

Motor-Skill Learning in Alzheimer's Disease: A Review with an Eye to the Clinical Practice

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Abstract Since elderly people suffering from dementia want to go on living independently for as long as possible, they need to be able to maintain familiar and learn new practical skills. Although explicit or declarative learning methods are mostly used to train new skills, it is hypothesized that implicit or procedural techniques may be more effective in this population. The present review discusses 23 experimental studies on implicit motor-skill learning in patients with Alzheimer's disease (AD). All studies found intact implicit motor-learning capacities. Subsequently, it is elaborated how these intact learning abilities can be exploited in the patients' rehabilitation with respect to the variables 'practice' and 'feedback.' Recommendations for future research are provided, and it is concluded that if training programs are adjusted to specific needs and abilities, older people with AD are well able to (re)learn practical motor skills, which may enhance their autonomy.

Keywords Alzheimer's disease · Procedural learning · Motor-skill learning · Rehabilitation · Implicit learning · Non-pharmacological interventions

Introduction

The aging population is growing rapidly and by 2050 the number of elderly people aged 85 years old or older in Europe and North America is estimated to be approximately 19 million (Román 2002). Since age is a high risk factor for dementia (Smith and Rush 2006), the expansion of the aging population and thus the number of people suffering from dementia has momentous consequences for national care systems as well as a large economic impact (Schölzer-Dorenbosch 2005). A way to contain these costly effects is by helping older people to stay independent for as long as possible, implying that the elderly must not stop learning. They apply old skills differently or acquire new skills, like learning how to use a walking aid, which gives rise to the following questions: Are demented elderly people able to learn such new skills? And are we, health professionals, able to train them?

As yet, psychopharmacological interventions, such as the use of cholinesterase inhibitors, may have some benefit in maintaining autonomy of elderly patients suffering from Alzheimer's disease (AD), as demonstrated by delayed nursing home placement (Becker et al. 2006). Recent pharmacological research also shows promising results for cognition: the treatments evaluated produced a moderate positive effect on global cognitive functioning (Grimley Evans et al. 2004; Schölzer-Dorenbosch 2005; Takeda et al. 2006). In their 2002 review on the placebo-controlled effects of rivastigmine on the cognition of AD patients, Birks et al. (2002) reported statistically-significant increases

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of 0.8 points on the Mini Mental State (MMS) Examination and 2.1 points on the Alzheimer's Disease Assessment Scale (ADAS-Cog). They also found benefits in the patients' activities of daily living, although the difference with placebo was not significant. Takeda et al. (2006) also reported reductions in the cognitive impairment of AD patients for donepezil and galantamine, but again, although showing potential, the improvements did not suggest a major difference in the daily lives of the patients.

These findings do not negate the importance of non-pharmacological approaches and it is possible that the interactions between medication and non-pharmacological approaches may be the most beneficial in maintaining patient's autonomy. In their review, Luijpen et al. (2003) conclude that the effect of non-pharmacological interventions with respect to cognition and affective behavior in dementia is similar to the effect of pharmacological regimens. Non-pharmacological treatments to improve autonomy in this patient population should hence be considered an additional option, especially since rehabilitation is increasingly being advocated as a means to optimize patients' overall functioning (De Vreese et al. 2001). Clare (2003) also concludes that neuropsychological rehabilitation applied in the context of progressive disorders like dementia do yield beneficial results.

In the present review we will focus on the ability of Alzheimer's patients to (re)learn practical motor skills. Currently, *explicit* or *declarative* learning methods are the starting points in most rehabilitation programs aimed at motor-skill learning in the cognitively unimpaired population (Van Cranenburg 2004). However, Zanetti et al. (2001) and Rösler et al. (2002) claimed that patients with dementia will profit more from *implicit* or *procedural* learning methods by showing that their AD cohorts were able to learn to waltz or to use a telephone when an implicit rather than an explicit learning approach was used. In implicit learning, skills are mastered without awareness, often simply by repeated exposure, and can be unconsciously revived from implicit memory (Buchner and Wippich 1998). The abovementioned studies were all focused on finding the best way to help older people with dementia learn or relearn practical (motor) skills, and although the results are encouraging, the patient samples were always small and it remains unclear how much was learned due to a lack of well-defined performance measures.

In the first part of our review we looked for corroborating evidence in experimental research for intact implicit motor-learning capacity in cohorts of elderly patients diagnosed with AD. In the second part we will elaborate on how these intact learning abilities can be utilized for their rehabilitation while taking the principles from theories of motor-learning into account. Two of the theories' core variables, i.e., practice and feedback (Schmidt and Wisberg

2000) will be discussed more extensively, also in the light of research exploring these variables in AD. The results will be translated into practical instructions for more targeted rehabilitation training programs for this patient group.

