Language deterioration in bilingual Alzheimer's disease patients: a longitudinal study

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Abstract

In the context of bilingual research, little is known about the effects of neurodegenerative disorders (NDs) on the processing of two languages in a bilingual. In a recent cross-sectional study, we showed that Mild Cognitive Impairment (MCI) and Alzheimer's disease (AD) had similar effects on lexico-semantic processes in the two languages of highly proficient bilinguals (Costa et al., *Neuropsychologia*, 2012, 50, 740-53). In the present longitudinal study, we extend this finding by looking at the pattern of language deterioration over time in the same population of Catalan-Spanish bilingual patients. All the participants completed three language-processing tasks (picture naming, word translation and word comprehension), both in their dominant (L1) and non-dominant (L2) language. At one year, the final group was made up of 50 patients: 15 with MCI and 35 with AD. For AD but not MCI, the language deterioration over time was the same in both languages, as previously reported in the cross-sectional study. The results are discussed in the frame of the hypothesis of shared lexico-semantic processing in highly proficient bilinguals and the influence of executive control deficits in language production.

Keywords: Bilingualism; Alzheimer's disease; Language deterioration

1. Introduction

The way in which brain disease affects the two languages of a bilingual has been the subject of research in the field of bilingualism for a long time. A growing body of research has focused on defining the pattern of language recovery after acquired brain damage, such as that caused by vascular diseases or tumours. Surprisingly, there has been little research on the impacts of such damage on people with age-related disorders, including neurodegenerative diseases (NDs). The study of NDs offers a good opportunity to examine how languages decline over time as the cognitive impairment progresses. Moreover, the increased prevalence of such diseases (Alzheimer's Disease Association, 2015), with the incidence increasing due to an increase in life expectancies, further motivates research in this area.

In the context of language deterioration in bilingual speakers, Alzheimer's disease (AD) is one of the most studied ND. The interest in AD is due to the fact that semantic memory, in addition to long-term episodic memory, is affected from the early stages of the disease (Adlam, Bozeat, Arnold, Watson, & Hodges, 2006; Garrard, Lambon Ralph, Patterson, Pratt, & Hodges, 2005; Hodges & Patterson, 1995; Rogers, Ivanoiu, Patterson, & Hodges, 2006; Salmon, Shimamura, Butters, & Smith, 1988). The well-documented deficit of word finding in AD patients has been attributed to impaired lexical/semantic retrieval and/or a breakdown of semantic word representations (e.g., Hodges, Patterson, Graham, & Dawson, 1996). Crucially, this impaired lexical retrieval has been related to the defective functioning of executive control (EC), such as monitoring, updating and inhibiting the processes at play during word selection (e.g., Taler & Philips, 2008). Thus, studies of bilingual AD patients may shed light on how damage at the lexico-semantic level influences the word retrieval of the two languages.

The available evidence on language impairment in bilingual AD patients is mixed, with some studies reporting parallel deterioration and others reporting differential deterioration of the two languages. As shown in Table 1, most studies have included only small groups of individuals, and only one study has examined the language performance of bilingual patients with AD across time (Ivanova, Salmon, & Gollan, 2014). Longitudinal studies are preferable to cross-sectional ones because they can assess changes in the performance of individual patients over time. Moreover, the longitudinal study of the same patients assessed in an earlier cross-sectional study found that the pattern of language impairment changed, from differential at the beginning to parallel over time (Ivanova et al., 2014).

The present study consisted of a one-year follow up of the same population of bilingual patients with AD and Mild Cognitive Impairment (MCI) who were assessed in our previous cross-sectional study (Costa et al., 2012). MCI patients were included as being in the preclinical stage of AD, with an interest to see whether and to what extent the two languages decline before the dementia symptoms. Moreover, to the best of our knowledge, there are no longitudinal studies of bilingual speech production in MCI patients.

That cross-sectional study revealed parallel deterioration in both languages in the two groups of Catalan-Spanish bilingual patients, who performed three linguistic tasks involving word comprehension and production. The aim of the present study was to explore the deterioration in the two languages of these patients over time. Specifically, the study explored how the progression of the disease after one year influenced their language performance and whether the decline in the two languages was parallel. Before detailing the present study, we will briefly review the evidence of parallel and differential language deterioration in bilingual speakers with AD. Given that only one study (Costa et al., 2012) has looked at the issue in MCI patients, the review will be based on the evidence of language deficits in bilingual AD patients.

1.1. Parallel or differential language deterioration in bilingual speakers with AD?

Previous studies of bilingual AD patients have examined the pattern of language deterioration of the lexico-semantic system (Costa et al., 2012; de Picciotto & Friedland, 2001;

De Santi, Obler, Sabo-Abramson, & Goldberger, 1990; Friedland & Miller, 1999; Gómez-Ruiz, Aguilar-Alonso, & Espasa, 2012; Hyltenstam & Stroud, 1989; Ivanova et al., 2014; McMurtray, Saito, & Nakamoto, 2009; Meguro et al., 2003; Mendez, Perryman, Pontón, & Cummings, 1999; Salvatierra, Rosselli, Acevedo, & Duara, 2007; for a review see Stilwell, Dow, Lamers, & Woods, 2015). As can be seen in Table 1, most of the cross-sectional studies found differential language impairment, with the non-dominant language more affected by AD in most cases. For instance, in a study by Mendez et al. (1999) of 51 bilingual patients with different types of dementia (31 of whom had AD), caregivers reported decreased use of the non-dominant language (English) and word intrusions from the dominant to the non-dominant language. Similarly, highly proficient English-Afrikaans bilingual AD patients showed a tendency to retrieve fewer words (in a verbal fluency task) in the non-dominant language than in the dominant one, as compared to controls (de Picciotto & Friedland, 2001). In another study, four Japanese-Portuguese bilingual patients with AD showed differential impairment of the two languages in a naming task (Meguro et al., 2003). Only one study found an unexpected pattern of differential language impairment in bilingual AD patients, with greater impairment in the dominant than in the non-dominant language (Gollan, Salmon, Montoya, & da Pena, 2010). Our previous study evaluated unbalanced bilinguals with AD and healthy controls using the Boston Naming Test. The AD patients who were English-dominant bilinguals were able to name 60% of the pictures in English and about 30% in Spanish. Their performance, compared to that of controls (80% in English and 40% in Spanish), revealed that the disease had a greater effect on the dominant language (20%) than on the non-dominant language (7%). Conversely, this pattern of language impairment was not found in the group of Spanish-dominant bilinguals.

Among cross-sectional research, three studies reported parallel deterioration of two languages (Costa et al., 2012; Gómez-Ruiz et al., 2012; Salvatierra et al., 2007). In a fluency task involving older bilinguals and AD bilinguals, AD had a similar effect on the dominant language (Spanish) and non-dominant language (English) performance of the AD patients (Salvatierra et al., 2007). We reported a similar result (Costa et al., 2012) in our study of Catalan-Spanish bilingual speakers affected by MCI (*n* = 24), mild AD (*n* = 23) and moderate AD (*n* = 24) in three tasks: picture naming, word translation and word comprehension. Although the patients' scores in the non-dominant language were poorer than in the dominant language, the language deterioration was the same for both languages, according to the degree of cognitive decline. These findings are similar to those reported by Gómez-Ruiz et al. (2012) with Catalan-Spanish bilingual speakers.

The main finding of our cross-sectional study (Costa et al., 2012) was that the three patient groups (MCI, mild AD and moderate AD) showed parallel deterioration of their two languages (Catalan and Spanish). We also found that the participants' naming performance was sensitive to item-specific variables, such as cognate status (i.e., words of the same concept that phonologically and orthographically overlap across languages) and word frequency. Specifically, increased cognitive decline was associated with larger cognate and word frequency effects, but with any differential degree of impairment between the two languages. This suggests that the pattern of linguistic impairment for both languages was similar for all types of words.

