Memory and Language in Bilingual Alzheimer and Parkinson Patients: Insights from Verb Inflection[1]

Luisa Cameli[1], Natalie A. Phillips[1], Shanna Kousaie[1], and Michel Panisset[2]

[1]Concordia University and [2]McGill Center for Research on Aging

Recent estimates reveal that over half of the world population is bilingual or multilingual (Grosjean, 1982; cited in Fabbro, 1999). This suggests that many Alzheimer (AD) and Parkinson (PD) patients speak more than one language, yet few studies have investigated language in bilingual AD, and none to our knowledge has examined language in bilingual PD. The scarcity of research in the area is surprising, first because of its applications for the services provided to these patients, and second because of its implications for theories of language and memory. Specifically, AD and PD each affect a neurofunctionally distinct memory system. As such, the inspection of language in bilingual AD and PD offers a truly unique insight into the nature of the relationship between memory and language, and into the neural underpinnings of language functions. The goal of this study is to test the usefulness of a neurolinguistic model that posits links between neurofunctionally separable memory systems and specific language functions in explaining language disturbances in bilingual AD and PD. Preliminary results are reported in this paper.

1. Introduction

1.1 Declarative and procedural memory

Memory is not unitary, and dissociations in the task performance of healthy and patient populations have prompted the proposal of various taxonomies. An influential taxonomy is that of declarative and procedural memory (Cohen & Squire, 1980; Cohen, 1984). Declarative memory literally refers to the ability to recount what one knows. It is flexible in that it integrates new information from various modalities. For instance, bird-related knowledge can be expanded by reading on ornithology and by bird watching. Converging evidence from lesion and neuroimaging studies suggests that regions of mesial temporal lobe that include the hippocampus, entorhinal cortex, and parahippocampal cortex, sustain declarative memory. These areas interact with cortical brain regions for the conscious retrieval of facts and events (reviewed in Gabrieli, 1998).

By contrast, procedural memory refers to memory for certain ways of doing things or for certain movements, independent from memory used to "tell about" the ability. Procedural memory is inflexible such that new information cannot easily be incorporated into an internalized database or procedure. For instance, a typist may not be able to tell the location of keys on the keyboard, and the ability to type does not allow the typist to play the piano. Subcortical structures, the basal ganglia in particular, are involved in skill learning and maintenance. These regions project to areas of the frontal

---

[1] Acknowledgements: The authors wish to thank M. Paradis for guidance throughout the development of this project, as well as H. Cohen. We are grateful to M. Ullman for advice and for sharing his database of English verbs. We are indebted to N. Merulla for implementing some of the tasks. Finally, our appreciation goes to H. Chertkow, S. Solomon, and H. Hall, for their assistance in patient recruitment. This research was supported by a Doctoral Award from the Alzheimer Society of Canada to L. Cameli, and a research grant from Canadian Institutes of Health Research (CIHR) to N. Phillips. Please address correspondence to L. Cameli, Department of Psychology, Concordia University, 7141 Sherbrooke St. West, Montreal, Quebec, H4B 1R6, Canada. E-mail: lcameli@vax2.concordia.ca.

 ISB4: Proceedings of the 4th International Symposium on Bilingualism, ed. James Cohen, Kara T. McAlister, Kellie Rolstad, and Jeff MacSwan, 452-476. Somerville, MA: Cascadilla Press.

cortex through specific striatal-thalamic-cortical loops that sustain particular motor, perceptual, and cognitive skills (Gabrieli, 1998).

1.2 Metalinguistic knowledge and implicit linguistic competence

The nature of the relationship between memory and language remains unclear, yet interesting similarities can be noted between declarative memory and lexical functions, and between procedural memory and grammatical functions. Paradis (1994, 1997, 1998a, 1998b) has linked "metalinguistic knowledge" to declarative memory, and "implicit linguistic competence" to procedural memory (these terms are defined below). In a similar vein, Ullman (2001) highlights the association between the "memorized mental lexicon" and declarative memory, and between "computational mental grammar" and procedural memory.

According to Paradis, "metalinguistic knowledge" is dependent upon declarative memory. It is: 1) learned consciously, 2) available for conscious recall, 3) applied to the comprehension and production of language in a controlled manner, 4) dependent on the integrity of the hippocampal system, and 5) stored diffusely over large areas of tertiary cortex. Ullman (2001) refers to aspects of language to which these characteristics apply as the "memorized mental lexicon" and posits a correspondence in learning, representation, and processing, among lexical items, facts, and events. The individual who can perfectly recite a rule of grammar for a second language (L2), but is incapable of applying that rule when speaking, possesses good metalinguistic knowledge but poor implicit linguistic competence.

By contrast, "implicit linguistic competence" relies on procedural memory. It is: 1) acquired incidentally, 2) stored in the form of procedural know-how, without conscious knowledge of its contents, 3) used automatically, and 4) mediated by subcortical structures, mainly the basal ganglia and cerebellum. Ullman (2001) refers to aspects of language to which these characteristics apply as the "computational mental grammar". According to Ullman, the grammar contains rules, including operations and constraints, which underlie the productive combination of lexical forms into complex structures such as sentences or words (e.g., the past tense of regular verbs can be computed by adding "ed" to the verb stem, like "walk" + "ed" = "walked). Ullman (2001) posits a correspondence in learning, representation, and processing, to grammar, skills, and habits, respectively. Implicit linguistic competence in the absence of metalinguistic knowledge is displayed by the young child who can tell if a sentence in his/her native language (L1) is acceptable or not but yet cannot articulate a reason other than "that it does or does not sound right". An adult in the early stages of leaning would have more difficulty using this method to decide if an L2 sentence is grammatically correct or not.

Evidence for the dissociation between "metalinguistic knowledge/memorized mental lexicon" and "implicit linguistic competence/computational mental grammar" comes from research on aphasia (Damasio, 1992; Goodglass, 1993). Aphasics with damage to temporoparietal areas including Wernicke's area have been shown to display word-finding deficits in the absence of obvious defects in the syntactic structure of speech (i.e., their speech lacks content but does not bluntly disobey grammatical rules). By contrast, aphasics with damage to Broca's area that descends to the underlying white matter including the basal ganglia display agrammatism and poor syntactic comprehension, with relatively intact access to word meaning. Evidence for the association between "metalinguistic knowledge/memorized mental lexicon" and declarative memory, and between "implicit linguistic competence/computational mental grammar" and procedural memory, comes from research on neurodegenerative diseases such as Alzheimer's disease and Parkinson's disease, as follows:

1.3 Metalinguistic knowledge and declarative memory

Alzheimer's disease initially affects the hippocampus, entorhinal cortex, and the association cortices (Hyman, Van Hoesen, Damasion, & Barnes, 1984). These regions sustain declarative memory and, in fact, declarative memory impairment is a hallmark of AD (Gabrieli, 1998). Alzheimer's disease spares, at least at the outset, subcortical areas of the frontal lobes including the basal ganglia and, as expected, aspects of procedural memory are relatively spared in AD (Gabrieli, 1998). If declarative memory sustains metalinguistic knowledge (or the memorized mental lexicon) and not implicit linguistic competence (or the computational mental grammar), AD patients should display lexical deficits in the context of relatively intact grammatical processing. Cummings, Darkins, Mendez, Hill, and Benson (1988) found the speech of AD patients to contain a high proportion of closed-class phrases, ill-defined pronouns, and words/utterances that convey little or no information, as expected given the fact that anomia is typical of AD (Hodges, Salmon, & Butters, 1991). Their speech was in general grammatically correct, despite not being clear at a semantic level, and has been compared to that of Wernicke's aphasics (Mathews, Obler, & Albert, 1994).

1.4 Procedural memory and implicit linguistic competence

Parkinson's disease is characterized by the loss of dopamine in the basal ganglia and associated brain region such as the caudal nucleus (McDowell, Lee, & Sweet, 1978). These regions sustain procedural memory, and as expected, procedural memory has been shown to be impaired in PD (Gabrieli, 1998). Idiopathic PD spares the hippocampus, entorhinal cortex, and temporo-parietal cortex, and as predicted spares declarative memory (Gabrieli, 1998). If procedural memory sustains implicit linguistic competence (or the computational mental grammar) and not metalinguistic knowledge (or the memorized mental lexicon), PD patients should display grammatical deficits in the context of relatively intact lexical processing. Cummings et al. (1988) found the free speech of PD patients to be marked by diminished grammatical complexity, as evidenced by decreased phrase length, fewer dependent clauses, and more open-class phrases. Dysarthria, abnormally long hesitations, and impaired prosody also characterized PD speech. Similar findings were reviewed in Grossman (1999). By contrast, the naming ability of PD patients has been shown to be normal (e.g., Lewis, Lapointe, Murdoch, & Chenery, 1998).

1.5 Evidence from verb inflection

The Past Tense Generation task (PTG) requires the subject to generate the past tense of irregular and regular verbs that are embedded in meaningful sentences, and permits the concurrent evaluation of lexical and grammatical abilities. Based on the dual-system model of verb inflection, the past tense of regular verbs in L1 is generated productively by adding "ed" to the verb stem (e.g., "walk" + "ed" = "walked"). By contrast, the past tense of irregular verbs (e.g., "taught") must be retrieved from declarative memory since it cannot be derived from the stem (e.g., "teach"). In sum then, the dual-system model posits that generating the past tense of irregular verbs is a lexical function, whereas generating the past tense of regular verbs in L1 is a grammatical function. The performance of healthy and patient populations on the PTG has provided evidence for the dual-system model of verb inflection: For instance, it has been empirically demonstrated that the past tense of frequent irregulars is generated faster than that of less frequent irregulars, as expected if these are retrieved from declarative memory, whereas frequency has no effect on the latency to generate the past tense of regular verbs, as expected if these are generated productively (see Pinker, 1999; Ullman, 1999).

The PTG has been implemented in many languages including French (e.g., Rose & Royle, 1999), German (e.g., Marcus, Brinkmann, Clahsen, Wiese, & Pinker, 1995), and Italian (e.g., Orsolini, Fanari, & Bowles, 1998), and used to study language disorders such as specific language impairment (e.g., Ullman & Gopnik, 1999). The PTG is well controlled in that the stimuli used to test lexical and grammatical abilities can be matched on complexity (i.e., one word), syntax (i.e., tensed), and meaning (i.e., past). The demand on short-term memory can also be matched by making the sentences that embed the verbs the same length and complexity. These features of the PTG make it ideal to compare the performance of patient populations that differ in their cognitive impairment, such as AD and PD.

