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RESEARCH ARTICLE

Intact Procedural Knowledge in Patients with Alzheimer's Disease: Evidence from Golf Putting

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ABSTRACT. Can Alzheimer's disease (AD) patients efficiently learn to perform a complex motor skill when relying on procedural knowledge? To address this question, the authors compared the golf-putting performance of AD patients, older adults, and younger adults in 2 different learning situations: one that promotes high error rates (thus increasing the reliance on declarative knowledge) or one that promotes low error rates (thus increasing the reliance on procedural knowledge). Motor performance was poorer overall for AD patients and older adults relative to younger adults in the high-error condition but equivalent between similar groups in the low-error condition. Also, AD patients in the low-error condition had better performance at the final putting distance relative to those in the high-error condition. This performance facilitation for AD patients likely stems from intact procedural knowledge.

Keywords: Alzheimer, declarative knowledge, golf putting, motor learning, procedural knowledge

Alzheimer's disease (AD) dramatically alters declarative memory (Beaunieux et al., 2012), episodic memory (Jones, Livner, & Bäckman, 2006; for a review, see Storandt, 2008), and working memory (Baddeley, Baddeley, Bucks, & Wilcock, 2001; Perry & Hodges, 1999), while presumably leaving intact procedural memory (Eslinger & Damasio, 1986; for a review, see van Halteren-van Tilborg, Scherder, & Hulstijn, 2007). As a consequence, AD patients should have difficulty learning a novel motor skill because early learning generally relies on knowledge representations that are used by the most affected memory systems (i.e., declarative knowledge). However, if a manipulation induces predominant use of knowledge representations that are used by procedural memory (i.e., procedural knowledge, which is less accessible to conscious report and can be retrieved without attention), then AD patients may be placed on a higher learning trajectory. In the present study, we tested the hypothesis that AD patients can efficiently learn to perform a complex motor skill, golf putting, provided that the learning situation promotes development and use of procedural knowledge. Our approach was to manipulate knowledge type (procedural vs. declarative), using a low-error (implicit)/high-error (explicit) motor learning procedure (Masters, 1992; Maxwell, Masters, Kerr, & Weedon, 2001; for reviews, see, Chauvel et al., 2011; Masters & Poolton, 2012).

Learning in AD Patients

Several studies have shown that AD patients were able to retain the ability to learn a novel motor task, such as mirror tracing (Gabrieli, Corkin, Mickel, & Growdon, 1993; Rouleau, Salmon, & Vrbancic, 2002), bimanual tracing (Mochizuki-Kawai et al., 2004), maze learning (Grosse, Wilson, & Fox, 1991), or the pursuit rotor task (Libon et al., 1998). In these studies, the approach was to compare AD patients with older adults or patients with another type of amnesia or disease, when performing motor tasks. Generally, AD patients improved their performance with practice but did not reach a level of performance comparable to that of older adults. Because these studies did not manipulate the type of knowledge predominantly used during practice, the exact nature of the conditions that do or do not facilitate motor learning in AD patients is unknown.

Very few studies have sought to identify optimal learning conditions in AD patients. The first two attempts required participants to throw a bag filled with sand into a target placed on the ground (Dick, Andel, et al., 2000; Dick, Hsieh, Dick-Muehlke, Davis, & Cotman, 2000). Healthy older participants and AD patients performed this motor task in one of three conditions: constant condition (i.e., the throwing task was consistently performed from the same distance), blocked condition (i.e., the task was performed from the same distance within a block but distances varied from block to block), or varied condition (i.e., the task was performed from distances that varied from trial to trial). The results showed that throwing accuracy increased for AD patients in constant condition but no improvement was seen in blocked and varied conditions. In contrast, throwing accuracy increased for older adults in every learning condition. Keeping movement parameters as constant as possible may decrease the reliance on cognitive processing by memory systems altered by the disease, thus improving motor performance in AD patients.

