. For young observers in the target-present condition,

there was a Guidance \times Set Size interaction, $F(2, 26) = 4.87, p < .05$, with RT set-size slopes of 22 ms/item (intercept = 1,032 ms) and 10 ms/item (intercept = 756 ms) for noncued and cued conditions, respectively. There was a main effect of guidance for young observers, $F(1, 13) = 440.60, p < .001$, with mean RTs of 1,294 and 871 ms in the noncued and cued conditions. For older observers in the target-present condition, there was a Guidance \times Set Size interaction, $F(2, 28) = 3.44, p < .05$, with RT set-size slopes of 64 ms/item (intercept = 1,600 ms) and 43 ms/item (intercept = 1,660 ms) for noncued and cued conditions, respectively. There was a main effect of guidance for older observers, $F(1, 14) = 15.89, p < .01$, with mean RTs of 2,372 and 2,181 ms in the noncued and cued conditions.

Target-absent trials. For target-absent trials, there were interactions of Age Group \times Set Size, $F(2, 54) = 158.11, p < .001$, and Age Group \times Guidance, $F(1, 27) = 39.15, p < .001$. For young observers in the target-absent condition, there was a Guidance \times Set Size interaction, $F(2, 26) = 5.20, p < .05$, with RT set-size slopes of 44 ms/item (intercept = 1,022 ms) and 32 ms/item (intercept = 756 ms) for noncued and cued conditions, respectively. There was a main effect of guidance, $F(1, 13) = 313.52, p < .001$, with mean RTs of 1,552 and 1,136 ms in the noncued and cued conditions. For older observers in the target-

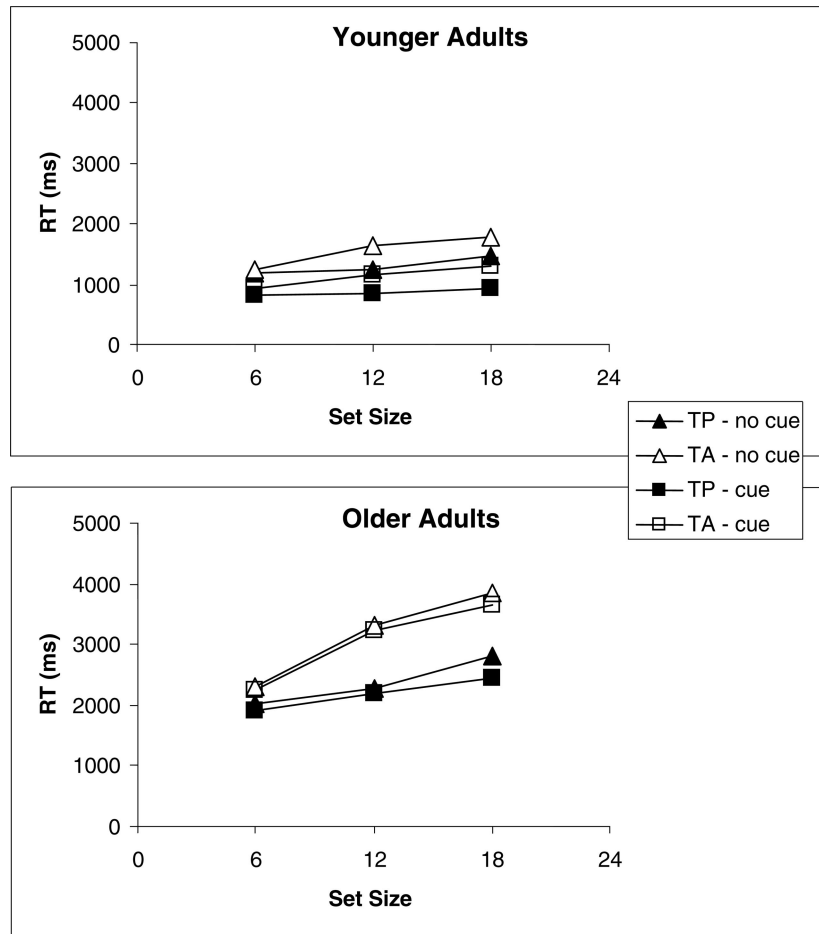


Figure 3. Correct response time (RT) for younger adults (top) and older adults (bottom) in Experiment 1. Results are plotted for target-present (TP) and target-absent (TA) trials by cued and noncued conditions.

absent condition, the Guidance \times Set Size interaction was not significant, $F(2, 28) = 1.48, p > .05$, with RT set-size slopes of 130 ms/item (intercept = 1,504 ms) and 116 ms/item (intercept = 1,643 ms) for noncued and cued conditions, respectively. There was a main effect of guidance, $F(1, 14) = 7.93, p < .05$, with mean RTs of 3,155 and 3,040 ms in the noncued and cued conditions.

