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Abstract: Young and old adults were asked, in 3 experiments, to make decisions about the identity of line segment patterns after either adding or subtracting line segments from the original pattern. On some of the trials, the line segments from the initial display were presented again in the second display to minimize the necessity of remembering early information during the processing of later information. Although this manipulation presumably reduced the importance of memory in the tasks, it had little effect on the magnitude of the age differences in any of the experiments. Because the 2 groups were equivalent in accuracy of simple recognition judgments, but older adults were less accurate when the same types of decisions were required in the context of an ongoing task, the results suggested that older adults may be impaired in the ability to retain information while simultaneously processing the same or other information.

Previous studies have found substantial adult age differences in the accuracy of decisions about whether a composite pattern synthesized from discretely presented line segments matches a comparison stimulus (Ludwig, 1982; Salthouse, 1987; Salt-house & Mitchell, 1989). Because synthesis operations can only be successful if all of the relevant information is still available at the time of the last operation, one plausible interpretation of these differences is that they are attributable to age-related reductions in the ability to remember spatial information. However, two recent investigations seem contradictory with respect to the role of memory factors in the age differences observed in mental synthesis. On the one hand, Ludwig (1982) has suggested that age differences in synthesis accuracy are independent of possible age differences in memory. Results from two of his experiments supported this interpretation. In the first experiment, Ludwig (1982) obtained measures of both synthesis and memory performance involving the same type of stimuli from young and old research participants, and found that age differences in the accuracy of the synthesis decisions were still significant after statistically controlling for the age differences in memory accuracy. In a later experiment in the same article, significant age differences in synthesis performance were found even when young and old adults were matched on level of recognition memory performance.

On the other hand, Salthouse and Mitchell (1989) reported the results of several experiments indicating that older adults remember less of the relevant stimulus information than young adults. The procedure in the Salthouse and Mitchell (1989) experiments involved examining the accuracy with which previously presented figural segments could be recognized in the context of the synthesis task. Both memory and synthesis trials, which were randomly intermixed in the same trial block, consisted of three frames of three segments each. The two types of trials differed, however, in that the comparison stimulus consisted of nine segments in the synthesis trials, but only three segments in the memory trials. Decisions in the synthesis trials concerned whether or not the nine segments matched the composite of the segments from the preceding three frames, while decisions in the memory trials concerned whether the three segments were identical to those presented in any one of the three preceding frames. Separate analyses were conducted on the data from individuals performing above and below the median in each age group. In contrasts of the better-performing members of each age group, older adults were generally less accurate than young adults at recognizing the identity of previously presented information, a result consistent with the view that the lower accuracy of older adults in synthesis decisions can be attributed to a failure to retain relevant information in memory.

The studies in this project were based on a different approach to the investigation of the involvement of memory in age differences in spatial manipulation tasks. The procedure consisted of comparing the performance of young and old adults in a standard condition, in which the segments from the first frame were removrf, with performance in a condition in which the segments from the first frame were still visible during the presentation of the segments from the second frame. The rationale for this comparison is based on the assumption that low performance of older adults in spatial manipulation tasks is caused by a failure to preserve early information during the presentation and processing of later information. If this is the case, then elimination of the need to preserve earlier information by redisplaying segments from the first frame during the second frame should reduce, or possibly even eliminate, age differences in the performance of spatial manipulation tasks.

In an attempt to examine the generality of the phenomenon, the first two experiments included a deletion task in addition to the integration or synthesis task previously investigated. Rather than adding line segments to the original stimulus, participants in this task were instructed to subtract line segments before attempting to make a decision about the comparison stimulus.