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Procedural Knowledge Predominates in Low-Error Conditions

Skill acquisition is often considered to involve a shift in the type of knowledge representation used from early to later stages of learning (Anderson, 1982; Fitts & Posner, 1967; for a review, see Rosenbaum, Carlson, & Gilmore, 2001). Nevertheless, declarative knowledge does not necessarily predominate over procedural knowledge early in learning (Koedijker et al., 2011; Masters, 1992; Masters, Maxwell, & Eves, 2009; Maxwell, Masters, & Eves, 2003; Maxwell et al., 2001; for a review, see Masters & Poolton, 2012). For instance, Maxwell et al. (2001) demonstrated that the relative predominance of these two types of knowledge during skill acquisition depends on whether learning conditions promote high error rates or low error rates. This was demonstrated by using a golf-putting task that was performed at distances near the hole (i.e., low-error condition) or farther from the hole (i.e., high-error condition). To assess the type of knowledge representations that were predominantly used, Maxwell et al. (2001) relied on two critical indicators: the number of declarative knowledge statements that the participants recalled having used during the learning phase and the influence of an attention-demanding secondary task on motor performance at the last putting distance (100 cm for both two learning groups). The amount of self-reported declarative knowledge was larger in the high-error conditions than in the low-error conditions, implying that there were quantitative differences in the type of knowledge used during learning (more declarative knowledge in the high-error condition than in the low-error condition). It was also found that an attention-demanding secondary task (tone counting), when performed simultaneously with the golf-putting task, disrupted motor performance in the high-error condition (thus suggesting a predominant use of declarative knowledge) but not in the low-error condition (thus suggesting the use of procedural knowledge). Taken together, there is converging evidence supporting the view that the type of knowledge representation accumulated during learning was influenced by error rates (as initially suggested by Baddeley & Wilson, 1994; for corroborating evidence, see Chauvel et al., 2012, Chauvel, Maquestiaux, Ruthruff, Didierjean, & Hartley, 2013). When applied to older adults, this low-error/high-error motor learning procedure provided evidence consistent with intact procedural knowledge but altered declarative knowledge (Chauvel et al., 2012).

Present Study: Goals and Predictions

Our main goal was to determine whether the presumed difficulties encountered by AD patients, when facing the challenge of learning a novel motor task, can be circumvented by a learning technique that promotes use of procedural knowledge. To this end, we took advantage of the high-error/low-error motor learning procedures developed previously to selectively manipulate knowledge type used by AD patients, older adults, and younger adults, when learning to perform a golf-putting task. Assuming intact procedural knowledge, we predicted that AD patients' performance in the low-error condition should be equivalent to that of older adults of the same age, as well as to that of younger adults. This prediction is also fueled by previous studies in AD patients which showed a superiority of errorless learning when applied to verbal tasks (Clare, Wilson, Carter, Roth, & Hodges, 2002; for a review, see Clare & Jones, 2008) or sequential tasks, such as composing a phone number (Lekeu, Wojtasik, Van der Linden, & Salmon, 2002; Thivierge, Simard, Jean, & Grandmaison, 2008). However, assuming impaired declarative knowledge, we predicted that AD patients' performance in the high-error condition should be poorer than that of older and younger adults. In high-error conditions, we also predicted that motor learning performance by AD patients to be linked with high levels of episodic memory and/or inhibition capacities.

Given the practical importance of helping AD patients to learn novel motor tasks, a more specific goal of the current study was to assess which technique would allow AD patients to reach the highest performance level. To this end, we simply compared motor performance of AD patients assigned to low-error condition or high-error condition, at the final putting distance (i.e., 125 cm, the same in the two learning conditions).

Method

Three groups—AD patients, older healthy adults, and younger healthy adults—of 24 participants were tested during a 1.5-hr session. None of them reported previous golfing experience. For the AD patients, this was confirmed by the spouse or a close relative. Questionnaires, assessments of balance, and general neuropsychological functioning were administered before the experiment. All of the participants performed 200 golf-putting trials spread over distances near the hole (low-error condition) or farther away from the hole (high-error condition). The participants were randomly assigned to one of the two conditions (low-error or high-error).[1] The last putting distance (125 cm) was exactly the same for those assigned to the low-error condition and those assigned to the high-error condition.[2]

Participants

Twenty-four AD patients (M = 81.8 years, SD = 4.9 years, 14 women), 24 older adults (M = 80.6 years, SD = 4.3 years, 18 women), and 24 younger adults (M = 23.0 years, SD = 3.5 years, 13 women) participated in the experiment. Descriptive statistics for general characteristics and scores on neuropsychological tests are summarized in (Table 1). AD patients were tested at Hôpital de la Pitié Salpêtrière (Paris, France) and all met the criteria of clinical diagnosis of probable AD, as defined by the National Institute of Neurological and Communicative Diseases and Stroke/Alzheimer's Disease and Related Disorders

TABLE 1. Descriptive statistics for general information and tests measuring balance and cognitive function in younger participants, older participants, and patients with AD.

