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Second language performances in elderly bilinguals and individuals with dementia: The role of L2 immersion

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With the population aging and an increase in the number of senior immigrant citizens in modern societies, public health systems will be increasingly burdened with the need to deal with the care and treatment of bi- or multilingual individuals with cognitive decline and dementia. This raises complex questions such as which language is better preserved in these elderly individuals, particularly for those facing dementias.

The main aim of the present investigation was to study in two groups of immigrant populations whether the first language (L1) or the second language (L2) are better preserved. For this purpose, we assessed by means of cognitive and neurolinguistics testing 20 late-bilingual individuals with neurodegenerative dementia of the Alzheimer and mixed type, and compared their results to a matched control group consisting of 19 subjects.

Our results suggest that L1 is not better preserved in individuals with dementia. We report a parallel decline of second language across groups, regardless of the presence of dementia, as well as a significant correlation between language immersion and L2 relative performances ($r = 0.379$, $p = 0.03$). Moreover our data suggest that individual with dementia may have a relative sparing of syntactic L2 comprehension. These results suggest that these elderly individuals who have lived in a host country for many years, such as the subjects here investigated, may preserve similarly their L2 as much as their L1, irrespectively of the presence or absence of neurodegenerative disease, and even preserve some features of L2 processes in dementia. These results emphasize the role of immersion in language preservation.

1. Introduction

Cognitive decline in elderly populations is usually associated with decreasing attentional abilities, thus potentially affecting language performance in general, and also the ability to speak several languages (Ardila & Ramos, 2008; Costa et al., 2012). Neurodegenerative dementias, such as Alzheimer's disease, have also been associated with language impairment, independently of the linguistic status of the individual. Lexico-semantic aspects of language are classically affected earlier in the disease process, impacting word-retrieval and speech fluency (Kemper et al., 1993). Naming, written language and verbal

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comprehension for words and sentences can also be affected. Automatic aspects of language are classically preserved longer and are progressively impaired only in the late phase of the disease (Faber-Langendoen et al., 1988; Mendez, Perryman, Pontón, & Cummings, 1999; Paradis, 2008). Moreover, language control can be altered in individuals with dementia, resulting in involuntary intrusion by the dominant language during conversation into the other language (Mendez et al., 1999).

Although language proficiency in elderly bilinguals is not necessarily poor and is function of many determinants, some studies have suggested a faster deterioration of the second language (L2) (Ardila & Ramos, 2008; Mutchler & Brallier, 1999). The discussion as to whether the first language (L1) or L2 is more affected by cognitive decline goes back to the early days of neuropsychology. Indeed, in the late 19th century, French neurologist Ribot (1882) claimed that cognitive functions appearing late during phylogeny and ontogeny are among the earliest to show signs of decline during aging (i.e., last in, first out). In the case of bilinguals, especially when L2 is not learnt from birth onwards, this would be translated into an earlier loss of L2. Because of the way in which memories are created, earlier and embodied memories may be more strongly connected to the first language, whereas later acquired memories will be associated with explicit language processing at the time of the experience, particularly for L2 (Paradis, 2008; Ullman, 2001). Since earlier memories or highly automatized processes are better preserved in dementia, one could expect the associated L1 to be less affected by incipient cognitive decline. In addition, the procedural and declarative memory system is a determining factor in the use and hence the loss of language. Alzheimer's disease (AD) tends to affect declarative memory first, while procedural memory is preserved longer (Gómez-Ruiz, Aguilar-Alonso, & Espasa, 2012). A late bilingual relies more on declarative memory for L2, which may also be less automatic and less efficient than for L1 (Birdsong, 2006) hence L2 may be more affected by AD. Moreover, according to the principles of the adaptive control model (Green & Abutalebi, 2013.), aging may interfere with language control abilities that in turn may preferentially affect the less available language (usually the one in which the speaker is less proficient or to which the speaker is less exposed to), and hence resulting into a lesser availability of that particular language. L2 proficiency and L2 exposure are key features to be investigated in the elderly, since both have been linked to increased grey matter densities in the aging brain: higher L2 proficiency is associated with increased grey matter density in anterior temporal lobe areas (Abutalebi et al., 2014) while higher L2 exposure is associated with increased grey matter densities in the inferior parietal lobules (Abutalebi, Canini, Della Rosa, Green, & Weekes, 2015). Both areas are sensitive to aging (i.e., cortical thinning) and these effects are most prominent in dementia (Domoto-Reilly, Sapolsky, Brickhouse, Dickerson, & Alzheimer's Disease Neuroimaging Initiative, 2012).

