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Active Versus Passive Procedural Learning in Older and Younger Adults

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Twenty-four older and 24 younger adults were compared on procedural learning tasks (i.e. Tower of Hanoi puzzle). Half of the participants in each group went through active training (i.e. standard administration), and the other half through passive training (i.e. followed instructions read to them). The effect of the different types of training was tested immediately and one week after training. In addition the different groups were tested on a more difficult version of the task. The results demonstrate that active training leads to better performance than passive training on the more difficult task. The magnitude of this advantage was consistent for both age groups. Furthermore, active training seems to leave more durable traces in memory than passive training. The effect of elaboration in procedural versus declarative memory is discussed with relation to the effect of age.

INTRODUCTION

Older adults are reported to perform more poorly than young adults on different memory tasks (Burke & Light, 1981; Light, 1991; Poon, 1985). In recent years, there has been an increasing interest in the residual learning capabilities of amnesic patients and of older adults. The dissociation between impaired and preserved memory task performance has been proposed to reflect different memory systems—declarative versus nondeclarative (Squire, 1994). A subtype of nondeclarative memory is skill/procedural learning, which is measured by tasks such as the Tower of Hanoi puzzle (TOHP). The TOHP is a well-studied procedural task, and the ability to solve it has been found to be preserved in amnesics (Cohen & Corkin, 1981; Cohen, Eichenbaum, Deacedo & Corkin,

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1985; Cohen & Squire, 1980). In this task, participants are required to move a number of disks placed on one of the three pegs, to another peg in a minimum number of moves.

While it is well established in amnesia that procedural learning is preserved, findings regarding the effect of age on procedural memory tasks are still inconclusive. Moscovitch, Winocur, and McLachlan (1986) presented younger adults, older adults, and memory-impaired participants with either normal sentences or sentences in which letters were rotated. Participants were then tested for both recognition and reading speed. Although the younger group read faster than the older group, both groups improved at the same rate over the sessions. Another procedural task, serial reaction time, was originally introduced by Nissen and Bullemer (1987). Here, the subject's task is to press keys in the corresponding repeated sequence of asterisks appearing on the computer screen. The learning of the sequence, which is evident by the reduction of reaction time over training, is demonstrated even in participants who report no awareness of the repeated sequence (Willingham, Nissen, & Bullemer, 1989). Howard and Howard (1989) have compared younger and older adults on this task. In their study, although the older group's overall reaction time was slower than that of the younger group, both groups displayed a parallel decrease in reaction time over training sessions. Other procedural tasks that have also been found to be preserved are rotor pursuit (Heindel, Butters, & Salomon, 1988) and mirror tracing (Gabrieli, Corkin, Mickel, & Growdon, 1993; Mickel, Gabrieli, Rosen, & Corkin, 1986). Some other studies, however, have reached the opposite conclusion, that is procedural memory is age-sensitive. Wright and Payne (1985) reported that older adults' performance on rotor pursuit and mirror tracing tasks was inferior to that of younger adults. Of particular interest is the study by Davis and Bernstein (1992) who compared the performance of older and younger adults on the TOHP. In their study, all participants made four solution attempts in four sessions (i.e. a total of 16 trials). Participants in their 20s and 80s were compared on the average number of moves required for the four attempts in each session. Results showed that the older the participants, the more moves they required to solve the puzzle.

Previous studies have demonstrated that the depth of processing of the information is more critical to the retention of information over time than just the intention to learn (i.e. incidental vs. intentional learning). Hyde and Jenkins (1969) showed that when deep processing took place (i.e. pleasantness judgement), even under incidental learning, performance was as good as under intentional learning. Furthermore, the more elaborate the encoding, the more durable the traces are in memory (Craik & Lockhart, 1972). The level of processing model was used as an explanation for the memory decline associated with age. It has been claimed that older adults, as compared with younger adults, engage in less deep processing of information (for review see Burke & Light, 1981 and Kausler, 1994).

Several studies have demonstrated that procedural learning is independent of conscious recollection of the information learned. This is true for young as well as for elderly participants (Howard & Howard, 1989; Willingham et al., 1989). However, most procedural tasks usually require more active involvement in the learning process as compared to the learning of declarative information. For example, solving the TOHP, one of the most common procedural tasks, requires the planning and executing of every single move. By contrast, in a typical declarative task a subject is only required to listen to a list and then recall as many words as possible.

