Automatic Category Search and Its Transfer: Aging, Type of Search, and Level of Learning

Arthur D. Fisk,1 Wendy A. Rogers,2 Brian P. Cooper,1 and D. Kristen Gilbert3

1Department of Psychology, Georgia Institute of Technology.
2University of Georgia.
3Pepperdine University, Los Angeles.

We examined the site of learning as a function of task type and age. Two experiments examined whether learning in semantic category search is exclusive to trained elements of categories or generalizable to other elements of the trained categories. Specifically, we examined how practice searching for small subsets of exemplars from taxonomic categories transferred to untrained elements of those categories. Young and old adults received extensive practice on memory search (Experiment 1) or visual search (Experiment 2) tasks. Participants then transferred to conditions assessing whether learning was exclusive to the trained words or generalizable to other elements of the trained categories. The site of learning in memory search appears to be at the category level for both young and old adults.

Level of learning in visual search appears to differ as a function of age. Young adults' learning generalizes to the category level, whereas older adults' learning is specific to the trained words.

Recent studies conducted to investigate aging and skill acquisition have provided evidence that the extent of age differences in performance improvement may vary with the type of task and the type of learning underlying that improvement (e.g., Fisk & Rogers, 1991a; Fisk, Cooper, Hertzog, Anderson-Garlach, & Lee, 1995a; Rogers & Fisk, 1991; Rogers, Fisk, & Hertzog, 1994). Localizing these age differences in performance and in learning is important for motivating cognitive theory (e.g., Rogers et al., 1994; Salthouse, 1991) as well as for designing intervention strategies for a wide range of applied issues (e.g., Fisk & Rogers, 1997; Rogers, Fisk, & Walker, 1996). In addition, such research has been useful in elucidating sources of age differences in skilled performance; and equally important, it has pointed toward aspects of cognition that are relatively preserved with normal aging.

One such task where minimal age-related differences in performance improvement are observed is consistent memory search (Fisk & Rogers, 1991a). Also, there is at least some evidence that the learning underlying the observed performance improvement in consistent memory search is similar for younger and older adults (Fisk et al., 1995a; Hertzog, Cooper, & Fisk, 1996). In contrast, consistent visual search appears to result in substantial age-related performance and learning differences (e.g., Cooper, 1994; Fisk & Rogers, 1991a; Rogers et al., 1994). The pattern emerging from the search-detection literature is that older adults learn less than younger adults when the search-related skill is dominated by visual search components; however, when skilled performance is initially dominated by working memory that can be reduced with practice, older adults improve at a slower rate but to the same degree as young adults.

In this study we further explored the similarities and differences in learning that occur as a function of type of search and age. The study was designed to examine whether learning occurring for young and old adults in a category-search task is exclusive to the trained elements of the categories or generalizable to other elements of the trained categories. Specifically, we examined how practice at searching for small subsets of exemplars from taxonomic categories transfers to untrained elements of those categories. That is, will practice at detecting lion, tiger, apple, pear, etc. improve detection of other untrained animal and fruit names? If transfer does occur, is the extent of transfer moderated by age, and if so, does the type of task moderate these differences?

Search-Detection Tasks

When examining and discussing search-detection results, it is important to distinguish between two major classes of search effects. The classes of effects are based on the relationship between the target and distractor sets and the amount of practice (see Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). One class, varied mapping (VM) effects, occurs when individuals cannot consistently attend to stimuli across trials. The other class, consistent mapping (CM) effects, occurs when individuals receive extensive practice and can attend (and/or respond) consistently to stimuli across the practice opportunities. The two classes of effects are differentiated by the qualitative and quantitative differences between CM and VM search performance (for a review see Shiffrin, 1988). The processing that occurs with VM tasks has been referred to as controlled processing, and the processing that develops with CM practice has come to be referred to as automatic processing.

Search-detection tasks have proven to be a fruitful procedure to investigate automatic processing (see Shiffrin, 1988, for a review). Practice-related changes in attentional processes involved in the detection or localization of stimuli have been well documented over a wide range of stimulus properties (e.g., physical features and semantic properties). For
example, Fisk and Schneider (1983; Schneider & Fisk, 1984) demonstrated that the basic characteristics of CM and VM search demonstrated by Schneider and Shiffrin (1977) and Shiffrin and Schneider (1977) extend to more complex search tasks in which the memory set consists of a category label (e.g., fruit) and the target and distractor items in the display consist of category exemplars (e.g., apple and dog).

**Improvement in visual search.** — Visual search is a task that requires participants to hold a single element in memory and determine if (or where) that element is contained within a multi-element probe display. If a probe item matches the element held in memory it is called a target. Probe items that do not match the item held in memory are referred to as distractors. Important variables for performance improvement on the visual search task include the similarity and feature overlap of targets and distractors, the development of efficient search strategies, and the development of an automatic attention response. Search performance can improve through the development of efficient search strategies (Fisher, 1982, 1986; Fisher & Tanner, 1992). Individuals learn not only which features to search for but also the optimal order in which to search for those features (i.e., a target feature sequence). Fisher (1986) has demonstrated that feature overlap and search strategies play a critical role in the development of efficient search performance independent of the development of automatic processing (also see Rogers & Fisk, 1991).

Attention training involves the increase in the attention-attraction strength of consistently trained targets and distractors and the decrease in the attention-attraction strength of consistent distractor (for a review see Schneider & Detweiler, 1987; Shiffrin, 1988). After many trials of consistent practice an automatic attention response can come to be associated with the target item; that is, the CM target item will attract attention preferentially, relative to the other items in the display, and its associated response will automatically be activated (Dumais, 1979; Rogers, 1992).