Given these mixed results from the cross-sectional studies, it seems likely that follow-up studies would show that the general progression of the disease changes the type of language impairment over time. This is the case in the recent study published by Ivanova et al. (2014), in which they tested longitudinally the same group of AD patients that were tested in the study by Gollan et al. (2010). In the 2010 study, the dominant language was more affected than the non-dominant language, whereas when the AD patients were tested over time, the non-dominant language was more affected (in Spanish-dominant bilinguals). The authors attributed these contrasting results to two possible mechanisms of impairment. First, the larger impairment of the dominant versus the non-dominant language was explained by AD having a greater impact on the lexico-semantic system of the dominant language than of the non-dominant language because the lexical items from the dominant language may have richer (or more) associations with semantic representations than those from the non-dominant language. Second, the greater decline in the non-dominant language over time was explained by deficits of control in the extra-linguistic domain. As a result of these deficits, AD patients found it more difficult to name words in the non-dominant language than in the dominant language. It is possible that the disease progression might also affect the integrity of EC and then, in turn, the abilities to control the two languages. This would make it more difficult to reduce interference by the dominant language and affect the non-dominant language to a greater degree as it is more dependent on controlled processes for lexical retrieval (for a review see Abutalebi, 2008). The idea that all the linguistic processes, from the conceptual selection to the speech output monitoring, require the participation of EC is also supported by research in monolingual language production (e.g., Jongman, Roelofs, & Meyer, 2015; Roelofs & Piai, 2011; Ye & Zhou, 2009). Moreover, some theories have proposed that a lack of inhibitory control and working memory deficits are responsible (e.g., Hasher & Zacks, 1988), to differing extents, for the impaired language performance found in elderly adults as well as in cognitive decline. For instance, in their review on language performance in AD and MCI, Taler and Philips (2008) suggested that the deficits in the executive components of word retrieval might be responsible for the impaired performance in verbal fluency tasks. Similarly, Doung et al. (2006) proposed that the lexico-semantic processing deficits in MCI and AD patients are related to difficulties in inhibiting information while performing semantically explicit but not implicit tasks. Therefore, in the context of bilingualism, the decrease of EC functioning in bilingual AD patients might result in deficits of within-language control, and also in an increase of cross-language interference.

Finally, it is important to highlight that the reported differences in language deterioration patterns might be explained in terms of differences in language proficiency and/or age of second language acquisition. Indeed, among others, these variables related to bilingualism are known to modulate the neural representation of the two languages (e.g, Hernandez & Li, 2007; Perani et al., 1998, 2003; Perani & Abutalebi, 2005) and language recovery after brain damage (e.g., Lorenzen & Murray, 2008; Gray & Kiran, 2013).

Given these mixed results, it is unclear how AD affects the two languages of bilinguals. One way to shed light on this issue is to gather more data on AD patients and investigate how their performance declines over time as the disease progresses. This approach allows us to compare each individual's performance longitudinally with his or her baseline, therefore avoiding possibly confounding effects of differences in pre-morbid language proficiency and knowledge.

INSERT TABLE 1 ABOUT HERE

1.2. Present study

The aim of the present study was to investigate the lexico-semantic deterioration over time in two languages of the same groups of highly proficient Catalan Spanish bilingual patients with AD (n = 35) or MCI (n = 15), who were assessed previously in a cross-sectional study (Costa et al., 2012). As mentioned previously, the inclusion of MCI patients was motivated by the clinical relevance of knowing how language deficits might be affected before a possible conversion to AD, and in particular, in a bilingual population.

The language performance of the patients in three language tasks (picture naming, word translation and word comprehension) at baseline was compared with that at 6 and 12 months.

The pattern of language deterioration across time was evaluated to determine the effect of disease progression on the two languages (i.e., whether it declined at the same rate or differentially). To do so we assessed the effect of language deterioration in MCI and AD patients following up both groups over time. Moreover, we also compared the two patient groups to see whether since the preclinical stage of disease (MCI) bilingual language production is also affected, supposed to be a lesser extent (for a review on language impairment in monolingual speakers with MCI and AD, see Taler & Phillips, 2008).

Our hypothesis was that if two languages have the same organization principles, and likely similar representation, we would expect parallel deterioration over time. Indeed, this was the case with the early and highly proficient bilinguals we tested as well as in our previous cross-sectional study (Costa et al., 2012). Parallel impairment would contradict the results of Ivanova et al. (2014), who found a more affected non-dominant language in AD patients when tested over time. However, the Spanish-English patients in their study for whom the most affected language was the non-dominant one were non-balanced bilinguals. This means that the language most affected was the one spoken least and the one with a lexico-semantic connection that was poor because it was acquired later in life (see Table 1).

Therefore, the differential impairment of the two languages in our early and highly proficient bilinguals could be explained by extra-linguistic deficits, such as those of EC. As hypothesised by Ivanova et al. (2014), the EC deficits would leave the non-dominant language more vulnerable to interference by the dominant language. This is reasonable since control deficits, for instance of inhibitory control (e.g., Hasher & Zacks, 1988), have been proposed to be the underlying mechanisms of word finding failures in monolingual AD patients (e.g., Taler & Philips, 2008; Duong et al., 2006). Moreover, it has been proposed that a non-dominant language should be more dependent on controlled processes during lexical retrieval (e.g., Abutalebi, 2008) and thus more affected by AD. In our previous study, we did not find evidence of such language control deficits in AD patients (for similar results see Gómez-Ruiz et al., 2012). Indeed, language control deficits have mostly been described in patients with lesions not typically found in AD (hippocampus and mesio-temporal lobe), such as lesions on the basal ganglia (Abutalebi, Miozzo, & Cappa, 2000; Aglioti & Fabbro, 1993; Calabria, Marne, Romero-Pinel, Juncadella, & Costa, 2014; Cattaneo et al., 2015; Mariën, Abutalebi, Engelborghs, & De Deyn, 2005) and/or the frontal lobes (Fabbro, Skrap, & Aglioti, 2000). However, it is possible that the disease progression might also affect the integrity of the EC and therefore the ability to control the two languages.

To sum up, we have the two hypotheses:

1. We expect parallel decline of both languages in AD, based on the claim that they have same organization principles in highly proficient bilinguals;

2. Furthermore, we expect the same pattern over time for MCI, but less affected compared to AD patients, given that they only show preclinical cognitive symptoms of dementia (Taler & Phillips, 2008).

2. Methods

2.1. Participants

Sixty-five bilingual speakers were recruited for the study (Costa et al., 2012). However, due to attrition (*n* = 15), the final population consisted of 50 patients. The performance of these patients was analysed at three assessment times: baseline, 6 months and 12 months. The patients were recruited from three different hospitals: Hospital Universitari de Bellvitge, Hospital de la Santa Creu i Sant Pau and Hospital General de Granollers. At baseline, the participants were diagnosed with probable AD (*n* = 35; 9 males and 26 females) or MCI (*n* = 15; 9 males and 6 females).

Patients with potentially confounding neurological and psychiatric disorders, clinically known hearing or vision impairments and a past history of alcohol abuse, psychosis or major depression were excluded from the study. The diagnosis was based on neurological and neuropsychological evaluations (most of which are listed in Table 3, as detailed below), according to the clinical criteria of the National Institute of Neurological and Communication Disorders and Stroke Alzheimer disease and Related Disorders Association for AD (McKhann et al., 1984) or MCI (Petersen et al., 1999). All participants were enrolled in the study after having received a diagnosis based on the previous criteria and done by neurologists with expertise on NDs. All the AD patients received acetylcholinesterase inhibitors as drug treatment, whereas the MCI participants did not receive any drug treatment.

Language history was assessed using a questionnaire administered to the participants and an interview with the patient and some relatives. All the participants scored quite well in their self-assessed knowledge of the two languages (Table 2), and they reported that they had used both languages regularly during, at least, the last 60 years. On average, the age of regular use of non-dominant language was 4.6 years for MCI and 4.3 years for AD patients; therefore, all the participants were considered early bilinguals.