Ullman, Corkin, Coppola, Hickok, Growdon, Koroshetz, & Pinker (1997) had AD and PD participants generate the past tense of regular verbs, irregular verbs, and pseudo-verbs. As predicted based on the dual-system model of verb tense inflection and on the selective memory deficits of the two patient groups, AD patients demonstrated preponderant impairments in declarative memory and made more errors producing the past tense of irregular than regular verbs and pseudo-verbs, whereas

PD patients made more errors producing the past tense of regular verbs and pseudo-verbs than irregular verbs.

1.6 Verb inflection in bilinguals

Ullman (2001) reviewed evidence from bilingual aphasia, neuroimaging, and psychophysiology, which indicates that the lexicon/grammar dissociation observed in L1 is much weaker in L2. More specifically, whereas grammar in L1 is dependent upon procedural memory, L2 grammar, when learned after puberty in an academic context, is dependent to a great extent upon declarative memory. An example of the evidence supporting this distinction is the observation of a critical period for the acquisition of grammar but not for the lexicon (Birdsong, 1999; Johnson & Newport, 1989), as well as differences between L1 and L2 speakers in processing closed-class words (e.g., prepositions), which have grammatical functions, but not in processing open-class words (e.g., nouns), which have lexical functions (Weber-Fox & Neville, 2001).

With the exception of Brovetto and Ullman (2001), the PTG has not yet been used to test the lexicon and grammar in bilinguals to our knowledge. Brovetto and Ullman compared the performance of native English speakers to that of Spanish and Chinese English-L2 speakers on the PTG. The native English speakers displayed frequency effects for irregular verbs but not for regular verbs, in English, as predicted if the past tense of irregular verbs is retrieved from declarative memory whereas that of regular verbs is generated productively by adding “ed” to the stem. L2 speakers of English showed frequency effects for both irregular and regular English verbs, indicating that they were retrieving the past tense of both types of verbs from declarative memory. This finding is consistent with the argument that grammar in L1 is dependent upon procedural memory but L2 grammar, when learned after puberty in an academic context, is dependent to a great extent upon declarative memory, and is also in accordance with the aphasia, neuroimaging, and psychophysiological, evidence reviewed in Ullman (2001).

1.7 This study

The goal of this study was to examine verb inflection in bilingual healthy older adults (NC), and in bilingual AD and PD patients. The design was a Group (NC, AD, PD) X Verb type (Irregular, Regular, and Pseudo) X Language (L1, L2) mixed factorial, with group as the between-subjects factor. Subjects were French-English or English-French bilinguals, who had acquired their L2 after puberty. The PTG was adapted to allow us to measure response latency. A battery of memory tests was selected to document selective declarative memory deficits in the AD patients and selective procedural memory deficits in the PD group.

From the literature review, and based on the dual-system model of verb inflection, the following predictions were made for healthy bilinguals: In L1, they were expected to show frequency effects for irregular verbs but not for regular verbs, since the former are retrieved from memory and the later are generated productively. In L2, they were expected to show frequency effects for both irregular and regular verbs if the past tense of both verb types is retrieved from memory. Since bilinguals may not be as fluent in L2 as in L1, greater accuracy for L1 verbs was anticipated, especially for irregular verbs, which may be more vulnerable to exposure (or lack thereof) to the past tense form.

For the population of interest, the AD and PD patients, the following hypotheses were generated:

1) Given the neuropathology of AD, these patients were expected to be impaired on tests of declarative memory but not on tests of procedural memory. This finding would be consistent with the literature on memory in AD (Gabrieli, 1998). In L1, AD patients were expected to make more errors in generating the past tense of irregular verbs than regular verbs and pseudo-verbs. This would replicate Ullman et al. (1997). In L2, AD patients were expected to make more errors than normal controls for both regular and irregular verbs, since in L2 both rely on declarative memory to a great extent. The predictions for L2 have not been tested in AD, to our knowledge. However, the observation that AD patients switch into L1 to a greater extent than into L2 (Hyltenstam & Stroud, 1989, 1993; Santi, Obler, Sabo-Abramson, & Goldberger, 1989) and prefer L1 to L2 (e.g., Mendez,

Perryman, Ponton, & Cummings, 1999) is consistent with the view that AD affects an L2 more than an L1 (Obler, 1999; Paradis, 1999). Frequency effects were not expected for AD subjects because these are the product of successful retrieval from declarative memory.

2) Given the neuropathology of PD, these patients were expected to be impaired on tests of procedural memory but not on tests of declarative memory. This finding would be consistent with the literature on memory in PD (Gabrieli, 1998). In L1, PD patients were expected to make more errors in generating the past tense of regular verbs and pseudo-verbs than irregular verbs. This would replicate Ullman et al. (1997). In L2, PD patients were expected to perform similarly to normal controls, since the generation of the past tense of irregular and regular verbs in L2 minimally involves procedural memory. The prediction in L2 has not been tested yet in PD, and we are not aware of studies on bilingual PD patients. Similarly to the NC subjects, PD patients were expected to display frequency effects for irregular verbs in L1 and L2 and for irregular verbs in L2. If the patients compensate for their inability to productively generate the past tense of regular verbs in L1 by retrieving the past tense forms from declarative memory (e.g., "walked"), then we would expect to also see frequency effects for regular verbs in L1.

3) In sum, a double dissociation was expected in the memory performance of the patient groups, with AD patients being selectively impaired on tests of declarative memory and PD patients being selectively impaired on tests of procedural memory. A double dissociation was similarly expected in the PTG performance of the patients, with AD patients being more impaired in generating the past tense of irregular verbs in L1 and L2 and regular verbs in L2 and PD patients being more impaired in generating the past tense of regular verbs in L1.

2. Method

2.1 Participants

Ten healthy elderly controls (NC), nine PD patients, and two AD patients, were tested. Healthy participants were recruited through advertisements, whereas neurologists referred the patients. Participants were screened for major past or current health or mental problems. Those with conditions known to affect cognition (other than AD and PD) were excluded. Ethical approval was obtained and all participants gave informed consent. All participants were French-English or English-French bilinguals. Bilingualism was assessed with the History of Bilingualism questionnaire, and the English Background and French Background questionnaires from the Bilingual Aphasia Test (Paradis, 1987). Generally, to be included in the study, participants had to report: 1) feeling equally or almost equally comfortable in English and French, 2) using L2 at least 30% of the time on a daily or weekly basis, and 3) having learned L2 enough to speak it fluently after puberty. Subject characteristics are reported in Table 1. All participants learned their L2 academically, with the exception of three PD patients and one AD patient who learned their L2 entirely through conversation, and learned their L2 after puberty, except for one NC participant who learned her L2 at 8 years of age.

The younger AD patient was mildly demented whereas the older one was moderately demented, based on the Mini Mental State Exam. Information on health and language volunteered by the AD patients was verified with their spouses. PD patients were not demented based on evaluations by the referring neurologist. The decision to select non-demented PD patients was motivated by the fact that dementia in PD could indicate concomitant AD, or another disorder altogether. On the Hoehn and Yahr scale (Hoehn & Yahr, 1967), seven PD patients were within Stages 1 and 2, whereas two were within Stages 3. None of the patients were within Stages 4 or 5. All PD patients were medicated and each was tested at a time of day when he/she reported the symptoms were least.

Table 1
Characteristics of the participant groups.

	NC	AD	PD
Sample size	10	2	9
Age range	61-74	75 and 83	55-79
Mean age	67	79	65
Mean Years of education	15	12	15
Number of French native speakers	8	2	7
Mean Age when became fluent in L2	16	18	20
Range for age when became fluent in L2	8-20	16 and 20	15-30
Mean Percent of the time spent in L2 (listening, talking, reading)	40	45	39

2.2 Declarative and procedural memory tests

Memory was assessed in each participant's L1 in the non-verbal and verbal domains. Only tests that do not required a manual response were selected. Declarative memory was assessed in the non-verbal modality with the Batterie d'Efficience Mnésique (BEM-144; Signoret, 1991) and in the verbal modality with the Rey Auditory Verbal Learning Test (RAVTL; Lezak, 1983). The BEM required subjects to recognize simple designs, whereas the RAVLT required them to learn and remember a list of simple nouns. The RAVLT has been shown to be sensitive to AD (see Spreen & Strauss, 1991). The BEM has not been used in research on AD to our knowledge, but it was chosen because it does not require subjects to draw, as opposed to more commonly used tasks that require copying a figure and/or drawing it from memory after a delay.

Procedural memory was evaluated in the non-verbal modality with the Serial Reaction Time task (SRT; Westwater, McDowall, Siegert, Mossman, & Abernethy, 1998) and in the verbal domain with the Mirror-Reading task (Deweer, Ergis, Fossati, Pillon, Boller, Agid, & Dubois, 1994). The SRT is a measure of sequence learning. The participant tracks a star that appears on a computer monitor following a spatial sequence. Participants are usually unaware of the sequence but yet their tracking speed increases with increasing exposure to the sequence. The Mirror-Reading task measures the acquisition of the ability to read words printed backwards. These tasks were chosen because they have been shown to be sensitive to PD (Westwater et al., 1998 for the SRT; Koenig, Thomas-Anterion, & Laurent, 1999 for the mirror-reading task) but not to AD (Knopman & Nissen, 1987 for the SRT; Deweer, Pillon, Michon, & Dubois, 1993 for the mirror-reading task).

2.2.1 BEM

This test required subjects to recognize 24 simple and abstract designs. Each black and white design measured 6 cm^2 and was printed on a separate 8.27 X 11.69 in. page. Each design was presented for 5 s and the participant was asked to observe it carefully because it would have to be recognized among 3 foils later. After a 30-minute delay, each of the 24 designs was presented among 3 foils. Each black and white design measured 6 cm^2 and each foil appeared only once. The participant was told that he/she had seen one of the four designs, presented in one column on the page, and asked to point to the one he/she recognized. The number of designs correctly recognized was measured.

2.2.2.RAVLT

This test required subjects to learn and remember a list of words. The participant heard a list of 15 familiar nouns (List A), read at a rate of one word per second, and was asked to recall as many as possible in any order. This procedure was repeated five times. For each recall, the minimum time allowed was 45 s and the maximum was 2 min. After the five trials, the participant heard another list of 15 words (List B) and was asked to recall as many words as possible from this list only. Following this interference trial (i.e., List B), the participant was asked to recall the words from List A. Following a 30-minute delay, recall was tested unexpectedly for List A and recognition evaluated for Lists A and B. For the recognition test, List A and B words were presented among 20 foils. Some of the foils were semantic associates of the target words whereas others were phonetic associates. The French version of the RAVLT was obtained from M. Jonesgotman. There were six measures of interest: 1) The number of words recalled on the first learning trial, 2) The number of words recalled on the final learning trial, 3) The total number of words recalled across the five learning trials, 4) The number of words recalled after interference, 5) The number of words recalled from List A after the delay, and 6) The number of words from List A and B correctly recognized.