**Improvement in memory search.** — Memory search is a task that requires participants to hold a number of stimuli in memory (collectively called the memory set). The participant's task is to study the memory set and, after it is removed from view, to determine if a single displayed item is from that memory set. The major distinction in procedure between memory search and visual search is that in memory search there are multiple items in the memory set and only a single item in the probe display. Performance improvement and learning in CM memory search seems to occur for reasons different from those in visual search (Corso, Fisk, & Hodge, 1992; Fisk et al., 1995a). When the major task component(s) require consistent memory search, the learning appears to be due to unitization of the memory set elements. Coactivation of target set elements in short-term memory leads to unitization of those items such that one element can activate the entire set (Fisk et al., 1995a; Schneider & Detweiler, 1987; Schneider & Fisk, 1984). Thus, the learning and underlying automatism in CM memory search appears to differ from that observed in CM visual search. The learning in memory search is primarily due to memory set unitization, whereas the learning in visual search can result from development of efficient search strategies and from attention training (see Fisher, 1982; Shiffrin, 1988, for a review).

**Age and Skilled Search-Detection**

The study of age differences in the development of skilled visual search has revealed that even after extensive practice, old adults' CM performance remains attention-demanding and under the influence of control processes (e.g., Fisk & Rogers, 1991a; Rogers, 1992; Rogers et al., 1994). The difference between young and old adults' CM visual search performance coupled with the similarity between old adults' CM and VM performance, even after extensive practice, indicates that old adults learn general and perhaps stimulus-specific search strategies but are unable to develop automatic processing in visual search (e.g., Rogers & Fisk, 1991; Rogers et al., 1994).

In contrast, old and young adults appear to develop automatic processing to CM stimuli in consistent memory search (Fisk & Rogers, 1991a; Fisk et al., 1995a; Hertzog et al., 1996). Fisk et al. (1995a) isolated the learning underlying performance improvement in VM memory search to that of memory set unitization. Memory set unitization is assumed to be a form of associative learning (McClelland, Rumelhart, & Hinton, 1986; Schneider & Fisk, 1984; Shiffrin & Schneider, 1977). Examination of the data from the Fisk et al. (1995a) study suggested that this type of learning was similar for both young and old adults, and not compromised in fundamental ways due to normal aging.

To summarize, there is a consistent finding that performance improvement appears to be similar for old and young adults when the task is dominated by component processes capable of leading to unitization of memory set elements (and therefore reduction in working memory requirements). In contrast, old and young adults differ in the extent of learning within tasks dominated by consistent visual search components. Old adults learn only general task strategies and develop what Fisher (1986) refers to as optimal feature search strategies. Further understanding of the structure of learning within memory and visual search is important for a more complete picture of age-related patterns of skill acquisition. The site of learning, regardless of the type and quality of learning, is not necessarily a given (e.g., Fisk & Jones, 1992; Schneider & Detweiler, 1987; Schneider & Fisk, 1984), especially from an age-related perspective. A missing piece of the puzzle for a finer-grained understanding of age-related skill development involves the level or specificity of the underlying learning occurring within the above mentioned learning domains. If older adults' learning is more localized to the specific trained stimuli than that of young adults, and the level of learning does not differ as a function of the type of task, then important constraints must be placed on the models of skill acquisition and aging. Regardless of the outcome of the present studies, understanding the level of learning within an age group is important for development of instructional strategies.

**Experiment 1: Memory Search and Its Transfer**

An important, unresolved age-related issue pertains to the level of learning occurring within the learning domain repre-
resented by consistent memory search. The question of interest for the present experiment is whether training on some exemplars of a given category generalizes or transfers to other, untrained members of that category. This issue is important for at least four reasons. First, the level at which learning occurs has not been previously established for either young or old adults for memory search. Second, transfer effects will provide evidence as to whether the level of learning observed previously (Fisk & Rogers, 1991a; Fisk et al., 1995a) was due to rapid learning of the (lower level) individual trained elements of the category or due to learning resulting from (higher level) category activation. Third, if transfer to untrained elements of trained categories is similar for both young and old adults, then stronger empirical evidence would be available to suggest that unitization is not fundamentally compromised by normal aging. Although performance improvements have been shown to be similar across age groups when this type of learning is assumed, similar age-related performance improvements are not always the result of the same underlying learning (e.g., Fisk & Rogers, 1991a; Rogers et al., 1994). Fourth, results showing transfer would indicate that the benefits associated with this class of automaticity (Fisk et al., 1995a) can develop for higher-order stimuli and behaviors (Fisk, Oransky, & Skedsvold, 1988), not just single instances. Such a finding would be of pragmatic importance as our field moves toward development of principled approaches to age-related training interventions for addressing improved quality and safety in activities of daily living (Rogers et al., 1996).

To address the transfer issue, it was first important to ensure that the participants developed skilled memory search. Therefore, in the first phase of the experiment participants received training (1200 trials across 20 practice blocks) on CM memory search only. A restricted set of category exemplars was used during training. Given this type and amount of practice we could determine the degree to which young and old adults’ performance improved and became similar in CM search.

Following training, in the second phase of the study, we assessed learning by transferring subjects to three within-subjects experimental conditions. As during training, all conditions remained consistently mapped. In the trained target words/trained target categories (T/T) condition, participants searched for the same words from the categories used during training. In the untrained target words/trained target categories (U/T) condition, participants searched for untrained words from the categories used during training. In the untrained target words/untrained target categories (U/U) condition, participants searched for words from semantic categories that never had been experienced by a given participant within the experimental context. (The specific categories used in this condition were novel to a given participant as far as training within the experiment but were well-learned semantic categories from a lifetime of exposure outside the experimental context.) The distractor words were changed at transfer but were the same for all conditions. This type of design was required so that we could control for and assess the effects of distractor learning but not provide display context that could cue the response decision (Rogers, Lee, & Fisk, 1995; Schneider & Fisk, 1984).

Decreased performance in the T/T condition, relative to performance at the end of training, allowed us to assess the extent of performance improvement during training due to distractor learning (Dumais, 1979; Rogers, 1992). This assessment is important because it has been argued that although learning in visual search is crucially dependent on both target and distractor learning, learning in memory search (unitization) is less related to distractor learning (Fisk et al., 1995a). Such an assessment of target set versus distractor set learning in memory search, particularly from an age-related perspective, is lacking in the literature.

