Acquisition and Long-Term Retention of a Gross Motor Skill in Alzheimer’s Disease Patients Under Constant and Varied Practice Conditions


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This study examined the acquisition and long-term retention of a gross motor skill, namely, tossing, in 23 moderately to severely demented Alzheimer’s disease (AD) patients and 22 healthy older adults. To identify optimal learning strategies, subjects received 10 weeks of training under either constant or variable practice conditions. Accuracy at the tossing task was assessed immediately, one week, and one month following training. AD patients given constant practice were able to learn and retain the tossing task as well as healthy adults. Although controls performed equally well in both conditions, AD patients showed significantly less improvement when practiced at various distances from the target. By the one-month post-test, these patients had lost any minimal gains achieved through practice. In comparison, AD patients receiving constant practice showed essentially no forgetting across post-tests. The inability to benefit from varied practice suggests that AD patients may have difficulty accessing and/or forming motor schemas.

ONE of the most interesting findings in recent research investigating the memory impairment in Alzheimer’s disease (AD) is the discovery that motor learning may represent an island of saved functioning in the midst of the devastating cognitive losses associated with this dementia. Since 1986, a handful of studies has clearly demonstrated that AD patients can learn motor- or movement-based information (Dick, 1992; Dick, Kean, & Sands, 1988) as well as some rather complex perceptual-motor skills such as the rotary pursuit (Bondi & Kaszniak, 1991; Eslinger & Damasio, 1986; Heindel, Butters, & Salmon, 1988; Heindel, Salmon, Shults, Walicke, & Butters, 1989) and serial reaction time tasks (Grafman et al., 1990; Knopman, 1991). In comparison, numerous studies examining memory for verbal, visual, and spatial information have shown that AD patients perform at a level far below that of normal older adults (Bäckman, Mantyla, & Herlitz, 1990; Nebes, 1992).

This stark contrast between the relatively intact performance of AD patients on many motor tasks, and the inability of these impaired individuals to learn verbal, visual, and spatial material, supports the notion that memory is not a unitary function. In fact, these disparate findings are consistent with the common distinction between procedural and declarative learning (Squire, 1987) and suggest that the two memory systems are affected differently by AD. Procedural memory, which has been linked to the acquisition of movement-based information, involves skills, rules, and plans (i.e., “knowing how to” throw a ball or ride a bicycle). In comparison, the declarative memory system processes and stores factual information (e.g., “knowing about” balls or bicycles). While declarative memory requires the conscious, or explicit, recollection of a previous event, procedural learning occurs implicitly, that is, when an individual automatically utilizes prior experience with a task to improve performance. For example, in studies of motor skill acquisition in AD, procedural learning takes place when repeated practice at a motor skill such as the rotary pursuit task enhances the patients’ tracking performance.

Evidence that AD patients can acquire the rotary pursuit task within a few learning trials (Eslinger & Damasio, 1986) suggests that the procedural memory system in AD may be preserved. However, additional studies examining the nature and extent of motor learning in AD are needed to substantiate this conclusion. Questions about how AD patients learn new motor skills, whether learning is limited to certain types of motor tasks, and the ability of these impaired individuals to retain motor information over extended periods of time, remain unanswered. Prior studies have only shown that AD patients can (a) acquire laboratory tasks involving fine motor skills, (b) learn these tasks under identical or constant practice conditions, and (c) retain these tasks for short periods of time following training (Eslinger & Damasio, 1986; Heindel et al., 1988, 1989). This experiment extended previous research by comparing the acquisition and long-term retention of a gross motor skill, namely a tossing task, under constant and variable practice conditions in AD patients and healthy controls.

A number of researchers (Eslinger & Damasio, 1986; Heindel et al., 1988, 1989) have successfully demonstrated that AD patients can, for example, acquire the rotary pursuit task when tracking is performed at the same (“constant”) speed across learning trials. While AD patients perform this fine motor skill nearly as well as normal adults under constant practice conditions, Schmidt’s (1975) theory of
motor learning suggests that this type of practice may not lead to the best acquisition, retention, and transfer. In the variability-of-practice hypothesis, Schmidt proposes that practicing a skill under variable as opposed to constant conditions leads to superior learning. To benefit learning, practice should involve variations within the same class or group of movements. According to Schmidt, movements within the same class are governed by a generalized motor program and share certain invariant characteristics, such as the relative timing of the action’s components, the sequence of events comprising the action, and the spatial configurations of the limbs performing the action. Variable practice within a class of movements — for example, practicing movements which differ in duration and/or force but retain the same order of elements and fundamental temporal structure — leads to the formation of motor schemata. Schmidt has described motor schemata as encompassing the relationship of the movement outcome to the corresponding movement parameters (recall schema) as well as to the sensory consequences (recognition schema). These schemata are assumed to be more stable, allow for better inter- or extrapolation of novel parameters, and permit better prediction of sensory consequences than movement information associated with constant practice. Consequently, variable practice is believed to lead to superior retention and transfer performance.