In light of this review, in the present study we would like to address the following questions: First, will active and passive learning of a procedural task (i.e. Tower of Hanoi) have a differential effect (a) on retention over time of the learned task, and (b) on the ability to transfer the learned skill to a more difficult task? In addition we would like to see whether the two learning methods affect younger and older adults differentially.

METHOD

Participants

Two groups of people participated in the presenting study: a group of younger adults and a group of older adults. The younger group consisted of 24 volunteers (8 males and 16 females), whose ages ranged from 18 to 27 years (M =21.92) and whose educational level ranged from 12 to 16 years of schooling (M =12.83). The older group consisted of 24 (9 males and 15 females), whose ages ranged from 60 to 79 years (M = 65.83), and whose educational level ranged from 4 to 24 years of schooling (M =13.08). All the older adults, when tested, were alert and oriented to time and place. They were retired middle-income people. The two age groups did not differ in the number of years of schooling [$t(46) = .33$, $P > .05$]. All participants were reported to be in good health and had no uncorrected vision or hearing problems. None of the participants had a history of alcohol or drug abuse or psychiatric illness.

Testing material

Tower of Hanoi Puzzle. (Cohen & Corkin, 1981; Cohen et al., 1985). A computerised (for PC) version of the task was used. Participants were seated in front of the computer screen. Three pegs, numbered 1 to 3, are presented on the screen. At the outset, four disks are arranged on the leftmost peg, with the largest disk at the bottom and the smallest disk on the top. Participants were told that the goal is to move the four disks in the minimum number of steps from the leftmost peg to the rightmost peg. They were also told that they can move only one disk at a time, they cannot place a large disk on a small disk and they can use the middle peg as well. In order to move disks, participants must press 1, 2, or 3 on the keyboard, choosing first the peg number from which to move the disk, and then the peg number to which to move the disk. The computer automatically registers the number of moves and the time required to solve the TOHP. The minimum number of moves necessary successfully to complete the four-ring problem is 15, whereas five disks necessitate a minimum of 31 moves.

Procedure

Participants were tested individually, in two sessions one week apart. They were told that they were participating in a learning and memory experiment. The experiment was carried out in five stages, as follows:

Stage 1: Baseline measure. Participants were asked to solve the TOHP (with 4 disks) with as few moves as they could. At this stage the individual baseline level was established. The number of moves and time required for each participant successfully to complete the problem was recorded. These measures served as a baseline for both age groups on the two training conditions. Performance after the different training conditions was compared to baseline values.

Stage 2: Training. In this stage, the participants from each group, younger and older adults, were randomly divided into two subgroups: "active'' and "passive". The "active" group was asked to solve the TOHP again (with 4 disks) with as few moves as they could. The "passive" group was also presented with the TOHP (also with 4 disks), but asked to solve it by following the experimenter's verbal instructions. The sequence dictated to the "passive" group participants was the optimal solution (i.e. 15 moves). The procedure for both the "active" and the "passive" group was repeated three times, consecutively.

Stage 3: Immediate Test. In order to measure the immediate effect of the two training methods, all participants were once again asked to solve the TOHP (with 4 disks) in an "active" manner (i.e. without any intervention by the experimenter).

Stage 4: Transfer. In order to assess ability to transfer the learned skill to a more difficult task, all participants were asked to solve a more difficult level of the TOHP in the "active" manner, with five disks requiring a minimum of 31 moves to complete.

Stage 5: Delayed Test. The delayed effect of the different training methods was tested in the second session, one week later. All participants were again asked to solve (i.e. in an "active" manner) the TOHP with four disks.

RESULTS

Two separate dependent measures were employed to analyse the data: number of moves for solution and puzzle solution time.