Performance in the U/T condition provides the data for evaluation of the level of learning in CM semantic category memory search. In this condition participants are searching for untrained words from a trained category. For example, they may have been trained on wolf, horse, bear, and lion from the category of four-footed animals. The U/T condition would contain untrained four-footed animal words such as goat, zebra, and so on. A comparison of the T/T and U/T conditions provides an index of whether learning has occurred at the higher semantic category level, or is wordspecific (e.g., Schneider & Fisk, 1984). In addition, the extent to which age-related differences exist in the level of learning was assessed.

The U/U condition provides a baseline to evaluate the level of stimulus-related learning at transfer uncontaminated with task-specific learning (Fisk, Cooper, Hertzog, & Anderson-Garlach, 1995b). This condition involves searching for untrained words from an untrained category and thus provides an index of general learning and an important comparison to the U/T condition.

**METHOD**

**Participants.** — Eighty-seven young subjects between the ages of 17 and 33 were recruited from the Georgia Institute of Technology campus and the Atlanta metropolitan community, and 87 older adults between the ages of 63 and 82 were recruited from the Atlanta metropolitan community. As part of a different study, 8 days prior to participating in the present study, subjects completed a battery of ability tests. For descriptive purposes we have provided those ability data in Table 1, which contains mean age as well as the mean data from the ability measures for each age group. The subjects’ corrected or uncorrected visual acuity was at least 20/40 for both distance and near vision, and those subjects taking more than two drugs that are rated to have more than minimal effects on attention (Giambrone & Quilter, 1988) were not included in this experiment. (Participants were also screened for high dosages of a single attention-affecting drug.) Students received a combination of course credit and monetary compensation for their participation, and all other participants received monetary compensation.

**Apparatus.** — Microcomputers were programmed to control the timing of the displays, present the stimuli, and collect responses. All computer programs were developed using Psychological Software Tools’ Micro Experimental Laboratory software (Schneider, 1988). The data were collected using either Epson Equity I+ microcomputers with
The stimulus set. Four of these categories served as the CM target set, four to seven letters long, were chosen as exemplars. Each category (Battig & Montague, 1969; Howard, 1980), two blocks consisted of the trained target categories. The distractor words and categories were the same as those used for the T/T condition. The distractor words and categories were those used for the T/T condition, (b) Untrained target words/trained target categories (U/T condition). This condition used words not only to study the memory set but also to rest their eyes between trials by briefly refocusing their gaze. Participants were instructed to press the space bar to initiate the trial. A plus sign was then presented in the center of the screen to allow the participant to localize his or her gaze. After 500 ms, the probe display of one word was presented. The participant’s task was to indicate whether or not the word in the probe display was a member of one of the categories in the memory set by pressing the appropriate key on the numeric keypad.

The training session consisted of 20 blocks of 60 trials. Memory set size was manipulated within a block. Thus, there were 20 trials per memory set size within a block, and a target was present on half of the trials. At the conclusion of the session, each participant had completed a total of 1200 CM trials. Training was self-paced, with participants requiring between 70 and 90 minutes to complete the training session.

Training procedure. — Following the training phase of the experiment, participants completed the memory-search transfer phase. There were three transfer conditions, manipulated within subjects. The transfer conditions were: (a) Trained target words/trained target categories (T/T condition). This condition utilized new distractor categories and words but included as target stimuli the trained words from the trained categories. (b) Untrained target words/trained target categories (U/T condition). This condition used words that the participants had not seen before within the experimental context but that were from the semantic categories trained during the training phase. The distractor words and categories were those used for the T/T condition. (c) Untrained target words/untrained target categories (U/U condition). This condition used categories not trained within the experimental context; hence, the words were also untrained. The distractor words and categories were the same as those used for the T/T condition.

Participants completed nine blocks of 60 trials. The first two blocks consisted of the trained target categories. The third block consisted of untrained target categories. The same categories were used in the T/T and U/T conditions. These two conditions were randomized within 60-trial blocks. To equate the number of practice trials, participants completed two blocks of trained category conditions (for a total of 60 trials of practice for each condition) before completing one 60-trial block with new categories.
AGING AND SEARCH TRANSFER

For the blocks with trained target categories, half of the target-present (positive) trials used trained exemplars (T/T condition) and half of the target-present trials used untrained exemplars (U/T condition). Also, within these blocks of trials the T/T and U/T conditions were randomly permuted with the constraint that 15 target-present trials occur for each condition. For the trial blocks assessing performance in the U/U condition, there were a total of 60 trials (20 each memory set size), and a target was present on half of the trials. Thus, for each transfer condition, participants received 180 trials of training, with 90 of those trials being used to assess target detection capability (target-present trials). Participants were informed that new stimuli would appear during the transfer phase, but that the procedure for individual trials was identical to that used in the training phase.

RESULTS AND DISCUSSION

Training — Performance improvement in this task was not the emphasis of the current experiment. However, prior to evaluating transfer to untrained words from the trained categories, it is critical to evaluate the extent of improvement for both the young and the older adults. Therefore, the initial set of analyses was conducted to determine whether or not the training resulted in performance improvement for both young and old adults. The major effects of interest were the overall effect of practice and the final level of performance. An in-depth treatment of the training data can be found in Cooper (1994).

Young adults were faster than old adults, \( F(1,172) = 103.88, p < .0001, M_SE = 094250 \). The average response time (RT) was 538 ms and 685 ms for the young and old adults, respectively. RT decreased as a function of practice, \( F(19,3268) = 209.30, p < .0001, M_SE = 18643 \), and older adults demonstrated a larger absolute decrease in RT with practice compared with the younger adults, \( F(1,3268) = 11.50, p < .0001, M_SE = 18643 \). With practice, the young adults improved response times from 702 ms to 505 ms, and the old adults improved from 948 ms to 642 ms.