As to the focus of our research, only a few systematic experimental studies have addressed the interesting issue of which language is more affected by cognitive decline, with quite opposing results. For example, in a study of early, high-proficient Catalan-Spanish bilinguals with AD, increasing severity of the disease was associated with decreased performance in picture naming and word translation in both L1 and L2, hence showing that both languages are similarly affected (Costa et al., 2012). Similar results with parallel impairment of both languages were also found in late bilinguals, regardless of the age of acquisition of L2 (Manchon et al., 2015). On the other hand, a greater sensitivity of L1 to cognitive decline in dementia has also been described. In a study of elderly English-Spanish bilinguals, both early and late bilinguals had higher naming scores in their non-dominant language, suggesting a greater sensitivity of L1 to Alzheimer's dementia (Gollan, Salmon, Montoya, & da Pena, 2010). This result was attributed by the authors to the fact that the connections from conceptual representations to the language area are stronger in the dominant than the non-dominant language. Since both languages share the same brain regions in proficient bilinguals, the probability that any damage caused by a neurodegenerative disease will affect a language, all the more so if primarily directed to the semantic representations, is higher for the more represented (first) language.

A review paper selected nine articles out of 186 relevant articles on the topic and their results suggest that both languages are equally affected by AD. Production of the non dominant language was more impaired, but this was the case both for controls and patients. (Stilwell, Dow, Lamers, & Woods, 2016). However, in many of these studies, the role of immersion itself, although explicitly mentioned, has been less specifically analyzed. This point seems important to be calculated in such studies, as it has been done in experimental studies on healthy bilinguals. A study investigated the effects of immersion on the language learning process of L2 (Spanish) and on L1 (English) in a group of American students studying abroad in Spain, compared to another group of students, only exposed to Spanish at school during class. The students were tested on a translation-recognition task and a verbal-fluency task. The immersion group performed better on both comprehension and production task in L2. Their results also showed a diminished access to L1 in the immersed group (Linck, Kroll, & Sunderman, 2009).

In the present study, we investigated a group of elderly late L2 acquisition bilinguals in the early and moderate stages of AD, and a healthy bilingual control group, who acquired French as a second language and remained immersed in a French-speaking environment. The pattern of oral language impairment, for both comprehension and production of language, was examined and correlated with language immersion and proficiency. Thus, our study aimed at investigating the pattern of differential language impairment in these bilingual individuals with AD relative to bilingual controls exposed to similar L2 immersion.

2. Methods

2.1. Subjects

The study was conducted on 20 individuals with dementia (13 females) and 19 controls (11 females). Both groups were recruited through the Neurology Departments of the hospitals of Fribourg, Lausanne and Geneva, in Switzerland. Some of the subjects had previously been tested in a pilot study (Manchon et al., 2015). All individuals with dementia had acquired French

as a second language after the age of seven. Their first language was German for fourteen individuals, Spanish for two and Italian for four. These individuals were compared to 19 cognitively healthy bilinguals. These controls fulfilled the same bilingualism criteria. Thirteen had German as L1, two Spanish and four Italian. Our subjects were Swiss German-speaking participants using mostly a swiss german dialect and german in official setting. There was no difference in the MMSE between German speaking and non-German speaking L1 and L2. As to demographic data, the 20 individuals with dementia and the 19 controls were respectively $75.5, \pm 5.6$ years, and 69.1 ± 8.5 years old (unpaired *t*-test, $t = 2.6$, $p = 0.014$). There was no significant difference in their level of education (respectively, 9.60 ± 2.76 and 11.41 ± 3.22 , $t = -1.82$, $p = 0.078$) and they were all late bilinguals (age of L2 acquisition at > 7 years old). The mean age of L2 acquisition was slightly higher in the controls (20.4 years old) than in the individuals with dementia (14.7 years old). Global cognitive functioning and dementia severity was assessed through the Mini Mental State Examination (MMSE, max score 30).

The individuals with dementia had been clinically diagnosed by cognitive neurologists as having degenerative or mixed dementia. Sixteen had probable and three possible Alzheimer's type dementia (McKhann et al., 2011); these last three individuals had neuroimaging pattern of mixed Alzheimer's and vascular dementia. However since these three subjects had a neuropsychological pattern suggestive of underlying Alzheimer disease, with encoding memory deficit and multi-domain impairment, and they were treated as a homogenous group. Subjects with unaided sensory disorders, other causes of dementia (notably Parkinson's dementia), major psychiatric disorders or other major illnesses were excluded from the study. The study was approved by the local Ethics Committee (Protocol 279/11). All subjects were given appropriate information and signed an informed consent form.