Number of moves. Figure 1 presents the mean number of moves required by the two age groups to solve the TOHP, as a function of the two training conditions and the three different trials. A mixed-design ANOVA was used to analyse the effect of age group (younger and older adults) by training (active vs. passive) and by trial (baseline, immediate, and delayed test). The first two are between-subject factors and the third is a within-subject factor. Overall, the older group needed more moves than the younger group to solve the TOHP [$F(1, 44) = 14.84$, $P < .001$]. The other two main effects did not reach significance. The triple interaction was the only interaction to reach significance [$F(2, 88) = 3.47$, $P < .04$]. The above analysis was broken down into two simpler analyses in order to detect the source of the triple interaction: First, by comparing the two age groups in the two training conditions on baseline performance compared to immediate test only, and then comparing the immediate with the delayed test. In the first comparison the age group main effect was the only significant effect [$F(1, 44) = 14.88$, $P < .001$]. In the second analysis, in addi-

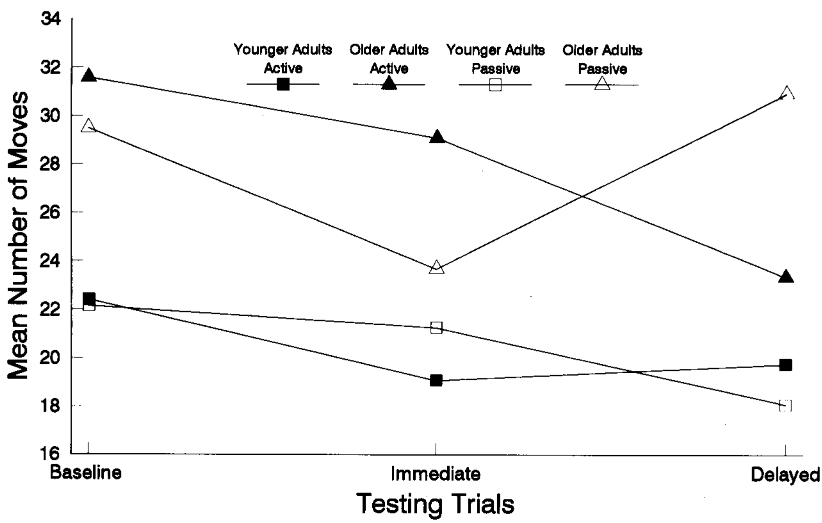

FIG. 1. The mean number of moves required by the two age groups to solve the TOHP, as a function of the two training conditions and the three different trials.

tion to the significant age group main effect [$F(1, 44) = 10.23$, $P < .003$] the triple interaction was significant as well [$F(1, 44) = 6.98$, $P < .01$]. As can be seen in Fig. 1 the younger group's performance remained constant across trials equally in both training modes. On the other hand, the elderly group did not change significantly from baseline following active training (31.59 to 29.08), but showed a decrease in the number of moves required to solve the TOHP in the delayed measure (29.08 to 23.33). This improvement was manifest in the immediate test following passive training (29.50 to 23.67), but reverted back to baseline level on the delayed test (23.67 to 30.92).

Table 1 presents the mean number (and standard deviation) of moves required by the two age groups in the two training conditions to solve the transfer puzzle with 5 disks. A mixed-design ANOVA was used to analyse the effect of group (younger and older adults) by training (active vs. passive). Both main effects, but not the interaction between them, reached significance. Overall, the older group required more moves than the younger group to solve the TOHP [$F(1, 44) = 10.60$, $P < .002$]. Following active training, both groups required fewer moves to solve the more difficult puzzle [$F(1, 44) = 5.17$, $P < .03$].

Solving time. The same analyses as above were conducted with solving time as the dependent measure. Figure 2 presents the mean time (in seconds, required by two age groups to solve the TOHP, as a function of the two training conditions and the three different trials.

A mixed-design ANOVA was used to analyse the same effects as in the number of moves measure. Overall, the older group required more time than the younger group to solve the TOHP [$F(1, 44) = 4.64$, $P < .04$]. There was an overall decrease in the time required to solve the TOHP from trial to trial [$F(2, 88) = 5.64$, $P < .005$]. The most pronounced change is the decrease in time from pre- to post-training for all groups (see Fig. 2). The type of training did not have a significant effect on the time required to solve the TOHP. None of the interactions reached significance.