Studies investigating the variability-of-practice hypothesis have yielded mixed results. While research with adults has not consistently linked superior performance to variable practice (Lee, Magill, & Weeks, 1985; van Rossum, 1990), studies utilizing healthy or mentally retarded children as subjects have provided empirical support for the hypothesis (Edwards, Elliott, & Lee, 1986; Shapiro & Schmidt, 1982). Variable practice may be most beneficial for children because they have a relatively small repertoire of well-learned movements and, unlike adults, have not yet developed motor schemata for the relatively simple tasks used in these studies (Shapiro & Schmidt, 1982). In AD, motor schemata appear to be compromised, as suggested by the presence of impairments in motor-based activities of daily living (e.g., eating, dressing) (Vitaliano, Russo, Breen, Vitiello, & Prinz, 1986; Zanetti, Bianchetti, Frisoni, Rozzini, & Trabucchi, 1993). These impairments may reflect deterioration in the motor schemata governing daily living skills or in the ability of AD patients to access the schemata. If variable practice enhances motor learning in children by fostering the development of schemata, perhaps this type of practice could similarly benefit AD patients by strengthening the schemata involved in specific movements. The present study tests this possibility by comparing the pre- and post-test tossing performance of AD patients and healthy controls under constant and variable practice conditions. On the one hand, assuming that motor schemata deteriorate in AD, variable practice should lead to better acquisition and retention of the tossing task than constant practice in the present study. On the other hand, if motor learning is completely spared in AD and motor schemata remain intact, AD patients, like their unimpaired peers, should learn and retain the tossing task equally well under constant and variable practice conditions.

While one of the preceding hypotheses, based on schema theory, may prove true in this study, an alternative theory of skill learning lends itself to a third possible outcome, namely that AD patients would not benefit from variable practice. Instance theory (Logan, 1988) emphasizes the role of memory for individual episodes in accurate performance of a skill. Rather than developing a schema that extracts the essential or defining features of a skill from multiple practice experiences, the subject draws on episodic memory of the training instances to accurately perform a task. According to Logan, accurate performance initially depends on the development and deliberate implementation of an algorithm. The shift from attention-demanding, effortful performance to fluent, automatic execution of a skill involves a transition from algorithm-based to memory-based performance. During practice, a subject automatically forms separate memory representations of each training instance, even when trials are identical. As practice continues, the subject may reapply the algorithm; however, memories for training instances are also being retrieved in parallel from long-term memory. The probability that a subject executes a task based on automatically retrieved memories before the algorithm completes its run increases with the number of practice trials. Although Logan proposes that a slowly executed algorithm is eventually abandoned in favor of memories for instances, others (Malt, 1989) suggest that schematic representations of a skill coexist with individual memories of the practice trials.

Damage to the hippocampus, an early and prominent feature in AD (Hyman, Van Hoesen, Damasio, & Barnes, 1984) interferes with the encoding, storage, and retrieval of episodic information (Bondi & Kasznik, 1991). Severe memory deficits would hamper acquisition of the tossing task in AD patients, if accurate performance depends on the automatic encoding and retrieval of individual practice trials. Explicit or declarative contamination may occur in this motor task, but only under variable practice conditions. Although instance theory does not address the issue of practice conditions, it can be implied that variable practice involves the ability to retrieve and compare specific training experiences. However, when practice is constant, that is, when training experiences do not differ, the subject is not required to make multiple comparisons and can perform the task accurately simply by rerunning the same motor program.