INSERT TABLE 2 ABOUT HERE

2.2. Materials

The materials consisted of 54 name representing objects belonging to various semantic categories: animals, vegetables, body parts and so on (see Appendix A – List of stimuli). The same set was used for the three tasks: picture naming, word-picture matching and word translation. Black-and-white line drawings depicting these 54 objects were used in the picture naming and word-picture matching tasks (Snodgrass & Vanderwart, 1980). The frequencies of

Spanish and Catalan words were obtained from the LEXESP (Sebastian-Galles, Cuetos, Martı, & Carreiras, 2000) and the Catalan Dictionary of Frequencies (Rafel i Fontanals, 1996) databases, respectively. Given that the frequency values are based on corpuses with different sizes it was not possible to match languages on frequency. There were no differences in the mean phonological length (Spanish: 5.27, Catalan: 5.20, $p = 0.80$), mean letter length (Spanish: 5.64, Catalan: 5.66, $p = 0.95$) or mean syllable length (Spanish: 2.51, Catalan: 2.31, $p = 0.15$) of the Spanish and Catalan names. Half of the items were cognates and half were non-cognates. The frequency of the words in the two sets (cognates and non-cognates) was matched both in Spanish (cognates: 54.65, non-cognates: 54.65, $p = 1$) and Catalan (cognates: 4156.55, non-cognates: 3341.81, $p = 0.63$). Cognates and non-cognates in both languages were also matched for familiarity (cognates: 6.1, non-cognates: 6.1, $p = 0.98$) and visual complexity (cognates: 3.0, non-cognates: 2.8, $p = 0.39$) according to Spanish norms (Sebastian-Galles et al., 2000).

2.3. Procedure

At baseline, different questionnaires about socio-demographic information and bilingualism were administered. At all three test times, the participants performed the picture naming, word-picture matching and word translation tasks in one of the two languages in two different sessions one week apart. The participants were tested in the two languages (Catalan and Spanish) in different sessions, and the order of the language testing was counterbalanced. Data from these tests were also collected at baseline, 6 months and 12 months: the MMSE, which measures the degree of cognitive decline; the CERAD Word List Memory (Morris et al., 1989) and Benton Visual Retention Test, both of which measure long-term episodic memory; forward and backward Digit spans (Pena-Casanova et al., 2009), which measure short-term memory and working memory, respectively; the Pyramids and Palm Trees Test, which measures semantic memory (Howard & Patterson, 1992); and the semantic fluency test in the dominant language, which measures language production (see Table 3 for details). Some of the tests listed in the Table 3 have been used for diagnosis (collected from medical records) and some of them used only for the study. The instructions of the tests were given according the language dominance or preference of each patient. Semantic fluency was also performed according the languages preferred by the patient. Given that this is one of the standard tests used in the neuropsychological assessment, it is a clinical practise to do it only in one language. The only exception is the CERAD test, which measures the verbal episodic memory, that it has been administered in Spanish because we do not have a Catalan version of it with normative data.

In the picture naming task, the participants were asked to name aloud the pictures presented on a computer screen. The experimental software was DMDX (Forster & Forster, 2003), and the verbal responses were recorded. Each picture remained on the screen until the participant responded or for a maximum of 5 sec.

In the word translation task, the experimenter read words aloud one at a time, and the participants were asked to provide the translation word in the other language.

In the word-picture matching task, each target picture was presented with three distractor pictures. Each distractor picture was either semantically, phonologically or visually related (similar shape) to the target picture. The experimenter read the target word aloud, and the participant was asked to point to the picture that matched the presented word.

INSERT TABLE 3 ABOUT HERE

2.4. Data analysis

The percentage of correct responses for each participant in each language was calculated.

First, the data were analysed using a repeated-measures ANOVA, with the time (baseline, 6 months and12 months) and language dominance (dominant vs. non-dominant) used as within-subject factors and the group (MCI, AD) used as a between-subject factor.

Second, a repeated-measures ANOVA using the type of error as a within-subject factor was also run for each language separately. In further analyses we looked at the effects of semantic category and cognate status on errors in picture naming and word translation. We defined the errors as follows.

For naming, the errors were classified as follows: 'omission', when a participant was unable to name the object; 'semantic paraphasia', when a participant produced a word semantically related to the target; 'cross-language intrusion', when the participant produced the correct word but in the non-requested language, 'visual', when the participant did not recognise the picture; 'phonological paraphasia', when the participant deleted, substituted or added phonemes to the correct word related to the picture; and 'unrelated', when the participant produced a word that was not semantically or phonologically related to the target.

For word translation, the errors were classified as follows: 'omission', if the participant was unable to translate the word; 'semantic paraphasia', if the participant produced a word semantically related to the target; 'phonological paraphasia', if the participant deleted, substituted or added phonemes to the correct translation of the word; and 'unrelated', if the participant produced a word that was not semantically or phonologically related to the target. In case of translation, we did not use the term cross-language intrusion because the incorrect response given by the participant was in the same language; therefore, it was a repetition of the word read aloud by the experimenter. For this reason we preferred to use the term 'same language'.

Finally, regression analyses were conducted on the percentages of correct responses for each language, with neuropsychological measures as predictors. Neuropsychological measures that were sensitive to decline over time were subjected to regression analyses to explore their relative contribution to the deterioration of the two languages. Details of the regression procedures are reported in Section 3.5.

3. Results

3.1. Picture naming

The effect of language was significant (F (1, 48) = 8.80, $p < .01$, $\eta_p^2 = .15$), with the participants scoring better in their dominant language (91.5%) than in their non-dominant language (89.0%). The effect of time was also significant (F (2, 96) = 6.14, $p < .01$, $\eta_p^2 = .11$). According to the post-hoc analysis, the performances at 12 months (88.2%) were poorer than those at 6 months (91.0%, $p = .04$) and those at baseline (91.5%, $p = .05$). However, the interaction between language dominance and time was not significant (F (2, 96) = .50, p= .61, $\eta_p^2 = .01$), suggesting parallel deterioration of the two languages over time (Fig. 1).

The effect of group was also significant (F (1, 48) = 12.71, $p < .01$, $\eta_p^2 = .21$), with the performances of the MCI better (95.9%) than those of the AD patients (84.6%). This group difference was still significant when age was used as a covariate in the analyses (F (1, 47) = 8.11, $p < .01$, $\eta_p^2 = .15$).

The effect of the time × group interaction was not significant (F (2, 96) = 2.66, $p = .07$, $\eta_p^2 = .05$). However, the performance of the AD patients declined between baseline (86.7%) and 12 months (81.3%, $p < .01$) and between 6 months (85.9%) and 12 months ($p < .01$). No language decline was found in the MCI patients over time ($p > .50$ for all).

INSERT FIGURE 1 ABOUT HERE

3.2. Word translation

The effect of language was significant (F (1, 48) = 5.92, $p < 0.05$, $\eta_p^2 = .11$), with the participants scoring better in translating into their dominant language (90.6%) than into their non-dominant language (88.8%). The effect of time was also significant (F (2, 96) = 4.27, $p < .05$, $\eta_p^2 = .08$). The post-hoc analysis revealed that the performances from baseline (90.8%) declined at 6 months (89.7%, $p < .05$) and 12 months (88.6%, $p < .05$).

However, the interaction between language dominance and time was not significant (F (2, 96) = .25, p= .78, $\eta_p^2 = .005$), suggesting parallel deterioration of the two languages over time.

The effect of group was also significant (F (1, 48) = 23.09, $p < .0001$, $\eta_p^2 = .32$), with the MCI patients performing better (94.6%) than the AD patients (84.6%) (Fig. 2). This group difference was still significant when age was entered as a covariate in the analyses (F (1, 47) = 19.82, p < .0001, $\eta_p^2 = .29$).

The effect of the time × group interaction was not significant (F (2, 96) = 2.78, $p = 0.06$, $\eta_p^2 = .05$). However, the translation performance of the AD patients declined between baseline (86.4%) and 12 months (82.6%, $p = .01$) and between 6 (85.3%) and 12 months ($p < .05$). In contrast, there was no difference in the performance of the MCI patients over time ($p > .05$ for all).