Materials and Methods

Computerized searches of the literature using the databases of PubMed and PsycLIT were conducted spanning a 20-year period, from 1985 up to and including 2005. The search terms (any field) used were procedural learning, sequence learning, motor-skill learning, or motor learning in combination with Alzheimer's disease. Only reports published in English were considered. For inclusion in this review the studies had to meet the following criteria: (a) a clinical diagnosis of Alzheimer's disease based on specified and generally accepted criteria; (b) a procedural task with motor responses; and (c) task performance expressed in time or error measures, and not only in fMRI or other imaging data. Ultimately, 23 studies were included in this review. Three studies will only be discussed in the second part of the review since they explicitly examined the role of feedback and type of practice.

Experimental Research of Implicit Motor-Skill Learning in Alzheimer's Disease

Implicit Learning Ability

The main results of the studies generated by our search of the literature are shown in Table 1. Four studies using a Maze test in which blindfolded participants had to trace a complex pathway found that the AD patients were able to learn new motor-skills implicitly (Kuzis et al. 1999; Sabe et al. 1995; Starkstein et al. 1997; Taylor 1998). The nine studies that applied a Rotor-Pursuit task, in which participants had to maintain contact between a hand-held stylus and a rotating spot, also reported preserved learning abilities in their AD samples (Beatty et al. 1995; Deweer et al. 1994; Dick et al. 1995, 2001; Heindel et al. 1988; Heindel et al. 1989; Jacobs et al. 1999; Libon et al. 1998; Willingham et al. 1997). This is in agreement with the findings of Poe and Seifert (1997) based on a Puzzle-Assembly task and the results of Rouleau et al. (2002) involving a Mirror-Tracing task. Also, a Serial Reaction-Time Task (SRTT) was used in which participants needed to respond as fast as possible when a stimulus appeared in one of four places by pressing a corresponding response key (Grafman et al. 1990; Knopman and Nissen 1987; Knopman 1991; Willingham et al. 1997). Again, the AD patients showed implicit learning as reflected by the

Table 1 Summary of results of experimental studies on motor-skill learning in Alzheimer's disease

Author	Year	Sample size and types	Task(s)	Amount of learning ^a	Results on learning capacity
Sabe, L., et al.	1995	20 AD with comorbid depression, 35 AD without comorbid depression, 14 depressive, non-demented patients, 16 healthy controls	Maze test	AD: 19% Co: 22% GroupxTrial: $p < 0.05$	The AD patients showed significant deficits in declarative learning but only a minor (although statistically significantly) drop in procedural learning. The AD group with comorbid depression showed a similar learning pattern as the non-depressed AD group.
Starkstein, S.E., et al.	1997	55 AD (13 with mild, 12 with severe and 30 without anosognosia)	Maze test	AD no: 48% AD mild: 39% AD severe: -16% –	There was no group difference in declarative learning. As to procedural learning, the patients with severe anosognosia showed a significantly poorer performance whereas the patients with mild or no anosognosia showed no deficits.
Taylor, R.	1998	58 AD, 58 multi-infarct dementia	Maze test	– –	When age and overall neuropsychological functioning were taken into account, Maze performance was better in the AD patients than in the patients with multi-infarct dementia
Kuzis, G., et al.	1999	15 AD, 15 PD, 10 PD and dementia, 24 healthy controls	Maze test	AD: 10% Co: 39% –	The AD group showed deficits on all measures of explicit memory. There were no significant between-group differences in the measures of implicit memory between the AD, control, and PD groups.
Heidel, W.C., et al.	1988	10 AD, 10 HD, 4 amnesic 20 healthy controls	Rotor Pursuit	AD: 147% Co: 115% GroupxTrial: n.s.	The AD patients showed preserved motor-skill learning while the patients with HD showed no motor learning.
Heindel, W.C. et al.	1989	16 AD, 13 HD, 17 PD, 22 healthy controls	Rotor Pursuit	AD: 101% Co: 118% GroupxTrial: n.s.	The AD patients showed preserved motor-skill learning while the patients with HD showed impaired motor learning.
Beatty, W.W., et al.	1995	4 AD, 1 corticobasal degeneration	Rotor Pursuit	– –	The AD patients showed preserved motor skill learning
Deweere, B., et al.	1994	13 AD institutionalized, 10 healthy controls, 17 AD out patients, 9 healthy controls	Rotor Pursuit	AD in: 86% Co: 48% GroupxTrial: n.s. AD out: 161% Co: 139% GroupxTrial: n.s.	Explicit memory was severely impaired in the AD patients but they showed normal procedural learning.
Dick, M.B., et al.	1995	12 AD, 12 healthy controls	Rotor Pursuit	AD: 47% Co: 81% GroupxTrial: n.s.	Performance significantly improved during the first 40 trials but additional practice provided no further beneficial effects. The AD patients showed minimal retention problems across four retention tests.
Libon, D.J., et al.	1998	16 AD, 14 vascular dementia	Rotor Pursuit	AD: 60% –	The AD patients obtained a lower score on a verbal-learning task-recognition index and high scores on the Rotor Pursuit.
Jacobs, D. H., et al.	1999	12 AD, 12 healthy controls	Rotor Pursuit	AD: 124% Co: 106% GroupxTrial: $p = 0.473$	The AD patients and the controls were able to learn the motor task.