Experiment 1

Method

Subjects

Participants were 20 college students (ages 17 to 27, M = 20.5 years) and 20 community-residing older adults (ages 58 to 72, M = 65.7 years). There were 11 men and 9 women in each group, and the groups did not differ (i.e., p > . 1) in years of formal education (young = 14.1, old = 14.3), or in self-reported health on a 5-point scale ranging from 1 for *excellent* to 5 for *poor* (young = 1.5, old = 1.6). Consistent with much of the earlier literature, the young adults had significantly higher Wechsler Adult Intelligence Scale–Revised (WAIS-R; Wechsler, 1981) Digit Symbol Substitution scores than did the older adults (young = 72.5, old = 50.4; t (38) =6.2l, p < .01).

Procedure

All participants received the tasks in the same sequence: Digit Symbol, spatial integration, and spatial deletion. Trials in the latter two tasks were presented on a microcomputer, each in a repeatable set of 8 practice trials followed by two experimental blocks of 50 trials each.

The stimuli and procedures in both the integration and deletion tasks were very similar to those described in Salthouse and Mitchell (1989). The major differences were that (a) the stimulus segments were always presented in two frames, with the comparison stimulus consisting of nine segments for the integration task and six segments for the deletion task; and (b) on a randomly arranged one-half of the trials in each trial block, a dotted-line copy of the segments from the first frame was visible in the second frame.

The decision in the integration task was whether the comparison stimulus matched the synthesized composite formed by integrating the segments of the first frame with the segments of the second frame. Participants were allowed to inspect each frame as long as desired, and they indicated when they were ready for the next figure by pressing a key. (These study times were analyzed in each of the experiments in this report, but the results are not discussed because the only consistent effects related to age were that older adults inspected the frames for longer durations than did young adults.) The comparison stimulus, which was identical to the composite of the segments from Frame 1 and Frame 2 on 50% of the trials and differed by two segments on 50% of the trials, appeared 1 s after the key press terminating inspection of the second frame. Responses to the comparison stimulus were to be made as accurately as possible by pressing the "/" key on the computer key-board for SAME and the "Z" key for DIFFERENT.

Figure 1 illustrates the sequence of events for trials in the integration task under no-copy (top row) and copy (bottom row) conditions. Notice that the first frame contains six segments, the second frame three segments, and the comparison stimulus nine segments.

The deletion task was identical to the integration task except that the sequence of displays was reversed, and the decision involved whether the comparison stimulus matched the residual after deleting the segments of Frame 2 from the pattern of Frame 1. In other words, trials contained displays similar to those in Figure 1 but in a right-to-left order, with the first frame containing nine segments, the second frame three of those segments, and the comparison stimulus six segments.

Results and Discussion

The primary dependent variable in both the integration and deletion tasks was the percentage of correct decisions in the no-copy and copy conditions. Means of this variable for each group are displayed in Figure 2A for the integration task, and in Figure 2B for the deletion task.

As suggested by the patterns apparent in Figure 2, in both tasks there were significant ($p < .01$) main effects of age, $F(1,38) = 28.13$, $MS_e = 148.47$, for integration; $F(1, 38) = 34.86$, $MS_e = 108.48$, for deletion; and of no-copy-copy, $F(1, 38) = 52.45$, MS_e, = 57.22, for integration; $F(1, 38) = 80.84$, $MS_e = 72.77$, for deletion, but no interaction of the two (i.e., both *Fs* < 1.0).

Additional analyses were conducted after creating a new ability factor by dividing participants in each group into high-ability and low-ability subgroups based on a median split on the measure of accuracy in the no-copy condition in each task. The results of these analyses were similar to those described above and also failed to reveal significant interactions of the ability factor with age (i.e., $F < 1$). The absence of Age × Ability inter actions suggests that the patterns of age differences are not markedly different among the best-performing and lowest-performing members of the two groups.

The results of this experiment appear inconsistent with the view attributing age differences in spatial manipulation tasks to an inability to preserve early information during the processing of later information. The primary expectation from that position was that the age differences should be greatly reduced in the copy condition because memory requirements were presumably minimized by displaying the information from the first frame during the presentation of information from the second frame. Accuracy was greater in the copy condition than in the no-copy condition, but this was true for both groups, and therefore, whatever benefits were associated with the repeated information were equally experienced by old and young adults.