INSERT FIGURE 2 ABOUT HERE

3.3. Word-picture matching task

The effect of language was not significant (F (1, 48) = 0.76, p = 0.39, η_p^2 = .01), but the effect of time was (F (2, 48) = 3.42, p < 0.05, η_p^2 = .07). The post-hoc analysis showed that the performance had declined significantly at 12 months (97.6%) compared to the baseline (99.2%, p < .05). However, the interaction between language dominance and time was not significant (F (2, 96) = .78, p = .46, η_p^2 = .01), suggesting parallel deterioration of the two languages over time.

The effect of group was also significant (F (1, 48) = 6.98, p < .05, η_p^2 = .13), with the MCI patients performing better (99.7%) than the AD patients (97.2%). This group difference was still significant when age was used as a covariate in the analyses (F (1, 47) = 4.48, p < .05, η_p^2 = .09).

The time × group interaction was significant (F (2, 96) = 4.27, p < 0.05, η_p^2 = .08). Post-hoc analyses revealed that only AD patients deteriorated over time (baseline: 98.8%; 12 months: 95.47%, p < .05) where MCI patients performed the same at baseline (baseline: 99.6%) and at 12 months (99.8%, p = .27).

As we found that the data in the task were not normally distributed in both groups, we further analysed them using non-parametric tests (see details in Appendix B). We compared MCI and AD patients at baseline and at 12 months with the Mann-Whitney U test and each group separately at baseline and at 12 months with the Wilcoxon test.

MCI patients did not differ in performance between baseline and 12 months for the dominant language (Z= -1.34, p = .18) or the non-dominant language (Z= - .45, p = .65). In contrast, AD patients showed a significant decline over time, both for the dominant (Z= -2.70, p < .01) and non-dominant language (Z= - 3.79, p < .01).

Moreover, for the dominant language, the two patient groups performed the same at baseline (Z= - 0.64, p = .52) but significantly different at 12 months (Z= - 2.72, p < .01).

Similarly, for the non-dominant language, the groups performed the same at baseline (Z= -1.45, p = .15) and differently at 12 months (Z= - 3.56, p < .001).

Therefore, these results confirm that the performance of the AD patients in the word-picture matching task deteriorated further over time while that of the MCI patients did not.

3.4. Error analysis

3.4.1. Type of errors

The error analyses of the picture naming and word translation tasks were conducted separately. Given that language deterioration was consistently found only in the AD patients in the 1-year follow-up first assessment, the analysis was restricted to this group. A repeated-measures ANOVA was conducted to compare their performance between baseline and 12 months, considering the type of error, language (dominant vs. non-dominant) and time (baseline, 12 months) as within-subject factors.

AD patients made few errors in the word-picture matching task (baseline: 1.2%; 12 months: 4.5%) therefore this made not possible the analysis of their performance in terms of type of errors. Indeed, 74% (n=26) of AD patients after one year scored at ceiling and the rest of patients only made few semantic and visual related errors.

Picture naming. As reported above, the participants made more errors in the non-dominant language than in the dominant language ($F(1, 33) = 5.33$, $p < .05$, $\eta_p^2 = .14$), and the number of errors increased from baseline to 12 months ($F(1, 33) = 10.82$, $p < .01$, $\eta_p^2 = .25$) (Fig. 3). Interestingly, the effect of 'type of error' was significant ($F(5,165) = 7.56$, $p < .001$, $\eta_p^2 = .19$). The post-hoc analysis revealed that omissions, semantic paraphasias and cross-language intrusions were significantly more frequent than the other types of errors ($p < .05$ for all). Furthermore, the magnitude of these errors was modulated by time (type of error × time interaction: $F(5, 165) = 2.85$, $p < .05$, $\eta_p^2 = .08$) and language (type of error × language interaction: $F (5, 165) = 3.85$, $p < .01$, $\eta_p^2 = .10$) but not by both together (type of error × language × time interaction $F (5, 165) = .96$, $p = .44$, $\eta_p^2 = .03$). The post-hoc analyses revealed that omissions and cross-language intrusions were more frequent in the non-dominant language ($p < .05$ for both) and that they increased over time but without a significant differential increase in the two languages.

INSERT FIGURE 3 ABOUT HERE

Word translation. The analysis revealed that patients made more errors in the non-dominant language than in the dominant language ($F (1, 33) = 4.43$, $p < .05$, $\eta_p^2 = .12$), and that the number of errors increased from baseline to 12 months ($F (1, 33) = 28.41$, $p < .01$, $\eta_p^2 = .24$) (Fig. 4). Interestingly, the effect of type of error was significant ($F (4, 132) = 40.51$, $p < .001$, $\eta_p^2 = .55$). The post-hoc analysis revealed that omissions, semantic paraphasias and same language errors were significantly more frequent than the other types of errors ($p < .05$ for all). In addition, the magnitude of these errors were modulated by time (type of error × time interaction: $F (4, 132) = 5.90$, $p < .001$, $\eta_p^2 = .15$) and language (type of error × language interaction: $F (4, 132) = 3.14$, $p < .05$, $\eta_p^2 = .09$) but not by both together (type of error × language × time interaction $F (4, 132) = .31$, $p = .88$, $\eta_p^2 = .01$). The post-hoc analyses revealed that omissions were more frequent in the non-dominant language (*p*s < 0.05), and that they increased over time and without significant differential increase in the two languages.

INSERT FIGURE 4 ABOUT HERE

3.4.2. Semantic category effects

An analysis was performed in order to see whether the errors were affected by semantic categories, as being one of the organizational principles of semantic organization. The items used belonged to different categories (please see Appendix A) but the number of members was not the same for all categories, meaning that some were more represented (for instance, animals) and some were less represented (for instance, body parts). As it might be a problem for dissociation of semantic category-specific deficits, we classified each item as 'man-made' or 'natural'. This allowed us to have a more balanced number of items for each of the two categories.

We then compared the total number of errors by classifying them as either man-made or natural for picture naming and word translation separately. We did not find an effect of category at any time assessment for either task.

In the picture naming task, 54.5% of errors in the dominant language at baseline were for natural items while 45.5% were for man-made items (χ^2 (1) = 3.22, p = .07); at 12 months, 51.4% of errors were for natural items and 48.6% were for man-made items (χ^2 (1) = .23, p = .63). For the non-dominant language, 50.2% of the errors at baseline were for natural items and 49.8% were for man-made items (χ^2 (1) = .007, p = .93); at 12 months 48.1% of the errors were for natural items and 51.9% were for man-made items (χ^2 (1) = .63, p = .43).

In word translation, 54.2% of the errors in the dominant language at baseline were for natural items and 45.8% were for man-made items (χ^2 (1) = 3.34, p = .07); at 12 months, 45.6% of the errors were for natural items and 54.3% were for man-made items (χ^2 (1) = 3.32, p = .07). For the non-dominant language, 54.1% of errors at baseline were for natural items and 45.9% were for man-made items (χ^2 (1) = 3.57, p = .06); at 12 months, 48.9% of errors were for natural items and 51.1% were for man-made items (χ^2 (1) = .13, p = .72).

In a further analysis, we examined whether the semantic category effect was modulated by the type of error.

In picture naming, we found that for semantic paraphasias there were more errors for natural items than for man-made items. For the dominant language, we found a higher number of semantic paraphasias for natural items than for man-made items at baseline (68.7% vs. 31.3%, χ^2 (1) = 17.19, $p < .001$) and at 12 months (76.4% vs. 26.6%, χ^2 (1) = 28.51, $p < .001$). Similarly, for the non-dominant language, semantic paraphasias for natural items were higher than for man-made items at baseline (77.8% vs. 22.2%, χ^2 (1) = 47.80, $p < .001$) and at 12 months (72.9% vs. 27.1%, χ^2 (1) = 18.37, $p < .001$). Moreover, cross-language intrusions showed the same category effect at 12 months both for the dominant (natural: 70.2% vs. man-made: 29.8%, χ^2 (1) = 13.78, $p < .001$) and non-dominant language (natural: 58.6% vs. man-made: 41.4%, χ^2 (1) = 5.17, $p < .05$).