	Younger adults ($n = 24$)			Older adults ($n = 24$)			AD patients ($n = 24$)		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
General characteristics									
Mean age (years)	23.0	3.5	18–31	80.63	4.3	74–91	81.8	4.9	73–90
Years of education	15.7	2.1	12–20	14.8	4.0	9–21	11.1	4.0	5–17
Depression (Geriatric Depression Scale 15)				2.4	2.0	0–7	2.9	2.8	0–11
Apathy scale (MARIN)							45.8	12.0	25–65
Instrumental Activities of Daily Living Scale							9.9	3.2	2–14
Dynamic balance									
Timed Up and Go test (s)	4.9	0.7	3.4–6.3	8.8	3.2	5.2–20.1	12.8	3.6	6.9–22.2
Neuropsychological tests									
Mini-Mental State Examination (/30)				29.0	1.0	27–30	21.5	2.2	18–26
Executive function/working memory									
Victoria Stroop Test									
Part A (time on second plate)	10.3	1.2	7.7–13.1	14.8	3.5	9.7–26.3	21.7	14.3	9.6–55.0
Part B (time on second plate)	12.7	1.8	10.2–18.0	20.3	3.4	12.1–29.1	37.1	29.7	17.0–106.0
Part C (time on second plate)	18.7	3.8	13.4–41.1	31.3	9.1	19.7–52.0	53.7	26.1	21.0–113.0
Trail making test									
Part A (s)	24.3	6.3	14.0–41.1	40.7	16.5	24.8–103.0	76.7	28.6	43.0–119.0
Part B (s)	46.6	11.0	23.7–63.0	92.1	24.6	49.7–138.1			

Note. AD =Alzheimer's disease.

Association (NINCDS-ADRDA) (McKhann et al., 1984). AD patients underwent a neurological examination, standard blood tests, an electroencephalogram, and a standard neuropsychological assessment. Computed tomography scans revealed no anomaly other than diffuse cerebral atrophy. They were included only if they showed unequivocal evidence of cognitive deterioration over a period of at least six months, as assessed by neurological and neuropsychological assessments. The patients were at an early stage of the disease, as indicated by their score of 21.5 (SD = 2.2, range = 18–26) on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975). They demonstrated significant impairment of declarative memory abilities, as indicated by their scores on free recall or delayed recall tests (RL/RI 16; Van der Linden et al., 2004), a test of episodic memory in French similar to the Free and Cued Selective Reminding Test. The patients displayed a mean score of 3.5 (SD = 2.6, range = 0.3–7) for immediate free recall of a list of words, a mean score of 7.9 (SD = 3.4, range = 2.7–15.3) for immediate total recall of a list of words, a mean score of 1.9 (SD = 3.0, range = 0–10) for delayed free recall of a list of words, and a mean score of 6.6 (SD = 5.1, range = 0–15) for delayed total recall of a list of words. None of the patients had symptoms of depression, as indicated by their score of 2.9 (SD = 2.8) on the 15-item Geriatric Depression Scale (Sheikh & Yesavage, 1986). None had symptoms of apathy, as indicated by the MARIN apathy scale (M = 45.8, SD = 12.0). Level of performance on the 14-point Instrumental Activities of Daily Living Scale (Lawton & Brody, 1969) was low (M = 9.9, SD = 3.2). AD patients were screened for normal or corrected-to-normal vision and hearing.

Older and younger adults were volunteers recruited from Institut Universitaire de Gériatrie de Montréal (Canada), Université Paris-Sud (Orsay, France), and from surrounding local communities. All of them gave their written informed consent before participation. Older adults showed normal general cognitive functioning, as demonstrated by high scores on the Mini-Mental State Examination (see Table 1). Older and younger adults were screened for normal or corrected-to-normal vision and hearing. They also had no history of neurological disease and did not take any medication that might have affected cognition. The study was approved by the local research ethics committee, and informed written consent was obtained from each participant.

Apparatus

Participants attempted putts to a hole that was 11.4 cm in diameter on an even, level artificial-turf indoor green (200 cm × 270 cm) raised 15 cm above ground level to allow a collecting duct to be fitted beneath the hole. Standard white golf balls were used. Identical right- and left-handed putters (length 87 cm or 90 cm) were available to suit each participant's preference.