Experiment 2

The results of Experiment 1 are puzzling because it was expected that the tasks should have been trivially easy for both groups in the copy condition. Participants in these trials simply had to remember either the complete pattern of solid and dotted lines (for the integration task) or only the pattern of dotted lines (for the deletion task). Young adults did achieve close to a ceiling level of performance in this condition, with an average of over 90% correct, but the older adults showed much lower accuracy, with an average of less than 80% correct.

One possible explanation for the lower performance of older adults in the copy trials is that they experienced greater confusion than young adults by the mixture of copy and no-copy trials within the same block of trials. In an attempt to investigate this interpretation, the copy and no-copy trials in the current experiment were presented in separate blocks, and participants were fully informed of the optimum strategy with the copy trials. That is, they were told that they should remember the pattern composed of both solid and dotted lines in the integration task, and only the pattern of dotted lines in the deletion task.

A second modification in procedure from the first experiment was that participants also performed a recognition memory task with patterns consisting of either six or nine segments. The purpose of this task was to provide a direct examination of the ability of young and old adults to remember patterns of line segments. If participants are performing optimally in the copy trials, then their performance in these trials should be equivalent to that in this “pure” recognition memory task.

Method

Subjects

Participants consisted of 20 college students (ages 18 to 22, M = 19.6 years) and 20 community-residing older adults (ages 60 to 85, M = 67.7 years). There were 12 men and 8 women in each group, and the groups did not differ (i.e., $p > .1$) in self-reported health on the same scale described earlier (young = 1.4, old = 1.6). The older adults in this experiment averaged slightly (young = 13.7, old = 15.2, $t(38) = 2.66$, $p < .05$) more years of education than the young adults. As in the previous experiment, the young adults had significantly higher WAIS-R Digit Symbol Substitution scores than the older adults (young = 63.1, old = 46.0, $t(38) = 4.29$, $p < .01$).

Procedure

All participants received the same sequence of tasks, consisting of Digit Symbol, recognition memory, spatial integration, and spatial deletion.

The recognition memory task involved the presentation of 25 six-segment patterns and 25 nine-segment patterns randomly intermixed in a single experimental block preceded by a repeatable practice set of four trials. The stimuli were constructed in the same manner as those in the integration and deletion tasks, with one-half matching or SAME, and one-half DIFFERENT by having the positions of two segments altered. The stimulus patterns were exposed for 2 s, followed after a 1-s retention interval by the comparison stimulus pattern. Responses of SAME and DIFFERENT were to be made as accurately as possible by pressing the "/" key for SAME and the "Z" key for DIFFERENT.

The integration and deletion tasks were identical to those of Experiment 1 except that in each task, all of the no-copy trials were presented in the first block and all of the copy trials presented in the second block. Although this fixed sequence of conditions introduces a confounding of condition by order, presentation of the no-copy trials before the copy trials was considered necessary to ensure maximum benefit of the copy manipulation. That is, it was feared that the value of the copy information may not have been fully appreciated until after participants had some experience with the no-copy trials.

Results and Discussion

The major results of this experiment are displayed in Figure 3. Figure 3A illustrates accuracy in the no-copy and copy conditions of the integration task, and accuracy with nine-segment stimuli in the recognition memory task. Accuracy in the no-copy and copy conditions of the deletion task, and with six-segment stimuli in the recognition memory task, is illustrated in Figure 3B.

The first item to be noted in Figure 3 is that the major results of Experiment 2 were replicated, particularly the failure to eliminate the age differences in the copy condition. Statistical analyses confirmed this observation as the Age × No-Copy Copy interaction was not significant for either the integration task or the deletion task (i.e., both *Fs* < 1.0). The copy main effect was significant ($p < .01$) in both tasks, F (1, 38) = 82.43, MS_e = 48.93, for integration; F (1, 38) = 96.46, MS_e = 60.63, for deletion; but the main effect of age was significant ($p < .01$) in the integration task, F (1, 38) = 14.51, MS_e = 172.84, and not in the deletion task, F (l, 38) = 2.96, MS_e = 169.00, $p > .05$.