In word translation, the semantic category effect was less consistent. Patients made more errors for natural items in their dominant language only in case of omissions at the 12-month assessment (61.5% vs. 38.5%, χ^2 (1) = 12.93, $p < .001$), and in their non-dominant language when they exhibited semantic paraphasias, but only at baseline assessment (67.7% vs. 30.3%, χ^2 (1) = 8.28, $p < .01$).

3.4.3. Cognate effect

In this analysis, we examined whether one linguistic variable as a cognate status would have a similar effect on the two languages (see Appendix A). To do this, we compared the total number of errors by classifying them as referring to cognate or non-cognate words. The analyses were performed separately for tasks (picture naming and word translation), languages and assessment times (at baseline and at 12 months). We also looked at whether the type of error made was affected by the cognate status of the items.

We consistently found that patients made more errors for non-cognates than for cognates. This was true for both production tasks, languages and both at baseline and follow-up. Moreover, in regard to the types of errors affected by the cognate status, we found parallel effects in both languages.

In picture naming, patients made more errors for non-cognates than for cognates in their dominant language at baseline (57.4% vs. 42.6%, χ^2 (1) = 12.78, $p < .01$) and at 12 months (55.2% vs. 44.8%, χ^2 (1) = 4.16, $p < .05$). The same was found for the non-dominant language at baseline (62.4% vs. 37.6%, χ^2 (1) = 52.76, $p < .001$) and at 12 months (65.4% vs. 34.6%, χ^2 (1) = 21.77, $p < .001$). At baseline, for both languages, the effect of cognate status was significant for omissions (dominant language: 71.7% vs. 28.3%, $p < .001$; non-dominant language: 61.6% vs. 38.4%, $p < .01$) and cross-language errors (dominant language: 90.4% vs. 9.6%, $p < .001$; non-dominant language: 83.5% vs. 16.4%, $p < .001$). At 12 months, only cross-language intrusions showed an effect of cognate status on both languages (dominant language: 96.6% vs. 6.4%, $p < .001$; non-dominant language: 72.7% vs. 27.3%, $p < .001$).

In word translation, patients made more errors for non-cognates than for cognates in their dominant language at baseline (73.8% vs. 26.2%, χ^2 (1) = 118.37, $p < .001$) and at 12 months (76.8% vs. 23.2%, χ^2 (1) = 135.97, $p < .001$). For the non-dominant language, we found the same at baseline (82.4% vs. 17.6%, χ^2 (1) = 241.44, $p < .001$) and at 12 months (85.2% vs. 14.8%, χ^2 (1) = 21.77, $p < .001$). This cognate advantage was similar for omissions, same-language errors and semantic paraphasia in both languages and in both assessment times ($p < .05$ for all).

3.5. Relationship between language deterioration and cognitive decline

Regression analyses were run to determine whether language deterioration was related to the degree of cognitive decline over time. The previous cross-sectional study revealed that the MMSE score was correlated with a decline in the dominant and non-dominant languages, an index of general cognitive decline (Costa et al., 2012). We confirmed this result by correlating the MMSE score at 12 month with the language impairment over time (picture naming: dominant language $r = .47$, $p < .05$; non-dominant language: $r = .49$, $p < .05$; word translation: into dominant language: $r = .35$, $p < .05$; into non-dominant language: $r = .36$, $p < .05$). This suggests that the severity of disease, irrespective of its degree of decline over time, was similarly related to impairment of the two languages.

In the present study, we also looked at this by considering the degree of cognitive decline over time in neuropsychological tests. As shown in Table 3, the performances of the AD patients were significantly worse after 12 months in the following tests: MMSE, CERAD (verbal episodic memory), Benton Visual Retention Memory Test (non-verbal episodic memory), Forward digit spans, Pyramids and Palm Trees Test (semantic memory) and semantic fluency. Therefore, only the differences in performance between 12 months and baseline tests were entered in the regression analysis as predictors. As the dependent variable of each regression, we used the decline in language performance in picture naming, word-picture matching and word translation tasks between 12 months and baseline. We averaged the performance in the picture naming and word translation tasks, resulting in one value (composite score) for each participant for each of the two languages. The word-picture matching task was considered separately as it did not involve production.

We used a stepwise model of linear regression in which all candidate variables were initially included, and then those variables that did not improve the model were deleted. The final model included only those variables that best explained the language deterioration over time.

Dominant language. For the composite scores of the language production tasks, the variable that explained the variance in the regression model (R^2 = .13, F (1, 30) = 4.25, p < .05) was the decline in the score of the Benton Visual Retention Memory Test, which measures impairments in episodic memory (β= .36, p < .05). For word-picture matching, any variable introduced in the analysis predicted the decline of performance over time in this task (F (7,30) = .96, p = .48).

Non-dominant language. Similarly, for the composite scores of the language production tasks, the only variable that explained the variance in the model (R^2 = .36, F (1, 30) = 15.96, p < .001) was the decline in the score of the Benton Visual Retention Memory Test (β= .60, p < .001). For word-picture matching, the Benton Visual Retention Memory Test was still the only significant variable (β= .38, p < .05) in the final regression model (R^2 = .15, F (1, 30) = 5.14, p < .05).

4. Discussion and conclusion

A recent review of language impairments in bilingual patients with AD suggested that the disease appeared to affect both languages similarly but noted that this general conclusion needed to be confirmed, given the limited number of studies on the subject (Stilwell et al., 2015). Recently, another study contradicted this suggestion, reporting differential impairment of the two languages in bilingual AD patients (Ivanova et al., 2014). To shed light on this issue, the present study investigated the performance of AD and MCI patients over time, similarly to the earlier study by Ivanova et al. (2014).

In the present study, the performance of two groups of patients (AD and MCI) previously studied (Costa et al., 2012) in three language tasks (picture naming, word translation and word-picture matching) was compared at baseline, 6 and 12 months. For AD, the main result was that after 1-year follow-up they showed a parallel decline in both languages in picture naming and word translation. Indeed, this parallel deterioration was supported by the non-significant interaction between language dominance and time of assessment in both tasks.

Interestingly, the results from picture naming and word translation tasks were consistent in both languages. Despite the fact that the two tasks may involve slightly different linguistic processes, AD patients showed parallel deterioration in both. In this study, word translation was used with the aim to see whether the connection of lexical representations of the two languages might be similarly affected by the disease. Some models of bilingual production suggest that the non-dominant lexical representations tend to be more strongly connected with those of the dominant language than vice versa (e.g., Kroll & Stewart, 1994; La Heij et al., 1996). Some support of this language asymmetry has been shown in studies with translation priming, which suggested that priming effects arise from the more-dominant to the less-dominant language, regardless of which of them has been acquired first (e.g., Basnight-Brown & Altarriba, 2007; Kiran & Lebel, 2007). Therefore, following brain damage, it would be expected that one language should be more impaired than the other. However, in the present study we did not observe differential impairment across time because of AD progression. One explanation for this result is that the architecture of lexical representations in early and highly proficient bilinguals does not follow the language asymmetry rules as the two languages were learnt at the same time (Hernández, Costa, Caño, Juncadella, & Gascón-Bayarri, 2010).

However, while we found that performance in the two languages did not differ across tasks, the two tasks may tap different linguistic processes. This is suggested by the analysis of errors. First, the errors made by AD patients in word translation were less affected by the semantic category than the errors in picture naming. In picture naming, the AD patients made more errors in natural/living items in all assessment times for semantic errors and also for cross-language intrusions at follow-up, replicating one of the most frequent category-specific deficits in AD (e.g., Chertkow, Whatmough, Saumier, & Duong. 2008; Laws, Crawford, Gnoato, & Sartori, 2007; Tippett, Meier, Blackwood, & Diaz-Asper, 2007; Zannino, Perri, Carlesimo, Pasqualetti, & Caltagirone, 2002). However, this effect was less consistent in translation, suggesting that the semantic properties of the words are task sensitive. One possible reason is that word translation is more based on the lexical and phonological proprieties of the links between the two languages and less on semantics. This hypothesis is consistent with previous findings that phonologically similar words (cognates) are easier to translate and show less involvement of semantic processing, than words with no overlap as non-cognate (e.g., Groot, 1992; de Groot, Dannenburg, & van Hell, 1994; for the role of semantics in translation see also Duyck & Brysbaert, 2008). Indeed, patients made fewer errors when the word to be translated was a cognate, indicating that phonology helped when the lexical connections overlapped for sounds. Also, the advantage of lexical similarity indexed by the advantage of cognate words was found to be significant for most of the errors in word translation but not in picture naming.