2.2.3 SRT

This test of sequence learning was implemented as described in Westwater et al. (1998). On each trial, an asterisk appeared at one of four locations at the bottom of the computer monitor. The four locations (1, 2, 3, 4) were equidistant along the horizontal axis. The asterisk appeared on the monitor in the following 10-trial sequence: 4231324321. Upon a response, the asterisk disappeared and 400 ms later it reappeared at a different location for the next trial. There were five blocks of trials. The first four blocks comprised 10 repetitions of the 10-trial sequence. The fifth block consisted of 100 trials presented in random order with the constraint that the asterisk did not appear at the same location consecutively. The blocks were separated by a 1-min pause. Before initiating the task, the participant was shown the four locations and was then instructed to name the location out loud as soon as the asterisk appeared on the monitor. Naming latency was recorded through Inquisit (Millisecond Software). Upon completion of the task, the participant was asked whether he/she noticed anything and if he/she believed his/her naming latency decreased with practice. If the participant referred to a sequence, he/she was asked to tell the order.

2.2.4. Mirror-reading

This test of skill acquisition and repetition priming was implemented to resemble that described in Deweer et al. (1994). All words were six to seven letters long. Word frequency varied between 1 to 22 occurrences per million words in written language. Word frequency norms for the English version were taken from Francis and Kucera (1982), whereas those for the French version were collected from Beaudot (1992). There were three sets of stimuli, one for each learning session. Each set consisted of 5 blocks of 10 word triads. Five word triads were unique to each block and five of the word triads were common to all blocks. The unique word triads were used to test skill acquisition, whereas the repeating triads were employed to assess repetition priming.

Within each block, the mean word frequency for the unique and for the repeat triads was of 8.6. The mean frequency for the first, second, and third words of triads was matched within each block and across blocks, and varied between 8.5 and 8.6. The mean frequency for each set of five unique triads within each block varied between 7.1 and 10.2. The frequency of each of the five repeat word triads varied between 5.3 and 13.7, for an average repeat triad frequency of 8.6. The order of the words within the repeat triads varied across the five sets in a block, such that it was never the same. This description of the stimuli applies to both the English and the French version. The triads were printed in black ink upper case in a 53-point size Arial font using Microsoft Word 2000. Accents were included for the French version. The words within each triad were separated by a hyphen (e.g., SLEEVE-KENNEL-TWISTER). Using Adobe Photoshop 5.5, each triad was flipped over a vertical axis, and printed on a transparency for presentation to the participants. Each 8 ½ X 11 inch transparency was placed on top of an 8½ X 11 off-white sheet of paper.

Participants were told that the words had been flipped on a vertical axis and that therefore words had to be read from right to left. If the participant did not understand, the transparency was flipped to show a practice item in normal text. Two single-word practice trials were given, as well as one practice trial with a word triad. Participants were encouraged to read each triad as fast as possible. If a participant made an error, he/she was asked to correct the error. The time it took each subject to read each triad was measured with a stopwatch. A maximum of 2 min was allowed to read a triad. Each block of 50 triads was interspersed with other tasks.

After completing the three blocks of 50 triads, recognition was tested for the triads that were common to all blocks. There were five triads that were present for each set of 10 triads, within each block. This means that 15 words were repeated throughout the task. For the recognition test, these 15 words were embedded in 30 foils not semantically nor phonetically related to the repeat words. The average frequency of the foils was of 8.6, the same as that of the repeat words. Each of the 45 words was printed forward (i.e., not flipped) on an 8 ½ X 11 white sheet of paper in the same font as the other stimuli. The participant was shown each word and asked if he/she had read the word backward earlier in the test.

2.3 The past tense generation task
2.3.1 English version of the PTG

The PTG was comprised of three experimental conditions within each language: the regular verb, irregular verb, and pseudo-verb, conditions. For the English version, verbs were defined as regular if adding "ed" to the stem (e.g., "walk-walked") generates the past tense. They were defined as irregular if generating the past tense requires modifying the stem (e.g., "teach-taught"). Pseudo-verbs were English sounding pronounceable verbs that do not exist (e.g., "tunch"). The English verbs were selected from M. Ullman's database.

2.3.2 French version of the PTG

For the French version, it was necessary to choose between the imperfect tense (*imparfait)* and the perfect tense (*passé composé)* to mark the past. To mark the imperfect tense of a regular verb, the phoneme [ε] must be added to the stem, whereas to generate the perfect tense, an auxiliary verb must be inserted ("to be" or "to have") and the phoneme [é] added to the stem. The imperfect tense was selected for this study because it does not require an auxiliary verb and it is the only tense that can be defined for regular verbs as "stem" + "phoneme [ε]". Using the imperfect tense avoids this limitation of the perfect tense: If the auxiliary verb had been provided to the participants, we would not have known if the participant generated the correct verb tense (e.g., "aim<u>é</u>"), the infinitive (e.g., "aim<u>er</u>"), or the subjunctive 2nd person plural (e.g., "aim<u>ez</u>"), since all three are pronounced the same. Alternatively, if the auxiliary verb had not been provided to participants, the latency to generate the past tense form would have been confounded with the latency to generate the auxiliary verb. The imperfect tense does not share these limitations.

For this study, a French verb was defined as regular if it belonged to the first group of verbs, those that end in "er" in the infinitive and follow the same conjugation as "aimer". Over 10,000 verbs fall within this category (Bescherelle, 1981). The third person singular in the present tense was considered as the stem because it provides the sound part of the verb that does not change with inflection. Irregular verbs belong to the third group of French verbs, which include the verbs that do not belong to the first (those that end in "er" in the infinitive) or to the second group (those that end in "ir" in the infinitive). The third group of verbs forms a dead conjugation and contains the greatest number of irregularities (Bescherelle, 1981). For each irregular French verb in this study (e.g., "peindre") less than 27 verbs follow the same conjugation, many of which are rarely used (e.g., "aveindre", "geindre"). As is the case for English verbs, the inflection of irregular verbs requires modifying the stem, but in addition, the inflection of irregular verbs in French requires adding the phoneme [ε]. In sum then, for the French version, regular verbs require adding the phoneme [ε] to the stem to generate the imperfect tense (e.g., "aime-aimait"), whereas irregular verbs require modifying the stem and adding the phoneme [ε] (e.g., "boit-buvait"). Pseudo-verbs were French sounding (e.g., "codume") pronounceable non-existent verbs modeled after verbs in the first group (those that follow "aimer").

2.3.3 Verb characteristics

For each language, there were 50 regular, 50 irregular, and 40 pseudo-verbs. Regular and irregular verbs were matched pair-wise on past tense frequency within and across language. Thus, for each English irregular verb, there was an English regular verb, a French irregular verb, and a French regular verb, with comparable spoken word frequency. English frequency norms were from the Associated Press Corpus and Montreal-French frequency norms from Beauchemin, Martel, and Theoret (1992). English verbs were selected from a database provided by M. Ullman. The past tense frequency for each French verb was obtained by adding the occurrence of the imperfect tense in the first, second, and third person singular, as well as in the third person plural. This was because these sound exactly the same. For instance, "je parle, tu parles, il parle, ils parlent", are all pronounced [parl]. Their imperfect tense, "je parlais, tu parlais, il parlait, ils parlaient", are also pronounced the same [parlɛ]. This is equivalent to how verb frequency was calculated in English, where the value for a verb (e.g., "walked") combines occurrences for several persons (e.g., "I walked, you walked, he walked, we walked, they walked"). The raw frequency of occurrence was converted to a frequency of occurrence per 1,014,232 words. This number was then natural log transformed after being augmented by 1 to avoid ln(0). For the whole set of verbs, the transformed frequencies varied between 0 and 6.9. The mean frequency was 2.4 (SD = 1.9) and 2.4 (SD = 1.6) for the English irregulars and regulars respectively, and 2.2 (SD = 2.1) and 2.4 (SD = 2.2) for the French irregulars and regulars respectively.

2.3.4 Sentences

The verbs were embedded into meaningful 2-sentence phrases. An example of an English phrase is: "Every day, I work on the computer. At the office yesterday I ____ on the computer." An example of a French phrase is: "Tous les soirs, Émilie chante une chanson. Son père jouait du piano hier pendant qu'Émilie ____ une chanson." The phrases were constructed such that only one tense was correct: the English sentence stem could only be completed with the past, and the French sentence stem solely with the imperfect tense. For the sentences to be meaningful, the content was allowed to vary. The structure of the phrase was kept constant such that the fist sentence in the English and French version was composed of a time indicator, followed by a verb in the present tense and a complement. In the English version, the first person singular was used, whereas in the French version, the third person singular was employed. The second sentence began with a phrase, most often related to the meaning of the previous sentence, and the words "Yesterday I" or "Hier pendant que [name (e.g., Émilie)]"for the three experimental conditions. In the French version, the second sentences began with an indication that an event took place or was occurring (e.g., "Son père jouait du piano.") This is because the imperfect tense refers either to an action that took place while another event was occurring or to an action that was taking place while another event occurred.

Interspersed among the experimental sentences, which all ended with the words "Yesterday I" or "Hier pendant que [name (e.g., Émilie)]", were foil sentences. These ended with "Tomorrow I will be" or "nous". The purpose of these foils was to ensure that a response could not be generated before the very end of the phrase. For the English sentence, for instance, the participant would not know whether to answer "worked" or "working" before the last few words. For the French sentence, the participant would not know whether to generate "jouait" or "jouions". In each language, there were 22 foils derived from 8 irregular verbs, 8 regular verbs, and 6 pseudo-verbs.

The phases were matched across verb type and language on the number of syllables from the first word of the sentence to the word immediately preceding the participant's response. The average number of syllables per sentence for the irregular verb, regular verb, and pseudo-verb, conditions was 14 for the English version, and 15, 15, and 14, respectively for the French version. A female native English-speaking Montrealer recorded the English sentences and a female native French-speaking Montrealer recorded the French sentences. The pace and clarity of speech as well as the amount of prosody used while recording the sentences was kept similar across the English and French versions.

2.3.5 Language testing procedure

We elected to test language in the auditory modality rather than in the visual modality. It was believed that having the participants listen to sentences would encourage them to use implicit linguistic competence in L1. Reading and writing were originally learned with effort and may not tap into implicit linguistic competence to the same extent that speech may. An exception was made for pseudo-verbs, which may be difficult to accurately perceive in the auditory modality, especially in L2, and retain in working memory. For phrases that contain pseudo-verbs, the first sentence was presented in the auditory and visual modalities. The sentences appeared at the center of the monitor in 1 cm tall X .05 cm wide medium-blue letters, against a dark purple background.

