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Received January 5, 1986
Accepted January 24, 1986

COGNITIVE TRAINING USING SELF-DISCOVERY METHODS

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Improvements in problem solving performance have been achieved when appropriate strategies are explained, demonstrated, or modeled for older adults. The present study attempted cognitive training of Raven's Progressive Matrices using guided self-discovery, but without directly providing strategies. Thirty-six older and 36 younger adults were pretested, underwent training, and were posttested. There were three training conditions: (1) participants were prompted by questioning to attend to all components of the matrix elements, (2) attentional training was augmented by questioning that prompted the participant to discover the correct solution, and (3) a practice-only control. There was significant improvement from pretest to posttest, but it was the same for all three groups, and there was no significant difference in improvement between younger and older adults. The study failed to find evidence for successful cognitive training when strategies must be self-discovered rather than simply adopted.

Age differences in problem solving are widely observed (Giambra & Arenberg, 1980; Rabbitt, 1977). The inferior performance of older adults has led to the use of a variety of training techniques in attempts to demonstrate that problem solving deficits are modifiable and susceptible to improvement. There is evidence that experimental intervention can affect the performance of older adults in problem solving tasks. This evidence will be reviewed briefly.

Using an immediate verbal feedback training technique, Hornblum and Overton (1976) improved the performance of older women, who had failed on a conservation of surface area task, on a similar measure of surface area conservation, and other concrete operational tasks. This improvement did not extend to other transfer tasks that might be considered to tap formal operations abilities. Rebok (1981)

This research was supported by grant AG01073 from the National Institute on Aging.

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provided verbal feedback to some but not to other older and middle-aged adults solving matrix problems. The relevant dimensions (form, color, number, or position) were ones that had previously been identified as most or least preferred by the individual. Participants in both age groups who received feedback improved their performance, but only on matrices that incorporated their two individually most-preferred dimensions as relevant. There were no differences between feedback and no feedback groups of older adults on matrices that incorporated as relevant values from one of their most and one of their least preferred dimensions. Mergler and Hoyer (1981) found that older adults who were trained in a procedure that involved (a) watching matrices being constructed, (b) having them explained, and (c) completing and explaining the matrices themselves outperformed an untrained group on a task that required the individual to invent a matrix problem. The benefits of training did not generalize to solving Raven's Progressive Matrices problems. To facilitate the improvement of older participants' performance on attribute identification tasks, Sanders and Sanders (1978); Sanders, Sterns, Smith, and Sanders (1975); and Sanders, Sanders, Mayes, and Sielski (1976) devised procedures that gradually increased the complexity of concept learning tasks over a series of problems. It was thought that the sequences would facilitiate development of solution strategies. For those participants who had particular difficulty in mastering the effective strategy, strategy hints and instructions to verbalize their thinking were incorporated into the training. Sanders et al. (1976) found that the training and reinforced training groups required fewer trials on the posttest and that they solved the posttest faster than the practice and control groups. Sanders and Sanders (1978) found similar results, one year after training, on a more difficult concept indentification transfer task. Denney and Denney (1974) utilized two modeling techniques in an effort to improve older adults' performance on a twenty-question problem. In one technique, experimenters modeled "constraint-seeking" questions by taking turns with the participant guessing which one of 42 possible pictures the other had chosen. In another condition, the experimenter verbalized an appropriate strategy for formulating "constraint-seeking" questions. Improvement was found in both groups in comparison to a practice-only control group. Further, the authors state that following training, the elderly performed as well as previously studied middle-aged women (Denney & Denney, 1973). In another twenty-question task, Hybertson, Perdue, and Hypertson (1982) found that participants in three middle-aged to older-aged groups increased the total

number of questions asked and the efficiency of those questions after efficient strategies were demonstrated and a visual display of attributes, intended to suggest a categorical strategy, was introduced.

