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Bilingual aphasia: assessing cross-linguistic asymmetries and bilingual advantage in sentence comprehension deficits.

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Abstract:

People with aphasia frequently have difficulties understanding semantically reversible sentences presented in derived word order. This impairment may be related to the inconsistent processing of morphological information, as well as to difficulties inhibiting the inverse interpretation of the sentence. Studies on bilingual aphasia may contribute to our understanding of these issues by shedding light on i) differences in processing of morphology across languages; ii) enhanced control mechanisms. We studied early Basque-Spanish bilingual speakers with aphasia and monolingual Spanish speakers with aphasia, as well as in unimpaired individuals. Using comparable sets of materials across languages, we combined behavioural and eye-tracking methods. Results indicate that i) at the group level, bilingual speakers perform better in Spanish than in Basque, particularly in sentences with Theme-Agent argument order. Individual case analysis shows a pattern of weak dissociation across languages in several participants; ii) bilingual people with aphasia do not outperform monolingual people with aphasia in comprehension accuracy, although

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gaze data suggests that bilingual speakers exhibit higher inhibition and monitoring abilities.

*Keywords:* aphasia, sentence comprehension, bilingualism, bilingual advantage, executive functions; eye-tracking.

1. **Introduction**

1.1. **Theories on sentence comprehension difficulties in PWA**

The comprehension of semantically reversible sentences presented in derived word orders has been shown to be particularly impaired in a large proportion of people with aphasia (henceforth PWA) with preserved lexical comprehension. PWA fail to interpret *who does what to whom* in sentences where animacy is not a reliable cue for agency-identification (e.g., semantically reversible sentences where all arguments are animate). In this case, sentence interpretation is dependent on syntactic relations. Difficulties are most prominent for sentences presented in Theme-Agent order (e.g., *The girl has been followed by the boy*) (e.g., Bastiaanse & Van Zonneveld, 2006; Burchert, De Bleser, & Sonntag, 2003; Caramazza, Capitani, Rey, & Berndt, 2001; Caplan & Futter, 1986; Caramazza & Miceli, 1991; Caramazza & Zurif, 1976; Grodzinsky, 1995, 2000; Mitchum & Berndt, 2008; Schumacher et al., 2015).

This error pattern has been reproduced in many group studies, although the individual variability is high. However, the appearance of errors in sentence presented in Theme-Agent argument order is not systematic. The specific linguistic computations are not completely enabled, and it is hard to predict when a PWA will misinterpret a given sentence (Caplan, Michaud, & Hufford, 2013; Caplan, Waters, DeDe, Michaud, & Reddy, 2007). Difficulty in predicting failure in thematic-role parsing is compatible with a processing account where reduced computational resources cause parser breakdown when the cognitive demands of the linguistic material exceed its processing capacities (e.g., Avrutin, 2006; Burkhardt, Avrutin, Piñango & Ruigendijk, 2008; Caplan, 2006; Caplan & Waters, 2013; Caplan et al., 2007; Haarmann, Just, & Carpenter, 1997). This account converges with studies on
healthy adults that show an age-related decline in sentence comprehension abilities related to factors such as syntactic complexity, word order, processing speed and auditory integration (e.g., Caplan, DeDe, Waters, Michaud, & Tripodis, 2011; Füllgrabe, 2013; Humes, et al. 2010; Obler, Fein, Nicholas, & Albert, 1991; Schneider, Daneman, & Murphy, 2005; Snell, 1997; Sung, 2016; Wendt, Dau, & Hjortkjaer, 2016; Wingfield, Peelle, & Grossman, 2003).