Performance at end of practice. — To further assess acquisition of skilled memory search, we examined performance for the last block of practice. At block 20, young adults were faster than old adults, \( F(1,172) = 126.20, p < .0001, M_SE = 38836 \). The effect of memory set size was significant, \( F(2,344) = 38.29, p < .0001, M_SE = 1882 \), and this effect was larger for the older adults, \( F(2,344) = 7.67, p < .001, M_SE = 1882 \). The effect of memory set size was greater for target-present trials, \( F(2,344) = 15.55, p < .0001, M_SE = 1620 \), and this difference was larger for the older adults, \( F(2,344) = 5.10, p < .01, M_SE = 1620 \). The reason for the effect of memory set size was the difference between set size 1 and 2, with this difference larger for the older adults, \( F(1,172) = 11.79, p < .001, M_SE = 2313 \). The difference between memory set sizes 2 and 3 was not significant \( F(1,172) < 1 \), and this difference did not interact with Age, \( F(1,172) = 1.43, p > .2, M_SE = 1606 \).

Summary of training results. — As expected, young adults were faster than old adults. Both groups responded more quickly with practice, but the older group improved more than the younger. This is consistent with previous findings in which older adults were initially slower than younger adults and thus showed the largest improvement with practice (e.g., Fisk & Rogers, 1991a; Rogers et al., 1994). Response time increased as a function of memory set size, and this effect was larger for the old adults. However, the effect of memory set size attenuated with practice, and this diminution of the memory set size effect was greater for the older adults. This finding is consistent with learning resulting from memory set unitization in that RT for higher memory set sizes is approaching that for memory set size 1.

One difference between the results of the current experiment and previous age-related findings (i.e., Fisk & Rogers, 1991a) is that the effect of memory set size was larger for the older adults at the end of practice. It is important to note that there was no difference between memory set sizes 2 and 3 for either age group. However, the difference between memory set sizes 1 and 2 was still significant after 1200 trials of practice, and the difference was larger for the older adults (13 ms and 39 ms for young and old, respectively). The amount of practice appears to be the reason for the differences between the present experiment and the Fisk and Rogers (1991a) study. An inspection of the Fisk and Rogers data reveals that after an equivalent amount of training (1200 trials), the difference between memory set sizes 1 and 2 was in fact larger for the older adults. The Fisk and Rogers data reveal that this age difference was eliminated with additional practice (a total of 1700 trials of practice). It should be pointed out that the set size effects found here are also quite consistent with other data in the literature (e.g., see Briggs & Johnsen, 1973; Fisk & Schneider, 1983; Kristofferson, 1972; Schneider & Shiffrin, 1977; Shiffrin, 1988). With the present level of practice, most consistent mapping studies produce some effect of load (usually nonlinear) especially when a single memory set element is used. At the levels of practice used here, performance most likely represents a mixture of automatic processing and serial, controlled search because automatic and attentive processes can occur concurrently with the first to finish triggering the response (Schneider & Detweiler, 1987). If the automatic process is unaffected by load, then the attentive processing will finish first more often when the processing load is small (also see Ellis & Chase, 1971; Jones & Anderson, 1982). Hence, curvilinear set size functions are not unexpected within this task domain even when automatic processing has developed. Most important, the data from the present experiment parallel both Fisk et al. (1995a) and Fisk and Rogers in that the reduction of memory set size 3 to the level of memory set size 2 occurs very early in practice for both young and old adults. Thus, the present training data are generally consistent with previous studies (e.g., Fisk & Rogers, 1991a; Fisk et al., 1995a) examining age-related effects of practice on consistent memory search.

Transfer. — We next evaluated the effects of the transfer manipulation to assess the locus of learning (i.e., semantic category level or word level). Figure 1 contains the correct trial RTs for young and old adults. For each transfer condi-
tion, memory set sizes 1, 2, and 3 are plotted for the first replication of each transfer condition. In addition, data from the last block of training were used as an additional condition for examining the effect of the inclusion of new distractor stimuli without changing the trained target words. The major findings reflect equivalent transfer for both young and old adults and can be summarized as follows: Response times varied as a function of transfer condition for both age groups. RTs were longest for the untrained target words/trained target categories (U/T) condition, for the untrained target words/trained target categories (T/T), and last block of training (Baseline) conditions, respectively. Similarly, the effect of memory set size was greatest for the U/U condition and decreased across the U/T, T/T, and Baseline conditions, respectively.

Further analyses revealed that older adults were not differentially affected by transferring from the Baseline to the T/T condition. Therefore, the effect of changing the distractors on trained target performance does not appear to vary with age group. Also, the young and old adults' performance was not differentially affected when both the distractors and specific target exemplars (but not the target semantic categories) changed. However, older adults were much more disrupted than the young adults when changing to a memory search with untrained semantic categories. This latter finding is entirely consistent with the differences due to age found at the beginning of training, another instance in which participants performed a memory search with untrained target categories. These observations are reflected in the following statistical analyses.

Response times varied as a function of Transfer Condition, \( F(3,516) = 247.95, p < .0001, MS_e = 21540 \), and the Transfer Condition × Age interaction was significant, \( F(3,516) = 13.32, p < .0001, MS_e = 21540 \). For the young adults, the average RT was 500 ms, 539 ms, 633 ms, and 674 ms for the Baseline, T/T, U/T, and U/U conditions, respectively. The old adults' average RT was 627 ms, 673 ms, 783 ms, and 903 ms for the Baseline, T/T, U/T, and U/U conditions, respectively. The Transfer Condition × Memory Set Size interaction was significant, \( F(6,1032) = 12.79, p < .0001, MS_e = 11292 \). The effect of memory set size was greatest for the U/U and decreased for the U/T, the T/T, and the Baseline conditions, respectively.