TABLE 1
Mean Number (and Standard Deviation) of Moves Required by the Two Age Groups, in the Two Training Conditions, to Solve the New Puzzle with Five Disks

	Training	
Group	*Active*	*Passive*
Young	41.50	56.58
	(11.87)	(17.91)
Old	60.92	65.92
	(14.24)	(16.47)

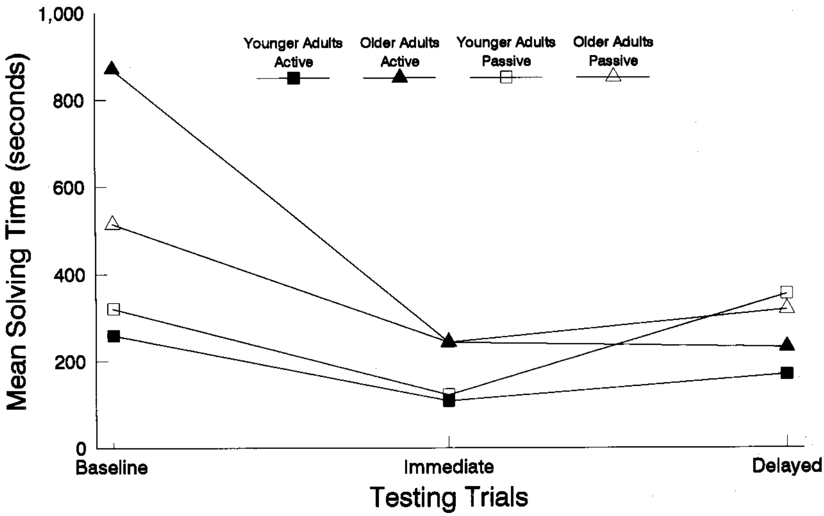

FIG. 2. The mean time (in seconds) required by the two age groups to solve the TOHP, as a function of the two training conditions and the three different trials.

Table 2 presents the mean (and standard deviation) of time (in seconds) required by the two age groups in the two training conditions, to solve the TOHP with 5 disks. A mixed design ANOVA was used to analyse the effect of group (younger and older adults) by training (active vs. passive). Both main effects, but not the interaction between them, were significant. Overall, the older group required more time than did the younger group to solve the TOHP [$F(1, 44) = 5.94$, $P < .02$]. Following active training participants required less time to solve the more difficult puzzle [$F(1, 44) = 5.88$, $P < .02$]. The nonsignificant interaction between these two factors suggests that both groups benefited to the same extent from active training.

The correlation pattern is an additional way in which the above hypotheses were tested. Table 3 presents the Pearson product–moment correlations

TABLE 2
Mean (and Standard Deviation) of Time (in seconds) Required by the Two Age Groups, in the Two Training Conditions, to Solve the New Puzzle with Five Disks

	Training	
Group	*Active*	*Passive*
Young	342.92 (331.62)	624.75 (520.49)
Old	626.33 (275.88)	902.08 (421.62)

between the different performance measures in the two training conditions. The most noticeable difference in the correlation pattern between the two training conditions is on the transference task. The performance on the transference task, whether measured by number of moves or solving time, is highly correlated with the post-training trial in the active but not in the passive condition. In other words, only better performance following active training predicted better performance on the transference task.

DISCUSSION

As indicated in the review above, there are discrepancies in the literature regarding the effect of age on procedural learning. Reasons such as sampling and selection of procedural tasks may contribute to this controversy. Another source of confusion is the selection of an adequate measure of task component that reflects procedural learning. Among the most common procedural tasks are the TOHP, serial reaction time, and reading speed. In different studies, different components of these tasks were used to measure procedural learning: overall performance, learning rate, retention over time, and transference of the learned skill (Davis & Bernstein, 1992; Howard & Howard, 1989; Vakil & Agmon-Ashkenazi, in press; Willingham et al., 1989).

TABLE 3
Pearson Product–Moment Correlations Between the Different Performance Measures in the Two Training Conditions

Measures	*2*	*3*	*4*	*5*	*6*	*7*	*8*
			Active training ($n = 24$)				
1. Baseline measure (moves)	.30	.41	.19	.50	.02	.11	–.05
2. Immediate test (moves)	–	.32	.64**	–.05	.81**	.06	.51
3. Delayed test (moves)		–	.33	.04	.17	.44	.25
4. Transfer test (moves)			–	–.05	.54*	.14	.75**
5. Baseline measure (time)				–	–.03	.09	–.06
6. Immediate test (time)					–	.19	.74**
7. Delayed test (time)						–	.37
8. Transfer test (time)							–
			Passive training ($n = 24$)				
1. Baseline measure (moves)	.25	.47	.10	.67**	.21	.47	.15
2. Immediate test (moves)	–	.45	–.01	.08	.68**	.47	–.12
3. Delayed test (moves)		–	.31	.18	.46	.19	.18
4. Transfer test (moves)			–	–.05	.04	.04	.36
5. Baseline measure (time)				–	–.40	.37	.29
6. Immediate test (time)					–	.25	.19
7. Delayed test (time)						–	.14
8. Transfer test (time)							–

*$P < .005$, **$P < .001$.