Constant practice may be a more effective means of teaching tossing to AD patients than variable practice, because repeated rerunning of the same motor program does not require an intact hippocampal memory system (Eichenbaum, 1992; Eichenbaum, Otto, & Cohen, 1994). However, the hippocampus may play an important role in variable practice, which appears to involve declarative as well as procedural memory. These researchers linked the hippocampus to relational processing, such as occurs in variable practice when the subject compares present task demands with a variety of past training experiences. AD patients, who lack this ‘‘representational flexibility’’ due to hippocampal damage, may fail to learn the tossing task under variable or hippocampal-dependent practice conditions. However, these impaired individuals may still be able to acquire the task under constant or hippocampal-independent practice conditions. According to Eichenbaum and his colleagues, procedural information can be encoded without the hippocampal systems.
campus, but task representations are inflexible; that is, accurate performance occurs only in situations replicating the original learning conditions. In a study that compared the effects of different practice conditions on place learning, Eichenbaum, Stewart, and Morris (1990) found that rats with hippocampal lesions were able to successfully learn the escape locus in a Morris water maze following constant but not variable practice. When the starting place was varied across trials, only intact animals were able to learn the escape locus. However, when the same starting position was used across trials, rats with hippocampal lesions learned the escape locus as rapidly as intact animals. Like animals with hippocampal lesions, AD patients may only be able to acquire certain skills under constant practice conditions. Whether produced experimentally in laboratory animals or through AD in humans, hippocampal damage may leave procedural learning intact but impair its flexibility.

METHODS

Subjects

Participants in this study included 28 AD patients and 24 healthy controls. Healthy older adults were recruited at a local senior center, while AD patients were identified through the University of California at Irvine Alzheimer’s Disease Research Center (UCI-ADRC) and Autumn Years, a residential facility specializing in the care of older adults with dementia. The 28 patients selected for participation (a) met the diagnostic criteria for probable or possible AD developed by the National Institute of Neurological and Communicative Disorders and Stroke (NINCDS) and the Alzheimer’s Disease and Related Disorders Association (ADRDA) (McKhann et al., 1984); (b) did not have a history of major psychiatric illness, chronic alcoholism, or other neurological disorders; and (c) were free of any physical impairment which would interfere with participation in the motor activity. The presence of multi-infarct dementia was ruled out through the patient’s medical history, including neuroimaging data (i.e., CAT and MRI scans), a neurological examination performed by the second author, and a score of 4 or less on the Hachinski Ischemic Scale (Rosen, Terry, Fuld, Katzman, & Peck, 1980). In addition, persons who had previously participated in motor-based activities similar to the experimental tossing task (e.g., bowling, softball, horseshoes) on a regular basis were excluded from this study to prevent the results from being confounded by prior experience. Consequently, over 80% of the healthy controls and 90% of the AD patients involved in this experiment were female.

Severity of dementia was assessed with the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975), Blessed Information, Memory, and Concentration test (BIMC; Blessed, Tomlinson, & Roth, 1968), Blessed Dementia Scale (BDS; Blessed et al., 1968), Clinical Dementia Rating (CDR; Berg, 1988; Hughes, Berg, Danziger, Coben, & Martin, 1982), and the Mattis Dementia Rating Scale (DRS; Mattis, 1976). In addition, functional competence was assessed with two measures developed by Lawton and Brody (1969), namely the Physical Self-Maintenance Scale (PSMS) and the Instrumental Activities of Daily Living Scale (IADLS). The PSMS assesses the degree of assistance an individual needs to perform six motor-based self-care activities (e.g., eating, dressing, toileting), while the IADLS measures level of dependence in eight more complex living skills (e.g., shopping, laundry, managing a checkbook). The healthy controls, who were paid $40 for their participation, received the MMSE, BIMC, DRS, PSMS, and IADLS to screen for cognitive and functional impairment. As affective disorders can have a negative impact on performance, only healthy older adults who were free of depression, as assessed by the Geriatric Depression Scale (GDS; Yesavage et al., 1983), were included in the study (M = 1.2, SD = 1.9). The GDS was not administered to the AD patients, as several studies have shown that this self-report instrument is insensitive to affective disorders in persons with dementia. For example, Burke, Houston, Boust, and Roccaforte (1989) found that the GDS was no better than chance in identifying depression in mildly impaired AD patients. In this study, AD patients with significant depressive features were excluded from participation based on reports from caregivers and staff.

During the 10-week training period, two healthy controls and five AD patients (three in the constant group and two in the variable group) failed to complete all 20 practice sessions. Data were excluded for the two healthy controls who attended the practice sessions intermittently and for five AD patients whose participation was discontinued due to physical illness, combativeness, or refusal. Table 1 shows selected demographic and psychometric characteristics of the 23 AD patients and 22 healthy controls who completed the study. While the two groups were similar in age and education, they differed significantly on three measures: the MMSE, t(43) = 12.6, p < .0001; BDS, t(43) = 12.6, p < .0001; and DRS, t(43) = 12.3, p < .0001. On these measures, the healthy controls performed in the normal range of cognitive functioning while scores of the AD patients fell in the moderate to severely impaired range. Similarly, clinician ratings of overall functioning on the CDR indicated at least moderately dementia in the AD patients (M = 2.2, SD = 0.6) in comparison to an absence of impairment in the healthy controls (M = 0). In terms of functional competence, AD patients demonstrated moderate impairment (PSMS: M = 2.89, SD = 0.7) in self-care activities and severe deficits or total dependence on others in instrumental activities of daily living (IADLS: M = 3.69, SD = 0.1). In comparison, healthy controls exhibited no impairment on either measure of functional competence.