Additional analyses were conducted including an ability factor created by dividing participants in each group into subgroups on the basis of accuracy in the no-copy condition. No interactions of age and ability were significant in the deletion task, and only one was significant in the integration task. This was Age × Ability × No-Copy–Copy, F (1, 36) = 7.61, MS_e = 37.93, $p < .01$, and was due to both subgroups of older adults averaging about 14% better accuracy in the copy condition compared to the no-copy condition, but low-ability young adults averaging 21% better and high-ability young adults averaging only 7% better. At least some of this interaction seems attributable to a ceiling effect limiting further improvement in the copy condition among the high-ability young adults.

The second noteworthy aspect of the results summarized in Figure 3 is that the young and old adults were nearly identical in performance in the recognition memory task. Two sets of analyses supported the impressions conveyed from Figure 3. The first consisted of *t* tests comparing accuracy of young and old adults with nine-segment and six-segment patterns. These revealed nonsignificant differences for both nine-segment stimuli, t (38) = 0.42, and six-segment stimuli, t (38) = 0.00. A second set of analyses consisted of *t* tests comparing young and old adults in the differences between accuracy in the recognition memory task and in the copy condition of the integration and deletion tasks. The mean difference between recognition memory accuracy for nine-segment patterns and accuracy of integration judgments in the copy condition was 4.4% for young adults and 14.8% for older adults, $t\ (38) = 3.41$, $p < .01$. The mean difference between recognition accuracy for six-segment patterns and deletion copy accuracy was 3.1% for young adults and 7.1% for older adults, $t\ (38) = 1.46$, $p > .05$.

The results just described indicate that both groups were less accurate in the copy conditions of the integration and deletion tasks than in the ostensibly comparable recognition memory task. However, the older adults had a significantly larger performance discrepancy than the young adults in the integration task, and their discrepancy was slightly, albeit not significantly, larger in the deletion task. Because the copy trials in the present experiment were blocked together rather than intermixed with the no-copy trials, it is apparently not the case that older adults failed to achieve accuracy equivalent to that in the recognition memory task in the copy trials because they were confused by the mixture of trial types within the same trial block.

Experiment 3

The major findings in Experiment 2 were that (a) the age differences in both the no-copy and the copy trials of the integration task from Experiment 1 were replicated, and (b) no significant age differences were found in the accuracy of recognition memory decisions. These results are surprising because the copy trials and the recognition memory trials were similar in many respects, and yet they exhibited quite different patterns of age effects.

One difference between the copy trials and the recognition memory trials was that the stimuli in the former consisted of a pattern of both solid and dotted lines, whereas stimuli in the latter consisted entirely of solid lines. It is therefore possible that the failure of the older adults to achieve comparable performance in the recognition memory and copy trials was attributable to an inability to perceive incomplete patterns as coherent and integrated stimuli. Previous research (e.g., Danziger & Salt house, 1978; Salthouse, 1988; Salthouse & Prill, 1988) has indicated that older adults have difficulties with perceptual closure tasks, and therefore problems of simultaneous integration or closure may have contributed to the age differences in the copy conditions of Experiments 1 and 2. The present experiment investigated this interpretation by including a condition in which the line segment information from the previous frame was displayed in solid lines identical to those used to display the new line segments from the second frame. That is, in this condition all of the line segments in the trial are simultaneously visible as solid lines during the second frame, and consequently from that point on the trial is identical to a recognition memory trial. If older adults are hampered by a difficulty in perceiving a single figure from solid and dotted lines, then the age differences should be eliminated in the solid condition because all segments are displayed in the same (solid line) format and no simultaneous integration is required.