1.2. Impact of cross-linguistic differences on sentence comprehension

Syntactic processing strategies yield different outputs across languages, depending on their morphosyntactic properties, as well as the position of the object in relation to the verb (i.e. VO/OV) (e.g., Bader & Lasser, 1994; Gibson 1991, 1998, 2000; Gibson et al., 2013; Nakatani & Gibson, 2010; Ros, 2018; Ros, Santesteban, Fukumura, & Laka, 2015; Santesteban, Pickering, Laka, & Branigan, 2015). Aside from structural differences between languages, it has been suggested that listeners rely on distinctive information cues to discern the Agent/Theme. Healthy speakers of richly inflected languages such as Italian or Turkish rely more strongly on morphological information (e.g., subject-verb agreement) to parse the sentence than English speakers who use word order information (Bates, Devescovi, & Wulfeck, 2001; Duman, Altinok, Özyirgin, & Bastiaanse, 2011). Thus, comprehension of sentences presented in derived word orders may be less impaired in a PWA speaker of a richly inflected language, such as Turkish, than in a PWA speaker of a less inflected language, such as English.

Nevertheless, it is still an open question whether sentence comprehension of PWA who speak different languages is affected differentially by the processing of specific morphological markers. The answer to this question is beyond a between-group comparison in cross-linguistic studies, since they do not account for confounds such as inter-subject/stimulus variability. Hanne, Burchert, De Bleser and Vasishth (2015) have found that processing case morphology is more vulnerable than processing agreement in PWA speakers of German. This finding suggests that the morphological markers that cue thematic-role assignment are particularly affected when compared to other type of linguistic markers. Aside from the intralinguistic comparisons mentioned above, the study of early bilinguals offers an alternative
approach to better understand language-specific morphological properties and their impact on comprehension deficits in PWA, from an interlinguistic point of view.

1.3 Sentence comprehension deficits in bilingual speakers

Studies on sentence comprehension abilities in people with bilingual aphasia are scarce (see Khachatryan et al., 2016). Abuom, Shah, and Bastiaanse (2013) studied sentence comprehension in a group of balanced bilingual Swahili-English speakers with agrammatism. They found an equal degree of sentence processing impairment across languages. Similar results were found in PWA speakers of structurally similar languages such as Galician and Spanish (Juncos-Rabadán, Pereiro, & Souto, 2009).

There are just two studies on bilingual PWA that contrast the presence and absence of case-morphology across languages and its impact on sentence comprehension deficits. Munarriz, Ezeizabarrena, and Gutierrez-Mangado (2016) studied a non-fluent, bilingual Basque-Spanish PWA performing a sentence comprehension task using wh-questions and relative clause sentences attending to Agent-Theme and Theme-Agent argument orders in both Basque and Spanish. They found a differential morphosyntactic impairment across languages, characterized by the preserved comprehension of all structures in Spanish, and a very selective impairment in Basque, affecting object-initial wh-questions and subject relative sentences. Venkatesh, Edwards and Saddy (2012) studied multilingual PWA while performing lexical and syntactic tasks in Hindi and English. Participants did not show cross-linguistic differences in the comprehension and production of single words, but differed in their sentence comprehension abilities, showing better performance in Hindi than in English. Both Basque and Hindi are morphologically rich languages with free word order. In Basque, the agent of the action is marked with ergative case marking, whereas Hindi displays split ergativity. Ergative or nominative case marking may signal the agent or the subject of the verb,

Because the ergative alienation of Basque, subject relative structures arguments follow non-linear Theme-Agent order, while object relative structures have Agent-Theme argument order. Carreiras, Duñabeitia, Vergara, de la Cruz-Pavía, & Laka, (2010) have shown in an experiment with healthy speakers of Basque, that subject relatives are harder to process than object relatives, shown by longer self-paced reading times and larger amplitudes in the P600. Listeners deploy an agent-first strategy for the ambiguous sentence-initial DP, yielding the object-gap relative clause making the lowest processing demands.
conditioned by the tense and aspect carried by the latter. In contrast, English and Spanish do not have morphological case (although it is reduced to the personal pronominal system in both languages). The results of Munarriz et al. (2016) and Venkatesh et al. (2012) are conflicting on the idea that case-morphology aids comprehension of sentences in derived word orders in PWA, and call for a more detailed analysis.