2.2. Evaluation of bilingualism

Proficiency and immersion in L2 were assessed using internally-developed questionnaires (scored by the examiner based on the patient's answers and validated by the family) (Tschirren et al., 2011) and consisting of a visual analogue scale. Proficiency in L2 was assessed on subjective visual scales for speaking, understanding, reading and writing and scores were reported as percentages, with the left end of the scale representing 0% and the right end representing 100%. Subjects were asked about their age of L2 acquisition and the duration of immersion in a French-speaking environment. Languages known by the subjects and used to communicate with their parents and partners were listed. Subjects were asked to estimate lifelong daily use and exposure of both languages and report them as percentages of use, starting from childhood (i.e., % of time for L1 and L2 spoken at home, at school, etc.) to the present day (i.e., % of time for L1 and L2 used at work, to watch television, to read a book, talk to friends, etc).

These questionnaires rated L2 proficiency at the level of oral and written expression, oral comprehension and reading in L2 (French), levels of exposure to and use of L1 and L2 as a percentage frequency of the languages used in childhood and languages currently spoken within the family (Tschirren et al., 2011).

The group of individuals with dementia matched the control group in all criteria evaluating the level of bilingualism except for the duration of L2 immersion, which was 11 years longer in individuals with dementia (55 years) than in controls (44 years). Table 1 reports the mean values, standard deviations and ranges for these variables for each group and the differences between both groups (unpaired *t*-test).

2.3. Evaluation of oral language

Language abilities were assessed for all subjects on different aspects of oral comprehension and production in both languages using several tests.

Table 1
Linguistic characteristics of individuals with dementia and controls.

Level of bilingualism	Individuals with dementia		Control subjects		P values
	Mean	SD	Mean	SD	
Level of expertise of L2 (French)					
Speak L2 (%)	85.74	14.24	80.42	11.75	0.258
Understand L2 (%)	89.37	12.08	86.32	13.22	0.588
Write L2 (%)	58.26	33.36	61.26	28.98	0.912
Read L2 (%)	77.90	24.71	75.68	23.60	0.709
Global L2 expertise	77.82	13.89	75.92	10.70	
Childhood before 6 years					
L1 taught at school (%)	86.84	31.59	98.68	5.74	0.129
L1 spoken at home (%)	92.11	23.65	100	0	0.05
Frequency of use of L2 in adulthood					
At workplace (%)	60.56	29.05	63.16	31.59	0.950
Watching the television (%)	53.95	29.18	52.63	26.21	0.881
Speaking with friends (%)	67.11	22.13	61.84	31.59	0.618
Reading a book (%)	45.28	32.61	51.32	29.43	0.415
History					
Number of years spent in a French-speaking area	55.38	14.73	44.24	8.71	0.012

The following subtests were selected from the Boston Diagnosis Aphasia Evaluation ([Mazaux, 1983](#)):

- 1) Verbal discrimination subtest: associating images to orally pronounced words – 72 points. The subject is shown a chart of images of six objects, six actions, six shapes, six symbols, six colors, and six figures represented by category and must point to the image corresponding to the word pronounced by the examiner. Each image is worth 2 points if correctly identified in less than 5 s, 1 point if correctly identified in more than 5 s, 0.5 point if identified with a clue from the examiner or if the wrong image is identified but in the correct category;
- 2) Order of execution: performing a series of 5 actions upon an oral command – 15 points. The examiner reads an order (e.g. close your fist). Each order contains 1 to 5 tested items (“fist” in the example), worth 1 point each;
- 3) Oral naming: naming of six objects, six actions, two shapes, six symbols, six colors, six figures, and three body parts – 105 points.

The subject is asked to name 36 images from the previously used chart for the verbal discrimination subtest and 3 body parts pointed by the examiner on himself. Each item is worth 3 points if named correctly in less than 3 s, 2 between 3 and 10 s, 1 between 10 and 30 s;

- 4) Performances in automatic language: counting aloud up to 21–3 points if the sequence is entirely correct, 1 point for 8 consecutive correctly listed digits, 0 for less.

The Bilingual Aphasia Test (BAT) ([Paradis, 2011](#)), was used for the following subtests:

- 1) Syntactic comprehension: selecting the image that corresponds to the orally-presented sentence – 51 points.

The subject is shown a group of 4 images representing one action performed by different characters. For example, the action “holding” is represented once by a girl holding a boy, once by a boy holding two girls, etc. The examiner then reads 4 to 8 sentences describing the images using only pronouns (“she holds him”, “he holds them”) and the subject must point to the corresponding image. The second part of this subtest consists of one image representing two related characters/objects, for example a cow and a farm. The examiner asks the subject to point to one of the image by asking: “Show me the cow’s farm/the farm’s cow”. Each correctly identified image is worth 1 point.

- 2) Repetition of words and non-words – 60 points.

The examiner reads 30 words and non-words randomly. The subject is asked to repeat the word and say whether the item consists of an existing word or not. Each item is worth 1 point for a correct repetition and 1 point for a correct lexical decision.