Each participant was given 11 practice trials: two with regular verbs, two with irregular verbs, three with pseudo-verbs, and four with foils. If the participant generated a verb that was different from that used in the sentence, he/she was asked to use the verb provided by the sentence. If the participant generated the wrong tense, he/she was told to use the past (or imperfect tense for the French version) and given an explanation of why the sentence structure required that tense. Participants were instructed to listen to the sentences for meaning. The sentences were presented over two speakers. The participant wore a microphone and had to say out loud the correct verb inflection immediately after hearing "yesterday I" or "tomorrow I will be" (or "hier pendant que [name]" or "hier pendant que nous" for the French version). The task was computerized and voice onset latency was recorded. For all sentences, the experimenter controlled the initiation of the phrases and of their ending. After the participant responded, a white arrow appeared on the monitor allowing the experimenter to decide whether the computer detected the participant's response as it occurred. After the participant responded, the experimenter initiated the ending of the phrase.

Each participant was asked questions about some of the sentences throughout the test to ensure that he/she was paying attention to the meaning of the sentence rather than to the verb. By default, there were 23 questions throughout the test. However, the number was allowed to vary such that more questions were added for participants who answered many questions wrong. To avoid fatigue and/or boredom, the 162 phrases were split into three parts of 52, 60, and 50 phrases each, which were interspersed with other tasks. Every part began with practice trials, 11 for part one, and 5 each for part two and three. The sentences were ordered randomly and the same order was used to test all participants.

2.4 Testing procedure

Participants were offered to perform the tests in the laboratory or in their home. Two normal controls, five PD patients, and the two AD patients elected to be tested at home. Each participant was tested over three separate days in sessions that lasted approximately 2 ½ hours each. Participants were given breaks as needed and given $45 for their participation. The testing order is presented in Table 2.

Table 2.
Testing order for all participants.

Session 1 (L1)	Session 2 (L1/L2)	Session 3 (L1/L2)
Mirror1	Elicited Speech	Elicited Speech
RAVLT/BEM learning	PTG	PTG
Mirror 2	BAT subtests	BAT subtests
RAVLT/BEM memory		
Mirror 3		
SRT		

Note: "/" indicates that the order was counterbalanced.

For each session, a native speaker administered the tests. Memory was evaluated in each participant's L1, generally on the first day. French and English were tested on separate days. Four NC and five PD participants were tested in L2 first. Both AD patients were tested in L2 first. On average, the two language sessions were separated by 6 days for the NC and for the PD groups, and by 11 days for the two AD patients.

Apparatus and Software: Participants were tested on a Pentium 1 IBM Thinkpad, model 385XD. The monitor of the thinkpad measured 12 in. Inquisit version 1.32 was used to run all computerized tasks (Millisecond software). Auditory stimuli were recorded using Cool Edit 2000 Software (Syntrillium Software Corporation) and presented via Dyna-Point speakers at a comfortable listening volume. A close-talk microphone headset (model Andrea NC-8) recorded the participant's responses.

3. Memory results

Data from all participants were included for the analyses. T-tests and Analyses of variance (ANOVAs) were used to compare the performance of the NC and PD groups. The .05 significance level was used and significant omnibus results were followed up with Tukey A post-hoc tests. Only significant results are reported. Since there were only two AD patients, one mildly and one moderately demented, AD data were examined separately for each patient. The score of each AD participant was compared to the mean score of the NC group to determine whether it fell below 3 SDs.

3.1 BEM

The results are presented in Figure 1. Scores represent the number of designs correctly recognized out of 24, divided by 2. The scores ranged from 7 to 12 for the NC group and from 8 to 12 for the PD group. There was no significant difference between the two groups on the number of designs correctly recognized ($t[17] = -1.49$, $p = .154$). Participant AD1 recognized as many designs as the NC group. The number of designs recognized by participant AD 2 fell within 3 SDs of the mean number of designs recognized by the NC group. However, no participant in the study recognized as few designs as AD2 did.

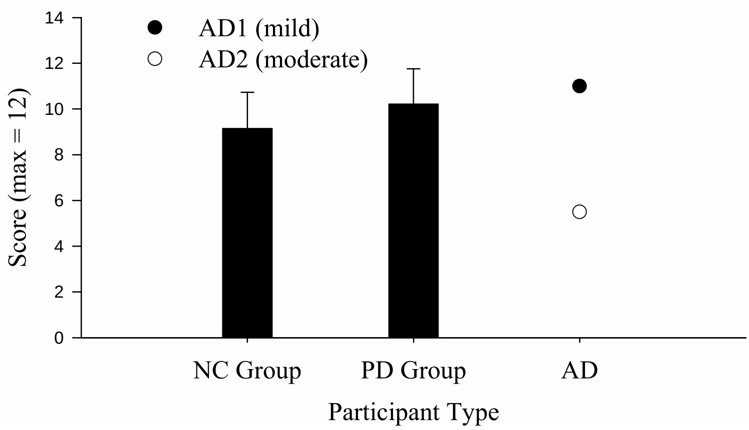

Figure 1. Score on the BEM for the NC and PD groups, and for participants AD1 and AD2.

3.2 RAVLT

The results are presented in Figure 2. T1 and T5 refer to the initial and final learning trials, respectively. TOT refers to the average number of words recalled across all five learning trials. There was no significant difference in verbal learning between the two groups: The NC and PD groups recalled a comparable number of words on the first learning trial ($t[17] = 1.23$, $p = .234$), on the final learning trial ($t[17] = -.83$, $p = .421$), and on average over the five learning trials ($t[17] = .08$, $p = .938$).

In Figure 2, AI refers to the number of words from List A recalled after interference. DR refers to the number of words from List A recalled after a 30-min delay. DRe refers to the number of words correctly recognized from List A. There was no significant difference in verbal memory between the two groups: The NC and PD groups recalled a comparable number of words after interference ($t[17]$ = .70, p = .491) and after a delay ($t[17]$ = .31, p = .759). They recognized a similar number of words from Lists A and B ($t[17]$ = -.42, .99 p = .678, .336, respectively). The NC and PD groups also made an equivalent number of false positive errors on the recognition test ($t[17]$ = 1.17, p = .258).

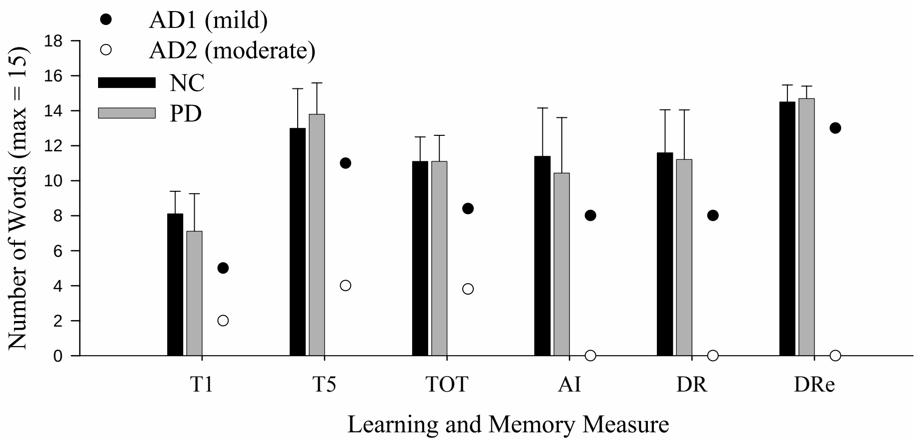

Figure 2. Number of words remembered on the RAVLT by the NC and PD groups, and by participants AD1 and AD2.

3.3 SRT

Participants made errors naming the location on less than 1% of trials. The computer failed to detect a voice response on approximately 8% of trials. Trials on which participant or computer errors occurred were excluded from the analyses. The average naming latency was calculated for each block for each participant. Outliers, defined as 3 SDs from the mean naming latency of each participant, were removed from the data.

A repeated-measures ANOVA was conducted on naming latency with Group (NC, PD) as the between-subjects factor and Block (Block 4, Block 5) as the repeated measure. A significant main effect of Block was observed ($F[1, 17]$ = 83.36, $p < .001$) revealing significantly longer naming latencies for Block 5, the random ordered block, than for Block 4, the last sequence learning block. This effect was equal in magnitude for the NC and the PD group (Group X Block, $F[1, 17]$ = .36, p = .559). The performance of participant AD1 was comparable to that of participants in the NC and PD groups, whereas that of AD2 was not, as illustrated in Figure 3. Several participants from the two groups noticed a sequence but were unable to articulate it.

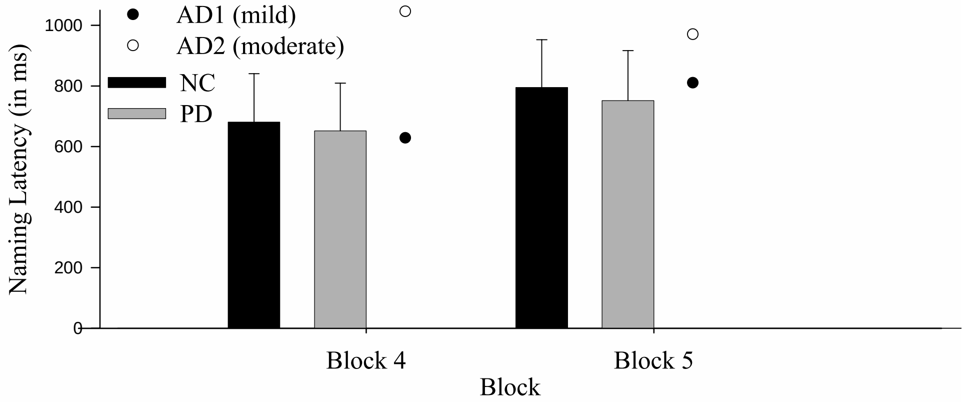

Figure 3. Naming latencies on the SRT for the NC and PD groups and for participants AD1 and AD2.

3.4 Mirror reading

Participant errors and time failures occurred on less than 1% of triads. Outliers, defined as 3 SDs from the mean reading latency of each participant, were removed from the data. Reading latency for the unique word triads (i.e., those that appeared once) was separated from that for repeat word triads (i.e., those that appeared in every set), such that skill learning could be separated from repetition priming.

3.4.1 Skill acquisition

A repeated measures Group (NC, PD) X Session (1, 2, 3) ANOVA was conducted on the latency to name unique word triads. A significant main effect of Session was observed ($F[2, 34] = 7.83$, $p = .002$). This effect was moderated by a significant Group X Session interaction effect ($F[2, 34] = 3.68$, $p = .036$). Tukey A post-hoc tests indicated that the reading latency of the NC group was significantly longer for Session 1 than for Session 3 ($p < .05$). Reading latency for Session 2 did not significantly differ from that for the other two sessions ($p_s > .05$). For the PD group, there was no significant difference in reading latency across the three sessions ($p_s > .05$). This interaction effect is illustrated in the top left panel of Figure 4. Only the mildly demented AD patient was able to complete the task. His data is presented in the top right panel of Figure 4. The patient's reading latencies were double those of NC participants, but skill learning, as expressed by a decrease in reading latency from Session 1 to Session 3, is clearly present.