Sentence processing in bilingual aphasia warrants further investigation for a number of reasons. It offers an opportunity to provide evidence in relation to the cross-language transfer of linguistic abilities, as it has been suggested for morphosyntactic strategies (Döpke, 2000; Santesteban & Costa, 2006; Wulfeck, Juarez, Bates, & Kilborn, 1986), therapeutic outcomes (see Ansaldo & Saidi, 2014; Kohnert, 2009), as well as for syntactic priming experiments (Hartsuiker, Beerts, Loncke, Desmet, & Bernolet, 2016; Hartsuiker, Pickering, & Veltkamp, 2004; Verreyt et al., 2013). Hartsuiker and Kolk (1998) reported for the first time within-language syntactic priming effects in a group of participants with Broca’s aphasia. They found that the accuracy of the production of syntactic structures was influenced by the syntactic structures previously presented. Going a step further, Verreyt et al. (2013) found that syntactic priming in bilingual PWA was not limited to priming within one language, but happened across languages as well. The finding supports the view that bilinguals employ a unified lexical-syntactic system, where syntactic representations are shared between languages.

1.4. Sentence comprehension, bilingualism and executive functions

Comprehension of sentences with derived orders using solely morphosyntactic cues requires inhibition of the dominant interpretation derived from constituent order. Inhibitory control processes, as well as mental flexibility and the ability to restore information from working memory are part of the executive functions (Friedman & Miyake, 2004; Friedman & Miyake, 2017; Miyake et al., 2000), which are impaired in some PWA (Hamilton & Martin, 2005; Peristeri, Tsimpli, & Tsapkini, 2011; Purdy, 2002). This is compatible with some studies that have suggested that syntactic processing deficits in PWA are related to working memory problems (e.g., Haarmann, et al., 1997; Ivanova, Dragoy, Kuptsova, Ulicea, & Laurinavichyute, 2015; Miyake, Carpenter, & Just, 1994; Sung et al., 2009; but see Caplan, et al.,
2013, for a review), and to inhibitory/cognitive control limitations (Dickey et al., 2007; Schumacher et al., 2015; Vuong & Martin, 2015; see Novick, Trueswell, & Thompson-Schill, 2005; 2010; for an overview Ardila, 2012; cf. Thothathiri & Mauro, 2018).

Some evidence suggests that bilingualism enhances executive function. In order to ignore irrelevant information and avoid language conflicts bilingual speakers exploit a more general inhibitory control system than monolingual speakers, as indicated by better performance and/or lower reaction times (RTs) on several tasks involving verbal and non-verbal executive functions, such as the Simon task (Bialystok, Craik, Klein & Viswanathan, 2004; Martin-Rhee & Bialystok, 2008), the Stroop test (Martin-Rhee & Bialystok, 2008), the attentional network task (Costa, Hernández, & Sebastián-Gallés, 2008), or a task switching test (Prior & MacWhinney, 2010) (cf. Duñabeitia et al., 2014; Paap & Greenberg, 2013). This may be related to the simultaneous activation of the two languages regardless of the language in use (e.g., Costa & Santesteban, 2004; Marian & Spiwey, 2003; see Kroll, Bobb, & Wodniecka, 2006 and Kroll & Dussias, 2013), as well as comparable patterns of neural activity across languages (e.g., Consonni et al., 2013; Díaz, Sebastián-Gallés, Erdocia, Mueller, & Laka, 2011).