Apparatus

The gross motor skill involved a closed, discrete throwing movement. More specifically, subjects were trained in the underhand toss of a 2 x 2 inch bean bag with the dominant hand at a 36-inch “archery type” target comprising four concentric circles. The target was placed upright on an adjustable easel. The bean bags, which were covered in Velcro, adhered to the felt target, thereby providing subjects with immediate visual feedback regarding performance. Five points were awarded for each toss hitting the center of the target, and successively lower scores were awarded for tosses which landed in the outer rings of the target.
Tossing was identified as an appropriate task for investigating skill learning and the variability-of-practice hypothesis in AD based on selection criteria outlined by Oxendine (1984) and Schmidt (1975). First, according to Schmidt, tasks that involve “ballistic” and “discrete” movements, that is, fast movements such as tossing with a clearly defined beginning and end, should be used to test the variability-of-practice hypothesis. Secondly, Oxendine recommended that researchers in skill learning select experimental tasks which (a) subjects are capable of learning and performing, (b) provide an easy and objective means of measuring improvement, and (c) exhibit high reliability of individual differences. In addition, experimental tasks should be relatively novel, allowing all subjects to start at a near-zero level of proficiency. Obviously, tossing is not a novel task; however, as Oxendine noted, it is very difficult to find a gross motor skill with which adult subjects have not had any experience. Although familiar, the tossing task met the remaining selection criteria and was particularly suitable for this study, as pilot testing demonstrated that even severely demented AD patients are able to perform this gross motor skill.

Design and Procedure
This experiment utilized a mixed design, with two between-subject factors, Group (AD Patients vs Healthy Controls) and Type of Practice (Constant vs Variable), and one within-subject factor, Test (Post-tests 1, 2, 3). The amount of practice was held constant at 10 consecutive weeks of training, with two practice sessions per week. During each practice session subjects received 32 trials, divided into 2 sets of 16, with a short rest interval in between. At the beginning of each session, the experimenter explained and demonstrated the task to the subject. If necessary, the experimenter guided the subject’s arm through the movement. Only valid tosses were entered into the data. To be considered a valid toss, a subject had to (a) throw underhanded with the dominant hand, (b) throw the bean bag a minimum distance toward the target, and (c) stand the designated distance from the target with both feet pointed toward the target. Following an invalid toss, which did not meet these criteria, the subject was verbally corrected and, if necessary, the task was demonstrated again.

To avoid the problems created by floor and ceiling effects, a pretest was used to equate task difficulty across subjects. First, the distance from the target at which subjects were able to obtain an average score of 1.5 (out of 5) points on the tossing task was established. Initially, subjects were given five trials at 3.0 meters from the target. Subjects with scores greater or less than 1.5 at 3.0 meters were moved further from or closer to the target, respectively, in an incremental fashion, and given additional blocks of four trials until the desired baseline score was achieved. As this procedure simulated the Variable Practice condition, the number of trials used to determine the baseline distance was kept to a minimum. Whether assigned to the Constant or Variable Practice condition, AD patients had to stand significantly closer to the target than healthy controls to achieve the desired baseline score. In the Constant Practice condition, AD patients achieved a mean score of 1.59 (SD = 0.30) at 2.74 meters (SD = 0.41 m) from the target, while healthy controls obtained this same mean score (SD = 0.26) at 5.4 meters (SD = 1.15 m), t(21) = 7.84, p < .0001. Similarly, in the Variable Practice condition, AD patients attained a mean score of 1.61 (SD = .42) at 2.77 meters (SD = .50 m) from the target while healthy controls were able to obtain a comparable mean score (M = 1.52, SD = .27) at 5.21 meters (SD = 1.14 m), t(20) = 5.16, p < .05. Once
baseline distances were established, subjects received a pretest composed of 64 trials given across two days.

Individuals assigned to the Constant Practice group performed all tosses during the practice sessions and subsequent post-tests at the baseline distance from the target. In the Variable Practice condition, subjects did not toss from baseline during the training; rather, they received practice at four distances surrounding the baseline (two closer and two further from the target). These distances fell at ±20 and 40% from the baseline. For example, if a subject's baseline distance was 10 feet from the target, practice was given at 6, 8, 12, and 14 feet. Subjects received a block of 4 trials at each distance during the first (trials 1-16) and second (trials 17-32) half of a practice session. The order of the four blocks within each set of 16 trials was randomized.