3.4.2 Repetition priming

A repeated measures Group (NC, PD) X Session (1, 2, 3) ANOVA was conducted on the latency to read repeat word triads. There was a significant main effect of Session ($F[2, 34] = 46.73$, $p < .001$), equivalent for the two groups (Group X Session, $F[2, 34] = .05$, $p = .954$). Repetition priming is shown for the NC and PD groups, and for AD1 relative to the NC group, in the bottom left and right panels of Figure 4, respectively. On the recognition test, the two groups and AD1 recognized almost all of the repeat triads ($t[17]=1.23$, $p = .236$ for the group comparison).

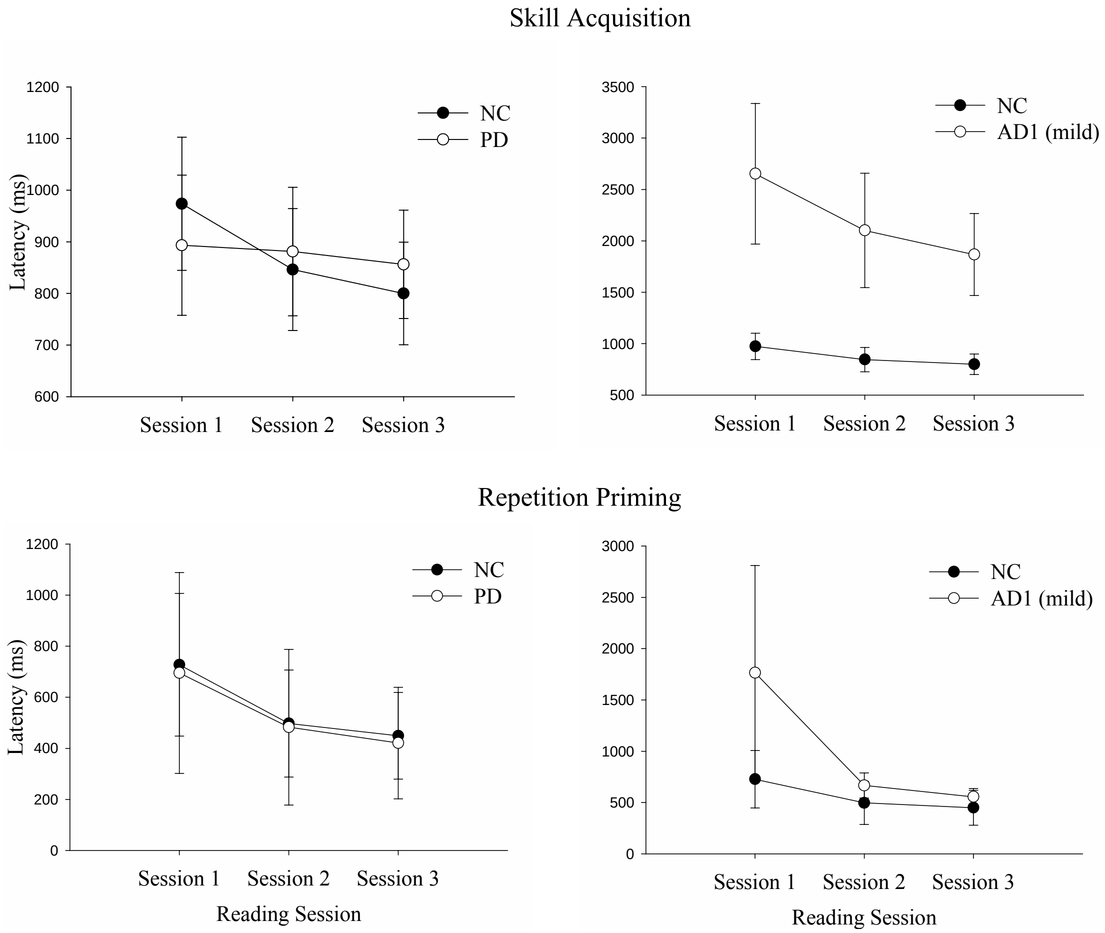

Figure 4. Skill Acquisition and Repetition Priming for the NC and PD groups (left) and AD1 (right).

4. Language results

4.1 Past tense generation overall accuracy

The analyses were conducted on each participant's initial response. The percentage of correctly generated regular verbs, irregular verbs, and pseudo-verbs, is illustrated for L1 and L2 in the top and bottom panels of Figure 5, respectively. A repeated measures Group (NC, PD) X Verb Type (Regular, Irregular, Pseudo-verb) X Language (L1, L2) ANOVA was conducted on the percentage of correct answers. There was a significant main effect of Verb Type ($F[2, 34] = 22.88$, $p < .001$) and a significant main effect of Language ($F[1, 17] = 16.69$, $p = .001$). These main effects were moderated by a significant Verb Type X Language interaction effect ($F[2, 34] = 25.60$, $p < .001$). Tukey A post-hoc tests indicated that the percentage of correct answers was significantly reduced for irregular verbs in L2 relative to that of any other verb type in L1 and L2 ($p_s < .05$). There was no significant main or interaction effect of Group.

The effect of AD on the percentage of correct answers was examined by comparing the score of each participant to that of the NC group. The ability of the AD patients to generate the past tense of English-sounding or French-sounding pseudo-verbs was clearly comparable to that of NC participants in both L1 and L2. By contrast, the verb inflection performance of each AD patient was below 3 SDs from that of the NC group for regular and irregular verbs in L1. In L2, only the performance of the moderately demented AD patient (AD2) was impaired, for regular verbs uniquely. The lack of a significant difference in L2 between the ability of NC participants and AD patients to generate the past tense of irregular verbs may be attributable to the sizeable variability in the performance of the NC group within the L2 irregular verb condition.

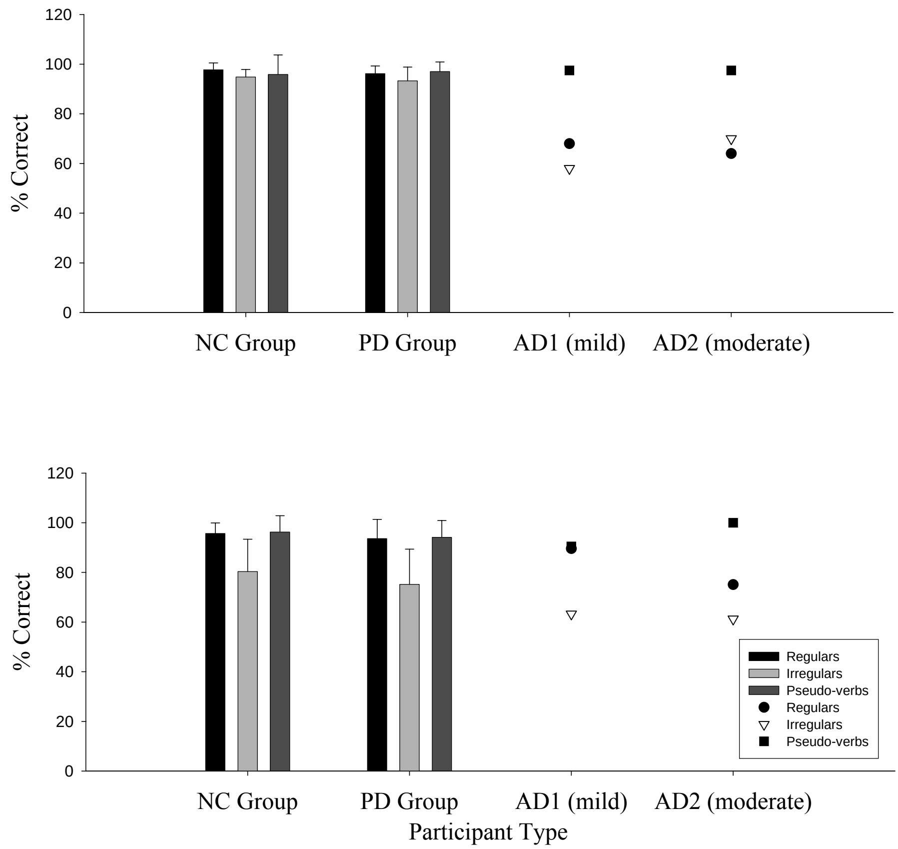

Figure 5. Percent of regular verbs, irregular verbs, and pseudo-verbs correctly inflected in L1 (top panel) and L2 (bottom panel), by the NC and PD groups, and by AD1 and AD2.

4.2 Specific errors

The frequency of specific types of errors was examined. These are presented in Table 3. Group (NC, PD) X Language (L1, L2) repeated measures ANOVAs were conducted on the following dependent measures for irregular verbs: 1) Regularization errors (e.g., "swim-swimmed"), 2) Irregularization errors, defined as an attempt to irregularize the past tense but producing a different form (e.g., "stick-stook"), and 3) Incorrect tense, either unmarked (e.g., "dig-dig") or incorrect (e.g., "take-taking"). There was a significant effect of Language on the number of regularization errors ($F[1, 17] = 20.52$, $p <.001$), irregularization errors ($F[1, 17 = 6,71$, $p = .019$), and incorrect tense marking ($F[1, 17] = 5.30$, $p =.034$), with more of these errors occurring in L2. There was no significant main or interaction effect of group.

For regular verbs, these errors were examined: 1) Irregularization errors, defined as inflecting a regular verb as though it was an irregular verb (e.g., "whip-wope"), and 2) Unmarked or incorrect tense. There was no significant main effect of Language or Group, nor interaction effect of the two on either measure.

Finally, for pseudo-verbs, irregularizations (e.g., "dreck-droke") were examined, together with responses indexing unmarked or incorrect tense. Significantly more irregularizations were performed by the PD patients than by the NC participants ($F[2, 17] = 4.93$, $p =.040$), this, irrespective of language

(Group X Language F[1, 17] = 0.43, p = .523, and Language F[1, 17] = 0.77, p = .390). The number of pseudo-verbs irregularized by the NC and PD groups is not large but it represents 7.5% of the total number of pseudo-verbs not inflected by adding "ed" (or "ait" for the French version) for the NC group versus 48.4% for the PD group. By contrast, there was no significant main or interaction effect of Group or Language on the number of pseudo-verbs that were left unmarked or that were inflected in an incorrect tense.

Table 3.
Average number of errors made by the NC and PD groups, and by participants AD1 and AD2.