This experiment also differed from the previous one by adding a second recognition memory task at the end of the experimental session to provide an assessment of memory performance both before and after the synthesis task. Limitations of time due to the presence of both the integration and deletion tasks in Experiment 2 precluded this manipulation in the previous experiment. The first recognition memory task was identical to that used in Experiment 2, but the second task consisted of 25 trials with a blank retention interval identical to 25 of the trials from the first task, and 25 trials in which an irrelevant dotted line was displayed during the retention interval. The purpose of this retention interval manipulation was to explore the possibility that there might be age differences in the susceptibility to distraction by irrelevant material.

Only the integration or synthesis task was presented in this experiment because there was no way to indicate the to-be-deleted segments when both the old segments from Frame 1 and the new segments from Frame 2 were displayed as solid lines. A second reason for abandoning the deletion task was that the results of Experiment 2 revealed a somewhat different pattern for the integration and deletion tasks. One interpretation of this difference is that deletion is an optional transformation in that the accuracy of the decisions is not dependent on subtracting line segments from the original stimulus display. That is, the segments in the comparison stimulus in the deletion task were always a subset of the segments from the original stimulus, with mismatches created by altering line segments common to both patterns. It was therefore possible to reach accurate decisions by simply remembering the original stimulus pattern and not attempting any mental deletion or subtraction of line segments.

Method

Subjects

Participants were 20 college students (ages 17 to 24, M =20.7 years) and 20 community-residing older adults (ages 60 to 77, M =70.0 years). There were 9 men and 11 women in each group, and the groups did not differ (i.e., $p > .1$) in years of education (young = 14.4, old = 15.1). Although all participants rated their health as good to excellent (i.e., ratings of 3, 2, or 1), the older adults had a slightly lower average rating of self-assessed health than the young adults (i.e., young = 1.3, old = 1.8, t (38) = 2.35, $p < .05$). As in the previous experiments, the young adults had significantly higher WAIS-R Digit Symbol Substitution scores than the older adults (young = 67.5, old = 44.4, t (38) =8.03, $p < .01$).

Procedure

All participants received the same sequence of tasks, consisting of Digit Symbol, first set of recognition memory trials, spatial integration, and second set of recognition memory trials.

The first recognition memory task was identical to that employed in Experiment 2. The second set of recognition memory trials consisted of the presentation of 25 nine-segment patterns with a blank 2-s retention interval, and 25 nine-segment patterns with an irrelevant display of three dotted line segments throughout the retention interval. Both types of trials were randomly intermixed in a single experimental block preceded by a repeatable practice set of four trials. One-half of the trials were SAME or matching trials, and one-half were DIFFERENT by having the positions of two segments altered. Responses of SAME and DIFFERENT were to be made as accurately as possible by pressing the “/” key for SAME and the “Z” key for DIFFERENT.

The integration task consisted of three blocks of 50 trials each, with approximately one-third of the trials in each block consisting of no copy, faint-copy, and solid-copy trials. The no-copy and faint-copy trials were similar to those displayed in Figure 1, and the solid-copy trials differed from the faint-copy trials only in that all of the line segments were displayed as solid lines.

Results and Discussion

An initial analysis was conducted on the accuracy in the three sets of recognition memory trials with nine-segment stimuli. Average percentages of correct decisions for the recognition of nine-segment stimuli at the beginning of the session, at the end of the session, and at the end of the session with interpolated irrelevant dotted line segments were, respectively, young = 94.2,.2, and 93.0; and old = 92.2, 95.8, and 91.0. These values are all quite similar, and the age differences were not significant, t (38) < 1.15, p > .10, in any of the contrasts. A composite memory measure was therefore created by averaging these three values for each research participant. Means of this composite measure also did not differ significantly across age groups (young = 95.7, old = 94.0, r (38) = 1.23, p > .10).