Individual observers' performance. In Figure 4, parametric plots of noncued (x -axis) versus cued (y -axis) RT are presented for target-present and target-absent trials, with diagonal ($y = x$) lines drawn to indicate locations where the RTs are equal across conditions. Data points for all young observers lie below the line, indicating a cuing effect; in contrast, older observers' data points straddle the line. A few older observers performed very much like the young observers in both overall RT and size of cuing effect (distance from the $y = x$ line), but most had longer RTs than the young observers, and also many had no cuing effect (their data points lie on or above the $y = x$ line).

As a follow-up, individual observers' data were analyzed to determine whether the cued trials were significantly faster than the noncued trials. For the young group ($n = 14$), 14 and 11 observers had significantly lower RT on cued trials than on noncued trials for

target-present and target-absent trials, respectively ($p < .05$). Correspondingly, for the older group ($n = 15$), 4 and 2 observers had significantly lower RT on cued trials than on noncued trials for target-present and target-absent trials, respectively ($p < .05$). The proportions of observers exhibiting the cuing effect differed across age group for target-present trials, $\chi^2(1, N = 29) = 16.54, p < .001$, and for target-absent trials, $\chi^2(1, N = 29) = 12.46, p < .001$. It should be noted that greater variability in the older observers' responses would reduce the power to find significant cuing effects. These cuing effect analyses, however, corresponded closely with the point estimates of the cuing effects in Figure 4.

Discussion

Overall, observers from both age groups had lower search times in the cued condition than in the noncued condition. The target-present trials were most diagnostic of guided search: For young observers, there were cuing effects (noncued RT – cued RT) of 423 ms, which was 39% of their mean target-present RT. Their search-slope ratio (noncued:cued) was approximately 2:1, which indicated that the younger observers confined their search to the relevant subset on guided trials. In addition, the intercept de-

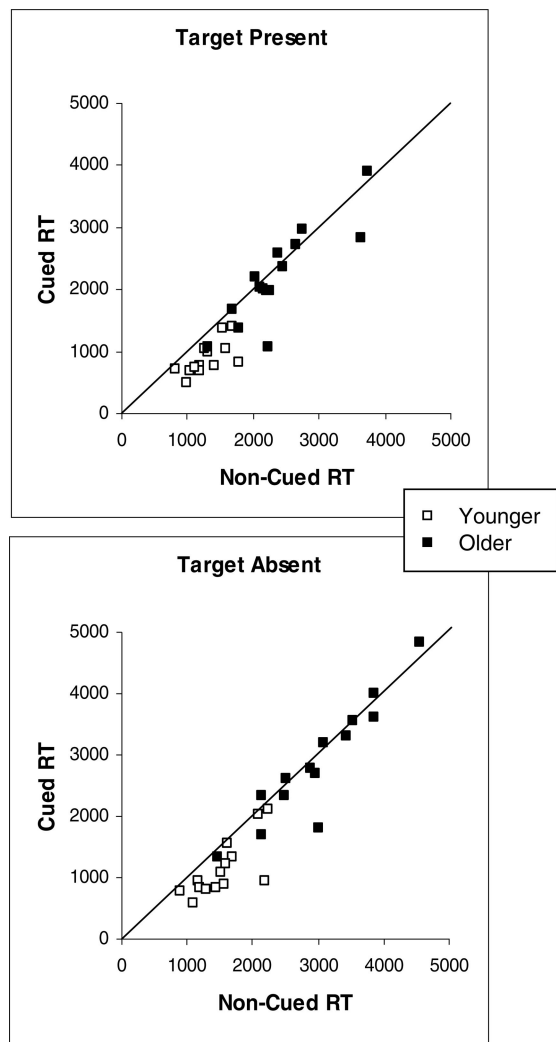


Figure 4. Parametric plots of noncued (x -axis) versus cued (y -axis) correct response time (RT) for Experiment 1. Each marker represents an individual observer in the target-present condition (top) or target-absent condition (bottom). Markers below the diagonal $y = x$ line indicate cuing (guidance).