Plemons, Willis, and Baltes (1978) analyzed the underlying relational rules in several test items from the Cattell-Horn measures for Figural Relations and used the relational rules most frequently found in test items to develop training materials. Training consisted of eight practice sessions on figural-relations type items and the format included immediate verbal feedback, modeling of rule-based task solutions by the experimenter, individual practice on new materials, group discussions, and review of previous lessons. Those participants received eight training sessions, two one-hour sessions per week for four weeks; participants in the control group received no training. In comparison with the no-contact control group, the treatment group improved performance on the same pretest measure (the Figural Relations Diagnostic Test) on each of three posttest occasions. Performance on a near transfer measure (the Cattell-Horn Tests of Figural Relations) improved only on the first posttest occasion. Neither group improved on a posttest measure of induction and verbal comprehension, designed to test transfer of training. A replication by Willis, Blieszner, and Baltes (1981) refined the training programs and extended the battery of tests to assess further transfer of training. The training and no-contact control groups again differed significantly on each of the near-transfer figural relation measures (Adult Development and Enrichment Project Figural Relations Test, Culture Fair Test, and Ravens Progressive Matrices), but not on the far-transfer measures (ADEPT Induction, Induction Composite, Perceptual Speed, and Vocabulary).

To summarize the studies reviewed, successful training programs have utilized approaches that, together with direct instruction or feedback, model more efficient strategies or solutions than those used spontaneously. The evidence suggests that older adults do benefit from training under these conditions. However, when Denney (1980) attempted to change the problem solving performance of older adults without direct training, she was unsuccessful. Increasing motivation by paying for good performance, imposing a delay between administration of the instructions and the beginning of the task, and insuring prior success on another task all failed to improve performance.

Older adults' performance can be improved, though, without direct intervention. Practice alone without specific training has also led to improvement (Plemons et al., 1978; Sanders et al., 1975; Willis et al., 1981). Labouvie-Vief and Gonda (1976) included a practice-only control group in a study examining training on inductive reasoning problems. Those participants with nonspecific training or practice showed greater improvement on the transfer tasks than did participants in cognitive training, anxiety training, or control groups. Hofland, Willis, and Baltes (1981), using two measures of figural relations and induction, examined practice effects across eight retest sessions. Test performance on two figural relations and induction measures increased significantly across consecutive retests with no evidence for a performance asympote. Denney (1980) manipulated the effect of practice by interspersing four practice sessions using a different set of stimuli, between two pretest trials and two posttest trials on a twenty question task. In contrast to the results of Hofland et al. (1981), no significant differences between the practice and no practice groups were found, indicating that practice had no effect on the elderly adults' performance. The results did not differ in her replication of the study. Sanders et al. (1976) also found no significant difference between groups who had three additional sessions of practice and groups that had none on a concept identification task.

The results of practice on similar problems are not unequivocal. Even in a conservative interpretation, though, they show that for some groups of individuals and some problems, practice alone can lead to significant improvement. Further, the problems for which practice alone has been found to help include complex and difficult tasks. The conclusion is warranted that the older adults had available more effective problem-solving strategies than they first exhibited. At the least, these results emphasize the importance of including a practice-only control group in training studies as a means of assessing the differential contribution of intervention techniques.

The improvements seen with practice alone are consistent with the view that age deficits in problem solving are not due solely to a loss of basic ability by older adults. If this is so, it should be possible to achieve even greater gains than those realized from practice by providing conditions that aid the individual in discovering the bases of more effective problem-solving strategies without resorting to training techniques that directly provide strategies or demonstrate strategy selection. The problems used to test this hypothesis in the present study were matrices requiring extraction of figural relations. These were selected because they are difficult and because the underlying relational rules can be extracted.

One class of figural relations problems in which age differences are reliably found is Raven's Progressive Matrices (e.g., Cunningham, Clayton, & Overton, 1975; Raven, 1948; Rimoldi & Vander Woude, 1969). A review of think-aloud protocols that we had previously collected from younger and older individuals solving Raven's problems suggested that older adults often failed to notice relevant dimensions on which the elements differed, or they noticed a dimension but failed to realize the relationship among elements on that dimension. Consistent with this possibility, Rebok (1981) found that older adults did less well at matrix problems in which nonpreferred elements were relevant to the solution. It is plausible that they failed to attend to the nonpreferred elements.