Mean levels of accuracy in the three conditions of the integration task, and accuracy in the composite memory measure, are displayed in Figure 4. Performance in the integration task was analyzed with an Age (young, old) × Copy (no-copy, faint-copy, solid-copy) analysis of variance. The age, F (l, 38) = 31.20, MS_e = 97.76, and copy, F (2, 76) = 246.03, MS_e = 26.38, effects were both significant (p < .01) , but their interaction was not (F < 1.0) . The absence of a significant interaction is also supported by nearly identical improvements from the no-copy to the faint-copy trials of 19.0% and 19.5% for young and older adults, respectively, and from the faint-copy to the solid-copy condition of 5.0% for young adults and 4.7% for older adults.

The existence of significant age differences in the copy conditions of the integration task, and the absence of significant differences in the measure of recognition memory performance, implies that young adults have a smaller discrepancy between copy and recognition performance than older adults, t Test comparisons of the difference between the composite measure of memory accuracy and accuracy in the copy conditions of the integration task confirmed this implication. Young adults were 5.9% more accurate in the memory measure than in the faint-copy trials of the integration task, compared to a difference of 14.0% for older adults, t (38) = 3.90, p < .01. The memory performance of the young adults was only 0.9% better than that in solid-copy trials, compared to a discrepancy of 9.3% for the older adults, t (38) = 4.48, p < .01.

An analysis of variance with an ability factor created by splitting the participants in each group into two subgroups on the basis of the median accuracy in the no-copy trials was also conducted. None of the interactions of age and ability were significant (i.e., F < 1.0), thus suggesting that similar age trends were evident in both high-performing and low-performing members in each age group.

The results summarized in Figure 4 both replicate and extend the results of the first two experiments. The earlier results are replicated by the finding that young adults are more accurate than older adults in both the no-copy and faint-copy integration trials, and the finding that the two groups are equivalent in the accuracy of simple recognition decisions. The previous results are extended by the discovery of significant age differences in the solid-copy integration trials.

A particularly interesting feature of these results was that young adults performed at nearly the same level in the solid copy and recognition memory trials, but that older adults were substantially less accurate in the solid-copy trials than in the very similar recognition memory trials. An implication of this pattern of results is that the older adults were apparently sensitive to a distinction between the solid-copy and recognition memory trials that was unimportant or irrelevant to the young adults.

As mentioned earlier, the solid-copy trials in the integration task were identical to the recognition memory trials from the time of the presentation of the second frame to the SAME/ DIFFERENT decision based on the comparison stimulus. The primary difference between the two types of trials is that the second frame in the solid-copy trials was preceded by a first frame containing line segments that could not be ignored on a substantial proportion of the trials. That is, because it was impossible to distinguish among the no-copy, faint-copy, and solid-copy trials until the presentation of the second frame, it was important for participants to attend to the segments in the first frame in order to be able to integrate them with the second frame segments in the no-copy trials. Because the necessity of attending to (and presumably processing) the prior information in the solid-copy trials appears to be the primary difference between the solid-copy integration trials and the recognition memory trials, it can be inferred that this factor presents particular problems for older adults.

General Discussion

The three experiments in this article all replicated the phenomenon that young adults are more accurate than older adults in spatial integration or mental synthesis decisions. In addition, in each study age differences were found favoring young adults even under copy conditions in which it was not necessary to remember the information from the first frame. This consistent pattern of results, together with the finding of no age differences in the accuracy of simple recognition judgments, could be interpreted as suggesting that memory factors are unimportant in the age differences in spatial manipulation tasks.