increased by 276 ms in the guided condition, which would be consistent with a speeding of fixed processes such as initiating the search and responding. The results for the younger adults are similar to those of Wolfe et al. (2004). In contrast, the cuing effect for older observers, although significant, was only 191 ms or 8% of their mean target-present RT. The older adults' slope ratio was about 3:2, and the intercept actually increased by 60 ms from noncued to cued conditions. It appears from these results that older adults were only able to effect a weak sort of guidance. Because, when compared with young observers, older observers were both higher in overall RT and their cuing effect was smaller, this represents an unambiguous age-group deficit in guidance (Cerella et al., 1980; Loftus, 1978). As shown in Figure 4, most of the older observers failed to use the cue to guide search (points not below the $y = x$ line).

For both age groups, overall RT and search slopes indicated that guidance did not differ across SOA, which replicated the Wolfe et

al. (2004) findings for SOAs equal to or greater than 200 ms. Therefore, the age-group deficit in guidance was not due to a delay in the older adults' implementation of search strategies (unless it could be shown that they were delayed by more than 800 ms). They appeared to have had a reduced ability to execute some other component(s) of guided search, which could include encoding the cue and implementing a top-down search mechanism, among other processes. In this context, encoding would entail more than perception alone. There is much evidence that older adults can perceive a simple stimulus like a cue with an exposure duration of much less than 200 ms. For instance, Gottlob and Madden (1998) found that simple masked targets (T s of various orientations), presented parafoveally with a duration of 200 ms, could be identified by older adults with high accuracy, and Cerella et al. (1982) found that older adults could identify two masked letters presented centrally with an exposure duration of 80 ms. Whereas the older adults most probably were able to perceive the cues, it is possible that they were not able to set search parameters in response to the cue. Therefore, it was decided to investigate whether doubling the cue duration would result in improvements in the ability of older observers to effect guided search.

Experiment 2

In this experiment, only older observers were tested. The procedure was identical to that of Experiment 1, except that the cue duration was increased to 400 ms (from 200 ms), which resulted in a 200-ms translation of the cue-target SOAs. If the age-group deficit in guided search in Experiment 1 was a result of insufficient encoding time for the cue, then this manipulation would increase the effect of guidance for the older adults.

Method

Observers

Ten naive older observers, recruited as for Experiment 1, participated. A computerized vocabulary test was administered; the mean score was 15.8 ($SE = 1.5$). A computerized version of the digit-symbol test was also administered; mean RTs were 1.39 s ($SE = 0.06$). These scores did not differ significantly from those for older observers in Experiment 1.

Procedure

The procedure was identical to that of Experiment 1, except that the cue duration was increased from 200 ms (Experiment 1) to 400 ms, which also translated the SOA range by 200 ms.

Results

Accuracy and RT on correct trials, for Session 2 only, were analyzed as in Experiment 1. For accuracy, there was a main effect of target presence, $F(1, 9) = 13.74$, $p < .01$, with miss rate ($M = .06$, $SE = .01$) higher than false alarm rate ($M = .03$, $SE = .01$). There were no other significant effects involving accuracy. For correct RT (see Figure 5), there were four factors overall: guidance (cued, noncued), target presence (absent, present), SOA (400, 550, 700, 850, 1,000), and set size (6, 12, 18). There was an effect of guidance, $F(1, 9) = 84.53$, $p < .001$, with noncued trials ($M = 2,726$ ms, $SE = 227$) measuring higher in RT than cued trials ($M = 2,364$ ms, $SE = 227$). This represented an overall cuing