In order to investigate the locus of the Transfer Condition × Age interaction, post hoc comparisons were conducted. The difference between the Baseline and the T/T conditions was significant, \( F(1,172) = 46.31, p < .0001, MS_e = 10022 \), but this difference did not interact with age (\( F < 1 \)). Older and younger adults were not differentially affected by moving from the Baseline to the T/T condition; therefore, this analysis indicates that the effect due to changing the distractors, on target detection, does not significantly vary with age group. The difference between the T/T and the U/U conditions was significant, \( F(1,172) = 204.29, p < .0001, MS_e = 13277 \), but this effect did not interact with age, \( F(1,172) = 1.24, p > .25, MS_e = 13277 \). Thus, young and old adults were not differentially affected by changing to untrained exemplars of trained categories. The difference between the U/T and the U/U conditions was significant, \( F(1,172) = 62.36, p < .0001, MS_e = 26864 \), and this effect was larger for the older adults, \( F(1,172) = 15.14, p < .0001, MS_e = 26864 \). Thus, older adults were more disrupted than the young adults when search requirements changed from searching for untrained elements of trained categories to searching for untrained elements of untrained categories.

The above patterns and statistical effects occur for proportion disruption scores, in addition to absolute RTs. When amount of disruption is calculated relative to baseline, the averaged percent disruption for the young adults was 8%, 22%, and 35% for the T/T, U/T, and U/U conditions, respectively. For the old adults the averaged percent disruption was 7%, 24%, and 43% for the T/T, U/T, and U/U conditions, respectively. There was a main effect of Transfer Condition, \( F(2,344) = 2345.26, p < .0001, MS_e = .054 \). The Transfer Condition × Age interaction was also significant, \( F(2,344) = 8.72, p < .0003, MS_e = .054 \). The
difference between the T/T and the U/U conditions was significant, $F(1,172) = 243.18, p < .0001$, $MS_e = .0389$, and this difference did not interact with Age ($p > .05$). The difference between the T/U and the U/U conditions was significant, $F(1,172) = 65.54, p < .0001$, $MS_e = .0697$, and this effect was larger for the older adults, $F(1,172) = 11.63, p < .001$, $MS_e = .0697$. Transfer for the untrained target words from the trained target categories (U/T condition) was also calculated relative to the trained target words from the trained target categories (T/T condition) using the untrained target words from the untrained target categories (U/U condition) as a baseline in the manner reported by Schneider and Fisk (1984). In this case, transfer was larger for the older adults (52%) compared with the young adults (31%). However, caution must be used in interpreting this measure because the calculation is based on the U/U condition, in which the older adults were more disrupted than the young adults; therefore, the age-related difference in relative transfer could be inflated.

An analysis was performed on the accuracy data for all conditions, including the Baseline condition. For the young adults, accuracy across conditions was 95%, 97%, 88%, and 88% for the Baseline, T/T, U/T, and U/U conditions, respectively. Averaged accuracy for the older adults was 97%, 97%, 91%, and 91% for the Baseline, T/T, U/T, and U/U conditions, respectively. Older adults were more accurate than the young adults, $F(1,172) = 30.75, p < .0001$, $MS_e = .0190$. There was a main effect of Transfer Condition, $F(3,516) = 268.60, p < .0001$, $MS_e = .0339$. There was no information for explicitly deciding what pattern of data to expect for old adults. Old adults may not show learning in consistent visual search at the same level as young adults; this would be shown by little or no difference between performance on untrained words from a trained category relative to untrained words from an untrained category. This pattern of results would provide stronger evidence that learning in visual search is different for old and young participants. The results will reveal important information on the question of the type of learning that is occurring in CM visual search for older participants. Even though there is strong evidence that older adults develop optimal search, the nature of that optimality is not known. This experiment will evaluate whether or not optimal search, the nature of that optimality is not known. The purpose of this experiment then was to determine, within the domain of visual search, the level of transfer (or lack thereof) old adults would exhibit to untrained words from a trained category.

**Summary of transfer results.** — The results of this study extend the previous findings of Fisk et al. (1995a) by showing that memory set unitization underlying performance improvement for both young and old adults can occur at levels of processing higher than the physical features or the elemental word level of the stimuli. That is, there was positive transfer to untrained words from the trained category in comparison with untrained words from an untrained category. Thus, the current results contribute to a more global theory of aging, memory, and skill acquisition. It has been documented by other researchers that older adults are quite capable of semantic category-level processing (e.g., Byrd, 1984; Howard, 1980, 1983; Mueller, Kausler, Faherty, & Oliveri, 1980). In addition, the results from priming studies suggest similarity between old and young individuals in both extent and depth of semantic activation (e.g., Balota & Duchek, 1988; Madden, Pierce, & Allen, 1993). The results of the current study are consistent with this previous research and extend those results to lexically based skills acquired subsequent to senescence. The results of the current experiment also hold open the generalization of instructional strategies for training relatively complex tasks of this domain encountered in daily living (e.g., Fisk & Rogers, 1991b) to the older adult population.

**Experiment 2: Visual Search and Its Transfer**

Given the similarity between age groups of transfer for learning within memory search, we conducted a brief follow-up study to examine older adults’ transfer capability within a different learning domain. Although the learning in memory search is not limited to the individual stimulus level, this same degree of generalization may not occur in visual search. Both young and old adults improve with consistent visual search training. Yet, it has been argued that the learning is restricted to improvement in optimal search (Fisher, 1986) for older adults (Rogers et al., 1994). Contrary to the previous memory search experiment, data exist concerning young adults’ level of learning in consistent visual search (Fisk & Jones, 1992; Hodge, 1991; Schneider & Fisk, 1984). Thus, the a priori expectation is that young adults will demonstrate learning beyond the individual stimulus level in visual search and show a high degree of transfer to untrained words from the trained category.

There is no information for explicitly deciding what pattern of data to expect for old adults. Old adults may not show learning in consistent visual search at the same level as young adults; this would be shown by little or no difference between performance on untrained words from a trained category relative to untrained words from an untrained category. This pattern of results would provide stronger evidence that learning in visual search is different for old and young participants. The results will reveal important information on the question of the type of learning that is occurring in CM visual search for older participants. Even though there is strong evidence that older adults develop optimal search, the nature of that optimality is not known. This experiment will evaluate whether or not optimal search is specific to particular aspects of the trained stimuli or whether it generalizes to optimal selection of more global stimulus characteristics (such as semantic features).