However, we currently favor an alternative interpretation that has the advantage of providing a possible explanation of the apparent discrepancies between the Ludwig (1982) and Salthouse and Mitchell (1989) studies. The basis for this interpretation is a distinction between isolated memory assessment and within context memory assessment (also see Salthouse, in press, and Salthouse, Mitchell, Skovronek, & Babcock, 1989, for further discussion of this distinction). When memory is evaluated in a task designed explicitly for the purpose of measuring memory, all of the individual’s processing efforts or capacities can be devoted to performing that task. Under these conditions, as exemplified in the recognition tasks of Experiments 2 and 3, there appear to be few or no age-related differences. However, if memory is assessed in the context of other ongoing tasks, then the individual is required to remember the relevant information while also engaged in attempting to process information. These joint demands of storage and processing, which serve to define the concept of working memory (Baddeley, 1986), may present special difficulties for older adults. The principal support for this interpretation in the current studies is the discovery that older adults were less accurate than young adults when memory was assessed in the context of the integration task (i.e., in the performance of copy trials), but not when it was assessed in isolation (i.e., in the recognition memory trials).

The discrepancy between Ludwig’s results and those of the current studies might be resolved by postulating that the memory measures in Ludwig’s experiments, just like those in the recognition memory tasks in Experiments 2 and 3, reflected memory with minimal demands for concurrent processing. They may therefore provide rather poor estimates of the actual likelihood of retaining relevant information in the integration task. However, measures of the accuracy of recognizing the contents of previous stimulus frames in the Salthouse and Mitchell (1989) experiments, and of the accuracy of integration decisions in the copy trials in the current experiments, do seem to reflect the effectiveness of memory while engaged in other processing (i.e., attempting to integrate).

The preceding interpretation is still quite speculative, but it does suggest some interesting possibilities for future research. For example, this perspective implies that the presence or absence of age differences in many simple tasks is a function of whether (and if so, how much) current processing is required while information is being retained. It also suggests that the most informative assessments of working memory may not be derived from tasks explicitly designed to measure memory, but rather obtained during the performance of other ongoing tasks.