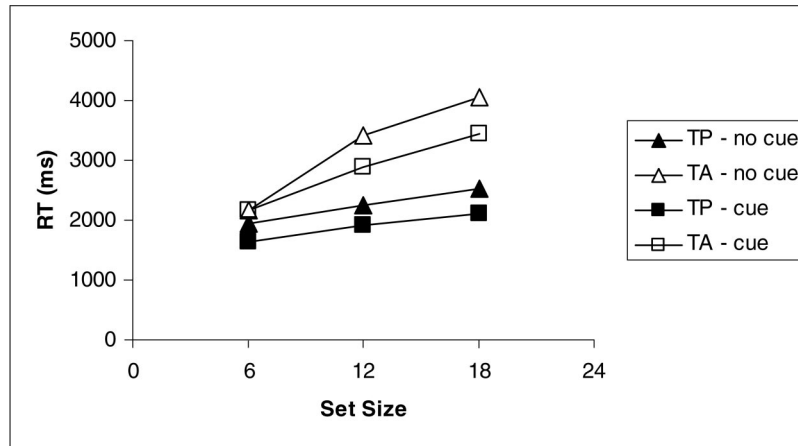


Figure 5. Correct response time (RT) for older adults in Experiment 2. Results are plotted for target-present (TP) and target-absent (TA) trials by cued and noncued conditions.

effect of 362 ms, which was 14% of mean RT. There was no effect of SOA, $F(4, 36) = 0.88, p > .05$. There was also an effect of target presence, $F(1, 9) = 586.50, p < .001$, with participants in target trials ($M = 2,068$ ms, $SE = 227$) performing faster than nontarget trials ($M = 3,022$ ms, $SE = 227$). Finally, there was an effect of set size, $F(2, 18) = 243.09, p < .001$, with RTs of 1,978, 2,624, and 3,032 ms ($SE = 227$), for set sizes of 6, 12, and 18 items, respectively.

The highest order interaction was that of Guidance \times Target Presence \times Set Size, $F(2, 18) = 4.31, p < .05$. For target-present trials, there was no Guidance \times Set Size interaction, $F(2, 18) = 0.39, p > .05$, with RT set-size slopes of 46 ms/item (intercept = 1,701 ms) and 37 ms/item (intercept = 1,444 ms) for noncued and cued conditions, respectively. There was a main effect of guidance, $F(1, 9) = 46.84, p < .001$, with mean RTs of 2,250 and 1,892 ms in the noncued and cued conditions. For target-absent trials, there was a Guidance \times Set Size interaction, $F(2, 18) = 13.85, p < .001$, with RT set-size slopes of 160 ms/item (intercept = 1,290 ms) and 106 ms/item (intercept = 1,570 ms) for noncued and cued conditions. There was a main effect of guidance, $F(1, 9) = 45.20, p < .001$, with mean RTs of 3,209 and 2,842 ms in the noncued and cued conditions.

Tests on individual observers ($n = 10$) indicated that 6 and 3 observers had significantly lower RT on cued trials than on noncued trials for target-present and target-absent trials, respectively ($p < .05$). This lack of a guidance effect for certain older observers is also illustrated in Figure 6; more than half of the point estimates for the cuing effect were not below the $y = x$ line.

Experiment 2 correct RT was compared with the older adults' Experiment 1 correct RT. For target-present trials, the only significant effect involving experiment was the interaction of Experiment \times Guidance, $F(1, 23) = 5.49, p < .05$, manifested by a 168-ms larger cuing effect in Experiment 2 than in Experiment 1 (noncued RT - cued RT). For target-absent trials, there was an Experiment \times Guidance \times Set Size interaction, $F(2, 46) = 6.42, p < .01$, with noncued/cued slope ratios of 1.22 in Experiment 1 and of 1.51 in Experiment 2. There was also an Experiment \times Guidance interaction, $F(1, 23) = 14.18, p < .001$, manifested by a 252-ms larger cuing effect in Experiment 2 than in Experiment 1.