Three post-tests were administered to all subjects at the baseline location. During each post-test, subjects received a total of 64 trials across two days. The first post-test (PT1) was given within 4 days ($M = 4.1, SD = 1.5$) after practice ended. Long-term retention of the tossing skill was assessed with two additional post-tests. The second post-test (PT2) was given one week ($M = 7.7$ days, $SD = 2.5$) following PT1. An additional month later ($M = 29.5$ days, $SD = 4.1$), subjects received the third post-test (PT3).

The practice sessions and post-tests were conducted separately with AD patients and healthy controls by 10 experimenters utilizing three targets. Typically, three experimenters were assigned to each target, with one experimenter assisting the thrower, a second retrieving the bean bags, and the third recording the scores. Subjects at each target took turns performing the tossing task and received reinforcement from their peers and the experimenters. Three strategies were used to minimize experimenter effects and create a similar motivating environment for subjects in the two practice conditions. First, the experimenters assigned an equal number of Constant and Variable Practice condition subjects to each target. Secondly, while the same subjects always practiced together at a target, the experimenters alternated among the targets and switched roles. Thirdly, while subjects' responses to each other's performance could not be controlled, the experimenters were trained to limit their verbal feedback in the following standardized manner:

5 points: “Excellent, a perfect shot, do it again!”
4–3 points: “Very good, almost made it, just a little more”
2–1 points: “OK, good for you, now just try to throw it here”

When a subject hit the bulls-eye, the experimenters applauded and encouraged other participants to do the same.

Data Analyses

Means were determined by averaging scores for the 64 trials comprising each pre- and post-test. Each individual's mean scores on the pre- and post-test measures were entered into mixed factorial analyses of variance (ANOVAs) to investigate the effects of the two practice conditions on acquisition and retention of the tossing task in AD patients and healthy controls. To check for a violation in the assumption of homogeneity of variance, Bartlett's $F$ test was computed using data from the pretest, with $M = 2.42$ and modified $M = .58$. Since $F(3,41) = 2.84$, the variances of the AD patients and healthy controls prior to training were assumed to be equal. In addition, both Huyn-Feldt and Greenhouse-Geisser corrections were employed to control for heterogeneity of variance. Huyn-Feldt (H-F) is conservative, but liberal compared to Greenhouse-Geisser (G-G). As no discrepancies in significance occurred, the reported $p$-value pertains to the more conservative G-G correction. Means are reported as significantly different when the corrected $F$ tests achieved alpha levels of .05 or greater. When significant interactions occurred, post hoc comparisons were made using both the Scheffé method and Fisher’s PLSD test. The more conservative Scheffé method is recommended for complex comparisons like those made in this study; it ensures that the Type I error rate does not exceed the probability level specified for the overall ANOVA. However, due to the exploratory nature of this research, the less stringent Fisher’s PLSD was also used to investigate differences between means. While Fisher’s PLSD provides less protection against Type I errors, this post hoc procedure minimizes Type II errors. Both post hoc procedures were used based on the assumption that in exploratory research, Type II errors are to be guarded against as rigorously as Type I.

RESULTS

Mean scores on the pre- and post-test measures are shown in Figure 1 for each group according to type of practice. When a 2 (Group) × 2 (Practice Condition) × 4 (Test) ANOVA was performed on all the data, significant effects occurred for Test, $F(3,123) = 71.7, p < .0001$; the two-way interactions of Group by Type of Practice, $F(1,41) = 4.10, p < .05$, Group by Test, $F(3,123) = 3.32, p < .05$, and Test by Type of Practice, $F(3,123) = 4.34, p < .01$; and the three-way interaction of Group by Type of Practice by Test, $F(3,123) = 5.13, p < .01$. This analysis clearly demonstrated that the two practice conditions affected the performance of AD patients and healthy controls differently. While healthy controls receiving variable practice were able to perform the tossing task as well or better than those given constant practice, AD patients showed the opposite pattern.

Figure 1. Mean scores and standard deviations on pre- and post-tests for each group according to type of practice, constant (left) or variable (right).
More specifically, post-test performance of healthy controls under the two practice conditions was not statistically different; however, AD patients given constant practice achieved significantly higher scores than those receiving variable practice. Separate analyses were conducted with data from the constant and variable practice conditions to clarify the differential effects of the two types of practice on healthy controls and AD patients.