That is, semantics and phonology are two processes that might be differentially involved in word translation and picture naming.

In the word-picture matching task, AD patients showed a decline in performance over time, which was similar for both languages. This would suggest that word comprehension and the abilities of associating words to visual stimuli got worse as the disease progressed. However, the magnitude of such a decline over time was very small, and the performances of the AD patients after 1 year were not dramatically impaired. Indeed, most AD patients after 1 year performed at the task ceiling, and the errors found in the patient groups were few and restricted only to some patients. This would also suggest that, if this task measures semantic memory functioning to some extent, its deterioration in AD patients over time might explain the decline in picture naming and word translation. However, given that word-picture matching is not a purely semantic task, we cannot explain language deterioration in production tasks in these terms. Furthermore, the decline of semantic memory (as measured with a neuropsychology test, such as the Pyramids and Palm Trees Test) did not predict language deterioration either in the dominant or non-dominant language in the regression analyses. Therefore, its contribution, if any, is very small.

One possible explanation for the decline in the performance of the AD patients is that it is related more to deficits in failure access during lexical retrieval than to degradation of semantic memory. This idea in line with the findings of many studies of the relation between semantic and word-finding deficits in AD patients (e.g., Giffard et al., 2002; Giffard, Desgranges, & Eustache, 2005; Hernandez, Costa, Juncadella, Sebastian-Galles, & Rene, 2008; Laisney, Giffard, & Eustache, 2004; Martins & Lloyd-Jones, 2006; Nebes, 1989; Ober, Shenaut, Jagust, & Stillman, 1991; Perri et al., 2003; Perri, Zannino, Caltagirone, & Carlesimo, 2011). This is also related to the idea that the deficits of lexical retrieval may be explained at least in part by dysfunctions of the EC. As anticipated in the introduction, it has been shown that these two domains are related, and thus deficits of extra-linguistic control might have an impact on linguistic abilities (for a review of language impairments in AD and MCI see Taler & Phillips, 2008). It is also known that domain-general EC is linked to bilingual language control. Therefore, a deficit in the non-linguistic domain would have negative consequences for control mechanisms in the language domain (e.g., Abutalebi & Green, 2007; Abutalebi et al., 2008; Calabria et al., 2014; Cattaneo et al., 2015; Green, 1998; Kong, Abutalebi, Lam, & Weekes, 2014). The results of our study suggest that EC deficits, if any, should affect the lexical retrieval similarly in both languages. Therefore, this does not support the hypothesis that EC deficits may have more detrimental effects on the non-dominant language because it is more dependent on controlled processes (see Ivanova et al., 2014 for this hypothesis for differential language impairment in bilingual AD patients). One possibility for looking at this issue is to analyse the pattern of cross-language intrusions as a potential decline in language control abilities, as this type of error was reported to be the most frequent in people with pathological language switching (e.g., Abutalebi et al., 2000; Aglioti & Fabbro, 1993; Calabria et al., 2014; Fabbro et al., 2000; Mariën et al., 2005). Although cross-language intrusions were observed in the non-dominant language of the AD patients when they named pictures, these were not the most frequent errors observed; omissions and semantic errors were equally frequent. Importantly, cross-language intrusions did not significantly increase over time in a differential way in the two languages (for instance, more in the non-dominant language). However, we must acknowledge that we do not have other more sensitive measures of the efficiency of language control abilities such as reaction times. Therefore, it is also possible that EC and/or language control were to some extent affected in AD patients, but not to the degree where they affected the verbal response in the production tasks.

To determine whether the decline of performance in the linguistic tasks was related to specific deficits beyond the language domain, we performed regression analyses. We introduced in the regressions all those tests in which AD patients showed worse scores after 1 year, such as those measuring short-term memory, verbal and non-verbal episodic memory, semantic fluency, semantic memory and the degree of cognitive decline (MMSE). The decline in non-verbal episodic memory was the only neuropsychological measure that explained the deterioration in the two languages over time. This finding can be explained by the fact that episodic memory is the most affected cognitive function at the onset of AD, therefore also more vulnerable to decline as the disease progresses (e.g., Bertens, Knol, Scheltens, & Visser, 2015; Wolfsgruber et al., 2014) Therefore, as being the cognitive function that is more affected by AD, it comes out that it is also the most sensitive to language deterioration, compared to other cognitive domains.

The results from this longitudinal study replicate those of our cross-sectional study with the same bilingual participants (Costa et al., 2012). This consistency suggests that at least in early and highly proficient bilinguals, AD affects the two languages in a parallel way, and they are organised with the same linguistic principles. However, the findings of the present study do not exactly replicate those of the longitudinal study by Ivanova et al. (2014). That study found that Spanish-dominant bilingual patients showed a greater decline in their non-dominant language (English) than in their dominant language, whereas the language decline in English-dominant patients was the same in both languages. However, the Spanish-dominant bilinguals were exposed to their non-dominant language later (mean age = 13.75 years) than the English-dominant bilinguals (at birth). Therefore, this might explain the differential language decline in the Spanish-dominant bilinguals vs. the parallel decline in the English-dominant participants. The participants in the present study were early and highly proficient bilinguals. Therefore, we expected that a similar impairment would be found in both languages. This once again supports the idea that the age of second language acquisition and language proficiency may modulate the pattern of language deterioration and recovery after brain damage (Costa et al., 2012; Gollan et al. 2010; for a similar argument on bilingual aphasia see Lorenzen and Murray, 2008).

Finally, we found that MCI patients in our study did not show language deterioration over 1 year as AD patients. This suggests that the general cognitive decline they suffered was mild and had no impact on their linguistic abilities. As the rate of conversion to dementia of MCI patients is estimated at around 12% per year (e.g., Petersen & Morris, 2003), it was likely that in our sample most of the patients would not show severe cognitive decline. Previous follow-up studies with MCI patients have indeed shown that only those patients who convert to dementia decline their performance over time and they also score worse at baseline compared to stable MCI (e.g., Belleville, Gauthier, Lepage, Kergoat, & Gilbert, 2014; Summers & Saunders, 2012). Therefore, as in our MCI patients we did not observe conversions to AD, this would be the reason why they did not show significant language decline after 1 year.

To conclude, this study assessed the extent to which AD affected the two languages of early and highly proficient bilinguals. The results of the 1-year follow up revealed that AD had similar effects on the two languages in production tasks, such as picture naming and word translation. Further research will be needed to explore the role of EC and language control in AD and to examine the extent to which they might affect word production. Moreover, it would be interesting to explore how these linguistic and non-linguistic control deficits dissociate in the spectrum of NDs.

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Figure captions

Figure 1

Picture Naming accuracy broken down by Group of Participants, Language Dominance at baseline, 6 months and 12 months.

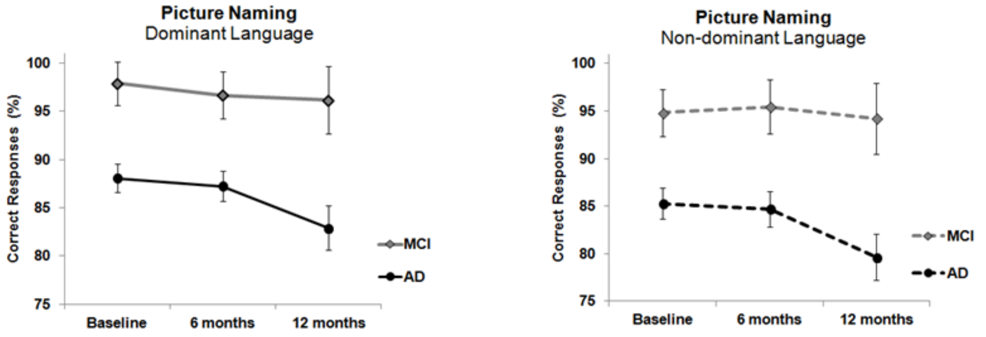

Figure 2

Word Translation accuracy broken down by Group of Participants, Language Dominance at baseline, 6 months and 12 months.