In the present study, except for learning rate, all these different components of the TOHP were analysed in order to assess the effect of age and training conditions on procedural learning. Furthermore, the number of moves as well as time required to solve the TOHP were analysed. Since participants in the passive learning condition followed instructions and solved the TOHP in the optimal number of moves (i.e. 15), there was obviously no point in analysing the learning rate in this study.

The *overall performance* of older adults was consistently inferior to that of younger adults, regardless of whether number of moves or time was used as the dependent measure. This finding is consistent with previous findings in the literature (Davis & Bernstein, 1992; for discussion see Vakil & Agmon-Ashkenazi, in press).

With number of moves as the dependent measure, the effect of type of training on *delayed performance* differed for the younger and older participants. The younger group did not show a differential effect for the two types of training on either immediate or delayed tests. On the other hand, elderly participants showed an interesting pattern of results. Passive training was beneficial for the immediate test but not for the one week delayed test, in which performance reverted back to baseline level. Although active training had little effect on the immediate test, it did have a significant effect on the one week delayed test. Solving time was sensitive to age effect and to the effect of training, but was not differentially affected by the type of training. Although not statistically significant, the pattern seen in the elderly group with number of moves, is evident in younger participants with the solving time measure. That is, while active training has a long lasting effect for at least one week, passive training has only an immediate effect (from 321.33 to 123.00) and then reverts to baseline level (123.00 to 353.73). Older adults show a similar but much less pronounced pattern. The reason that the differential effect of the training mode in the younger group is only expressed in the solving time measure but not in the number of moves may possibly be that they are performing very close to peak level (i.e. 19.75 and 18.08, when 15 is the minimum number of moves). Improvment is therefore expressed mostly in the solving time measure.

When required to *transfer* the learned skill to a more difficult task, participants who went through active training in the procedural task benefited more from the training than those who went through passive training. This was true whether the dependent measure is number of moves or time required to solve the TOHP. Furthermore, both age groups showed this advantage to the same extent with both dependent measures. The correlation pattern further supports these findings. Performance on the transference task, whether measured by number of moves or solving time, is highly correlated with the post-training trial in the active but not in the passive condition.

These results suggest that just like in declarative memory, shallow processing of a procedural task leads to fragile traces in memory, while deep elaborative processing leads to more durable traces in memory (Craik & Lockhart, 1972; Hyde & Jenkins, 1969). However, unlike the findings for declarative memory (Duchek, 1984; Eysenck, 1974), the level of processing effect is evident in elderly participants just as much as it is in younger participants.

An alternative interpretation of the dissociation between active and passive methods of training is that the former is indeed a procedural task, whereas the latter is a declarative task. In other words, participants who went through passive training may possibly have tried to retain the instructions without having to process the solving procedure. Furthermore, since participants were told that they are participating in a learning and memory experiment, they may have consequently engaged in a conscious declarative strategy. Although this interpretation has some validity to it, one cannot ignore the fact that at test all participants were instructed to “solve the puzzle with as few moves as they could”. They were not instructed to repeat a particular sequence of moves. In addition, they fact that *all* participants were told that they were participating in a learning and memory experiment cannot explain the dissociation in performance between the passive and active groups.

This discussion highlights another interesting theoretical issue. As mentioned above, most procedural tasks usually require more active involvement in the learning process, as compared to the learning of declarative information. The findings of the present study demonstrate that in the learning of the TOHP (as, likely, of other cognitive tasks), the dichotomy between active versus passive types of training could be a predictor of successful learning, as an alternative to the dichotomy between implicit versus explicit strategies of retrieval. In order to clarify this issue, an experiment is needed that would test the interaction between the different learning methods and the different retrieval strategies.

Finally, these findings also have important implications in terms of skill learning and rehabilitation. They suggest that for skill learning, all age groups benefit more over the long run from active–elaborative training than from passive types of training. Furthermore, skills learned under active training methods are expected to generalise better to similar tasks.

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