Experiment 2 correct RT was also compared with the young adults' Experiment 1 correct RT. Older observers were slower than young observers on both target-absent and target-present trials, $F(1, 22) > 34.14, p < .001$. The cuing effects for the young adults were greater than for the older adults by 65 ms (target-absent trials) and by 49 ms (target-present trials), but these differences were not significant. Therefore, the cuing effect was not larger for the Experiment 2 older adults than for the Experiment 1 young adults, as Cerella et al. (1980) and others state would be consistent with generalized slowing (in fact cuing effects were nonsignificantly smaller for the older adults). The cuing effects as a proportion of mean RT were also examined: For target-present trials, the proportions were 33% (young) versus 17% (older), and for target-absent trials, the proportions were 27% (young) versus 12% (older). These proportional cuing effects were not significantly different across age groups, possibly because of power limitations.

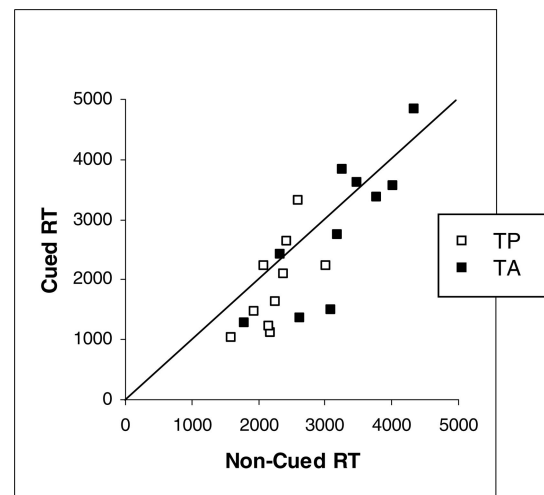


Figure 6. Parametric plot of noncued (x -axis) versus cued (y -axis) correct response time (RT) for Experiment 2. Each marker represents an individual observer in the target-present condition (TP; triangles) or target-absent condition (TA; squares). Markers below the diagonal $y = x$ line indicate cuing (guidance).

After examining the proportion of observers showing the cuing effect on the individual level, we found that the older observers were lower than the young observers. For the target-present condition, the difference in proportions was significant, $\chi^2(1, N = 24) = 4.15, p < .05$, and for the target-absent condition, the difference was just short of significance, $\chi^2(1, N = 24) = 3.84, p < .051$ (using Yates' correction for small sample size).

Discussion

Comparing older adult performance in Experiments 1 and 2, guidance increased from 8% to 17% of mean RT on target-present trials and from 4% to 13% on target-absent trials. Therefore, increasing the cue duration from 200 ms to 400 ms improved the ability of older observers to engage in guided search. The magnitude of the cuing effect (expressed as a difference in mean RT) did not differ from that of the young observers in Experiment 1, which could be interpreted as an age-group equivalence. The cuing effects might also be consistent with an age-group deficit, because equal cuing effects across age groups, coupled with overall slowing, would probably not be consistent with generalized slowing. The result for individuals (lower proportion of older adults showing an individual cuing effect) was consistent with the deficit view.

The improvement across experiments was rather surprising because, as stated before, a 200-ms unmasked cue (as in Experiment 1) was expected to have been effectively processed by the older adults. Although 200 ms may be long enough for older observers to encode a stimulus, it may have been that additional processes related to guided search were impaired by the short exposure duration. For instance, the cue may need to be converted into a visual or semantic representation for the guidance process, and maybe this could not be completed by the time of cue offset in Experiment 1. It also may have been that the older observers could only set search parameters while the cue was physically present. In any case, older adults had an increased ability to engage in guided search when the cue duration was increased from 200 ms to 400 ms, but it was not greater than that of the younger adults in Experiment 1 (as might be expected under generalized slowing).

General Discussion

The two experiments demonstrated age-related deficits in the ability to guide search when the target was unique to each trial and cued beforehand. Although the cue duration was expected to allow sufficient time for encoding in Experiment 1, the older adults showed very little guidance. When the cue duration was doubled in Experiment 2, the ability of the older adults to engage in guided search was increased such that their cuing effect did not differ from that of the younger adults in Experiment 1 (but the Experiment 2 cuing effect was probably still below the level consistent with generalized slowing). In both experiments, older adults most likely had sufficient time to engage in guided search, because Wolfe et al. (2004) found that young observers could effect guidance by 50-ms SOA and that older adults' performance did not improve over the entire range of cue-target SOAs (200–800 ms for Experiment 1, and 400–1,000 ms for Experiment 2).