The question is whether this potential advantage in executive functions extends to sentence processing abilities. Studies in unimpaired bilinguals have shown that speakers transfer syntactic parsing across languages (Dussias & Sagarrá, 2007; Frenck-Mestre & Pynte, 1997) and they are more resistant to sentence-level interference than their monolingual peers (Filippi, Leech, Thomas, Green & Dick, 2012). Recently, Teubner-Rhodes et al. (2016) have tested the bilingual advantage hypothesis in Spanish-Catalan bilingual speakers in sentence parsing routines by using object-first garden-path sentences, as well as subject-first non-ambiguous sentences. Crucially, they have reported that bilingual speakers outperform monolinguals in their comprehension of both garden-path and non-ambiguous sentences. This suggests that the bilingual advantage goes beyond sentences involving conflict in thematic-role assignment. It is associated with a more general conflict-monitoring mechanism, and it is not limited to the enhancement of inhibitory processes (see Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Martin-Rhee & Bialystok, 2008). Recently, Alladi et al. (2016) have reported
that the incidence of aphasia is similar in bilingual and monolingual speakers, whereas cognitive impairments due to stroke have significantly lower prevalence in bilingual than in monolingual speakers. The authors suggest these results are a consequence of mastering executive functions through a lifelong practice of language switching by bilingual speakers. In line with this, Penn, Frankel, Watermeyer, and Russell (2010) studied the neuropsychological correlates on executive functions in a small group of monolingual and bilingual PWA. Bilingual PWA showed better performance on standardized tasks, as well as within conversation, as described by response inhibition, interference control, working memory, and repair abilities. It is an open question whether this potential advantage also benefits bilingual PWA with sentence comprehension deficits compared to monolingual PWA.

1.5. The role of online investigation of sentence comprehension

Real time sentence resolution data are important to shed light on our understanding of comprehension deficits in PWA. The Visual World Paradigm (VWP) has been shown to be suitable in a variety of studies of sentence resolution in both PWA and healthy listeners. When participants are simultaneously presented with linguistic and visual information that is referentially related, the linguistic information drives visual attention shifts (Cooper, 1974; Eberhard, Spivey-Knowlton, Sedivy, & Tanenhaus, 1995). The shift is highly automatic and it becomes obvious within a narrow temporal window of approximately 200 ms after the disambiguating information becomes available (Matin, Shao, & Boff, 1993). Thus, the study of gaze fixation patterns within the visual display allows for inferences regarding how the participant processes linguistic information in real time. Although most of the studies on VWP focus on attention shifts towards the target stimuli, examining gaze fixations towards the competitor picture has a potential value to get insight into cognitive control and executive functions in terms of inhibitory abilities (Bartolotti & Marian, 2011; Thibaut & French, 2016; Trude & Nozari, 2017; see Miyake et al., 2000; Nozari, Trueswell, & Thompson-Schill, 2016; but see Blumenfeld & Marian, 2011). When several pictures are shown on the visual display, in order to successfully resolve the task, inhibitory mechanism must be activated towards the non-target elements to a varying degree, depending on the task and the relation between target and distractor/competitor (see Becker, 2010). There is evidence
suggesting that poorer ability to inhibit the distractor/competitor picture is related to immature or handicapped executive functions, as it has been shown in PWA and children in relation to Non-Brain-Damaged (NBD) adults (Laurinavichyute, Ulicheva, Ivanoca, Kuptsova & Dragoy, 2014; Thibaut & French, 2016).

We present a twofold study. Firstly, a cross-linguistic examination of sentence comprehension will be conducted in a group of Basque-Spanish bilingual PWA and matched NBD participants. Secondly, we will compare the performance of bilingual and monolingual speakers of Spanish in sentence comprehension, and the potential benefit that bilingualism may provide to PWA.

1.6. Linguistic backgrounds

1.6.1. Basque:

Basque is a language isolate, with very rich inflectional morphology. The subject, as well as the direct and indirect objects agrees with the inflected verb in person, number, and case. It is a free word-order language, with Subject-Object-Verb (SOV) as its base order (De Rijk, 1969; Erdocia, Laka, Mestres-Missé, & Rodriguez-Fornells, 2009). In addition, Basque is an ergative language (Levin, 1983; Ortiz de Urbina, 1989; Laka, 2006). According to Levin (1983) and Laka (2006), case morphology corresponds directly with thematic roles: ergative case corresponds to agents, absolutive case corresponds to themes, and dative case corresponds to goals. For example, the objects of transitive verbs and the subjects of unaccusative verbs have the same morphological (zero) marking (1-2), called “absolutive” (Ø), while the agentive subject of transitive verbs carries ergative case (-k) (1).