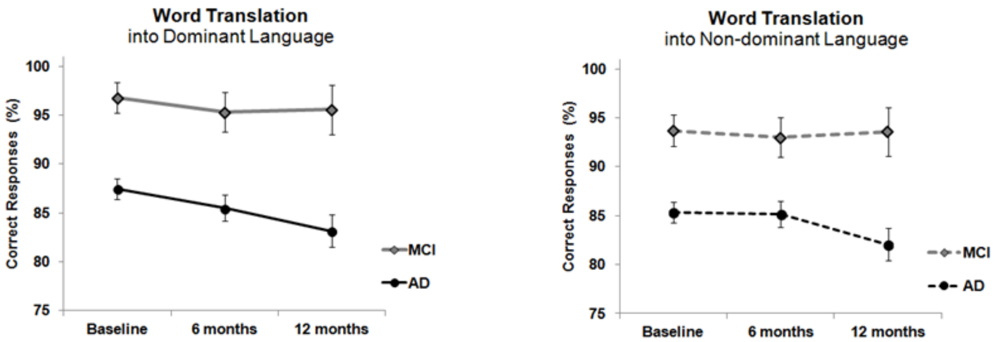

Figure 3

Distribution of error types in the Picture Naming task in AD patients broken by Language Dominance at baseline and 12 months.

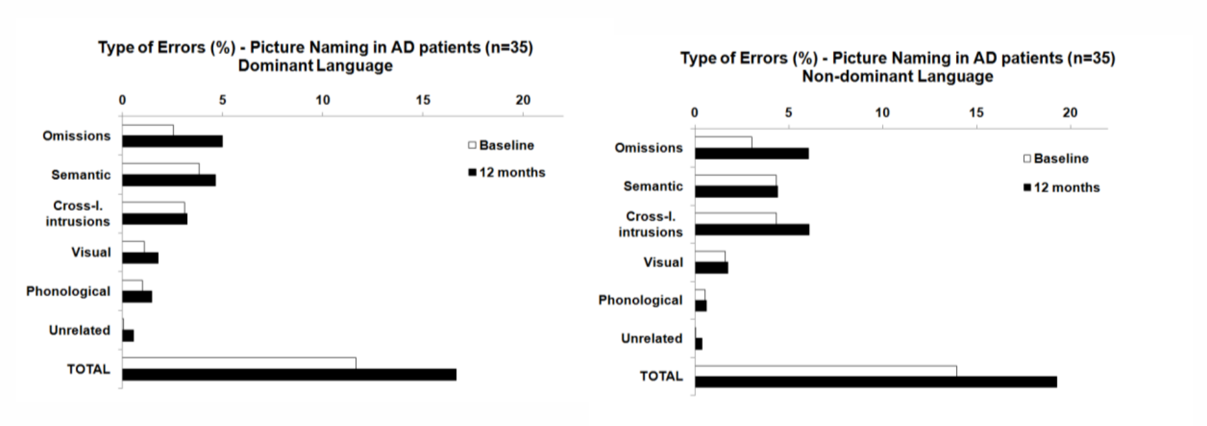

Figure 4

Distribution of error types in the Word Translation task in AD patients broken by Language Dominance at baseline and 12 months.

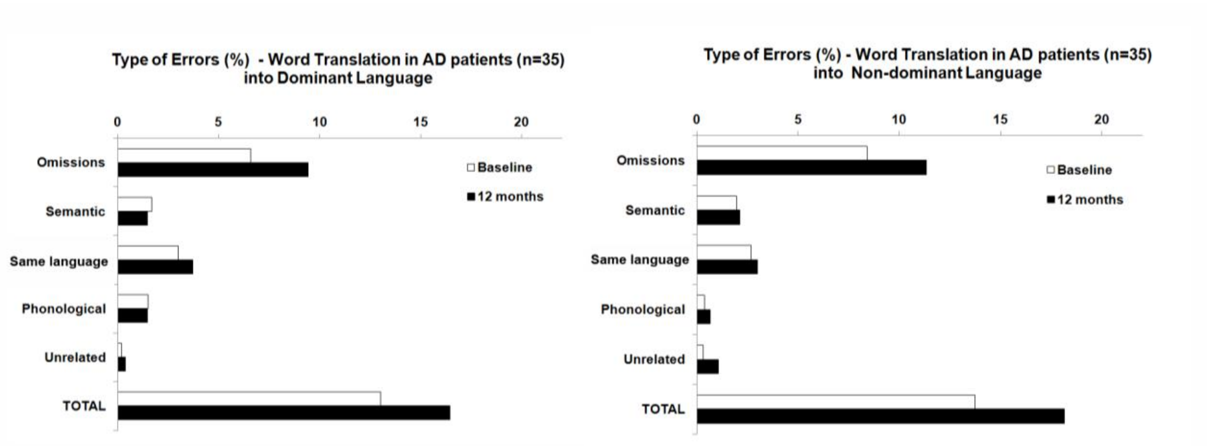

Table 1. Type of language deterioration found in studies with bilingual AD patients.

Authors	Languages	Age of L2 acquisition/exposure	Participants	Tasks/Measures	Language deterioration (Differential vs. Parallel)	Dominant/Non-Dominant language
CROSS-SECTIONAL STUDIES						
Fiedland and Miller (1999)	English and Afrikaans	12 yo	AD (n=4)	Spontaneous speech/conversation	Differential	Non-dominant
Mendez et al. (1999)	Different languages and English	13 yo	AD (n=31)	Conversational speech (Caregivers report)	Differential	Non-dominant
De Piccioto and Friedland (2001)	English and Afrikaans	7 yo	Healthy elderly (n=30), AD (n=6)	Semantic fluency	Differential	Non-dominant
Meguro et al. (2003)	Japanese and Portuguese	-	AD (n=4)	Picture naming, Reading, Word comprehension, Lexical decision	Differential	Non-dominant
Salvatierra et al. (2007)	English and Spanish	~ 20 yo	Healthy elderly (n=11), AD (n=11)	Semantic and Phonemic fluencies	Parallel	
Gollan et al. (2010)	English and Spanish	Spanish-dominant: AD ~ 33 yo; Elderly ~ 31 yo	Healthy elderly (n=42), AD (n=29)	Picture naming (Boston Naming Test)	Differential	Dominant
Gomez-Ruiz et al. (2012)	Catalan and Spanish	< 5 yo	Healthy elderly (n=12), AD (n=12)	Bilingual Aphasia Test	Parallel	
Costa et al. (2012)	Catalan and Spanish	< 6 yo	MCI (n=24), AD (n=47)	Picture naming, Word translation, Word comprehension	Parallel	
LONGITUDINAL STUDY						
Ivanova et al. (2014)	English and Spanish	English-dominant: birth; Spanish-dominant: AD ~ 14 yo; Elderly ~ 24 yo	Healthy elderly (n=14), AD (12)	Picture naming (Boston Naming Test)	Differential	Non-dominant

Table 2. Mean values and standard deviations (SD) for the variables related to the linguistic profile of the participants, broken down by Group of Participants (MCI and AD).

	MCI (N=15)		AD (N=30)	
	Mean	**SD**	**Mean**	**SD**
L1/L2 (Catalan/Spanish)	**10/5**		**29/1**	
Age of regular L1 use	**1.93**	0.5	**2.1**	0.2
Age of regular L2 use	**4.6**	3.0	**4.3**	2.2
L1 Speaking	**4.0**	0.6	**3.9**	0.4
L1 Comprehension	**4.0**	0.0	**4.0**	0.0
L1 Reading	**3.5**	1.4	**3.0**	0.9
L1 Writing	**2.2**	1.8	**1.5**	1.2
L2 Speaking	**3.6**	0.6	**3.4**	0.8
L2 Comprehension	**3.9**	0.3	**4.0**	0.0
L2 Reading	**3.5**	0.9	**3.4**	0.9
L2 Writing	**2.5**	1.1	**2.5**	0.9

Table 3. Mean values and standard deviations (SD) for age, education and neuropsychological tests, broken by Group of Participants (MCI and AD).