The purpose of this experiment then was to determine, within the domain of visual search, the level of transfer (or lack thereof) old adults would exhibit to untrained words from a well-trained semantic category. For example, and as in the previous experiment, we were interested in determining whether practice on words from a semantic category (e.g., colors) would improve an individual’s ability to search for other untrained color words. Successful transfer to words untrained within the experimental context would indicate
learning at the semantic category level. A lack of transfer would indicate learning localized to specific aspects of the trained words. To address this issue, we conducted a transfer experiment conceptually the same as the previous memory search transfer experiment and modeled after a study, examining only young adults, conducted by Schneider and Fisk (1984). Following extensive training on a visual search task, participants transferred to searching for new exemplars from the trained category. To eliminate transfer effects favoring young adults due to distractor learning, we also changed the distractor categories (Rogers, 1992; Shiffrin & Dumais, 1981). Comparisons were made between the trained words from the trained category (the T/T condition), untrained words from the trained category (the U/T condition), and untrained words from the untrained category (the U/U condition).

METHOD

Participants. — Twenty-four young adults ($M = 20.92$, $SD = 2.41$) and 24 older adults ($M = 72.12$, $SD = 4.44$) participated in the experiment. None of the participants in this study had taken part in the previous experiment or any of our other experiments. Of the 24 participants in each age group, 19 were women. The participants in the present study received training as part of a baseline condition in a study addressing other issues (Gilbert & Rogers, 1996). The young adults were college students enrolled in an introductory psychology course, and they received course credit for their participation. The older adults were community-dwelling individuals who received monetary compensation ($5.00 per hour) for their participation. All participants were screened for psychotropic drug use as well as visual acuity, as described in Experiment 1.

The older adults were significantly more educated than the young adults (older adults $M = 15.42$ years, $SD = 2.43$; young adults $M = 13.08$, $SD = 1.21$). Participants rated their health on a scale between 1 (excellent) and 5 (poor). There was no significant difference in health rating between the young and old adults (old adults $M = 1.67$, $SD = .76$; young adults $M = 1.75$, $SD = .61$). 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 (old 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 (old adults $M = 15.54$, $SD = 4.76$; young adults $M = 9.21$, $SD = 3.98$; $t(46) = 5.05$, $p < .001$).

Stimuli. — Memory set items were the unrelated semantic categories of birds, body parts, clothing, countries, earth formations, fruit, and musical instruments (Collen et al., 1975). The target and distractor items were high associates of each category (Battig & Montague, 1969; Howard, 1980). Each category set contained eight words between four and six letters in length. Three categories (animals, body parts, and colors) were assigned as target categories to replicate the stimuli used by Schneider and Fisk (1984). The remaining categories were assigned as distractor categories for training and as new target and distractor stimuli for the transfer phase of the experiment. Category assignment was counterbalanced across participants within an age group by a partial Latin-square and replicated across age groups.

Equipment. — IBM PS/2 microcomputers were programmed with PST’s Microcomputer Experimental Language (Schneider, 1988) to present the stimuli and collect responses. 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 workstations and were monitored by a research assistant. During all sessions, pink noise was played at approximately 55 dB(A) to mask background noises.

Training phase: Design and procedure. — Participants performed a consistently mapped, pure visual search task. 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). The memory set could be studied for up to 20 s. The participant pressed the spacebar to initiate the trial. A focus cross was presented in the center of the screen (corresponding to the center of the probe display) for 500 ms. After 500 ms the probe display appeared. The probe display consisted of four stimuli (words or placeholders) arranged in a rectangle around the focus cross. The task was to determine the location of the target word (i.e., lower left, lower right, upper left, or upper right of the display) and to press the appropriate key (labeled LL, LR, UL, UR). A target word was present on every trial. Display set size, either two, three, or four words, was manipulated within subjects. Within each block of 48 trials there were 16 trials of each display size, randomly permuted. When display set size was less than four words, placeholders were 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 a viewing distance of 45 cm, the visual angle of the height of the display was approximately 1.90° and the length of the display set was 4.79°. Visual angle from the location of the focus cross to the center of any word was 1.58°. Each of the eight exemplars from the target category served as a target a total of six times and their presentation order was permuted. Target location was also permuted across trials. The probe display was terminated when the participant responded or after a maximum of 6 s.

Participants completed 3,840 trials of CM practice (80 blocks of 48 trials per block) in 1-hour sessions on each of 4 consecutive days. Following practice, the development of an automatic attention response was assessed with a “reversal” task in which the roles of the target and distractor items were reversed (for reviews see Rogers, 1992; Rogers et al., 1994; Shiffrin & Dumais, 1981). Both age groups completed 240
reversal trials (five blocks of 48 trials) immediately following the last block of training.

**Transfer phase: Procedure and design.** — Following the training phase of the experiment, participants returned the following day to complete a single session of the transfer task. As in Experiment 1, there were three transfer conditions: (a) Trained target words/trained target category (T/T condition). This condition utilized the trained target words identical to those seen during training. (b) Untrained target words/trained target category (U/T condition). This condition used words that the participants had not seen before within the experimental context but the words were from the semantic category trained during the training phase. (c) Untrained target words/untrained target category (U/U condition). This condition used a target category not trained within the experimental context; hence, the words were also untrained. For all conditions, the words used as distractors were also untrained to prevent positive transfer due to distractor learning (Rogers, 1992; Shiffrin & Dumais, 1981). The trial procedure was the same as in the training phase of the experiment. As in Experiment 1, the T/T and U/T trials were intermixed within a block because all target words were drawn from the same category. (To illustrate, a participant might be presented with the category label Colors; the target item could be the word green, trained earlier, or purple, an untrained exemplar from that category.)