Table 1 (continued)

Author	Year	Sample size and types	Task(s)	Amount of learning ^a	Results on learning capacity
Dick, M.B., et al.	2001	18 AD, 18 healthy controls	Rotor Pursuit	AD: 27% Co: 36% GroupxTrial: n.s.	In normal-vision trials no differences in learning between the AD patients and the controls were found.
Dick, M.B., et al.	2003	99 AD, 100 healthy controls	Rotor Pursuit		The AD patients and controls receiving constant practice outperformed those in the blocked and random conditions. The AD patients only benefited from constant practice.
Poe, M.K. et al.	1997	9 AD, 14 healthy controls	Puzzle Assembly	– GroupxTrial: n.s.	Even when the subjects had no explicit memory of practicing the task, they all demonstrated savings upon relearning.
Rouleau, I., et al.	2002	12 AD, 12 healthy controls	Mirror Tracing	AD: 44% Co: 49% GroupxTrial: n.s.	Those AD patients that were able to perform the basic mirror-tracing task did not differ from the controls in level of performance, learning over trials, retention over a delay interval and generalization to other tasks
Knopman, D.S., et al.	1987	35 AD, 13 healthy controls	SRTT	AD: 22% Co: 38% GroupxTrial: n.s.	The AD patients showed learning of the repeated sequence, although they responded more slowly.
Graftman, J., et al.	1990	42 AD, 7 PSP, 44 healthy controls	SRTT	AD: 36% –	The AD patients and controls showed motor-skill learning while the PSP patients did not.
Knopman, D.	1991	16 AD, 17 healthy controls	SRTT	AD: 37% Co: 33%	The AD patients showed learning of the sequence but they showed an inferior level of learning when the data were log-transformed.
Ferraro, F. R., et al.	1993	27 very mild AD, 15 mild AD, 17 PD, 26 healthy controls	SRTT	AD mild: 11% AD very mild: 22% Co: 20%	The very mildly AD patients showed preserved learning comparable with the controls. The mildly AD patients and PD patients showed less implicit learning.
Willingham, D.B., et al.	1997	20 AD, 20 healthy controls	SRTT, Incompatible SRTT, Pursuit Tracking (randomized and repetitive pattern)	SRTT: AD: 52% Co: 60% GroupxTrial: p>0.2 Pursuit: AD: 12% Co: 17% GroupxTrial: p>0.2	The dementia ratings predicted the ability to perform tasks but not the ability to learn them. AD patients can have a performance deficit but they have no general deficit in motor-skill learning.
Hirono, N., et al.	1997	36 AD, 19 healthy controls	Bi-manual coordinated Tracing task	AD: 37% Co: 39% GroupxTrial: p=0.193	Skill learning in those AD patients that completed the tasks was as good as in the controls.
Dick, M.B., et al.	1996	23 AD, 22 healthy controls	Tossing		The AD patients given constant practice were able to learn and retain the tossing task similarly well as the controls. The AD patients showed less improvement when practicing at various distances.
Dick, M.B., et al.	2006	58 AD, 58 healthy controls	Tossing		The AD patients showed significant improvements under constant practice only. None of the practice conditions facilitated intermediate transfer in the AD patients whereas

Table 1 (continued)

Author	Year	Sample size and types	Task(s)	Amount of learning ^a	Results on learning capacity
					constant practice did benefit them on tests assessing near transfer.

AD= Alzheimer's disease; *HD*= Huntington's disease; *PD*= Parkinson's disease; *PSP*= Progressive supranuclear palsy.

^aexpressed as a percentage of the difference score between the last and first trial with respect to the score on the first trial. The Group \times Trial interaction for the AD and Co group is also reported when available.

difference in reaction times (RTs) between blocks with a fixed sequence of stimuli presentation (decreasing RTs) and a random block (prolonged RTs). However, there are indications that the implicit learning ability in AD patients is affected because they generated inferior outcomes when accuracy was taken into account (Willingham et al. 1997) or when the data were log-transformed because of the unequal variance in RT (Knopman 1991). Ferraro et al. (1993) found preserved implicit SRTT learning only in the "very mildly demented" group, and less in the "mildly demented" group although it is relevant to mention that none of the other studies used such a subtle severity classification.

Thus, irrespective of the task used, the studies assessing implicit motor-skill learning in AD we reviewed yielded positive outcomes. Indeed, in their 1997 study, Hirono and colleagues found that patients with mild AD were able to acquire motor and perceptual as well as cognitive skills in various procedural learning tasks.

It should be noted that in all studies the patients that could not perform the task were eliminated from the analyses. Yet, a failure to perform the prescribed task need not necessarily be related to learning problems. Willingham et al. (1997) attributed the phenomenon to other causes like the complexity of the instructions given or the type of skill to be performed. These factors may differ across tasks, which might explain their finding that the ability to complete one task did not predict the rate of improvement in another task. They conclude that AD patients have a performance deficit and not a generalized deficit in motor learning.