	NC Group	PD Group	AD1 (mild)	AD2 (moderate)
Irregular Verbs (e.g., dig)				
Regularization (e.g., digged)	2.9	3.2	2.0	3.0
Irregularization (e.g., dag)	1.0	1.4	2.0	1.5
Unmarked or incorrect tense	1.6	1.2	**4.0**	**4.5**
Regular Verbs (e.g., look)				
Irregularization (e.g., lak)	0.3	0.2	0	0.0
Unmarked or incorrect tense	0.8	0.5	0	1.5
Pseudo-verb (e.g., plag)				
Irregularization (e.g., plog)*	**0.2**	**0.9**	0	0
Unmarked or incorrect tense	0.7	0.4	0	1.0

4.3 Past tense generation latency

Trials that did not accurately measure naming latency were excluded from the analyses. These include trials on which the participant produced an error, trials on which the computer detected a sound other than the participant's verb generation (e.g., cough, sigh, etc.), and trials on which the computer failed to detect the participant's response. Outliers, defined as 3 SDs from the participant's mean latency, were excluded from the analyses. On average, 8.3% (SD = 5.2) and 17.5% (SD = 9.3) of trials were excluded from L1 and L2 data, respectively. A repeated measures Group (NC, PD) X Verb Type (Regular, Irregular, Pseudo-verb) X Language (L1, L2) ANOVA was conducted on the overall latency. There was a significant main effect of Language (F[1, 17 = 5.40, p = .033) and a trend toward a main effect of Verb type (F[2, 34 = 3.25, p = .051). These main effects were moderated by a significant Language X Verb type interaction effect (F[2, 34 = 7.12, p = .003). Tukey A post-hocs indicated that latency to generate the past tense of pseudo-verbs in L2 was significantly longer than that to generate the past tense of pseudo-verbs in L1 and the past tense of any other verb type in any language ($p_s < .05$). This effect is illustrated in Figure 6. This result was confirmed in participants who have French as an L1 (F[2, 26 = 3.39, p = .049) and English as an L1 (F[2, 4 = 55.26, p = .001).

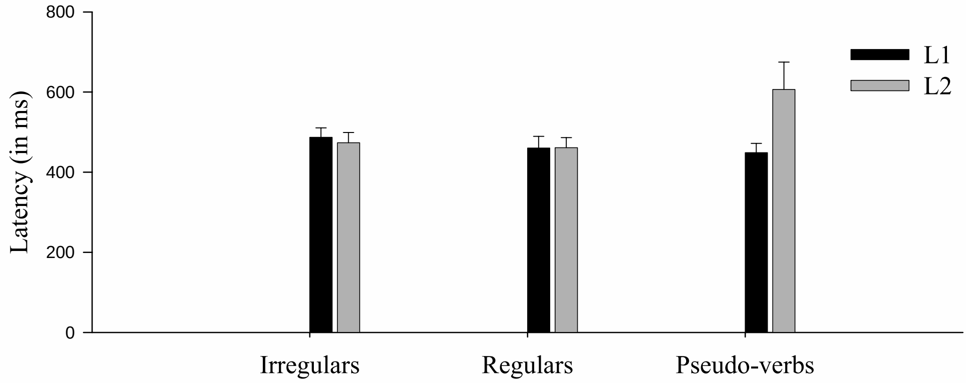

Figure 6. Latency to generate the past tense of irregular verbs, regular verbs, and pseudo-verbs, in L1 and L2.

4.4 Frequency effects

A subset of 22 low-frequency and 18 high-frequency, irregular and regular verbs, matched pair-wise on past tense frequency across verb type and language was used to test for frequency effects. Low-frequency irregular and regular verbs have a mean past tense frequency of 1.1 and 1.2 respectively, this for both the English and French versions. High-frequency irregular verbs have a mean past-tense frequency of 4.1 and 4.0 for the English and French versions, respectively; high frequency regular verbs have a mean past-tense frequency of 3.9 and 4.0 for the English and French versions, respectively.

A repeated measures Group (NC, PD) X Verb Type (Regular, Irregular) X Verb Frequency (Low, High) X Language (L1, L2) ANOVA was conducted on the latency. There was a significant main effect of Language ($F[1, 17 = 7.53$, $p = .014$) and a significant Language X Frequency interaction effect ($F[1, 17 = 5.33$, $p = .034$). These were moderated by a trend toward a significant Language X Frequency X Verb Type interaction effect ($F[1, 17 = 3.54$, $p = .077$). Tukey A post-hoc tests did not reveal any significant frequency effect, defined as a difference in the latency to respond to low versus high-frequency items within a specific verb/language condition. Significant differences ($p_s < .05$) were limited to latency for low frequency regular verbs in L2 being significantly higher than that for any of the four L1 conditions, and latency for low frequency irregular verbs in L2 being longer than that for L1 regular verbs (low and high frequency) and L1 high frequency irregular verbs. This effect is depicted in Figure 7.

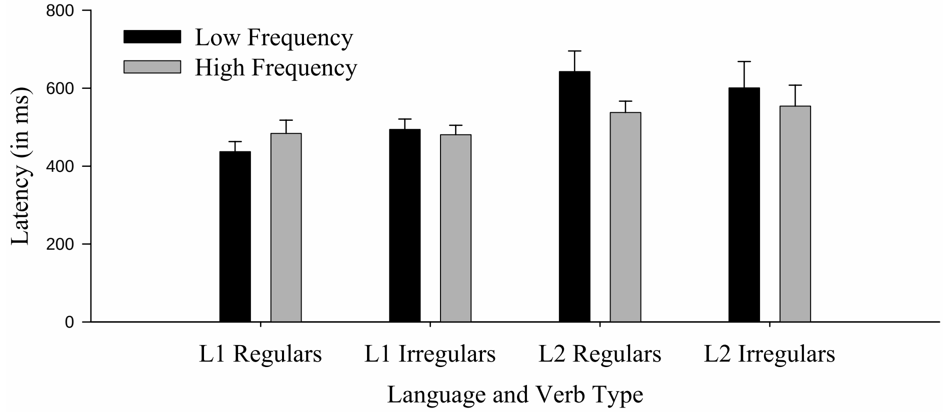

Figure 7. Latency to generate the past tense of irregular verbs, regular verbs, and pseudo-verbs, in L1 and L2.

An alternative way to test for frequency effects is to test the correlation between past tense frequency and response latency. Separate correlations were computed for each participant group, and for all participants combined. The correlations were computed separately for each language. Pearson's r was computed between past tense frequency and latency while controlling for stem frequency. All tests of significance are one-tailed because latency was expected to increase with decreasing past tense frequency. The results are reported in Table 4.

Table 4.
Correlation coefficients and probability levels of correlations between past tense frequency and verb tense generation, for the NC, PD, and AD, groups, and for all participants combined.

Gr		L1 Irregulars	L1 Regulars	L2 Irregulars	L2 Regulars
NC	n = 8	French r (47) = -.02 p = .440	French r (47) = -.05 p = .371	English r (41) = -.11 p = .232	English r (40) = -.01 p = .477
	n = 2	English r (40) = -.05 p = .375	English r (40) = .12 p = .226	French r (43) = .10 P = .252	French r (46) = -.11 p = .237
PD	n = 7	***French*** ***r (47) = -.24*** ***p = .047****	French r (47) = .10 p = .243	English r (41) = -.09 p = .285	English r (40) = -.06 p = .343
	n = 2	English r (41) = .07 p = .339	English r (39) = -.03 p = .432	French r (42) = -.17 p = .132	French r (47) = -.04 p = .381
AD	n = 2	French r (34) = -.13 p = .225	French r (43) = -.15 p = .156	English r (31) = .14 p = .225	English r (34) = -.15 p = .191
All	n = 15	***French*** ***r (47) = -.19*** ***p = .091(*)***	French r (47) = -.09 p = .262	English r (41) = .08 p = .310	English r (40) = -.19 p = .116
	n = 4	English r (41) = .02 p = .452	English r (40) = .02 p = .443	French r (45) = -.03 p = .410	French r (47) = -.09 p = .260

5. Discussion

Evidence was obtained for a double dissociation in the performance of AD and PD patients on tests of declarative and procedural memory: Despite poor declarative memory, the mildly demented AD patient was able to acquire a skill and to learn a sequence. The PD group, by contrast, was unable to acquire a skill but remembered words and designs very well. A similar dissociation was observed on the PTG, with AD patients making more specific errors for irregular verbs than the NC group, and PD patients irregularizing more pseudo-verbs than the NC group. The results are discussed in more detail next, for each participant group.

5.1 Memory and language in normal controls

The NC group remembered simple designs and learned a word list very well, on the BEM and RAVLT, respectively. They were able to learn to read words that were printed backwards on the mirror-reading task, and their performance improved with repetition on a test of implicit learning (SRT). The BEM and RAVLT results document good declarative memory, suggestive of intact medial temporal lobe functions, whereas the mirror-reading task and SRT results confirm normal procedural memory, indicative of healthy basal ganglia and basal-ganglia related circuitry. In sum, the memory findings were just as expected for a sample of healthy older adult.

The performance of the NC group on the PTG was 96% accurate in L1 and 92% accurate in L2. This level of accuracy approximates that reported by Ullman et al. (1997) who tested participants in L1 only. Verb type did not have an effect on accuracy in L1: Errors in producing the past tense of irregular verbs, regular verbs, and pseudo-verbs, were equally rare. By contrast, verb type had a significant effect on accuracy in L2, with subjects making more errors for irregular verbs than for regular verbs and pseudo-verbs. This finding may appear inconsistent with the hypothesis that the past tense generation of both irregular and regular verbs, in L2 only, is supported by declarative memory. However, the past tense of irregular verbs can be conceptualized as requiring more memorization than that of regular verbs. For instance, a student learning English as an L2 likely needs to spend more time studying the list of exceptions (e.g., “teach-taught”, “think-thought”, etc) than the list of regular verbs (e.g., “walk-walked”, “talk-talked”, etc). As such, the past tense of irregular verbs may be more vulnerable to forgetting than that of regular verbs, explaining the difference in accuracy between the irregular and regular verbs conditions in L2. Of course, it is also possible that for some of the irregular verb errors, the participant had never learned the correct past tense form to begin with. This is much more likely to occur in L2 than in L1, possibly explaining why accuracy was reduced for irregular verbs in L2 but not in L1. These hypotheses receive support from the fact that participants reported using their L1 in 60% of their current daily activities, and had a history of predominant L1 use.

Latency to generate the correct verb inflection was equivalent for regular and irregular verbs, in L1 and L2, with no significant difference between L1 and L2. In L1, the past tense of pseudo-verbs was generated as fast as that of regular and irregular verbs, but in L2, subjects took significantly longer to generate the past tense of pseudo-verbs than to generate that of regular and irregular verbs. This result can also be attributed to a difference in the amount of exposure to L1 and L2 that NC participants received over the years. Despite the fact that pseudo-verbs appeared on the computer monitor whereas real verbs did not, many participants asked: “Is ___ a verb in English/French?” These questions were raised in L2 only, and may reflect the fact that the participants were more likely to know, or trust that they know, most L1 but not L2 verbs.