- 3) Repetition of sentences – 7 points.

The examiner reads a full sentence and the subject is asked to repeat it. Each sentence is worth 1 point when all words are repeated correctly.

Finally, the Isaacs SET test ([Isaacs & Kennie, 1973](#)) was used for verbal fluency. Subjects are asked to produce as many nouns as possible from four semantic categories - colors, towns, animals and fruits - which alternate every 15 s. Each word is worth one point. Two words declined from the same, such as feminine and masculine, count for one.

A compound score was calculated with the results for oral comprehension (the sum of performances in the four following subtests: verbal discrimination, order of execution; syntactic comprehension and lexical decision task) and for oral production (the sum of performances in the four following subtests: oral naming, repetition of words and non-words, repetition of sentences and verbal fluency).

The choice of the BDAE and the BAT was based on the fact that these tests have been validated in French and German, the main languages of our groups. In total, eight tests were performed to assess oral language in each language.

2.4. Study design

The study was designed as a prospective three-center trial. A number was assigned to each subject for anonymity.

2.5. Experimental procedure

Subjects were studied twice, as each language was tested separately, between October 2012 and June 2014. Several native speaking examiners were involved to ensure that the examiner was fluent in the assessed language. The examiners were affiliated to one of the hospitals involved and were familiar with and well trained in administering neurolinguistic testing batteries. The time interval between L1 and L2 testing ranged from the same day to two weeks apart. The order of language testing was counterbalanced, so that half of the subjects had their L1 first and the rest their L2 assessed first.

2.6. Data analysis and statistics

Results were analyzed using IBM SPSS Statistics 22 Software. Language performances were calculated with individual scores for each linguistic task for the individuals with dementia and for the controls in L1 and L2: verbal discrimination, order of execution; syntactic comprehension, lexical decision task, oral naming, repetition of words and non-words, repetition of sentences and verbal fluency. Moreover, a compound score was calculated in each language for oral comprehension and for oral production.

Comparisons between groups (individuals with dementia versus controls), language (L1 versus L2) and interactions were then calculated through repeated measure ANOVAs with performance as the variable, group as between-subject factor and language as within-subject factor.

Finally, we calculated the correlation between the duration of immersion in a French-speaking environment (number of years) and relative preservation of L2 global comprehension and production scores obtained by calculating the difference between global scores for L2 and L1 (L2 score - L1 score) for global oral comprehension and global oral production using Pearson's test, for the individuals with dementia, the controls and both populations together.

3. Results

3.1. Dementia severity

The control group had a higher mean MMSE score (L1 = 28 ± 2.1 ; L2 = 27 ± 1.7) than the dementia group (L1 = 19.8 ± 5.0 ; L2 = 20.4 ± 4.67) confirming that the dementia group was indeed cognitively impaired and that controls were in the normal range (unpaired *t*-test: L1: $t = -6.8$, $p = 0.000$; L2: $t = -6.6$, $p = 0.000$). There was no interaction between groups and language concerning the MMSE scores ($F(1,38) = 0.311$, $P = 0.578$).

3.2. Language performance

The controls scored better than the individuals with dementia (group effect, $F(1,38) = 20.779$, $p < 0.003$) in the global language score, the global comprehension and production scores, and all individual subtest. Global oral production score did not show any difference between L1 and L2 for the whole population, (language effect, $F(1,38) = 0.595$, $p = 0.48$). Global score for oral comprehension showed either no effect of language ($F(1,38) = 383.0967$, $p = 0.84$). The interaction between group and language regarding global production and comprehension was not significant, indicating a similar impairment of L1 and L2 global scores in both populations, individuals with dementia and controls, irrespective of the cognitive impairment. Scores for individual tasks, were not different between L2 and L1 neither showed interactions, except scores of syntactic comprehension, which showed interaction between languages and groups (uncorrected statistics ($F(1,38) = 4.67$, $p = 0.037$)).

The main results are shown in [Table 2](#).

We applied the general linear model separately to patient and control group.

In the patients group the test of within subjects contrast gave the following results: Oral Comprehension effect, $F(1,19) = 0.56$, $p = 0.46$; Oral Production effect, $F(1,19) = 0.116$, $p = 0.73$; In the Control group the test of within subjects contrast gave the following results: Oral Comprehension effect, $F(1,18) = 3.1$, $p = 0.09$; Oral Production effect, $F(1,18) = 0.59$, $p = 0.45$. Even if the *F* values showed a trend for L1 oral comprehension preservation in the control group, this was not significant.