Constant Practice

Results of a 2 (Group) × 4 (Test) ANOVA were not significant for the main effect of Group (p = .77) and the interaction of Group by Test (p = .92). Clearly, AD patients were able to acquire and retain the tossing task as well as healthy controls. The only significant finding in this analysis was the main effect for Test, F(3,63) = 41.9, p < .0001. As can be seen in Figure 1, both AD patients and healthy controls performed the tossing task significantly better during all three post-tests than during the pretest. Differences in performance at the three post-tests were examined in an additional 2 (Group) × 3 (Post-test) ANOVA. Once again, the only significant effect was for Post-test F(2,42) = 4.72, p < .05. For the healthy controls, Fisher’s PLSD tests yielded significant differences (p < .05) between PT1 and PT2 (mean difference = .229) as well as PT1 and PT3 (mean difference = .24), but not between PT2 and PT3 (mean difference = .01). When these comparisons were repeated with the Scheffé method, none was significant. Figure 1 shows that AD patients also performed the tossing task better after the 1-week (PT2) and 1-month (PT3) delay than immediately following training (PT1); however, Fisher’s PLSD tests indicated that the mean differences between these post-tests as well as between PT2 and PT3 were not significant.

Variable Practice

A 2 (Group) × 4 (Test) ANOVA produced significant results for Group, F(1,20) = 8.22, p < .01; Test, F(3,60) = 33.62, p < .0001; and the interaction of Group by Test, F(3,60) = 10.1, p < .0001. Although pretest scores of the two groups were similar, as illustrated in Figure 1, AD patients performed the tossing task significantly worse than the healthy controls at all three post-tests. This was confirmed in a 2 (Group) × 3 (Post-test) ANOVA which resulted in a significant main effect for Group only, F(1,20) = 12.16, p < .01.

Further analyses were conducted in an attempt to identify reasons for the AD patients’ comparatively poor learning in the variable practice condition. Performance data for AD patients and healthy controls at each of the four practice distances (closest, close, far, farthest) were entered into separate 2 (Group) × 10 (Week) repeated measures ANOVAs. The ANOVA for the “closest” distance (baseline–40%) yielded no significant findings. Neither group improved significantly at performing the easiest throw, with scores of the healthy controls and AD patients increasing only 5 and 2%, respectively, by the end of training. However, a significant main effect for Week, F(9,180) = 2.24, p < .05, occurred in the analysis of data from the “close” distance (baseline–20%). In this case, accuracy increased significantly across training in both groups, with 14 and 19% improvements in healthy controls and AD patients, respectively. Finally, the interaction of Group by Time proved significant in both the “far,” F(9,180) = 3.12, p < .01, and “farthest,” F(9,180) = 2.34, p < .05, distance analyses. At the “far” distance (baseline + 20%), AD patients showed only a 3% increase in accuracy, while healthy controls improved by 22%. Similarly, AD patients showed no improvement at the “farthest” distance (baseline + 40%), while healthy controls’ accuracy at performing the most difficult throw increased 12%.

Inter-Individual Differences

Correlational analyses examined the relationship of post-test performance on the tossing task and measures of neurological and neuropsychological functioning. Although the MMSE, BIMC, and DRS were highly correlated, none of these mental status tests or the two functional measures (PSMS, IADL) showed a significant relationship to post-test performance in either healthy controls or AD patients. For example, MMSE scores of AD patients showed low correlations with performance on PT1 in both the constant (r = .15) and variable (r = .14) practice conditions. When the relationship of post-test performance to the subtests of the DRS (Attention, Initiation and Perseveration, Construction, Conceptualization, and Memory) was investigated, none of the correlations even approached significance. While dementia severity did not predict post-test performance, level of cognitive impairment was correlated with baseline distance from the target (r = .60, p < .05). AD patients who stood closest to the target at pretest tended to have lower MMSE scores.

Finally, to determine whether disturbances in the basic parameters of movements interfered with motor learning in AD patients, results of the neurological examination were correlated with post-test scores. Although AD patients in the two practice conditions were similar neurologically, significant correlations were limited to the constant practice condition. Measures of strength (r = -.59) and rigidity (r = .65) showed a significant relationship to post-test performance at the .05 level. AD patients in the constant practice condition who exhibited upper arm weakness and decreased flexibility during the neurological examination tended to score lower on the tossing task at post-test. However, post-test performance was unaffected by inter-individual differences in movement rate and rhythm, coordination, and the presence of frontal lobe signs (root, grasp, snout, and labellar). Similarly, the correlational analyses suggested that any impairments in basic motor reflexes, eye movement patterns, and depth perception did not interfere with acquisition of the tossing task in these AD patients.