Performance and Amount of Learning

From the above discussion of results we can presume that at least a subgroup of AD patients show preserved implicit learning abilities, but to what extent? Here, two aspects in motor learning should be differentiated, i.e., overall performance level and amount of learning (e.g., the increment in Total Time on Target in the Rotor-Pursuit

task). All the studies found preserved motor-skill learning in AD patients although their overall performance levels in terms of reaction and movement time were always inferior to those of the controls. However, when we take the level of learning into account, the results are less consistent. Some of the results were not reported with enough detail to show unambiguously the amount of learning the AD patients showed compared to the controls (Poe and Seifert 1997). Some comparative studies did not include a healthy control group in addition to the patient groups (Beatty et al. 1995; Grafman et al. 1990; Libon et al. 1998; Starkstein et al. 1997; Taylor 1998), preventing patient-control comparisons from being made. The AD patients in the SRTT studies showed the same amount of learning (decrease in RT during the blocks with the fixed sequence) as the normal controls (Ferraro et al. 1993; Knopman and Nissen 1987; Knopman 1991; Willingham et al. 1997). In the nine studies that used a Rotor-Pursuit or Tracking task there were also no patient-control differences in amount of learning (Deweert et al. 1994; Dick et al. 1995, 2001; Heindel et al. 1988; Heindel et al. 1989; Hirono et al. 1997; Jacobs et al. 1999; Rouleau et al. 2002; Willingham et al. 1997). Two of the studies using a Maze test reported learning abilities in the AD group but less improvement across trials compared to the controls, (Kuzis et al. 1999; Sabe et al. 1995) findings which are perhaps explainable by the use of a task without visual feedback.

Taken together, the reviewed studies all showed preserved implicit motor-skill learning in AD patients regardless of the task used. Their performance levels, however, never reached the levels of the healthy controls, demonstrated by their prolonged reaction and movement times. The AD patients' level of learning also differed depending on the task to be performed. Visual feedback appears to have a positive effect on their learning pace. They also seem to experience more problems with implicit learning when performing the SRTT, a task that involves two learning processes. The subjects have to master both spatial and motor regularities (Mayr 1996), and it is the learning of spatial regularities that may be compromised in AD

patients, a process that is less implicated in the Rotor-Pursuit task in which normal implicit learning for the patients was found.

Training Patients with Alzheimer’s Disease: Variables in Motor Learning

The studies discussed provide evidence that AD patients can learn new motor skills in an implicit way. It is therefore worthwhile to establish what would be the best way to train them. In the next section we will give a brief account of the two variables *practice* and *feedback* that play a role in (re) training motor skills. We will subsequently discuss the variables in relation to the findings reported in the relevant AD studies and conclude by making recommendations of how to enhance the acquisition of new motor skills in this population.

We will first, however, briefly address the existing views on the presence or absence of distinguishable learning stages in explicit and implicit learning. Generally, with explicit learning people tend to pass through three stages in the acquisition of motor skills (Fitts and Posner 1967). The first is the cognitive stage in which the focus is on understanding the task and developing strategies to perform it, requiring cognitive activity such as attention and executive functions. The second phase is the associative stage: the learner has selected the best strategy and now begins to refine the skill. Here, cognitive aspects are less important. And finally, there is the autonomous stage in which the skill becomes automatic, requiring a low degree of attention. Variables such as practice and feedback can be structured differently to enhance learning at each stage. Feedback in the cognitive stage, for example, may need to be more specific and applied more frequently to enhance learning, while feedback may be weaned toward the third stage of learning (Tse and Spaulding 1998).

In implicit learning, on the other hand, there is no clear distinction between these three stages. It has been proposed that in implicit learning the three stages might overlap or be ordered differently. There is support for a parallel development of implicit and explicit knowledge in learning (Willingham and Goedert-Eschmann 1999).

Practice: Theory and Outcome Studies with AD Patients

The principle, “The more you practice, the more you learn,” implies that the amount of practice should be maximized in therapy. But does more practice indeed improve the performance in AD patients? Dick et al. (1995) found that on the Rotor Pursuit both the AD and control group had reached their optimal performance after 40 trials because subsequent practice failed to yield any additional augmenting effect. It

would be interesting to determine whether this also holds for other tasks like the Maze test in which, relative to the controls, an inferior amount of learning was observed for AD patients (Kuzis et al. 1999; Sabe et al. 1995).

Since fatigue also plays a role in learning, the next question is how to alternate practice with rest to maximize learning in patients. Schmidt and Wrisberg (2000) distinguish two types of practice. In ‘massed practice,’ the greater proportion of the sessions is dedicated to training, while in ‘distributed practice’ the duration of rest equals or is greater than that of practice. To date, the effects of alternating these two training methods in the generally older AD patient group still requires further investigation.

Another factor that merits closer attention in the context of training programs for AD patients is whether the task should be learned as a whole or per constituent component. Training the components of a task separately before combining them into the whole pattern can be effective if the task itself can be naturally divided into components that reflect the inherent goal of the task (Schmidt 1988). For example, learning to drive a car can be easily divided into the components “learning to shift gear” and “learning to steer,” which can be trained individually. Learning to reach and grasp an item, on the other hand, does not lend itself well for phased training since reaching and grasping are integral components of a single, continuous movement.