In order to control for aging and L2 immersion we have selected a subset of participants by deleting outliers, i.e. the three oldest patients with a longer immersion and the three youngest controls with a shorter immersion. In this final sample, 17 individuals with dementia and 16 healthy controls were matched in terms of age (Patients 74 ± 4 years, Control 71 ± 7 years,

Table 2

Language performances and comparisons between L1 and L2. Data are reported in mean (\pm Standard Deviation). Effects are reported in *f* (*p* value). Significant effects are highlighted with a *. Individuals with dementia are here coined as "patients".

Language test scores	Controls L1		Controls L2		Patients L1		Patients L2		Main effect of group	Main effect of language	Interaction
	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
BAT Syntactic comprehension	48.05	3.08	45.74	3.45	38.0	8.36	38.95	6.86	$F:22.57$ ($p = 0.000$) *	$F:1.22$ ($p = 0.277$)	$F:4.67$ ($p = 0.037$)
Oral naming (BDAE)	102.05	4.12	103.47	3.42	88.65	16.82	87.75	22.55	$F:9.98$ ($p = 0.003$) *	$F:0.089$ ($p = 0.767$)	$F:0.77$ ($p = 0.385$)
Fluency (Isaacs set Test)	32.47	7.90	29.58	5.96	20.40	8.36	19.35	8.93	$F:21.77$ ($p = 0.000$) *	$F:4.14$ ($p = 0.49$)	$F:1.06$ ($p = 0.310$)
Global Oral Comprehension	163.08	6.07	161.03	4.70	137.10	20.17	142.20	17.60	$F:68.67$ ($p = 0.000$) *	$F:3.09$ ($p = 0.84$) *	$F:1.45$ ($p = 0.237$)
Global Oral Production	173.63	9.59	171.74	8.14	143.85	25.13	142.65	30.92	$F:19.15$ ($p = 0.000$) *	$F:0.51$ ($p = 0.480$)	$F:0.026$ ($p = 0.874$)
Immersion (years)											
									Mean	SD	
Patients									55.38	14.73	
Controls									44.24	8.71	

unpaired *t*-test, $t = 1.4$, $p = 0.15$) and immersion (Patients 45 ± 14 years, Control 52 ± 9 years, unpaired *t*-test, $t = 1.5$, $p = 0.14$). The results of this analysis showed also similar performances in both languages. Global oral production score did not show any difference between L1 and L2, (language effect, $F(1,31) = 0.77$, $p = 0.49$), no interaction between group and language). Global oral comprehension scores were also similar in both languages ($F(1,31) = 0.13$, $p < 0.91$), and no interaction between groups and language ($F(1,31) = 1.68$, $p < 0.21$) was found. The pattern remained the same for the Swiss German sub-group. In the selected age-matched subset, the interaction for syntactic comprehension scores between languages and groups (control versus individuals with dementia) remained significant (uncorrected statistics; $F(1,31) = 4.50$, $p = 0.042$).

3.3. Correlation between comprehension/expression performances and immersion in the second language

We calculated the correlation between the duration of immersion in a French-speaking environment and the difference between global scores for L1 and L2 (L2-L1) for global oral comprehension and global oral production using Pearson's test, for the whole population (dementia group and controls). There was a significant positive correlation between immersion duration and comprehension ($r = 0.379$, $p = 0.03$, see Fig. 1). On the other hand, the correlation between immersion duration and production skills was not significant ($r = 0.106$, $p = 0.57$). When the populations are taken separately, the correlation between immersion duration and comprehension is marginally significant for the individuals with dementia ($r = 0.474$, $p = 0.065$) and non-significant for the controls. The correlation between global production and immersion was non-significant in either group (patients: $r = 0.217$, $p = 0.419$; controls $r = 0.0063$, $p = 0.809$). These results are summarized in Table 3.

4. Discussion

In the present study, we examined language performance in individuals with neurodegenerative dementia and their matched healthy controls, in their first language (L1) and in their later-acquired second language (L2). In order to assess language performance in these two aging populations, we administered to the participants a number of subtests of well-recognized neurolinguistics testing batteries such as the BAT, the BDAE and the Isaacs SET test in order to investigate the main linguistic features for both L1 and L2 of our participants.

We report, first, a group effect, i.e., the control group performed better for both L1 and L2 as opposed to the group consisting of the individuals with dementia. Second, we observed an absence of interaction between group and language, indicating that L2 was not more impaired in the dementia group compared to the healthy control group. Finally, the absence of language effect suggests similar effect on L1 and L2 by aging and neurodegenerative disorders of Alzheimer type. Moreover an interaction was found for syntactic comprehension in L2 (uncorrected statistics). This last result indicates that L2 syntactic processing is at least preserved in our group. The interaction may suggest a trend for better preserved L2 syntactic processing in individuals with neurodegenerative disorders, in particular here Alzheimer's disease. These aspects will be discussed in detail.