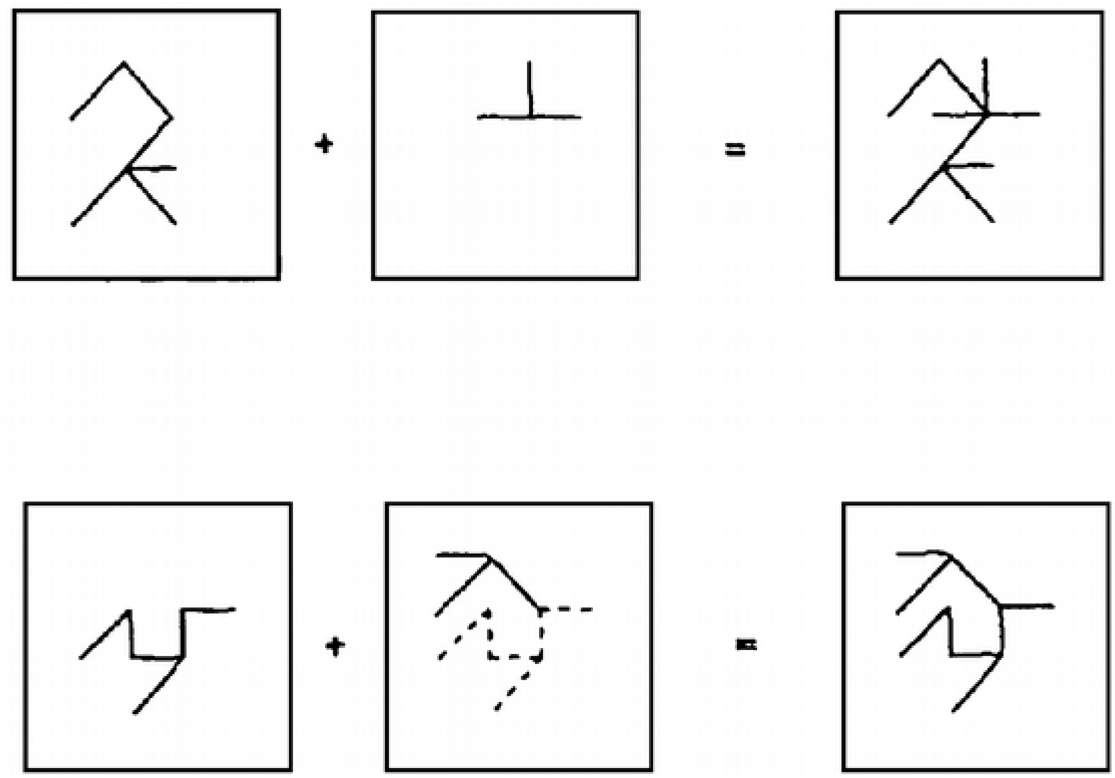

Figure 1. Illustration of sequence of stimulus displays in the integration task under no-copy (top) and copy (bottom) conditions

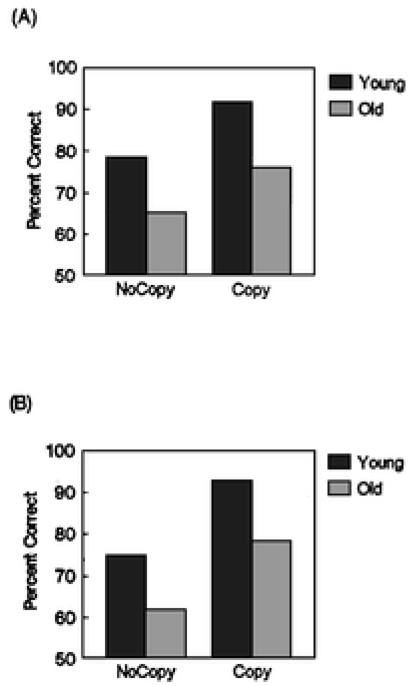

Figure 2. Mean levels of accuracy for young and old adults in the no-copy and copy conditions for the integration (A) and deletion (B) tasks, Experiment 1

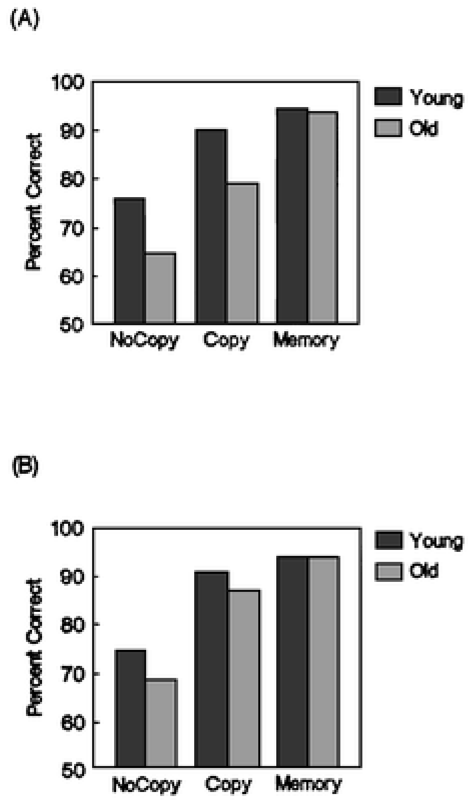

Figure 3. Mean levels of accuracy for young and old adults in the no copy, copy, and memory conditions for the integration (A) and deletion (B) tasks, Experiment 2

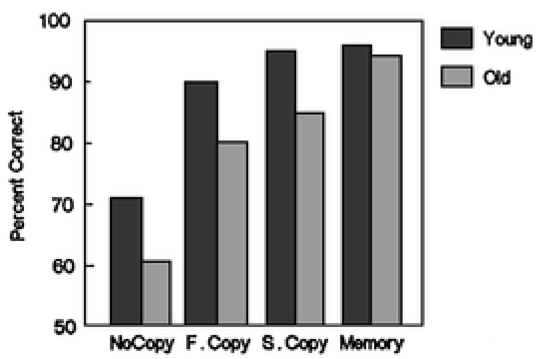

Figure 4. Mean levels of accuracy for young and old adults in the no-copy, faint-copy, solid-copy, and memory conditions in Experiment 3

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