The amount of variation in the practice session(s) is also a topic for further study. Task variables like the beanbag’s weight and throwing distance in the Tossing task can be practiced in a random design so that the weight and distance can be varied systematically. Alternatively, they can be offered in a blocked design in which only one task variable per block is practiced repetitively. Another option is to use a constant design in which only one combination of task variables is trained. Note that over time, the connotation of the two terms has shifted: random and blocked practice now refer to the rehearsal of several distinct skills whereas varied and constant practice implies the rehearsal of different variations of the same skill (Schmidt and Wrisberg 2000). Nevertheless, in our report we will use the ‘old’ terms (random, blocked and constant) in their original meanings since these were terms and interpretations used in the reviewed literature. Early evidence suggests that random practice might be most effective for the acquisition and generalizability of a motor skill, whereas during the acquisition of a specific motor skill, performance benefits most from blocked practice (Schmidt 1988).

All available studies reviewed on this matter (Dick et al. 1996, 2000, 2003) show that AD patients learn best under constant practice conditions. According to Dick and his 1996 team, humans use their episodic memory of the training trials to accurately perform a task while learning a

skill. They suggest that because AD patients experience problems with episodic memory, constant practice is more effective because repeated running of the same motor program does not require an intact episodic memory. The second reason why random practice may be less effective is that other cognitive functions that play a role in random practice, like the ability to switch tasks and divide attention, are affected in AD patients.

Dick et al. (1996, 2003) explained the AD patients' superior learning performance under constant practice conditions in terms of the schema theory originally developed by Schmidt (1975), and likewise propose a more open-loop account of motor control. Schmidt assumes the existence of generalized motor programs (GMPs) that are acquired through practice and that define the "form" of the action. These GMPs can be altered to meet environmental demands by a closed-loop system using sensory feedback. Schemata, e.g., for varying weight and distances in tossing, are learned and allow the action to be scaled to the environment (Schmidt 2003). When they considered their results in terms of this theory, Dick et al. (1996, 2003) concluded that AD patients can develop and access a GMP in training situations that emphasize movement consistency. However, they do not form the motor schemas needed to successfully achieve a movement when the environmental demands change because they are unable to encode and to store the different types of information about a motor pattern.

There are three other training approaches that can produce the desired learning effect: guidance, observation, and mental practice (Schmidt 1988). Guidance should only be used at the onset of training because experiments have shown that practice under unguided conditions seems to be more effective for retention and transfer (Shumway-Cook and Woollacott 1995). Observation conveys information about how a skill should be performed and seems to be especially beneficial for the acquisition of new movement patterns (Magill 1993). Our automated computer search and an extra search combining the three keywords with Alzheimer dementia both failed to generate any relevant studies that employed one of these training methods. The only study that provided some additional information on the topic is a report by Dick et al. (1988) which showed that AD patients could recall preselected (subject-defined) movements more accurately than constrained (experimenter-defined) movements on a linear positioning apparatus. This was explained by the patients' ability to profit from mental preparation of the movement prior to its execution. Without further systematic investigation, however, it cannot be inferred that the ability to profit from mental preparation also means AD patients will profit from mental practice. More research into the effects of all three practice types in AD is needed.

Feedback: Theory and Outcome Studies with AD Patients

A second crucial variable that influences motor learning is type of feedback. Intrinsic feedback encompasses the sensory information generated by motion, and extrinsic feedback entails information from an external source like a therapist (Schmidt and Wrisberg 2000). There are various ways to provide extrinsic feedback. It can be delivered during or after the movement, immediately following movement completion or delayed, and in a verbal or a non-verbal fashion. It can contain information on average performance (summary feedback) or it may reflect each movement or performance (constant feedback; Schmidt 1988). It is generally believed that constant feedback enhances only motor performance, not the level of learning (Shumway-Cook and Woollacott 1995). With less frequent feedback, learners have to rely more on other cues, which entails more elaborate encoding (Schmidt 1988). Extrinsic feedback can moreover be divided into 'knowledge of results,' in which the movement outcome is given in terms of the goal, and 'knowledge of performance,' so that the feedback concerns the movement pattern itself (e.g., in a Tossing task: increase the swing of your arm).

In almost all studies on motor-skill learning in AD, visual feedback was employed. Only the Maze tasks were administered under blindfolded conditions and the amount of learning in the AD patients proved inferior to the amount found for the controls (Sabe et al. 1995; Kuzis et al. 1999). In most Rotor-Pursuit tasks, the velocity of the target was individualized to equate initial performance. Controls generally tracked at a faster rate than the AD patients (Deweert et al. 1994; Dick et al. 1995; Jacobs et al. 1999; Libon et al. 1998). Possibly, AD patients can only perform this task at a slower rate because they rely more on visual feedback than controls.

Only one study using a Rotor-Pursuit task explicitly examined the role of visual feedback on performance in AD patients, showing a drop in performance when the visibility of the moving target was reduced during the learning phase (Dick et al. 2001). In contrast to that of the normal controls, the patients' performance did not improve across trials in the restricted-vision condition. In the full-vision condition the patients showed normal learning.