	MCI (n=15)					***AD (n=35)***					
	Baseline		**12 months**		***Time diff.***	**Baseline**		**12 months**		***Time diff.***	***Group diff.***
	Mean	***SD***	**Mean**	***SD***	***p values***	**Mean**	***SD***	**Mean**	***SD***	***p values***	***p values***
Age (years)	**73.7**	*4.6*				**78.4**	*6.4*				0.01
Education (years)	**12.1**	3.9				**11.3**	4.4				0.53
MMSE	**27.1**	*2.2*	**25.6**	*3.2*	*0.06*	**20.5**	*2.4*	**17.8**	*5.1*	*<0.01*	<0.01
Pyramids and Palm Trees Test	**51.0**	*1.1*	**50.2**	*1.9*	*0.06*	**47.7**	*3.3*	**45.0**	*4.2*	*<0.01*	<0.01
Semantic fluency	**12.3**	*4.0*	**12.2**	*3.9*	*0.88*	**8.9**	*3.5*	**6.6**	*2.9*	*<0.01*	<0.01
CERAD Delayed Recall	**2.1**	*1.9*	**1.9**	*1.9*	*0.54*	**0.1**	*0.3*	**0.1**	*0.2*	*0.90*	<0.01
CERAD Recognition	**16.9**	*2.3*	**16.3**	*2.9*	*0.23*	**12.9**	*3.3*	**12.5**	*3.5*	*0.48*	<0.01
Benton Visual Retention Test	**6.3**	*1.7*	**6.1**	*2.0*	*0.80*	**4.3**	*1.9*	**3.0**	*2.5*	*<0.01*	<0.01
Forward digit span	**4.7**	*0.8*	**4.9**	*1.1*	*0.63*	**4.7**	*1.0*	**4.3**	*1.4*	*0.06*	0.36
Backward digit span	**3.6**	*1.1*	**3.7**	*1.5*	*0.67*	**2.8**	*1.1*	**2.4**	*1.2*	*0.01*	<0.01

Appendix A – List of stimuli

Catalan name	Spanish name	English name	Cognate status	Frequency in Spanish	Frequency in Catalan	Semantic category	Man-made
aixeta	grifo	faucet	Non-cognate	9,77	762	tool	Yes
ànec	pato	duck	Non-cognate	9,24	548	animal	No
arbre	árbol	tree	Cognate	93,26	11669	nature	No
armari	armario	closet	Cognate	27,53	334	furniture	Yes
cadira	silla	chair	Non-cognate	64,48	1081	furniture	Yes
camell	camello	camel	Cognate	5,86	543	animal	No
cavall	caballo	horse	Cognate	95,57	2338	animal	No
cirera	cereza	cherry	Cognate	6,39	3731	vegetable	No
conill	conejo	rabbit	Cognate	12,79	1019	animal	No
cuc	gusano	worm	Non-cognate	8,35	1213	animal	No
cullera	cuchara	spoon	Cognate	4,62	367	kitchen tool	Yes
destral	hacha	ax	Non-cognate	6,39	1136	tool	Yes
elefant	elefante	elephant	Cognate	12,97	528	animal	No
escala	escalera	ladder	Cognate	19,01	582	tool	Yes
escombra	escoba	broom	Cognate	3,01	3910	kitchen tool	Yes
església	iglesia	church	Cognate	119,55	376	building	Yes
espelma	vela	candle	Non-cognate	24,87	367	kitchen tool	Yes
esquirol	ardilla	squirrel	Non-cognate	9,95	344	animal	No
finestra	ventana	window	Non-cognate	134,83	1024	furniture	Yes
formatge	queso	cheese	Non-cognate	16,16	383	food	Yes
forquilla	tenedor	fork	Non-cognate	4,62	1490	kitchen tool	Yes
fulla	hoja	leaf	Non-cognate	72,3	32928	nature	No
gàbia	jaula	cage	Non-cognate	16,34	259	other obj	Yes
ganivet	cuchillo	knife	Non-cognate	22,2	6592	tool	Yes
gat	gato	cat	Cognate	57,2	1615	animal	No

gos	perro	dog	Non-cognate	98,24	741	animal	No
granota	rana	frog	Non-cognate	12,26	12587	animal	No
llapis	lápiz	pencil	Cognate	9,42	571	tool	Yes
lleó	león	lion	Cognate	0,18	5146	animal	No
llibre	libro	book	Cognate	308,74	2759	entertainment	Yes
lluna	luna	moon	Cognate	2,13	1255	nature	No
martell	martillo	hammer	Cognate	6,23	7024	tool	Yes
mirall	espejo	mirror	Non-cognate	76,21	1472	furniture	Yes
mitjó	calcetín	sock	Non-cognate	9,77	5030	clothes	Yes
molí	molino	windmill	Cognate	10,3	5975	building	Yes
mussol	búho	owl	Non-cognate	6,04	297	animal	No
orella	oreja	ear	Cognate	44,41	18107	body part	No
ou	huevo	egg	Non-cognate	49,38	795	food	No
ovella	oveja	sheep	Cognate	12,08	4095	animal	No
paella	sartén	pan	Non-cognate	3,73	1556	kitchen tool	Yes
papallona	mariposa	butterfly	Non-cognate	14,92	1747	animal	No
pa	pan	bread	Cognate	57,02	804	food	No
plat	plato	plate	Cognate	50,98	1614	kitchen tool	Yes
poma	manzana	apple	Non-cognate	19,36	3632	vegetable	No
porta	puerta	door	Cognate	338,94	8900	furniture	Yes
pou	pozo	draw-well	Cognate	20,78	1668	building	Yes
raïm	uva	grape	Non-cognate	10,12	274	vegetable	No
raspall	cepillo	brush	Non-cognate	5,86	1079	tool	Yes
rellotge	reloj	watch	Cognate	61,82	17339	tool	Yes
taula	mesa	table	Non-cognate	189,9	13	furniture	Yes
telèfon	teléfono	telephone	Cognate	88,82	2468	tool	Yes
tisores	tijeras	scissors	Cognate	5,86	19349	tool	Yes
ull	ojo	eye	Non-cognate	551,05	414	body part	No
ulleres	gafas	glasses	Non-cognate	29,13	606	clothes	Yes

Appendix B – Normality tests (Kolmogorov–Smirnov)

Normality test (Kolmogorov–Smirnov) in MCI patients

MCI patients (n=15)	Picture naming L1 Baseline	Picture naming L1 12 months	Picture naming L2 Baseline	Picture naming L2 12 months	Word-Pict Matching L1 Baseline	Picture naming L1 12 months	Word-Pict Matching L2 Baseline	Picture naming L2 12 months	Word translation L1 Baseline	Word translation L1 12 months	Word translation L2 Baseline	Word translation L2 12 months
St. deviation	2.31	4.05	5.56	6.21	.85	.48	.065	.65	3.60	3.81	6.25	4.84
Z value	.84	.95	.79	1.16	1.75	2.07	.199	1.99	.96	.04	1.14	.95
p value	.47	.32	.55	.14	.004	< .001	.001	.001	.32	.33	.15	.32

Normality test (Kolmogorov-Smirnov in AD patients

AD patients (n=35)	Picture naming L1 Baseline	Picture naming L1 12 months	Picture naming L2 Baseline	Picture naming L2 12 months	Word-Pict Matching L1 Baseline	Picture naming L1 12 months	Word-Pict Matching L2 Baseline	Picture naming L2 12 months	Word translation L1 Baseline	Word translation L1 12 months	Word translation L2 Baseline	Word translation L2 12 months
St. deviation	10.22	16.03	10.89	12.78	2.37	7.19	2.16	6.68	7.00	11.31	7.36	8.9
Z value	.97	1.16	1.25	1.09	2.26	1.71	2.16	1.57	.84	1.18	1.29	.96
p value	.30	.13	.09	.18	< .001	.006	< .001	.01	.47	.12	.07	.31