Contrary to expectations, verb past tense frequency did not affect the time that it took NC participants to generate the past tense of irregular L1 and L2 verbs, or L2 regular verbs. It had been hypothesized that the past tense of high frequency irregular verbs would be generated faster than that of low frequency irregular verbs, in both L1 and L2, since these must be retrieved from declarative memory. Past tense frequency was expected to have a comparable effect, though perhaps weaker, on the latency to generate the past tense of regular verbs in L2 since these were mostly learned using declarative memory. The failure to detect frequency effects in this study may be due to the small sample size. Alternatively, it may be attributable to a methodological limitation. The sentences were presented over speakers and the participant was asked to listen and generate the verb. It was thought that spoken sentences would elicit implicit linguistic competence and minimize the likelihood that participants would treat the sentences and the verbs in a declarative manner. The disadvantage of this method was that the participants had time to retrieve from memory or to productively generate the past tense of the stems, while the sentences were being played. To discourage participants from doing so, the sentences were built such that the correct inflection could not be produced until the very last few words. In English, the participants could not answer correctly before hearing "yesterday I ___" or "tomorrow I will be ___", and in French, they could not respond before hearing "pendant que [name] ____" or "pendant que nous ____". This manipulation was ideal in English, as the participant could not prepare the stem part of the response in advance (e.g., TAUGHT or TEACHing). In French however, the stem change required to generate the past tense of irregular verbs is the same for the third person singular as for the first person plural (e.g., "bois-buvait" or "bois-buvions"). Thus, if a participant had been keen on answering correctly, generating the stem change early on could have been a strategy (e.g., BUVais or BUVions). This methodological factor is to consider because 80% of the participants were native French speakers. Finally, frequency effects have not been tested to our knowledge in older adults. It is possible that aging affected how regular and/or irregular verbs are processed in L1 and/or L2.

5.2 *Memory and language in AD*

Both patients displayed deficits on the tests of declarative memory. The mildly demented AD patient (AD1) remembered simple designs well, on the BEM, but the moderately impaired AD patient (AD2) did not. Although AD1 remembered an adequate number of words on the RAVLT, his performance was consistently poorer than that of the NC group on all of the measures (see Figure 2). AD2 exhibited clear difficulty learning the list of words, and was incapable of recalling any of the words after an interference trial, and after a delay.

By contrast, AD 1 was able to learn to read words printed backward as well as the NC group. His performance on a test of implicit sequence learning (SRT) was almost indistinguishable from that of the healthy participants. These findings are indicative of good procedural memory in the context of declarative memory deficits, and suggest impairments in medial temporal lobe function with relative sparing of the basal ganglia and basal-ganglia related circuitry.

AD2 was not able to do the mirror-reading test. To succeed on this test, the participant has to identify the letters, combine them, and retrieve from his/her lexicon an entry that matches the visual input. To avoid a ceiling effect in the NC group, the mirror-reading words were selected to be of low frequency. AD2 appeared unable to retrieve these words from lexical memory. Participant AD2 completed the test of implicit sequence learning (SRT), but his performance was abnormal. This may have been due to an inability to sustain attention for the entire 20-min period, as evidenced by the fact that this patient forgot what the task involved on a few occasions.

In L1, the accuracy performance of the AD patients was almost identical to that of the NC group for the inflection of pseudo-verbs, suggesting that their ability to implement the "+ed" or "+[ε]" procedure was intact. They were less accurate than the NC group in generating the past tense of irregular and regular verbs. Their difficulty inflecting the past tense of irregular verbs was just as predicted since the past tense of irregular verbs must be retrieved from declarative memory.

However, their difficulty inflecting regular verbs in L1 was unexpected since the past tense of regular verbs in L1 is generated productively, according to the dual-system model of verb inflection. Also, since AD patients performed like the NC participants in the pseudo-verb condition, why did they not perform normally in the regular verb condition? The pseudo-verb condition differed from the other two verb conditions in this respect: The stem remained displayed on the computer monitor until the participant responded. By contrast, in the regular and irregular verb conditions, the stem was presented in the auditory modality only, and had to be kept in working memory while the rest of the sentence was played over speakers. A deficit in working memory would thus affect performance in both the regular and irregular conditions, sparing performance in the peudo-verb condition. Even if

AD participants retained the ability to implement a procedure to generate the past tense of regular verbs, they could not be expected to generate correct outputs if they forgot the stem that had to be inflected. In fact, the most common type of errors that the AD participants made for regular verbs was to produce the past tense, correctly inflected, of a different verb. When specific errors were examined, AD patients were no more likely than the NC group to irregularize regular verbs, to leave them unmarked, or to inflect them in an inappropriate tense.

In L2, the pattern of performance of the AD patients, when combined, was similar to that of the NC group, though somewhat weaker. The failure to find a large difference between AD patients and the NC group for irregular verbs in L2 may be attributable to the fact that the NC participants made more errors for irregular verbs in L2, relative to all other conditions, and displayed much variability.

As expected the AD patients did not display frequency effects: There was no significant correlation between latency and past tense frequency, and no significant difference in the latency to generate the past tense of high versus low-frequency verbs. This finding was expected, since frequeny effects reflect successful retrieval from declarative memory, and the AD patients were shown to have impaired declarative memory. However, because the NC group failed to show the expected pattern of frequency effects, this interpretation cannot be made.

In sum, AD patients made specific errors selectively in generating the past tense of irregular verbs in L1 and L2. This finding replicates Ullman et al. (1997) in L1, and provides additional support, from L2 performance, for the involvement of declarative memory, and mesial temporal lobe structures, in the generation of the past tense of irregular verbs. The pattern of specific errors made by the AD participants may also highlight the lack of correspondence between declarative memory and the ability to inflect regular verbs and pseudo-verbs.

5.3 Memory and language in PD

As expected, the PD group performed as well as the NC group on non-verbal and verbal tests of declarative memory, the BEM and RAVLT respectively. Compared to the NC participants who became faster at reading the mirror image of words with practice, PD patients did not show learning. Their reading time remained approximately the same despite reading over 450 words backwards, replicating Deweer et al. (1994). Overall, the memory findings provide indication of impaired procedural memory in the context of good declarative memory, and suggest impairments in the basal ganglia and/or basal-ganglia related circuitry with relative sparing of medial temporal lobe function.

In the non-verbal domain, however, we failed to replicate Westwater et al. (1998). The NC group displayed implicit sequence learning on the SRT and so did the PD group. This learning was expressed as follows: The naming latency of the two groups was significantly higher on Block 5, in which the asterisk appeared randomly at one of four locations at the bottom of the computer monitor, than on Block 4, in which the asterisk appeared in the same sequence for the 40^{th} to 50^{th} time. This difference in RT between Blocks 5 and 4 could be an accurate reflection of sequence learning in PD or it could be the result of fatigue. The SRT took approximately 20 min to complete. For this length of time, the participant had to look at the computer monitor and attend to the asterisk. This test was always the last memory test to be administered, and several participants inquired about the duration of the SRT. Fatigue may have partly contributed to the increase in naming latency observed on the last block, Block 5, which was also the randomized block. If so, it is likely that PD patients experienced greater fatigue than did NC participants. As a consequence, fatigue could have increased the learning score (naming latency in Block 5 minus Block 4) of PD participants relative to that of the NC participants. In sum, it is possible that a mild deficit in sequence learning in PD patients went undetected on the SRT because of the confounding effect of fatigue.

Before the performance of the PD group on the PTG is discussed, a challenge that is specific to testing the hypotheses made for this group must be described. If a participant cannot retrieve the past tense of an irregular verb from declarative memory, he/she cannot compensate by implementing a procedure. Failure to retrieve the past tense of an irregular verb from declarative memory will necessarily result in an incorrect output. By contrast, if a participant cannot implement a procedure on-line to inflect a regular verb, he/she can compensate by either retrieving the form from declarative memory (whether it is stored as "walked" or "walk+ed", for instance) or retrieve the rule explicitly (+ed) and apply it to the input in a controlled manner. The use of either compensatory strategy would result in a correct inflection being produced. A defect in L1 grammar may therefore be difficult to detect on the PTG.

The overall accuracy of the PD group in generating the past tense of regular verbs, irregular verbs, and pseudo-verbs, in L1 and L2, was almost identical to that of the NC group. The specific errors made by the PD group were also very similar to that of the NC group, with this exception: PD patients displayed a tendency to irregularize pseudo-verbs whereas NC participants did not. The PD group did not however irregularize regular verbs any more than the NC group, nor did they leave more regular verbs unmarked, or inflect more regular verbs in the wrong tense. A possible explanation is that the PD patients were impaired in implementing a procedure to generate the past tense of regular verbs in L1, but were able to compensate by retrieving the correct output from declarative memory or by applying the "+ed" or "+ [ɛ]" procedure in a controlled fashion. Frequency effects for regular verbs in L1 for PD patients could have provided evidence supporting the hypothesis that the past tense of regular verbs had been retrieved from declarative memory. However, results from the frequency analyses cannot be interpreted meaningfully because the NC group did not show the expected pattern of frequency effects.

Alternatively, it is possible that the PD group was not impaired in generating the past tense of regular verbs in L1 because it is generated through the same mechanism that generates the past tense of irregular verbs in healthy individuals. A prominent model of verb inflection is the dual-system model, which has been used to guide our hypotheses. An alternate model is based on the connectionist approach to verb inflection. Based on this approach, the past tense of regular and irregular verbs is generated through a common mechanism that is dependent jointly on phonology and semantics (e.g., Joanisse & Seidenberg, 1999).

Ullman et al. (1997) provided evidence for the dual-system model by showing that AD patients are selectively impaired in generating the past tense of irregular verbs and PD patients in generating the past tense of regular verbs and pseudo-verbs. Connectionists argue that PD patients experienced difficulty inflecting regular verbs in English because of a phonological deficit and that AD patients were impaired in inflecting irregular verbs because of a semantic deficit. For French, however, deficits in inflecting regular verbs can less convincingly be attributed to a defect in phonology. In contrast to the subtle [t] or [d] sound that selectively marks the past tense of regular verbs in English, the [ɛ] sound that marks the imperfect in French is more easy to perceive and produce. In addition, the [ɛ] sound must be placed at the end of both regular and irregular verbs to mark the imperfect. This difference in the demand characteristics of the French and English versions of the PTG, combined with the connectionist posit that PD patients have difficulty inflecting regular verbs in English because of a phonological deficit, could explain why findings from the literature were not replicated in this study, which included mostly French native-speakers.