It can be tentatively concluded that for AD patients, constant visual feedback is important in learning motor skills, but more research is needed to confirm this hypothesis. We did not find any studies that were concerned with the frequency of external feedback, and whether knowledge of results and knowledge of performance makes a difference in this patient group. Based on the results cited above, it may be hypothesized that both forms of feedback knowledge probably place too much weight on the cognitive abilities in AD patients and therefore contribute little to successful performance.

Conclusions and Recommendations

People with Alzheimer's disease are able to implicitly (re) learn motor skills to a certain extent and under specific conditions. The experimental research to date shows preserved implicit motor learning irrespective of the task used. Patients are capable of acquiring motor skills without awareness simply by repeated exposure, although their performances will not reach normal levels. This is expressed in their protracted performance relative to that of unimpaired controls. Moreover, extent of learning will differ depending on the task to be mastered.

The preserved implicit learning ability in AD can be of use for physical therapists working with this elderly patient group. Physical therapists can call upon neuropsychologists to provide information on their patients' learning capacities since they have quantitative measures at their disposal to assess a patient's level of functioning. However, the memory and learning tests currently available in the clinical practice evaluate explicit or declarative memory (Spaan et al. 2003). In order to get a satisfactory differential picture of the learning capacities in demented patients, implicit (motor) learning tasks need to be added to the neuropsychological assessment.

The evidence of intact implicit learning in AD further prompted the question how these intact learning abilities can best be translated into rehabilitation programs targeting this patient group. Learning is central in rehabilitation and knowledge of the system under treatment, like the motor system, must be combined with knowledge of how learning principles must be applied to achieve a successful training program (Baddeley 1993). With respect to patients with dementia, apart from the subtype of dementia and its specific neuropsychological syndrome, the training programs should apply the principles that emerge from theories of learning.

The studies we reviewed showed that in (re)learning motor skills, constant, or rather frequent and consistent practice is important in AD patients. This way of learning draws less on episodic memory and other cognitive functions compromised in AD patients. These data also suggest that practice under dual-task conditions should also be avoided.

Because AD patients have difficulty in generalizing the motor skills learned during the sessions, training has to take place in an environment that closely resembles the one in which the skill is going to be used and presumably with tools used by the AD patient in his or her daily life. If, for instance, an AD patient is trained in the use of a microwave, the device used during the training should be the same as the one available in the patient's household. The amount of training a patient needs will depend on the task being trained. The role of fatigue is also important in

this respect. The effects of massed and distributed practice in this generally older patient group need to be addressed in future investigations.

Patients with AD appear to remain dependent upon visual feedback throughout training and performance. Screening and subsequent correction of visual problems or the use of visual aids can be effective in the training process in this group for whom vision problems are very common (De Winter et al. 2004). The type and point in time when external feedback needs to be given and its effect on learning in AD also warrants attention in future research.

In the introduction of our review we asked whether patients with Alzheimer's disease might have intact motor-skill learning abilities. The answer is twofold. Clearly, AD patients show preserved implicit learning abilities that can be utilized in teaching (motor) skills, yet transfer to other skills is minimal. Accordingly, the professionals delivering the training programs should tailor the contents to the particular needs and abilities of this patient group or the individual patient. When the above guidelines are kept in mind and when our knowledge on this topic are widened, non-pharmacological interventions might contribute significantly in helping elderly people suffering from dementia to keep their autonomy. The extent to which pharmacological intervention may enhance these behavioral mechanisms and foster independent living in AD patients has yet to be determined.

References

- Baddeley, A. (1993). A theory of rehabilitation without a model of learning is a vehicle without an engine: A comment on Caramazza and Hillis. *Neuropsychological Rehabilitation*, 3(3), 235–244.
- Beatty, W. W., Scott, J. G., Wilson, D. A., Prince, R. J., & Williamson, D. J. (1995). Memory deficits in a demented patient with probable corticobasal degeneration. *Journal of Geriatric Psychiatry and Neurology*, 8, 132–137.
- Becker, M., Andel, R., Rohrer, L., & Banks, S. M. (2006). The effect of cholinesterase inhibitors on risk of nursing home placement among Medicaid beneficiaries with dementia. *Alzheimer's disease and Associated Disorders*, 20(3), 147–152.
- Birks, J., Grimley Evans, J., & Iakovidou, V. (2002). *Rivastigmine for Alzheimer's disease (Cochrane Review)*. In: The Cochrane Library, Issue 4. Oxford: updat Software.
- Buchner, A., & Wippich, W. (1998). Differences and commonalities between implicit learning and implicit memory. In M. A. Stadler & P. A. Frensch (Eds.), *Handbook of implicit learning*. Thousand Oaks, CA.: Sage Publications.
- Clare, L. (2003). Rehabilitation for people with dementia. In B. A. Wilson (Ed.), *Neuropsychological rehabilitation, theory and practice*. Lisse: Swets & Zeitlinger B.V.
- De Vreese, L. P., Neri, M., Fioravanti, M., Belloi, L., & Zanetti, O. (2001). Memory rehabilitation in Alzheimer's disease: A review of progress. *International Journal of Geriatric Psychiatry*, 16, 794–809.