Several theoretical models could have predicted a better preservation of L1 compared to the later-acquired French, for different reasons. Most importantly, the language learned earlier in life has been classically proposed to be better protected from cognitive decline, by analogy with the different types of memory and the loss of recent memories in Alzheimer's disease (Paradis, 2008). Following this account later learned memories, such as a later learned L2, are more susceptible to cognitive decline. Likewise, L2 has been suspected to be more sensitive to declarative memory decline usually observed in neurodegenerative dementia (Birdsong, 2006) We have not observed such a finding in our study, given the absence of interaction between languages and group found.

It is difficult to compare our study to previous investigations, since most of them employed early L2 acquisition bilinguals. One of such studies assessed the impact of Alzheimer's disease on the two languages in early, highly-proficient Catalan-Spanish bilinguals and reported no differences for lexico-semantic tasks (Costa et al., 2012). The authors suggested that both languages of early bilinguals are equally sensitive to neurodegenerative diseases impacting on lexico-semantic language abilities. Likewise, Gómez-Ruiz et al. (2012) studied Catalan-Spanish bilinguals with Alzheimer's disease using the BAT and observed similar impairments for both languages (Gómez-Ruiz et al., 2012). Apart from differences of age of L2 acquisition, one further crucial difference between our and these two studies is that we investigated an immigration population while Costa et al. (2012) and Gómez-Ruiz et al. (2012) studied autochthonous populations of bilinguals, with quite similar exposure to L1 and L2. However, one notable investigation addressed an immigration population but still with early age of L2 acquisition (Salvatierra, Rosselli, Acevedo, & Duara, 2007). In that study, Spanish-English bilinguals with Alzheimer's disease were also reported to have no significant interaction between group and language. Indeed, subjects scored similarly in L1 and L2 on a verbal fluency task (Salvatierra et al., 2007). Noteworthy, the above-mentioned studies all observe a parallel impairment for both languages in bilingual individuals with dementia, which is consistent with our findings. As mentioned above, all these studies mainly focused on early bilinguals, unlike the present study and a previous pilot study, showing an equal impact of dementia for language processing in both languages in late bilinguals (Manchon et al., 2015).

Another study investigated language decline in Spanish-English bilinguals with probable Alzheimer's disease with a picture naming task. Results were analyzed both longitudinally by testing the subjects repeatedly over time; and cross-sectionally by comparing the results to cognitively healthy matched controls. The longitudinal analysis showed that both languages declined over time in the subjects with AD, but that decline was more important for the non-dominant language.

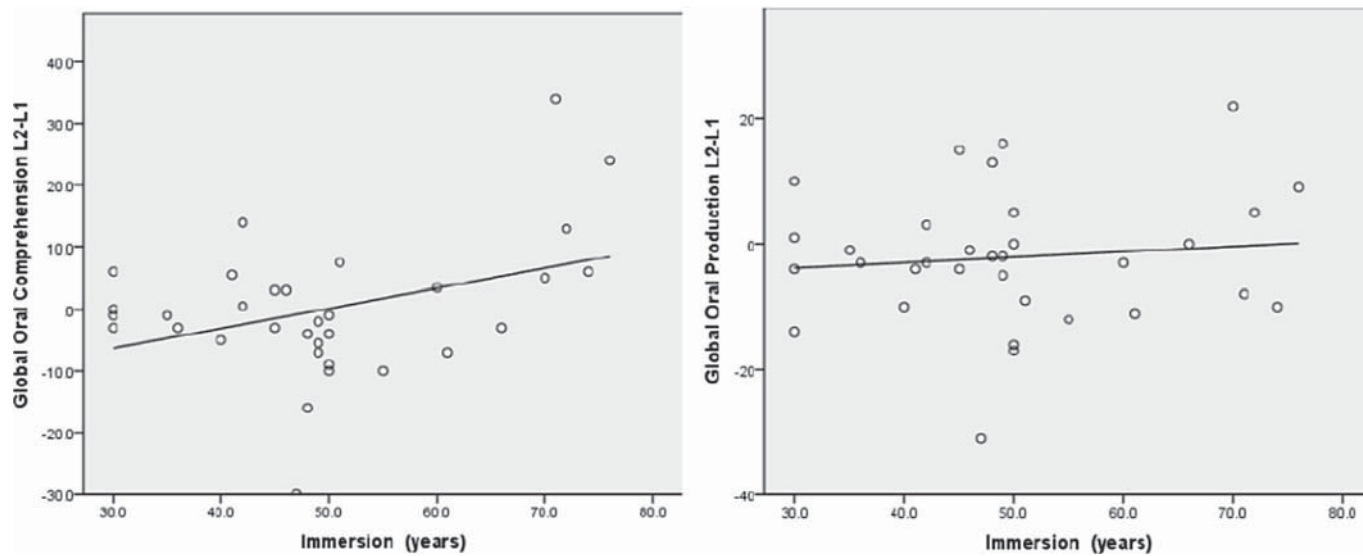


Fig. 1. Correlation graphs between L2. Immersion and the relative performances in L2(=L2 scores – L1 scores). The rho are $r = 0.379$, ($p = 0.03$) for the L2 relative comprehension scores and $r = 0.106$, ($p = 0.057$) for L2 relative production scores.