**RESULTS AND DISCUSSION**

**Training.** — As in Experiment 1, the emphasis of this task was not performance improvement. However, prior to evaluating transfer to untrained words from the trained category it is critical to evaluate the extent of improvement for both the young and the older adults. Therefore, the initial set of analyses was conducted to determine the degree to which young and old adults improved and whether or not that improvement was due to the development of an automatic attention response (assessed via the reversal manipulation). A complete treatment of the training data can be found in Gilbert and Rogers (1996).

During training there was a general improvement in performance across training, $F(15,660) = 8.01, p < .001, MS_e = 47623$. In addition, there was a main effect of age, $F(1,44) = 50.5, p < .001, MS_e = 34735$. Hence, the training data clearly indicate that both young and old adults improved their performance on the task. Although performance improved for both age groups, for consistency with previous studies it is important to determine whether or not an automatic attention response developed for either the young or old adults (Rogers et al., 1994). A sensitive measure of automatic process development for visual search tasks is the amount of disruption in performance that occurs when the roles of the CM targets and distractors are reversed. [The reader should see Rogers (1992), Rogers et al. (1994); and Shiffrin & Schneider (1977) for a discussion of this measure and its relationship to assessment of automatic processing in visual search. Also, consultation of Fisk et al. (1995a) and Shiffrin (1988) will reveal why such a measure was not used in the memory search experiment just reported.] A disruption score was calculated for each participant as follows: (Reversal RT – Final Training RT)/Final Training RT. As in previous studies, there was a significant age difference in amount of disruption in performance when the roles of the trained targets and distractors were reversed, $F(1,44) = 13.57, p < .001, MS_e = .03$. The young adults were disrupted more than the older adults (44% vs 27%). This finding suggests a major reason for the age-related difference in performance improvement: young adults developed an automatic attention response, and older adults either did not develop an attention response or the development is greatly attenuated (cf. Rogers, 1992; Rogers et al., 1994).

**Transfer.** — We can conclude that the training data are consistent with previous studies examining both young and old adults in consistent visual search. The transfer aspect of the study allowed the investigation of the level of learning shown by the older adults. We were interested in initial effects of transferring to untrained words from a trained semantic category on old adults’ performance; hence, we report data for the first group of trials for each condition. The transfer data are presented in Figure 2. Inspection of the young adults’ data in Figure 2 reveals a pattern of transfer previously reported (Hodge, 1991; Schneider & Fisk, 1984). Those data show that the young adults’ response times were fastest for the trained target words/trained target category (T/T) condition, intermediate for the untrained target words/trained target category (U/T) condition, and slowest for the untrained target words/untrained target category (U/U) condition. The older participants present a different pattern in their data. For the older adults, RTs were fastest for the T/T condition compared with the other two conditions and, importantly, the U/T condition produced performance very similar to the U/U condition. This present age-related pattern in the visual search transfer data stand in striking contrast with the memory search transfer data. Old adults appear to show no transfer to semantically similar stimulus material relative to untrained semantically unrelated material. Young adults, on the other hand, show positive transfer to a situation in which untrained words from a well-trained semantic category must be detected.

![Figure 2](https://example.com/figure2.png)

**Figure 2.** Response times (RTs) in ms for the visual search transfer conditions. Data are plotted as a function of age and transfer condition. T/T (open bar) refers to the trained words/trained category condition, U/T (closed bar) to the untrained words/trained category condition, and U/U (shaded bar) to the untrained words/untrained category condition.
We conducted a series of planned comparisons to determine if these differences were statistically significant. RT across the transfer conditions differed for the young adults, $F(2,46) = 8.51, p < .001, MS_e = 5219$. Compared with the U/U condition, young adults were significantly faster when responding to the trained words from the trained category (T/T) and to untrained words from the trained category (U/T), $t(23) = -3.57$ and $-2.20$, respectively. Furthermore, there was no difference in RT between words from the T/T and the U/T condition ($p = .32$). Thus, statistically, young adults could respond to untrained words from the trained category as quickly as to trained words from the trained category. The young adult data replicate previous findings (e.g., Hodge, 1991; Schneider & Fisk, 1984).

The older adults’ RTs also differed across conditions, $F(2,46) = 3.24, p < .05, MS_e = 7139$; however, this effect was reflected in a different pattern of transfer. Most important for the issue of transfer, the older adults’ performance did not differ between the U/T and the U/U conditions, $t(23) = 0.21$. The T/T condition was significantly faster than both the U/T and the U/U conditions, $t(23) = -2.82$ and $-2.55$, respectively.

Schneider and Fisk (1984) utilized a relative measure of transfer conceptually equivalent to the following formula: $(\text{U/U - U/T}) / (\text{U/U - T/T})$. Using this measure of relative transfer for the current young adults’ performance, we found that transfer was 63%. The transfer in our present study is consistent with that found by Schneider and Fisk for similar perceptually oriented conditions. For young adults, performance improvement is a combination of feature, word, and semantic learning; however, learning is clearly at the semantic level nonetheless. The transfer for the old adults was not different from zero, being $-14\%$. This is additional evidence that for the older adults, in this learning domain, the major locus of learning is at the general task level and at the specific, trained stimulus level (see Rogers et al., 1994) but not at the semantic level. Fisher (1982, 1986) has found that optimal feature search does not result in the development of an automatic process, although it is effective in reducing working memory load for the search task. Hence, the transfer data, coupled with data from other studies (e.g., Rogers, 1992; Rogers & Fisk, 1991; Rogers et al., 1994), converge to implicate optimal feature search as the predominate locus of older adults’ improvement in CM visual search. Furthermore, the present data argue that the feature learning shown by older adults is localized to the specific, trained stimuli. Older adults improved and became skilled performers on CM visual search tasks. However, the improvement is not due to attention training (Fisk & Rogers, 1991a; Rogers et al., 1994) and, as has been shown in the present study, the improvement is not just due to general task-specific skill (see also Rogers et al.). Optimal feature search has been suggested by previous data as the locus of learning (Rogers & Fisk, 1991), but the level of that learning has been previously unspecified.