Some conjectures can be made about the processes most likely contributing to the age-related impairments in guided search. It may have been that older observers had difficulty with converting

the cue into a set of search instructions. For instance, when the cue is a green narrow vertical rectangle, the observer most likely uses either a veridical or a semantic representation of the cue as a template for a search (Wolfe et al., 2004). The cue may allow observers to increase sensitivity to a target that matches the cue. It may also help the observer to segregate the display and search through a subset of items (although the particular search would be an "online" decision based on the composition of the target display). For example, given a green thin horizontal cue followed by a display containing green thin vertical and red thin horizontal items, the observer can segregate by orientation and search the horizontal items for a single green target, or the observer can segregate by color and search the green items for a single horizontal target. Older adults have been shown to conduct feature searches with small to no age-group decrements (Humphrey & Kramer, 1997; Plude & Doussard-Roosevelt, 1989), so it may have been that the older adults were deficient in executing the search instructions or segregating the display.

If we assume that 200 ms was a sufficient duration for older adults to encode the cue, then we need to explain why doubling the cue duration in Experiment 2 produced an increase in guidance. It is possible that the older adults had poor memory for the cue, which interfered with setting the search parameters (although there were no effects of SOA, which indicated that memory for the cue was not decaying over that interval). Doubling the cue duration may have increased the chances for the older adults to set the search parameters while the cue was still present. Even when the cue duration was doubled, however, a large proportion of the older adults were still unable to effect guidance.

It might be argued that the older adults were not motivated to use the cue because their search was efficient enough on no-cue trials. It was apparent, however, that search in the noncued condition was difficult. On noncued trials, search could be conducted by segregating the display into two parts and then searching one part for an anomalous item. Both of those processes would have to be conducted "on the fly" for each individual trial; it seems plausible that if a cue were provided, it would be beneficial to use it (as the younger observers' performance demonstrates).

The age-group deficit in the current task can be compared with other findings in aging and guided search. Madden, Whiting, Cabeza, and Huettel (2004) examined age-group differences in a guided search for an *E* or *R* among letter distractors. One item in the display was red, and the other items were gray. In the baseline condition, red was assigned at random to any item in the display, so color was not relevant to the search. In the guided condition, the red item was the target on most of the trials, so observers would benefit by searching the red item preferentially. Madden et al. (2004) found age-group equivalence in guidance, which can be explained in the current context by noting that, in their experiment, observers could adopt a single search set over all guided trials and that observers performed a feature search over all the items in the display (no segregation was necessary). Whiting, Madden, Pierce, and Allen (2005) found guidance in older observers in a feature search (even when the target varied over trials), which indicated that older observers were capable of looking for generalized feature "popout." Plude and Doussard-Roosevelt (1989) found guidance in older observers in a conjunction search, but in their design the target was constant over trials. The experiments by Scialfa and colleagues (Dennis et al., 2004; Ho & Scialfa, 2002; Scialfa et al.,

2000) all featured consistent targets within a session; even in the reversal sessions, a single target was presented for the entire session. All of these previous explorations of age-group differences in guided search, therefore, tested feature search under variable-target conditions or conjunction search under fixed-target conditions; in either type of search, guidance would be relatively simple (always search for a unique feature, or always search for a particular target). In contrast, the current task was a conjunction search under variable-target conditions; in this task, an increase in search speed would require guidance unique to each trial.

The current data suggest, therefore, that there are age-related decrements in using a cue to set search parameters on individual trials. On the other hand, it is possible that the older adults have difficulty setting search parameters, not because they are unique to each trial, but because they change across trials. This possibility is addressed in recent findings on age-group differences in costs associated with task switching. When different types of tasks are mixed within a block (i.e., AABBA), the time to complete the first B task is higher than the time to complete the second B task; this is called a specific switch cost. Three recent studies (Bojko, Kramer, & Peterson, 2004; Kramer, Hahn, & Gopher, 1999; Kray & Lindenberger, 2000) all found age-group equivalence or near-equivalence in specific switch cost, especially after a short amount of practice. This age-group equivalence suggests that the difficulty that the older adults had with the current task did not arise from the simple act of switching attentional set across trials but rather from the requirements of using a cue to adopt a unique search set on each trial.

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