Table 3

Correlation between comprehension/expression performances and immersion in the second language.

Immersion	Global oral comprehension L2-L1	Global oral production L2-L1
Patients	$r = 0.474, p = 0.065$	$r = 0.217, p = 0.419$
Controls	$r = 177, p = 0.497$	$r = 0.0063, p = 0.809$
Global population	$r = 0.379, p = 0.03^*$	$r = 0.106, p = 0.56$

However, in the cross-sectional analysis, the differences between patients and controls were larger for the dominant language, especially in the first testing session. The authors suggest that these seemingly contradictory results show that both languages are affected by AD, but decline in a different way depending on the stage of the disease's progression, with the dominant language being affected first, because it contains the most complex and weakly represented words (Ivanova, Salmon, & Gollan, 2014).

Similar results were reported in another study focusing on monolinguals and early bilingual individuals, divided in 3 diagnostic groups: cognitively healthy, diagnosed with mild cognitive impairment (MCI) and diagnosed with AD. The individuals tested were submitted to a language history questionnaire, the 15-items version of the Boston Naming Test and the 1-min semantic fluency task of the CERAD. They compared the results obtained by the bilingual subjects in their dominant language to the non-dominant language. MCI patients scored lower in their dominant language compared to the bilingual controls while AD patients scored lower in their non-dominant language, compared to both MCI patients and bilingual controls. These results suggest that the dominant language is affected early in the disease process, while the non-dominant language is affected later (Kowoll, Degen, Gladis, & Schröder, 2015).

Such preservation of the second language may also be due to the L2 immersion of our participants. Living in a French-speaking environment for decades may have a strong impact upon differential language preservation for elderly subjects. Most of our subjects had immigrated to a French-speaking environment as young adults. They often had francophone spouses and used French at their work place. L1 was the childhood, language in 92% of the time for the individuals with dementia and 100% of the time for the controls, and school language 87% of the time for the individuals with dementia and 99% for the controls. However, in adulthood, L2 was predominantly used (>60% of time) both at work and for leisure.

This everyday use plays a major role in language proficiency. An immigrant might only use his first language when travelling back to visit his family. In this case, the first language will not be used in the everyday life and the language of the host country might become more important.

Prior studies on dementia have shown similar L2 preservation in production tasks such as naming, translation (Costa et al., 2012; Gollan et al., 2010). Our results confirm such patterns and insists on the spared comprehension in the host language, as a consequence of long lasting immersion. As mentioned before, long-life L2 exposure has been linked to increased grey matter densities in areas such the inferior parietal lobules (Abutalebi et al., 2015) which are involved in with semantic and phonological (Seghier et al., 2004) and temporo-parietal lesions and whose impairment are associated with comprehension deficit in both acute deficits and degenerative situations (Kreiser et al., 2000). It is thus probable that such used-dependent neural plasticity may correlate with second language preservation in late life.

One unexpected finding is specifically the preservation of syntactic comprehension in L2 in the group with dementia. It is usually argued that in late L2 learners, syntactical processing is less automatized and, at best, processed through declarative memory resources (Ullman, 2001) as opposed to L2 syntax which relies on more automatic procedural memory resources. Keeping in mind that typically in dementia declarative memories are first affected by cognitive deterioration (Gómez-Ruiz et al., 2012) we expected to specifically observe decline of L2 syntactical processing. However, we report that L2 syntactical was preserved. We argue that the immersion in a L2 environment and the relative lifelong major exposure to L2 may nullify the usual pattern, i.e., L2 becomes more automatic and converges to L1 processing and representation (Abutalebi & Green, 2007). This is also in contrast with relative theories claiming age of acquisition effects specifically affecting L2 syntactical processing (Singleton, 2007) where it is usually reported that L2 syntax in late bilinguals is differently organized than L1 syntax. We underline that most of the studies highlighted differences in L1 and L2 syntactical processing in late bilinguals were reported in younger populations (i.e, typically in young adults). We, here, propose that these ages of L2 acquisition effects are less prominent when it comes to aging populations who were exposed lifelong to their L2 and importantly immersed in an L2 environment. Specifically for the age of L2 acquisition, we take as a comparison studies reporting structural brain differences (Mechelli et al., 2004): reported in young adults increased grey matter densities for early bilinguals as opposed to late bilinguals. On the other hand, Abutalebi et al. (2015) reported that these age of L2 acquisition effects are completely absent for elderly populations. The only difference for structural brain differences is given by exposure and eventually proficiency. In other words, for aging populations, the main determinant is rather for how long subjects have been exposed to and immersed in their L2. In the present study, our subjects, both individuals with dementia and healthy aging controls, were in average exposed for more than 40 years to their L2 with the results that L2 may remain preserved as L1.