Procedure

After completing the consent form, neuropsychological tests were administrated. Dynamic balance was measured by the Timed Up and Go test (Podsiadlo & Richardson, 1991). Attention and executive functions were evaluated using the Victoria Stroop test (Regard, 1981) and the Trail Making A and B tests (Reitan & Wolfson, 1985). Participants in the high-error condition performed the five putting blocks (40 putts per block) at the distance of 225, 200, 175, 150, and 125 cm (in that order). Participants in the low-error condition performed the five putting blocks (40 putts per block) at the distances of 25, 50, 75, 100, and 125 cm (in that order). Participants were instructed to put as many balls as possible into the hole. They were informed that there was no time limit to perform each block (less than 5 minutes was generally sufficient to perform a block of trials). Participants carried out some trials to become familiar with the turf before starting the learning phase.

Overview of Analyses

We carried out an analysis of variance (ANOVA) on the mean number of successful putts, with learning condition (i.e., at putting distances of 25, 50, 75, 100, and 125 cm in the low-error condition; at putting distances of 225, 200, 175, 150, and 125 cm in the high-error condition) as a within-subjects variable and type of group (AD patients, older adults, younger adults) as a between-subjects variable. This ANOVA was carried out separately for each learning condition (low error vs. high error) because the first four putting distances differed between the two learning conditions.

We also carried out three correlations restricted to the AD patients. The first analysis examined the relationship between the scores on the episodic memory test (RL/RI 16) and motor performance as a function of the learning condition. The aim was to test the predictions that better declarative memory capacities should be associated with better motor performance in the high-error condition (the one hypothesized to predominantly rely on declarative knowledge) but not in the low-error condition (the one hypothesized to predominantly rely on procedural knowledge). We also computed correlations between the score on the Stroop test, which measures inhibition (executive functions), and motor performance, as a function of the learning condition. As inhibition is important for error detection and corrections (Sharika, Ray, & Murthy, 2009), better inhibition capacities should be associated with superior motor performance in the high-error condition but not in the low-error condition. The third analysis examined the relationship between the scores on the Timed Up and Go test and motor performance. The aim was to evaluate whether motor capacities related to dynamic balance influenced motor performance.

Last, we carried out a factorial ANOVA on the mean number of successful putts at the final putting distance of 125 cm, with learning condition (low error vs. high error) and type of group (AD patients, older adults, younger adults) as two between-subjects variables. By doing so, our aim was to examine which learning condition culminated in the highest performance at the final putting distance (i.e., 125 cm).

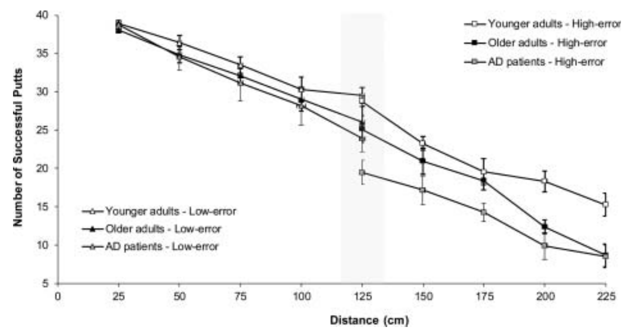

FIGURE 1. Mean number of successful putts performed by younger adults, older adults, and patients with Alzheimer's disease (AD) as a function of distance from the hole in the low- and high-error conditions. Bars show standard errors. The shaded area corresponds to the putting distance for which all the participants performed the last block of 40 putts.

Results

Learning Phase

Figure 1 shows the mean number of successful putts across the five putting distances by AD patients, older adults, and younger adults assigned to the low-error condition (the means in this condition are represented by triangle symbols) and those assigned to the high-error condition (the means in this condition are represented by square symbols). In the low-error condition, the average number of successful putts was equivalent between AD patients ($M = 31.3$, $SD = 3.9$), older adults ($M = 32.0$, $SD = 7.6$), and younger adults ($M = 33.7$, $SD = 3.6$), $F(2, 33) = 1.19$, $p = .317$ ($\eta_p^2 = .067$). Obviously, the number of successful putts gradually decreased from short distances (e.g., at 25 cm: $M = 38.6$, $SD = 1.9$) to longer distances (e.g., at 125 cm: $M = 26.5$, $SD = 5.1$), $F(4, 132) = 71.09$, $p < .001$ ($\eta_p^2 = .683$). This main effect of putting distance was not qualified by an interaction with group type, $F(8, 132) = 1.56$, $p < 1$.