Why would learning to optimally search the features of words speed performance of the search task? Optimal feature search reduces working memory load by allowing faster direct comparisons of the critical distinguishing features of the target stimuli (direct memory access) but continues to require control processing and does not result in modification of the attention-calling strength of the target stimuli (see Fisher, 1982; Fisher & Tanner, 1992). Thus, CM training in visual search appears to reduce either the need to hold critical features in memory or the time required to search working memory; both factors (capacity and speed) reflect major contributors to reduced performance seen in older adults (Salthouse, 1991).

Conclusions

We directly examined the capability of younger and older adults to transfer from specifically trained stimuli to semantically related and unrelated stimuli. The data add to our understanding of automaticity and aging in several ways. First, the present results expand the previous findings that automatic processing can develop for semantic information in visual search (e.g., Schneider & Fisk, 1984) to the learning domain represented by memory search tasks. For young adults, learning can occur at levels other than that of physical stimulus properties regardless of whether the learning is the result of utilization (memory search) or attention training (visual search). Second, from an age-related perspective, the site of the CM training effect in memory search appears to be the same for both young and old adults. Thus, not only is performance improvement the result of the same underlying learning mechanism, but the locus of that learning is also the same.

Such a finding of equivalent learning mechanism and site was not a given (e.g., Fisk & Jones, 1992). Learning can occur at many levels within a memory search task because consistency exists at many levels. For example, there is consistency between the letter to word mapping, the word to category mapping, the word to response mapping, and the category to response mapping. We have previously demonstrated that consistency at any level may in principle be capitalized on during training to facilitate task-specific performance (e.g., Fisk & Jones, 1992). Further, with young adults, training situations can be established such that learning takes place at the word level but not the category level. The degree to which attention is consistently focused at the word versus the category level is a critical factor in determining the locus of learning for young adults. Hence, older adults appear to focus on the same level of consistency as the young adults during learning in consistent memory search. Given the present findings in conjunction with other reports (e.g., Fisk & Rogers, 1991a; Fisk et al., 1995a), we conclude that our models of automaticity within working-memory-limited tasks can be general across age groups.

Learning, and the underlying site of the training effect, in visual search seem to be different as a function of age. Older adults improved performance at detecting exemplars from the semantic category. Yet, the 3,800 exposures did not facilitate detection performance of semantically related stimuli even when compared to the detection of semantically unrelated stimuli. Young adults do seem to develop automatic processing at the semantic level in visual search as shown here and in other experiments. Clearly, in visual search, older adults’ learning remains situation-specific and does not generalize to other category elements that share a
subset of semantic representations. The lack of semantic transfer in visual search shown by older adults is not due to a general inability to transfer to situations related to the training situations. Older adults showed a high degree of transfer when the task was memory search and the underlying learning was due to unitization of the search set. The lack of transfer could be a degradation of category structure (Fisk & Jones, 1992), but this explanation does not seem plausible in light of the literature on semantic activation and older adults (see Salthouse, 1991, for a review) and the strong positive transfer shown in memory search. Perhaps the results are due to differences in visual capabilities between old and younger adults. This explanation has been rejected in numerous other studies (e.g., Fisk & Rogers, 1991a; Rogers & Fisk, 1991; Rogers et al., 1994) and does not seem likely here. For such decline to be the main reason for the lack of transfer in visual search would require older adults to be insensitive to the various manipulations within and across the present studies.

What then is the reason for the older adults' apparent rigidity in learning in visual search but flexibility in memory search? If, as we have suggested, consistency in visual search facilitates primarily optimal feature search for older adults (e.g., Fisk & Rogers, 1991a; Rogers, 1992; Rogers & Fisk, 1991; Rogers et al., 1994), focusing attention on some other level of consistency would actually inhibit performance improvement for those individuals improving primarily via development of optimal search (Fisher, 1986; Fisher & Tanner, 1992). Hence, as with younger adults, the aging cognitive system appears capable of "tuning in" to a level of consistency to optimize performance.

The present data are also relevant to furthering progress in development of principled guidelines for age-related instructional design. Previously we have suggested principles for maximizing performance and learning (Fisk, Ackerman, & Schneider, 1987; Fisk & Rogers, 1992; Rogers, Maurer, Salas, & Fisk, 1997). In addition, we have suggested where training emphasis will be most effective for older adults (Fisk & Rogers, 1991b). These "processing principles" illustrate human performance guidelines for the development of knowledge engineering for understanding and developing training programs for complex, real-world tasks. The present data add to those principles by suggesting the importance of understanding higher-order, rule-based consistency. These data and other data in the literature (see Fisk & Rogers, 1992, for a review) suggest that consistency need not be related to the individual stimulus level for performance benefit to be derived from training. The data suggest that consistent relationships among stimuli (such as category structure as evaluated in the present study) should be identified when considering instructional design, especially when part-task training strategies are required.

If the trainer can identify consistent categories of information, efficient training can be developed by training at the level of the category (higher level) information source rather than just the individual elements. However, the present data argue strongly that such a benefit will accrue for older adults only (a) when the major initial task-limiting components are determined (through component task analysis) to be related to working memory constraints and (b) the knowledge structure contained within those components (or across components) can be modified via unitization. If the major task components require acquiring high-performance visual scanning for skillful performance, older adults will improve due to stimulus-specific, optimal strategic search. Such benefit will not generalize beyond the feature level; hence, category-based training will be ineffective for older adults.

ACKNOWLEDGMENTS

This research was supported by National Institutes of Health (NIA) Grant R01 AG-07654 and P50 AG-11715 under the auspices of the Center for Research on Applied Cognitive Aging (one of the Edward R. Roybal Centers for Applied Gerontology Research). Experiment I was part of a larger project performed as partial fulfillment of the Master of Science degree by Brian Cooper.

Address correspondence to Dr. Arthur D. Fisk, School of Psychology, Georgia Institute of Technology, Atlanta, GA 30332-0170.

REFERENCES