DISCUSSION

Clearly, the results of this study demonstrated that AD patients can acquire and retain gross motor skills as well as healthy older adults, but only under certain practice conditions. While AD patients and healthy controls were able to learn the tossing task equally well under constant practice conditions, the patients showed significantly less improve-
mportant than their healthy peers when practiced at various distances from the target. In fact, the minimal improvement shown by AD patients in the variable practice condition immediately after training was lost by the one-month retention test. In comparison, AD patients in the constant practice condition showed essentially no forgetting even one month following training. This study has advanced our knowledge of motor learning by identifying a successful method (i.e., constant practice) for teaching motor tasks to AD patients and demonstrating that these impaired individuals can retain procedural information across extended periods of time. Given appropriate practice, AD patients definitely can retain motor skills for longer than the few minutes (Eslinger & Damasio, 1986) or one to two weeks (Knopman, 1991) shown by previous researchers.

Surprisingly, neither AD patients nor healthy controls benefited from variable practice to the extent expected based on Schmidt's (1975) variability-of-practice hypothesis. Healthy controls did not, as this hypothesis would predict, show significantly greater learning and retention under variable than constant practice. While these unimpaired older adults showed equivalent levels of learning and retention under the two practice conditions, AD patients were unable to learn the tossing task when practice was varied. The possible reasons that the variability-of-practice hypothesis was not confirmed in this study differ for AD patients and healthy controls. First, the equivalent performance of the healthy older adults under the two practice conditions is not surprising given the inconclusive results of previous studies investigating the variability-of-practice hypothesis in adults aged 18–28 yrs (Magill & Hall, 1990; van Rossum, 1990). Variable practice, which fosters the development of motor schemata, may not benefit adults as much as healthy or mentally retarded children because the schemata governing movements like tossing are probably already well-developed in adults (Shapiro and Schmidt, 1982). In addition, the absence of a variability-of-practice effect in the healthy controls may have been related to the experimental design utilized in this study. Typically, researchers investigating the variability-of-practice hypothesis assess the benefits of two practice conditions (e.g., constant and variable practice) by administering a novel transfer test — one governed by the same motor program as the original task but unique to all subjects — following the completion of training (van Rossum, 1990). In this traditional design, the variability-of-practice effect is demonstrated when subjects receiving variable practice perform the transfer task significantly better than subjects given constant practice. The potential bias created when only one group receives practice at the criterion task while the other group never practices the criterion task is controlled by having all subjects perform a novel task following training. However, the amount of learning that has occurred during training may be more difficult to assess with a transfer paradigm than with the pre- and post-test design used in this study. While effectively demonstrating the impact of the two practice conditions on learning, this pre-and post-test design did not include a transfer task, and as a result the healthy controls may not have exhibited the expected variability-of-practice effect. To address this issue, research currently underway is examining the effects of various practice conditions on transfer as well as learning in both AD patients and healthy controls.

The relatively poor performance of AD patients in the variable practice condition may have been caused by (a) impairments which interfere with the ability to encode and store information necessary for schema formation and/or (b) declarative contamination. However, before considering these possible explanations for the current findings, the question of whether AD patients receiving variable practice would have shown greater learning with additional training must be addressed. While the number of trials was equivalent across conditions, it could be argued that AD patients in the variable practice condition actually received less training than their counterparts in the constant practice condition. That is, AD patients in the variable group received only 160 trials at any given distance from the target, in comparison to the 640 trials members of the constant group were given at a single distance.

To explore the possibility that this discrepancy in the amount of practice could account for differences in learning under the constant and variable practice conditions, four AD patients in each group underwent an additional 10 weeks of training. When these individuals' post-test scores immediately following 10 and 20 weeks of training were compared with pretest performance, gains achieved through further practice in the constant group were not replicated in the variable group. While the 34.2% improvement seen in the constant group immediately after 10 weeks of training was not statistically different from the 22% improvement demonstrated by the variable group, these two groups clearly responded differently to the additional practice. After 20 weeks of practice, the constant group performed the tossing task significantly better than at pretest, t(6) = 2.49, p < .05, showing a 69.2% improvement in accuracy. In comparison, the performance of the variable group declined, with less than 1% improvement over pretest following the additional training. Therefore, it can be concluded that differences in the amount of training AD patients in the constant and variable practice conditions received at any given distance from the target did not account for the absence of a variability-of-practice effect.