In the high-error condition, the main effect of group type was significant, $F(2, 33) = 10.87$, $p < .001$ ($\eta_p^2 = .397$). Post hoc comparisons showed a nonsignificant difference of 3.3 putts between AD patients ($M = 14.1$, $SD = 5.6$) and older adults ($M = 17.4$, $SD = 7.7$) but a significant difference of 5.5 putts for AD patients and older adults relative to younger adults ($M = 21.3$, $SD = 4.3$). Obviously, the number of successful putts gradually increased from long distances (e.g., at 225 cm, $M = 11.0$, $SD = 6.0$) to shorter distances (e.g., at 125 cm, $M = 24.8$, $SD = 6.2$), $F(4, 132) = 77.99$, $p < .001$ ($\eta_p^2 = .703$). The interaction between putting distance and group type was marginally significant, $F(8, 132) = 1.83$, $p = .077$ ($\eta_p^2 = .010$).

Correlations

Correlational analyses carried out for the AD patients confirmed that better declarative memory capacities (as assessed with the delayed tests of the RL/RI 16, a neuropsychological test solely administrated to AD patients) and better inhibition processes (as assessed with the Stroop Victoria test) were associated with better motor performance in the high-error condition: for the free delayed recall, $r(8) = .729$, $p < .05$; for the total delayed recall, $r(8) = .860$, $p < .01$; and for the Victoria Stroop test part C, $r(10) = -.691$, $p < .05$; however, this was not the case in the low-error condition: for the free delayed recall, $r(8) = .196$, $p = .64$; for the total delayed recall, $r(8) = .400$, $p = .33$ and the Stroop Victoria Part 3, $r(9) = .051$, $p = .987$.[3]

There was no significant relationship between AD patients' dynamic balance capacities (as assessed with the Timed Up and Go test) and their golf-putting performance, both for those assigned to the low-error condition, $r(8) = .409$, $p = .31$, and those assigned to the high-error condition, $r(8) = .412$, $p = .31$. Motor performance seemed uninfluenced by dynamic balance.

Performance at the 125-cm Putting Distance

The factorial ANOVA revealed a significant main effect of group type, $F(2, 66) = 14.81$, $p < .001$ ($\eta_p^2 = .310$). Post hoc comparisons showed that the average number of successful putts was lower for AD patients ($M = 21.8$, $SD = 5.1$) than for older adults ($M = 25.8$, $SD = 5.9$), which, in turn, was lower than for younger adults ($M = 29.3$, $SD = 2.9$). The main effect of learning condition was not significant, $F(1, 66) = 2.19$, $p = .143$ ($\eta_p^2 = .032$). The ANOVA did not reveal a significant group type by learning condition interaction, $F(2, 66) = 1.24$, $p = .297$ ($\eta_p^2 = .036$). We note a very low statistical power for this nonsignificant interaction, perhaps due to the nature of the experimental design (between subjects). As a consequence, and because we specifically thought out to examine which learning method can place AD patients on a higher learning curve, we compared putting performance at the final distance between AD patients assigned to the low-error condition and those assigned to the high-error condition using an independent t test. Given that motor performance was significantly higher in the low-error condition ($M = 23.9$, $SD = 3.96$) than in the high-error condition ($M = 19.8$, $SD = 5.50$), $t(22) = 2.13$, $p = .045$, the low-error learning method may place AD patients on a higher learning trajectory (see also the shaded area in Figure 1, that is the final performance of all participants).

Discussion

The aim of this study was to investigate whether AD patients are able to learn to perform a complex motor skill, golf putting, at a level of performance comparable to that achieved by healthy older and younger adults, provided that the learning method relies on procedural memory presumed to be relatively unaffected by the disease. To this end, we used a low-error/high-error motor learning procedure because it allows a selective manipulation of the type of knowledge representation (declarative or procedural) developed during learning. We hypothesized that AD patients should experience no benefit from high-error motor learning because it promotes predominantly use of declarative knowledge, known to be greatly altered by AD (due to associated deficits in episodic memory and executive functions). In contrast, we hypothesized that AD patients should greatly benefit from low-error motor learning because it promotes predominantly use of procedural knowledge that is assumed to be intact in AD.