- Deweer, B., Ergis, A. M., Fosatti, P., Pillon, B., Boller, F., Agid, Y., et al. (1994). Explicit memory, procedural learning and lexical priming in Alzheimer's disease. *Cortex*, *30*, 113–126.
- De Winter, L. J. M., Hoyng, C. B., Froeling, P. G. A. M., Meulendijks, C. F. M., & van der Wilt, G. (2004). Prevalence of remediable disability due to low vision among institutionalised elderly people. *Gerontology*, *50*, 96–101.
- Dick, M. B., Andel, R., Bricker, J., Gorospe, J. B., Hsieh, S., & Dick-Muehlke, C. (2001). Dependence on visual feedback during motor skill learning in Alzheimer's disease. *Aging, Neuropsychology and Cognition*, *8*(2), 120–136.
- Dick, M. B., Hsieh, S., Bricker, J., & Dick-Muehlke, C. (2003). Facilitating acquisition of a continuous motor task in healthy older adults and patients with Alzheimer's disease. *Neuropsychology*, *17*(2), 202–212.
- Dick, M. B., Hsieh, S., Dick-Muehlke, C., Davis, D. S. & Cotman, C. W. (2000). The variability of practice hypothesis in motor learning: Does it apply to Alzheimer's disease? *Brain and Cognition*, *44*, 470–489.
- Dick, M. B., Kean, M-L., & Sands, D. (1988). The preselection effect on the recall facilitation of motor movements in Alzheimer-type dementia. *Journal of Gerontology: Psychological Sciences*, *43*, 127–135.
- Dick, M. B., Nielson, K. A., Beth, R. B., Shankle, W. R., & Cotman, C. W. (1995). Acquisition and long-term retention of a fine motor skill in Alzheimer's disease. *Brain and Cognition*, *29*, 294–306.
- Dick, M. B., Shankle, R. W., Beth, R. E., Dick-Muehlke, C., Cotman, C. W., & Kean, M-L. (1996). Acquisition and long-term retention of a gross motor skill in Alzheimer's disease patients under constant and varied practice conditions. *Journal of Neurology*, *51B*(2), 103–111.
- Ferraro, F. R., Balota, D. A., & Connor, L. T. (1993). Implicit memory and the formation of new associations in nondemented Parkinson's disease individuals and individuals with senile dementia of the Alzheimer type: A Serial Reaction Time (SRT) investigation. *Brain and Cognition*, *21*, 163–180.
- Fitts, P. M., & Posner, M. I. (1967). *Human Performance* (2nd ed.). Belmont, CA: Brooks/Cole.
- Grafman, J., Weingartner, H., Newhouse, P. A., Thompson, K., Lalonde, F., Litvan, I., et al. (1990). Implicit learning in patients with Alzheimer's disease. *Pharmacopsychiatry*, *23*, 94–101.
- Grimley Evans, J., Wilcock, G., & Birks, J. (2004). Evidence-based pharmacotherapy of Alzheimer's disease. *International Journal of Neuropsychopharmacology*, *7*, 351–369.
- Heindel, W. C., Butters, N., & Salmon, D. P. (1988). Impaired learning of a motor skill in patients with Huntington's disease. *Behavioral Neuroscience*, *102*, 141–147.
- Heindel, W. C., Salmon, D. P., Shults, W., Walicke, P. A., & Butters, N. (1989). Neuropsychological evidence for multiple implicit memory systems: A comparison of Alzheimer's, Huntington's, and Parkinson's disease patients. *Journal of Neuroscience*, *9*(2), 582–587.
- Hirono, N., Mori, E., Ikejiri, Y., Imamura, T., Shimomura, T., Ikeda, M., et al. (1997). Procedural memory in patients with Alzheimer's disease. *Dementia and Geriatric Cognitive Disorders*, *8*, 210–216.
- Jacobs, D. H., Adair, J. C., Williamson, D. J. G., Na, D. L., Gold, M., Foundas, A. L., et al. (1999). Apraxia and motor-skill acquisition in Alzheimer's disease are dissociable. *Neuropsychologia*, *37*, 875–880.
- Knopman, D. (1991). Long-term retention of implicitly acquired learning in patients with Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology*, *13*(6), 880–894.
- Knopman, D. S., & Nissen, M. J. (1987). Implicit learning in patients with probable Alzheimer's disease. *Neurology*, *37*, 784–788.
- Kuzis, G., Sabe, L., Tiberti, C., Merello, M., Leiguarda, G., & Starkstein, S. E. (1999). Explicit and implicit learning in patients with Alzheimer disease and Parkinson disease with dementia. *Neuropsychiatry, Neuropsychology and Behavioral Neurology*, *12*(4), 265–269.
- Libon, D.J., Bogdanoff, B., Cloud, B. S., Skalina, S., Giovannetti, T., Gitlin, H. L., et al. (1998). Declarative and procedural learning, quantitative measures of the hippocampus, and subcortical white alterations in Alzheimer's disease and Ischaemic Vascular dementia. *Journal of Clinical and Experimental Neuropsychology*, *20*(1), 30–41.
- Luijpen, M. W., Scherder, E. J. A., Van Someren, E. J. W., Swaab, D. F., & Sergeant, J. A. (2003). Non-pharmacological interventions in cognitively impaired and demented patients: a comparison with cholinesterase inhibitors. *Reviews in the neurosciences*, *14*, 343–368.
- Magill, R. A. (1993). *Motor learning: Concepts and applications* (4th ed.). Indianapolis IN: Brown & Benchmark.
- Mayr, U. (1996). Spatial attention and implicit sequence learning: Evidence for independent learning of spatial and nonspatial sequences. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *22*(2), 350–364.
- Poe, M. K., & Seifert, L. S. (1997). Implicit and explicit tests: Evidence for dissociable motor skills in probable Alzheimer's dementia. *Perceptual and Motor Skills*, *85*, 631–634.
- Román, G. C. (2002). Vascular dementia may be the most common form of dementia in the elderly. *Journal of Neurology and Science*, *203–204*, 7–10.
- Rösler, A., Seifritz, E., Kräuchi, K., Spoerl, D., Brokuslaus, I., Proserpi, S-M., et al. (2002). Skill learning in patients with moderate Alzheimer's disease: a prospective pilot-study of waltz-lessons. *International Journal of Geriatric Psychiatry*, *17*, 1155–1156.
- Rouleau, I., Salmon, D. P., & Vrbancic, M. (2002). Learning, retention and generalization of a mirror tracing skill in Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology*, *24*(2), 239–250.
- Sabe, L., Jason, L., Juejati, M., Leigarda, R., & Starkstein, S. E. (1995). Dissociations between declarative and procedural learning in dementia and depression. *Journal of Clinical and Experimental Neuropsychology*, *17*(6), 841–848.
- Schmidt, R. A. (1975). A schema theory of discrete motor skills. *Psychological Review*, *82*, 225–260.
- Schmidt, R. A. (1988). *Motor control and learning: A behavioral emphasis* (2nd ed.). Illinois: Human Kinetics Publishers, Inc.
- Schmidt, R. A. (2003). Motor schema theory after 27 years: Reflections and implications for a new theory. *Research Quarterly for Exercise and Sport*, *74*(4), 366–375.
- Schmidt, A., & Wrisberg, C. A. (2000). *Motor Learning and Performance* (2nd ed.). Champaign, IL: Human Kinetics.
- Schölzer-Dorenbosch, C. J. M. (2005). Medicamanteuze behandeling van e ziekte van Alzheimer: De klinische praktijk in Nederland. *Tijdschrift voor Gerontologie en Geriatrie*, *36*, 122–126.
- Shumway-Cook, A., & Woollacott, M. H. (1995). *Motor control: Theory and practical applications*. Baltimore: Williams & Wilkins.
- Smith, G., & Rush, B. K. (2006). Normal aging and mild cognitive impairment. In D. K. Attix & K. A. Welsh-Bohmer (Eds.), *Geriatric Neuropsychology: Assessment and Intervention* (pp. 27–55). New York/London: Guilford.
- Spaan, P. E. J., Raaijmakers, J. G. W., & Jonker, C. (2003). Alzheimer's disease versus normal aging: A review of the efficiency of clinical and experimental memory measures. *Journal of Clinical and Experimental Neuropsychology*, *25*(2), 216–233.
- Starkstein, S.E., Sabe, L., Cuerva, A.G., Kuzis, G., & Leigarda, R. (1997). Anosognosia and procedural learning in Alzheimer's disease. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, *10*(2), 96–101.
- Takeda, A., Loveman, E., Clegg, A., Kirby, J., Picot, J., Payne, E., et al. (2006). A systematic review of the clinical effectiveness of donepezil, rivastigmine and galantamine on cognition, quality of