5.4 Conclusions

A double dissociation was observed in the verbal modality between the performance of AD and PD patients on tests of declarative and procedural memory, with the PD group being selectively impaired on a test of procedural memory and the AD group showing stronger impairment on the tests of declarative memory. An examination of the specific errors that NC participants, and PD and AD patients, made on the PTG provided partial evidence of a double dissociation in language ability. AD patients were impaired in generating the past tense of irregular verbs, relative to the NC group, whereas PD patients were not. PD patients displayed a tendency to irregularize pseudo-verbs whereas NC participants and AD patients did not. These dissociations are as predicted given the declarative memory and procedural memory deficit of AD and PD patients, respectively. A limitation of the reaction time data was the failure to observe normal frequency effects in the NC group. These preliminary results are based on a small sample size. More participants will be tested and future analyses may lead to more conclusive findings.

References

Baudot, J. (1992). Fréquences d'utilisation des mots en français écrit contemporain. Montreal: Presses de l'Université de Montréal.

Beauchemin, N., Martel, P., & Théoret, M. (1992). Dictionnaire de fréquences des mots du français parlé au Québec. New York: Peter Lang Publishing.

Bescherelle (1981). Le nouveau Bescherelle 1. L'Art de conjuguer. Dictionnaire de 12000 verbes. Quebec: Éditions Hurtubise.

Birdsong, D. (1999). Second language acquisition and the critical period hypothesis. New Jersey: Lawrence Erlbaum Associates.

Brovetto, C., & Ullman, M. T. (2001). First vs. Second language: A differential reliance on grammatical computations and lexical memory. Paper presented at the CUNY 2001 Conference on Sentence Processing, Philadelphia, Pennsylvania.

Cohen, N. (1984). Preserved learning capacity in amnesia: Evidence for multiple memory systems. In L. R. Squire and N. Butters (Eds.), The Neuropsychology of Human Memory (pp. 83-103). New York: Guilford Press.

Cohen, N. J., & Squire, L. R. (1980). Preserved learning and retention of pattern-analyzing skill in amnesia: dissociation of knowing how and knowing that. Science, 210, 207-210.

Cummings, J. L., Darkins, A., Mendez, M., Hill, M. A., & Benson, D. F. (1988). Alzheimer's disease and Parkinson's disease: Comparison of speech and language alterations. Neurology, 38 (5), 680-684.

Damasio, A. R. (1992). Aphasia. New England Journal of Medicine, 326, 531-539.

Deweer, B., Ergis, A. M., Fossati, P., Pillon, B., Boller, F., Agid, Y., & Dubois, B. (1994). Explicit memory, procedural learning and lexical priming in Alzheimer's disease. Cortex, 30, 113-126.

Deweer, B., Pillon, B., Michon, A., & Dubois, B. (1993). Mirror readings in Alzheimer's disease: Normal skill learning and acquisition of item-specific information. Journal of Clinical and Experimental Neuropsychology, 15 (5), 789-804.

De Santi, S., Obler, L. K., Sabo-Abramson, H., & Goldberger, J. (1989). Discourse abilities and deficits in multilingual dementia. In Y. Joanette and H. Brownell (Eds.). Discourse abilities in brain damage: Theoretical and empirical perspectives. New York, NY: Springer.

Fabbro, F. (1999). The neurolinguistics of bilingualism: An introduction. Hove: Psychology Press.

Francis, N., & Kucera, H. (1982). Frequency analysis of English usage: Lexicon and grammar. Boston: Houghton Mifflin.

Gabrieli, J. D. E. (1998). Cognitive neuroscience of human memory. Annual Review of Psychology, 49, 87-115.

Goodglass, H. (1993). Understanding aphasia. San Diego, CA: Academic Press.

Grossman, M. (1999). Sentence processing in Parkinson's disease. Brain and Cognition, 40 (2), 387-413.

Hodges, J. R., Salmon, D. P., & Butters, N. (1992). Semantic memory impairment in alzheimer's disease: Failure of access or degraded knowledge? Neuropsychologia, 30, 301-314.

Hoehn, M. M., & Yahr, M. D. (1976). Parkinsonism: Onset, progression and mortality. Neurology, 17, 427-442.

Hyltenstam, K., & Stroud, C. (1989). Bilingualism in Alzheimer's dementia: Two case studies. In K. Hyltenstam and L. K. Obler (Eds.). Bilingualism across the lifespan: Aspects of acquisition, maturity, and loss. Cambridge, MA: Cambridge University Press, 202-226.

Hyltenstam, K., & Stroud, C. (1993). Second language regression in Alzheimer's dementia. In K. Hyltenstam and A. Viberg (Eds.). Progression and regression in language. Cambridge, MA: Cambridge University Press, 222-242.

Hyman, B. T., Van Hoesen, G. W., Damasio, A. R., & Barnes, C. L. (1984). Alzheimer disease: cell-specific pathology isolates the hippocampal formation. Science, 225, 1168-1170.

Joanisse, M. F., & Seidenberg, M. S. (1999). Impairments in verb morphology after brain injury: A connectionist model. Proceedings from the National Academy of Sciences, 96, 7592-7597.

Johnson, J. S., & Newport, E. L. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. Cognitive Psychology, 21, 60-99.

Knopman, D. S., & Nissen, M. J. (1987). Implicit learning in patients with probable Alzheimer's disease. Neurology, 37, 784-788.

Koenig, O., Thomas-Antérion, C., & Laurent, B. (1999). Procedural learning in Parkinson's disease: Intact and impaired cognitive components. Neuropsychologia, 37, 1103-1109.

Lewis, F. M., Lapointe, L. L., Murdoch, B. E., & Chenery, H. J. (1998). Language impairment in Parkinson's disease. Aphasiology, 12 (3), 193-206.

Lezak, M. D. (1995). Neuropsychological Assessment (3rd ed.). New York: Oxford University Press.

Mathews, P. J., Obler, L. K., & Albert, M. L. (1994). Wernicke and Alzheimer on the language disturbances of dementia and aphasia. Brain and Language, 46, 439-462.

Marcus, G. F., Brinkmann, U., Clahsen, H., Wiese, R., & Pinker, S. (1995). German inflection: The exception that proves the rule. Cognitive Psychology, 29, 189-256.

McDowell, F. H., Lee, J. E., & Sweet, R. D. (1978). Extrapyramidal disorders. In A. B. Baker and L. H. Baker (Eds.), Clinical Neurology. New York: Herper & Row.

Mendez, M. F., Perryman, K. M., Ponton, M. O., & Cummings, J. L. (1999). Bilingualism and dementia. Journal of Neuropsychiatry and Clinical Neuroscience, 11 (3), 411-412.

Obler, L. K. (1999). Language in dementia: Implications for neurolinguistic theory. International Workshops on Language, Brain and Behavior. Jornades Cientifiques de l 'Institut d' Estudis Catalans (IEC), 63-72.

Orsolini, M., Fanari, R., & Bowles, H. (1998). Acquiring regular and irregular inflection in a language with verb classes. Language and Cognitive Processes, 13 (4), 425-464.

Paradis, M. (1987). The assessment of bilingual aphasia (reference manual for the BAT). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Paradis, M. (1994). Neurolinguistic aspects of implicit and explicit memory: Implications for bilingualism and SLA. In N. Ellis (Ed.), Implicit and explicit learning of languages (pp. 393-419). London: Academic Press.

Paradis, M. (1997). The cognitive neuropsychology of bilingualism. In A. M. B. de Groot & J. F. Kroll (Eds.), Tutorials in bilingualism: Psycholinguistic perspectives (pp. 331-354). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Paradis, M. (1998a). Language and communication in multilinguals. In B. Stemmer & H. A. Whitaker (Eds.), Handbook of neurolinguistics (pp. 417-430). San Diego: Academic Press.

Paradis, M. (1998b). The other side of language: Pragmatic competence. Journal of Neurolinguistics, 11 (1-2), 1-10.

Paradis, M. (1999). Language in dementia: Implications for neurolinguistic theory. Comment by M. Paradis. International Workshops on Language, Brain and Behavior. Jornades Cientifiques de l 'Institut d' Estudis Catalans (IEC), 73-76.

Pinker, S. (1999). Words and rules: The ingredients of language. New York, NY: Basic Books.

Pulvermüller, F., & Schumann, J. H. (1994). Neurobiological mechanisms of language acquisition. Language Learning, 44 (4), 681-734.

Rose, Y., & Royle, P. (1999). Uninflected structure in familial language impairment: Evidence from French. Folia Phoniatrica et Logopaedica, 51, 70-90.

Signoret, J. L. (1991). Batterie d'Efficience Mnésique BEM-144. Paris: Elsevier.

Spreen, O., & Strauss, E. (1991). A compendium of neuropsychological tests: administration, norms and commentary. New York: Oxford University Press.

Ullman, M. (1999). Acceptability ratings of regular and irregular past-tense forms: Evidence for a dual-system model of language from words frequency and phonological neighborhood effects. Language and Cognitive Processes, 14 (1), 47-67.

Ullman, M. (2001). The declarative/procedural model of lexicon and grammar. Journal of Psycholinguistic Research, 30 (1), 37-69.

Ullman, M., Corkin, S., Coppola, M., Hickok, G., Growdon, J. H., Koroshetz, W. J., & Pinker, S. (1997). A neural dissociation within language: Evidence that the mental dictionary is part of declarative memory, and that grammatical rules are processed by the procedural system. Journal of Cognitive Neuroscience, 9 (2), 266-276.

Ullman, M. T., & Gopnik, M. (1999). Inflectional morphology in a family with inherited specific language impairment. Applied Psycholinguistics, 20, 51-117.

Weber-Fox, C., & Neville, H. J. (2001). Sensitive periods differentiate processing of open- and closed-class words: An ERP study of bilinguals. Journal of Speech, Language, and Hearing Research, 44 (6), 1338-1353.

Westwater, H., McDowall, J., Siegart, R., Mossman, S., & Abernethy, D. (1998). Implicit learning in Parkinson's disease: Evidence from a verbal version of the serial reaction time task. Journal of clinical and experimental neuropsychology, 20 (3), 413-418.

ISB4: Proceedings of the 4th International Symposium on Bilingualism

edited by James Cohen, Kara T. McAlister, Kellie Rolstad, and Jeff MacSwan

Cascadilla Press Somerville, MA 2005

Copyright information

ISBN 978-1-57473-210-8 CD-ROM
ISBN 978-1-57473-107-1 library binding (5-volume set)

Ordering information

To order a copy of the proceedings, contact:

Cascadilla Press
P.O. Box 440355
Somerville, MA 02144, USA

phone: 1-617-776-2370
fax: 1-617-776-2271
sales@cascadilla.com
www.cascadilla.com

Web access and citation information

This paper is available from www.cascadilla.com/isb4.html and is identical
to the version published by Cascadilla Press on CD-ROM and in library binding.