Consistent with the assumption of intact procedural knowledge, in the low-error condition, the motor performance of AD patients was overall equivalent to that of older and younger adults. This performance equivalence demonstrates that AD patients, despite deficits in declarative memory, are able to learn to perform a novel motor skill as efficiently as age-matched adults, and also as their younger counterparts under these conditions. When the explicit, high-error motor learning technique was used, AD patients were relatively comparable to the older adults on the motor task, and both AD patients and older adults performed significantly less efficiently than younger adults. The fact that better declarative memory abilities (as assessed with the RL/RI 16 test) and inhibition processes (as assessed with the Victoria Stroop test part 3) were positively associated with better motor performance for AD patients assigned to the high-error condition is consistent with the view that explicit, high-error conditions promote use of declarative knowledge (Baddeley & Wilson, 1994, Pitel et al., 2006). Alternatively, the absence of a relationship between declarative memory abilities and motor performance in AD patients assigned to the low-error condition is consistent with the view that implicit, low-error conditions promote predominantly use of procedural knowledge.

For practical purposes, we also examined the efficiency of the two learning methods with respect to the level of motor performance achieved by the AD patients at the final putting distance (i.e., 125 cm). Motor performance was higher for AD patients in the low-error condition than for AD patients in the high-error condition. Therefore, based on these findings and others (e.g., Chauvel et al., 2012), low-error learning techniques can be viewed as an enhancer of motor performance in AD patients.

Overall, we have found evidence that AD patients' ability to learn a novel motor skill can be positively influenced by an implicit, low-error learning environment. Previously, it was demonstrated that implicit motor learning approaches could be used to develop procedural knowledge in younger adults (Maxwell et al., 2001) as well as in older adults (Chauvel et al., 2012) or in patients with Parkinson's disease (Masters, MacMahon, & Pall, 2004). The present findings demonstrate that this approach can also be useful for development of new skills by AD patients. The findings are in line with previous studies that have demonstrated relative preservation of procedural knowledge in AD patients (Dick, Andel, et al., 2000; Dick, Hsieh, et al., 2000; for a review, see van Halteren-van Tilborg et al., 2007) as well as the superiority of low-error conditions for promoting procedural learning on a computerized task in AD (Schmitz et al., 2014). The results are also consistent with rehabilitation studies showing better learning of everyday tasks with low-error conditions in AD patients (Lekeu et al., 2002, Bier et al., 2008, Thivierge et al., 2008) or in children presenting intellectual disabilities (Capio, Poolton, Sit, Eguia, & Masters, 2013).

In conclusion, AD patients' ability to learn a novel motor skill is increased in conditions favoring use of procedural knowledge relative to conditions favoring use of declarative knowledge. Based on these findings, higher levels of motor learning by AD patients are likely to be expected when implicit motor learning techniques are used by rehabilitation specialists (for a review, see Clare & Jones, 2008). These techniques could be combined with other learning methods (e.g., guidance, observation) that promote the use of procedural memory (van Tilborg, Kessels, & Hulstijn, 2011). A promising avenue for future studies may be to examine the extent to which the beneficial effects induced by implicit learning techniques persist over long periods of time or transfer to other abilities (for an attempt to do so with a cognitive task, see Hunkin, Squires, Parkin, & Tidy, 1998). Finally, future neuroimaging studies may discern whether the learning benefits observed in implicit motor learning conditions are genuinely mediated by intact neural networks or, in contrast, by compensatory neural networks (Willingham, Peterson, Manning, & Brashear, 1997).

NOTES

1. AD patients assigned to the low-error condition and those assigned to the high-error condition did not differ on demographic scores (age, education), motor scores (Timed Up and Go test), and on cognitive scores (Mini-Mental State Examination, MARIN apathy scale, Geriatric Depression Scale, Instrumental Activities of Daily Living, Stroop test, and Trail Making test).

2. Initially, our experimental design required that half of the participants perform a secondary tone-counting task while putting at the last distance of 125 cm. By doing so, our goal was to assess whether knowledge representations were attention demanding (thus suggesting the use of declarative knowledge) or attention free (thus suggesting the use of procedural knowledge). But we do not report these preliminary data because AD patients were unable to perform the tone-counting task (even by itself in isolation).

3. Note that the correlational analyses showed uneven degrees of freedom because some neuropsychological tests could not be completed by each AD patients (due to a lack of available time). It is also worth pointing out that no other correlation effects were found between Victoria Stroop test part 3 (inhibition processes) and learning performance (through the five blocks) for young and older adults in both learning conditions. For information purposes, in the Victoria Stroop test part 3, the following nonsignificant correlations were found: for young adults, $r(12) = .363$, $p = .911$; and for older adults in low-error conditions $r(12) = .446$, $p = .440$; for young adults, $r(12) = .266$, $p = .403$; and for older adults in high-error conditions, $r(12) = .127$, $p = .695$.

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