- life and adverse events in Alzheimer's disease. *International Journal of Geriatric Psychiatry*, 21, 17–28.
- Taylor, R. (1998). Spiral maze performance in dementia. *Perceptual and Motor Skills*, 87, 328–330.
- Tse, D. W., & Spaulding, S. J. (1998). Review of motor control and motor learning: Implications for occupational therapy with individuals with Parkinson's disease. *Physical and Occupational Therapy in Geriatrics*, 15(3), 19–38.
- Van Cranenburg, B. (2004). *Neurovalidatie; uitgangspunten voor therapie en training na hersenletsel*. Maarssen: Elsevier gezondheidszorg.
- Willingham, B. B., Peterson, E. W., Manning, C., & Brashear, H. R. (1997). Patients with Alzheimer's disease who cannot perform some motor skills show normal learning of other motor skills. *Neuropsychology*, 11(2), 261–271.
- Willingham, D. B., & Goedert-Eschmann, K. (1999). The relation between implicit and explicit learning: Evidence for parallel development. *Psychological Science*, 10(6), 531–534.
- Zanetti, O., Zanieri, G., Di Giovanni, G., De Vreese, L. P., Pezzini, A., Metitieri, T., et al. (2001). Effectiveness of procedural memory stimulation in mild Alzheimer's disease patients: A controlled study. *Neuropsychological Rehabilitation*, 11, 263–272.