The specific aim, then, of the present research was to determine whether the performance of older adults could be differentially improved without explicit instruction or modeling, by instead prompting them to attend to all components of the problem or by attention training augmented by self-discovery of the component relationships. Discovery as a method of learning has been shown to improve performance. Gagne and Brown (1961), investigating the effectiveness of three different learning programs, found that, in comparison to learning by rule and example, young boys who were asked to derive formulas for the sum of terms in unfamiliar number series, and who were guided to discover or who were asked to discover for themselves critical principles, showed significant learning gains. The best performances were by those boys in a guided self-discovery group that, in addition to guided discovery of important principles, was provided with systematic practice in the use of concepts necessary in the solving of new problems.

Groups of younger participants frequently have not been included in training studies. The primary focus has been whether or not older adults are capable of improving their performance. If they are, it is argued that the deficits must not be the result of irreversible loss of cognitive ability (Denney & Denney, 1974; Hybertson et al., 1982; Labouvie-Vief & Gonda, 1976; Plemons et al., 1978; Rebok, 1981; Willis et al., 1981). In the studies cited, only three have included young comparison groups (Hybertson et al., 1982; Mergler & Hoyer, 1981; Rebok, 1981). In two of those studies, older adults' performance was not differentially affected by training, though their absolute performance level improved (Hybertson et al., 1982; Rebok, 1981). If younger and older adults are equally facilitated by training, it is difficult to argue that the training affects processes responsible for age differences. Thus, the inclusion of a younger comparison group is important to test claims that factors such as reduced attention are responsible for problem solving deficits because they differentially affect older adults.

METHOD

Participants

Thirty-six older adults and 36 younger adults participated. The older adults were recruited from the City of Claremont (CA) Senior Program. There were 21 women and 15 men, average age 71.5 years (range, 58-88 years). Four had not completed high school, 10 were high school graduates, and 22 had at least some college. The average self-rating of health, using a scale from one to ten where ten was excellent, was 8.4. The younger adults were community residents. There were 20 women and 16 men with a mean age of 41.3 years (range, 25-57 years). Six were high school graduates and 30 had at least some college. Their average self-rating of health was 8.6.

Design and Procedure

Matrix problems in Set B, Set C, and Set D of the Raven's Progressive Matrices were analyzed for the underlying rule for solution. The level of difficulty increases across Set B, Set C, and Set D; in addition, within each set the solution rule for the matrix problems generally increases in difficulty over successive problems. Matrices within a set and with a common underlying rule were grouped together. From these groups, three subsets of three matrices were formed for the B, the C, and the D sets. One change was necessary to accomplish this: Set B, problem 7 was changed to use the rule for solutions of Set B, problems 8 and 9. The critical features of each matrix were extracted and the relationships between the elements and the correct solution described. These were arrived at first by assessments by the authors individually and then by group discussion leading to consensus.

A pretest-training-posttest design was used. All participants began with matrices Set A, problem 1, and Set B, problems 1, 2, and 3 as practice problems. Using latin squares, sequences of three, three-problem subsets—one subset each from B, C, and D Sets— were formed. The latin square insured that each sequence had one subset each from B, C, and D problems and one subset from each of three difficulty levels. After the practice problems each participant completed a pretest of three subsets, a training program, and, at the conclusion of training, a posttest of another three subsets. After completing all 31 problems, participants were asked to give their year of birth, extent of education, and a self-rating of health.

Twelve older and younger adults were assigned to each of three

training conditions with the restriction that one person be assigned to all three conditions before another was assigned to any. In one condition, participants were prompted by questioning to attend to all components of the matrix elements; in a second, attentional training was augmented by questioning that prompted the participant to discover the correct solution. The third condition was a practice-only control.