(1) Txakurr-a-k katu-a- Ø harrapatu du.
   dog-det-erg cat-det-abs caught aux.has  
   The dog has caught the cat

(2) Txakurr-a- Ø etorri da.
   dog-det-abs arrived aux.is  
   The dog has arrived
Given the freedom of sentence word order in this language, sentences starting with an absolutive marked (Ø) determiner phrase (DP) are temporarily ambiguous in Basque. Until disambiguation, the DP can correspond to the subject of an unaccusative verb (2), or to a sentence-initial object (3), or to a topicalized object in a OSV sentence (4) (see also Laka, 2012).

(3) (txakurr-a-k) katu-a- Ø harrapatu du.
   dog-det-erg cat-det-abs caught aux.has
   (The dog) has caught the cat

(4) Katu-a- Ø txakurr-a- k harrapatu du.
   cat-det-abs dog-det-erg caught aux.has
   The dog has caught the cat

When presented with temporarily ambiguous sentences such as (4), healthy speakers employ a “subject-first” processing strategy, and systematically revise their initial parsing routine when confronted with the second DP (Erdocia et al., 2009). There is evidence suggesting that healthy speakers of Basque use word-order information to resolve morphological ambiguities affecting sentence interpretations (for a review, Laka & Erdocia, 2012).

1.6.2. Spanish:

Spanish is a Romance language with subject-verb agreement for number and person. In addition, determiners, nouns and adjectives are inflected for gender and number. The base order is SVO, and sentence word order is quite flexible. Animate and definite objects are marked with the preposition ‘a’ except in passive constructions (Leonetti, 2003). In active voice (5) the subject is the agent, while for the passive voice (6) the agent of the sentence is realized as an adjunct by-phrase. The theme is the object of the active sentence and the subject of the passive sentence. In (7), the object is the antecedent of a subject-gap relative clause, and in (8) the object heads a cleft, with an object gap.

(5) La mujer ha peinado a la niña
   det woman aux.has comb-PTCP prep det girl
The woman has combed the girl.

(6) La niña ha sido peinada por la mujer.
    det girl aux.has be-PTCP comb-PTCP prep det woman

The girl has been combed by the woman.

(7) Veo a la mujer que peina a la niña.
    see prep det woman pron-rel comb prep det girl

I see the woman who combs the girl

(8) Es a la niña a la que peina la mujer.
    be prep det girl prep det rel-pron comb det woman

It is the girl who the woman combs

Psycholinguistic studies on Spanish have shown that processing semantically reversible theme-initial sentences demands more cognitive resources, as reflected in increased brain activity (Casado, Fernández-Frías, Martín-Loeches, & Muñoz, 2005; Del Río et al., 2011), reduced comprehension accuracy (Del Río et al., 2011), increased RT (Del Río et al., 2011; Del Río, López-Higes, & Martín-Arangoneses, 2012) and slower reading times (Bentacort, Carreiras, & Sturt, 2009), in comparison to agent-first structures. Studies using simple (Casado et al., 2005; Del Río et al., 2012), as well as embedded structures (Bentacort et al., 2009; Del Río et al., 2011) have found effects in relation to argument order, aside from syntactic complexity factors. In a similar manner to Basque, when presented with temporarily ambiguous theme-first sentences in Spanish, listeners prefer to interpret the sentence according to the subject-first bias, and to subsequently implement a full thematic-parsing routine if conflict is introduced at the disambiguation point (see Del Río et al., 2011).

1.7. Research questions

The present study analyses the processes involved in sentence comprehension in bilingual and monolingual speakers combining behavioural (accuracy and reaction time) and eye-tracking methods. The study has two parts: (1) a group of bilingual PWA and NBD performing a sentence comprehension task in Spanish and Basque; (2) a group of bilingual and monolingual PWA and NBD performing a sentence comprehension task in Spanish.
We aim to answer the following research questions:

i. What is the influence of different types of morphological markers (i.e., case-marking vs. prepositions) on sentence comprehension deficits in bilingual PWA?