In conclusion, we have emphasized in the present study the role of L2 exposure and immersion in determining eventual language preservation during healthy aging and for individuals with dementia. We propose that these factors determine eventual specific L1 or L2 related linguistic deficits in bi- or multilingual individuals with cognitive decline and dementia.

4.1. Limitations

Our results must be interpreted with caution. First of all, the number of participants was limited, due to difficulties in recruiting people who fulfilled our inclusion criteria. Healthy subjects were five years younger than individuals with dementia. Further, for obvious reasons, the assessment of pre-morbid L2 proficiency is subjective and retrospective. Hence, in clinical studies such as the present one can hardly differentiate which specific skills were lost from those which were never acquired. However, subjective assessments are often used in clinical settings to establish premorbid linguistic status and have been shown to provide satisfactory validity (Marian, Blumenfeld, & Kaushanskaya, 2007).

Notwithstanding these limitations, we strongly believe that our results contribute to a better understanding of language impairment in aging populations, suggesting that immersion has a significant impact upon language processing in elderly bilinguals. These findings are important in order to define how to assess and rehabilitate language deficits in bilingual individuals with neurodegenerative diseases.

Appendix 1

Language performances and comparisons between L1 and L2 for all tested subtests. Data are reported in mean (\pm Standard Deviation). Effects are reported in f (p value). Significant effects are highlighted with a *. Individuals with dementia are here coined as "patients".

Language test scores	Controls L1		Controls L2		Patients L1		Patients L2		Main effect of group	Main effect of language	Interaction
	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Verbal discrimination (nouns-images association)	70.97	1.93	71.24	1.51	63.40	8.39	64.33	7.85	F: 1.78 ($p = 0.190$)	F: 0.182 ($p = 0.672$)	F: 0.182 ($p = 0.672$)
Order execution	14.63	0.60	14.79	0.42	11.65	3.18	11.55	3.25	F: 19.06 ($p = 0.000$)	F: 0.00 ($p = 0.000$)	F: 0.22 ($p = 0.642$)
Oral naming (BDAE)	102.05	4.12	103.47	3.42	88.65	16.82	87.75	22.55	F: 9.98 ($p = 0.003$) *	F: 0.089 ($p = 0.767$)	F: 0.77 ($p = 0.385$)
Performances in automatic language (Serial counting)	3	0	3	0	2.9	0.30	2.9	0.45	F: 1.78 ($p = 0.190$)	F: 0.18 ($p = 0.672$)	F: 0.18 ($p = 0.672$)
BAT Syntactic comprehension	48.05	3.08	45.74	3.45	38.0	8.36	38.95	6.86	F: 22.57 ($p = 0.000$) *	F: 1.22 ($p = 0.277$)	F: 4.67 ($p = 0.037$)
Words and non-words repetition	29.26	0.93	29.21	1.13	26.10	3.65	27.30	2.25	F: 11.99 ($p = 0.001$) *	F: 3.85 ($p = 0.057$)	F: 4.66 ($p = 0.037$)
Lexical decision	29.42	1.43	29.26	0.87	26	3.43	26.70	3.33	F: 27.54 ($p = 0.000$) *	F: 0.61 ($p = 0.439$)	F: 1.09 ($p = 0.30$)
Sentence repetition	6.84	0.37	6.83	0.38	5.8	2.09	5.35	1.76	F: 6.84 ($p = 0.013$) *	F: 1.69 ($p = 0.202$)	F: 0.99 ($p = 0.325$)
Fluency (Isaacs set Test)	32.47	7.90	29.58	5.96	20.40	8.36	19.35	8.93	F: 21.77 ($p = 0.000$) *	F: 4.14 ($p = 0.49$)	F: 1.06 ($p = 0.310$)
Global Oral Comprehension	163.08	6.07	161.03	4.70	137.10	20.17	142.20	17.60	F: 68.67 ($p = 0.000$) *	F: 3.09 ($p = 0.84$) *	F: 1.45 ($p = 0.237$)
Global Oral Production	173.63	9.59	171.74	8.14	143.85	25.13	142.65	30.92	F: 19.15 ($p = 0.000$) *	F: 0.51 ($p = 0.480$)	F: 0.026 ($p = 0.874$)

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