The problems were administered to each participant individually. During the training problems, participants in the first condition, termed the Attention to Elements group, were prompted to attend to all of the dimensions of the matrix elements. They were asked to describe the elements in detail, and were prompted to continue their examination until all the dimensions had been described. At no time did the prompting questions name or identify the element to which attention should be directed. For example, if the participant described some elements as "flowers," the experimenter might prompt, attempting to elicit a description that would include recognition of the "flower's" placement in the matrix by saying, "Remember I want you to look carefully at each piece of the puzzle and to describe, in as much detail as you can, what you see." In this example, it would have been acceptable if the participant said, "All the figures in the first row are shaped like flowers," and recognized the flowers' unique features, "Each flower has four petals and the flower in the first drawing has a circle around it; the one in the second drawing has an X through it; the flower in the third drawing has a square around it." After completing a description of all puzzle features, the participant selected a response. Participants in the second condition, termed the Attention to Elements and Relations group, were prompted as in the Attention to Elements group, and selected a response. Then, whether the response was correct or not, the individual was prompted by questions to describe the relationships that led to his or her choice. If the response was incorrect, instead of explicit feedback as to the correct answer, the prompting to attend to relationships continued until the individual discovered and explained why the response had been incorrect and settled on the correct one. Participants in the Practice-only Control group were given the same instructions for the training problems as for the pretest problems.

RESULTS

The principal dependent variable was the number of correctly solved matrix problems. The independent variables were the age group, the training condition, and the trial (pretest, training, and posttest). An analysis of variance showed that the conditions did not differ at the pretest in the number of correctly solved matrices, $F(2,69) = 1.10$, $p < .05$, $\omega^2 = .03$. There was a significant difference between age groups, $F(1,70) = 26.28$, $p < .011$, $\omega^2 = .27$. Younger adults solved more problems (7.4) than did the older adults (4.9). There was no interaction between age group and trial, $F(1,70) = 1.12$, $p < .05$, $\omega^2 = .02$. The changes between pretest and posttest scores are shown in Table 1, older adults gained an average of 1.1 problems and younger adults gained an average of .6 problems. Overall improvement from pretest to posttest for all participants for both groups was significantly greater than zero, $t(71) = 3.71$, $p < .001$.

There was also significant overall improvement from pretest to training, $t(71) = 1.81$, $p < .04$. The age groups did not differ, though, $F(1,70) = .218$, $p < .05$, $\omega^2 = .00$; the mean change from pretest to training, shown in Table 1, was .4 problems for older adults and .3 problems for younger adults.

Examination of performance within sets on the pretest and posttest on Set B, Set C, and Set D indicated that, for both age groups, there was negligible improvement on the more difficult posttest Set C and Set D problems. Improvement was concentrated for both age groups on Set B posttest problems. Older adults solved 23.1% more Set B problems on the posttest than on the pretest and younger adults solved 9.2% more as shown in Table 2.

DISCUSSION

If successful training is to be used to support a claim that age deficits in problem solving are not due to loss of cognitive ability, three tests must be met. First, the training must not include direct instruction or modeling. Individuals could lose the ability to produce effective problem-solving strategies without losing the ability to mimic effective behaviors when they are demonstrated. For example, one can learn a simple algorithm for producing the derivative of a polynomial, giving the appearance of sophisticated problem solving without any real understanding of the calculus. Second, the improvements among older adults must be substantially larger than those among younger adults. It would be possible to argue that equivalent gains were the result of cognitive facotrs in older adults but non-cognitive factors in younger adults. A more parsimonious interpretation, though, is that the same factors account for improvement in both groups, and, consequently, that those factors cannot account for observed age differences. Third, if it is asserted that the deficits are due to failure to use available cognitive resources, the improvements among older adults should be greater for cognitive training than for practice alone. This is a conservative standard, since it would exclude problems for which practice elicited the same, previously unused abilities affected by training. In such instances, though, the second test of greater improvement in older adults than in younger adults should provide a clue to the nature of the improvement. The present study met the first test. It permitted the other two; both were failed.