Accuracy data will be analysed to shed light on this question. Better comprehension accuracy in Basque in relation to Spanish suggests that PWA show better-preserved processing of case-making than of prepositional cues. This is probably because in a free word order language like Basque, case morphology is a more reliable cue to parse agent and theme roles than the prepositional system used in Spanish. However, we have previously found that processing case morphology is particularly affected in PWA speakers of languages such as German (Burchert et al., 2003; Hanne et al., 2015) and Basque (Arantzeta et al., 2017). Therefore, no clear expectations can be drawn.

ii. Do bilingual PWA outperform monolingual PWA in comprehending semantically reversible sentences as a consequence of enhanced executive functioning?

Comprehension accuracy, reaction time and eye-tracking data will be analysed to get insight into this question. NBD participants are likely to perform at ceiling level in sentence comprehension, so we do not expect to be able to detect a bilingual advantage in NBD participants. In line with the evidence suggesting that a) bilingualism enhances executive functions, and b) difficulties comprehending reversible sentences in derived word orders may be due to impaired inhibitory processes, we hypothesise that i) monolingual PWA will be less accurate than bilingual PWA comprehending sentences in derived argument order because of their poorer inhibition capacities towards the interpretation represented by the distractor; ii) monolingual PWA will have longer reaction times than bilingual PWA in the correct answers; iii) monolingual PWA will fixate more on the picture showing the reverse interpretation of the sentence (i.e. competitor picture) while solving the task in the correctly answered trials.
2. Methods

This study obtained the approval of the Basque Clinical Research Ethics Committee (CEIC-E). All participants signed an informed consent form, as a voluntary agreement to participate in the study, about which they were fully informed.

2.1. Participants

Fourteen PWA (11 male and 3 female) ranging in age from 55 to 85 with a mean age of 66.1 (sd: 10.4) were included in this study. Seven of these participants were early bilingual speakers of Basque (L1) and Spanish (L2) and seven were monolingual speakers of Spanish. PWA were included in the study based on their observed aphasic syndrome without regard to their lesion localization (see Willmes & Poeck, 1993). They were all pre-morbidly right-handed as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971) and had chronic non-fluent aphasia as a consequence of a cerebrovascular accident. Visual neglect was excluded with the Behavioral Inattention Test (Wilson, Cockburn, & Halligan, 1987). Fourteen NBD participants were included (8 male and 6 female) ranging in age from 44 to 82 with a mean age of 62.9 (sd: 12.0). They were comparable in age range and educational level to the PWA (see Appendix A1 for individual demographic data). All subjects had normal or corrected-to-normal vision and hearing.

The bilingual group consisted of L1 Basque - L2 Spanish speakers. Information related to their linguistic profile was collected using the Bilingual Language Profile formulary (Birdsong, Gertken, & Amengual, 2012; adapted to Spanish-Basque by Arantzeta, 2016). Participants acquired Spanish at an early age (<5 years). They all reported speaking both Basque and Spanish for more than 20 years. Overall, individual data related to linguistic background and usage (see Appendix A2) suggested that all participants were balanced bilinguals. As expected for age reasons, all participants were literate only in Spanish³.

³ The Basque Country was under the Franco’s dictatorship from the late ’30s to the late ’70s. During this period, Basque was forbidden by law. The literacy language at schools was only Spanish, and Basque was the family/social language, which was frequently used clandestinely.
Prior to the participation of PWA into the experiment, their linguistic abilities were assessed. Bilingual speakers were assessed in both Basque and Spanish, while monolingual speakers were only assessed in Spanish. Linguistic assessment in Basque and Spanish was conducted with the Cognitive Neuroscience Laboratory language screening battery (CNL; Chialant, 2000; adapted to Basque by Erdocia, Santesteban, & Laka, 2003) and the extended version of the Boston Aphasia Test (BDAE; Goodglass, Kaplan, & Barresi, 2005; adapted to Spanish by García-Albea, 2005). In the former, the subparts of auditory discrimination, and lexical and sentence comprehension were assessed. Sentence comprehension was assessed using a spoken-sentence-to-picture-matching task, and included simple and embedded declaratives presented in both base word order (SOV) and derived word order (OSV). Lexical comprehension, commands, complex ideational material and syntactic processing (“touch A with B” and “embedded sentences”) of the BDAE were administered. See Appendix A3 for individual results in each section.