On the one hand, AD patients receiving variable practice may have failed to learn and retain the tossing task due to difficulties in accessing and/or forming motor schemata. The inability to acquire a task through varied practice suggests that the learner may not be forming the motor schemata needed to successfully achieve a goal movement when environmental demands (e.g., distance from the target) change. According to Schmidt (1975), schema formation depends on the capacity to process and store four types of information about a motor movement. More specifically, a schema is based on knowledge about (a) the initial task conditions, (b) actual execution or performance of the movement (e.g., sensory consequences of moving), (c) potential parameters of the movement (e.g., speed, direction, force), and (d) outcome or “success” of the response. In AD patients, the ability to encode and store these four types of information may be limited by extensive memory and other cognitive impairments, and consequently, as the lack of significant improvements in the variable practice condition...
suggests, these impaired individuals may be unable to form motor schemata. 

On the other hand, the differential benefits of variable practice for AD patients and healthy controls can also be attributed to the possibility that declarative contamination occurred during this training condition. Healthy controls, who retained the ability to recall and compare training experiences, could perform the tossing task accurately even when practice was varied. When shifted to a new distance from the target, a healthy control could draw on memories of past training experiences to make decisions, for example, about how hard to toss the bean bag or the angle at which to throw. Inferential use of memories is possible because hippocampal processing allows the unimpaired learner to make multiple comparisons among cues and develop a flexible memory representation based on relationships between those cues (Eichenbaum, 1992; Eichenbaum et al., 1990, 1994).

Due to hippocampal damage, AD patients participating in the study probably could not store memories of the practice trials. From the perspective of instance theory (Logan, 1988), AD patients in the variable practice condition were unlikely to perform the tossing task accurately in the absence of information about previous successes and failures. However, despite hippocampal damage, AD patients receiving constant practice demonstrated significant improvements across training and at the post-test, perhaps because this type of practice only involved adaptation to one visual-spatial configuration and tossing force. Based on animal studies, Eichenbaum et al. (1990, 1994) concluded that hippocampal processing is not essential when learning only requires adaptation to an individual set of stimuli and continual rerunning of the same neural processes. However, the individual memory representations developed during this type of learning are inflexible and can only be revealed in situations replicating the original learning conditions. Consequently, in the tussing paradigm, either severely impaired or intact learning was observed depending on the representational demands of the task.

While the tossing accuracy of AD patients did not improve when practiced at varying distances from the target, variable practice may facilitate learning of "continuous" or "open" motor skills in these impaired individuals. The tossing task can be described as "discrete," that is, as having a distinct beginning and end, while other motor skills, like the rotary pursuit task, would be considered "continuous" (Schmidt, 1975). In another classification of motor performance — "closed" vs "open" — the tossing task would be characterized as "closed" because it is performed under stationary conditions that allow the learner to plan required movements well in advance without fear of having to make adjustments. Closed tasks are self-paced, with the learner deciding the start, finish, and duration of the task. In "open" tasks, like driving a car, environmental conditions vary and changes are not predictable. Successful performance of open tasks depends on the learner's ability to make quick adjustments to the changing environment. Where a task falls on these two dimensions — discrete vs continuous and open vs closed — may directly impact the effectiveness of different forms of practice.

Finally, the present results have practical implications for enhancing functional skills in AD. Certainly, the ability of AD patients to learn and retain the tossing task for at least one month following training suggests that these impaired individuals have the potential to relearn basic activities of daily living involving a significant motor component (e.g., eating, dressing). Efforts to develop motor-based retraining programs (Josephsson et al., 1993) are clearly worthwhile, as the current findings suggest that such interventions could produce lasting changes. In addition, as neither severity of dementia nor degree of functional impairment showed a significant relationship to amount of improvement on the tossing task, motor-based interventions have the potential to benefit even severely impaired individuals with functional deficits. However, the effectiveness of such interventions may be limited by the presence of extrapyramidal motor impairments (e.g., reduced strength, increased rigidity). Most importantly, the results suggested that retraining efforts will only succeed if the AD patient practices the movements required to complete a particular activity of daily living in a consistent manner. That is, practice must involve invariant repetitions of a movement pattern rather than variations of the skill to be acquired. Consistent practice may be particularly important for maintenance of daily living skills (e.g., eating, dressing), which, like tossing, are self-paced (i.e., closed) and have a distinct beginning and end (i.e., discrete). The discovery that AD patients cannot benefit from variable practice, like healthy adults, suggests that other differences may exist between these two groups in the basic parameters of motor learning. Clearly, researchers ought to continue identifying such differences in order to ensure the effectiveness of future retraining programs.

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References


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