On the pretest, younger adults solved significantly more problems than did older adults. After training or practice on abstract relation problems, older adults solved 1.1 more problems on the posttest and younger adults solved .6 more problems. The results, however, showed no greater improvement among older adults than among younger ones. Studies by Hybertson et al. (1982) and Rebok (1981)

TABLE 1 Correctly Solved Matrix Problems

	Pretest	Training	Posttest
Old			
Attention to elements and relations	5.25	5.92	6.41
Attention to elements	4.50	5.00	4.92
Control	4.92	5.17	6.08
Young			
Attention to elements and relations	8.08	8.17	8.25
Attention to elements	6.77	7.42	7.46
Control	7.45	7.50	8.27

TABLE 2 Percent Correct

	Pretest	Posttest	Difference
Set B			
Old	53.7	76.8	23.1
Young	85.2	94.9	9.2
Set C			
Old	56.4	54.6	-1.8
Young	79.6	82.4	2.8
Set D			
Old	54.6	62.0	7.4
Young	82.4	87.0	4.6

that included younger comparison groups also found that, although the performance by older adults improved after training, younger adults were equally affected. These findings support the view of reduced capacity in older adults, but suggest that both younger and older adults have available unused resources. The fact that improvement by older adults was almost twice that of younger adults probably occurred because younger adults were near the upper limits of performance. At the posttest, younger adults were on the average solving 8.0 problems out of the possible nine problems whereas older adults were solving only 6.0 problems. The lack of differential improvement leaves unsubstantiated the hypothesis that inattention or inefficient strategy selection are among those factors that account for observed age differences.

Training older individuals to discover the bases of more effective problem solving did not improve performance; the results failed to show differentially improved performance with cognitive training that relied on discovery and that did not provide instructions nor model strategies. The present study adopted the rule analysis approach of Plemons et al. (1978) and Willis et al. (1981) in developing training materials. The relational rules (e.g., size, shape, position) necessary to solve the figural relation problems were identified and subsequent training problems that used the most frequently occurring rules were organized together. The studies differed, however, in training methods. Plemons et al. (1978) and Willis et al. (1981) used explicit instruction and modeling techniques, in contrast to our attempt to prompt individuals to discover for themselves efficient solution strategies. The results failed to show differentially improved performance with cognitive training that relied on discovery and that did not impose instructions nor model strategies. Self-discovery, however, has been shown in other studies to be an appropriate method of learning; Gagne & Brown (1961) conclude that discovery can significantly benefit learning over a rule and example method in adolescents. It could be contended that the failure of the present training is the result of its short duration. Mergler and Hoyer (1981) and Rebok (1981), however, found significant improvement in matrix problems with only one session of training indicating that the length of the present study should be enough for transfer to equivalent problems. The lack of successful training raises the question of the efficacy of the present design, but, in light of the above studies, it arguably provided an appropriate means of demonstrating improved problem solving performance.

The results do confirm findings of improvement with practice alone on abstract relation problems (Hofland et al., 1981; Labouvie-

Vief & Gonda, 1976; Plemons et al., 1978; Willis et al., 1981). Older adults were able to produce more effective problem solving strategies without the aid of experimenter-imposed prompting. Improvement, however, was concentrated on the simpler set of B problems. It seems likely that practice in solving more difficult problems benefitted performance on simpler ones. The inclusion of subsets with similar features may have aided in the extraction of critical elements and seeing problems with similar rules grouped together could have enhanced the salience of their cues, resulting in more appropriate strategy selection. The regrouping of Raven's test items on the basis of solution rules may have lead to unexpected improvement by providing the same opportunities for discovery and practice of simple concepts for the control group as for the treatment groups; not regrouping the test items might reduce the chance for systematic discovery on the part of the control group.

The issue remains that neither guided self-discovery nor practice reduced or removed age differences between younger and older adults. Older adults were not differentially facilitated by training that addressed inattention or inefficient strategy selection. It is uncertain whether the poorer performance of older adults is due to their inability to attend to relevant dimensions or to draw relationships between them. The failure to find either age differences or differences between treatment conditions leaves unanswered the question of whether older adults lose cognitive abilities needed to solve complex problems. A reliable finding that self-discovery training was successful in producing effective problem-solving strategies among older adults would resolve the issue. The present finding that guided self-discovery did not promote effective problem solving, instead, it is consistent with the possibility that deficits may not be simply failure to use available resources. If there continues to be a conspicuous absence of evidence of successful cognitive training without direct instruction or modeling, there will be a strong circumstantial case that age differences are due to a loss of basic cognitive ability.

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Received January 9, 1986
Accepted January 24, 1986