All PWA had preserved lexical comprehension abilities, and impaired sentence comprehension abilities. The latter was determined based on < 75% accuracy in the sentence comprehension task and syntactic processing composite score (i.e., “Touch A with B” and “Embedded sentences”), in Basque and Spanish, respectively. Bilingual and monolingual PWA did not differ in the language scores obtained across any of the subtests of the BDAE, as shown by two-sided t-test comparisons conducted in each section (see Appendix A3). In addition to the assessment related to the inclusion criteria, working memory was examined using the Forward Digit-span task (WAIS-III; Wechsler, 1997), where bilingual PWA could choose which language to use for counting.

2.2. Design and materials

The linguistic and visual materials used in this study were the same as in Arantzeta et al. (2017). They consisted of pairs of pictures shown together with auditorily presented sentences. One of the pictures matched the heard sentence (i.e., target), while the other represented the same action with reversed Agent-Theme thematic roles (i.e., distractor) (see Figure 1).

4 Participants were auditorily presented with a series of numbers that progressively increased in length, and they were required to repeat the numbers in the same order.
2.2.1. Linguistic stimuli:

Two sets of equivalent linguistic stimuli were used in Basque and Spanish. The original materials used in Arantzeta et al. (2017) were kept similar for the Spanish version. The same twenty-two transitive verbs and singular DPs were combined to create the items in Spanish. The stimuli were presented in four word order conditions in Basque (a) SOV; (b) OSV; (c) VSO; and (d) VOS; and six conditions in Spanish; (a) active; (b) passive; (c) subject relative; (d) object relative; (e) subject cleft; (f) object cleft. There were 20 trials per condition. In Basque, the experiment consisted of a total of 176 trials; 80 experimental items, 80 filler items and 16 practice items, while in Spanish, there were 126 trials, consisting of 120 experimental items and 12 practice trials.

In order to have fully comparable sets of stimuli across languages, sentence conditions were clustered as Agent-Theme and Theme-Agent. The former contained the Basque SOV, VSO and the Spanish active, subject relative and subject cleft conditions, while the latter contained the Basque OSV, VOS and Spanish passive, object relative and object cleft conditions. In both languages, the assignment of Agent-Theme roles into the DPs of the sentences was randomized across the conditions. For instance, in sentences with the verb ‘to comb’ and the DPs ‘girl’ and ‘woman’, ‘girl’ was randomly taken as Agent in half of the sentence conditions, and ‘woman’ in the other half.

In Basque, the Agent of the sentence is always overtly marked by means of the ergative case marker (-k) attached to the end of the DP, while the Theme is zero-marked for absolutive case (See 9-12. All sentences mean, “The wild boar has hurt the hunter”).

(9) Subject – Object – Verb (– aux)
    basurde-a-k   ehitztaria-a-Ø  zauri-tu   du
    wild boar-det-erg   hunter-det-(abs)   hurt-perf.   aux.has

(10) Object – Subject – Verb (– aux)
The set of stimuli in Basque contained filler items using 22 unaccusative verbs in combination with a single animate DP. To keep sentence length between target and filler stimuli constant, a temporal adverb was added. Filler stimuli were also presented in the four word order conditions of the experimental stimuli, although in this case the temporal adverb occupied the linear position of the grammatical object in the sequence. Filler stimuli were included in the original study to maintain the syntactic ambiguity implied in OSV constructions due to the case morphology of the language (see Arantzeta et al., 2017). In its absence in the case of Spanish, no filler stimuli were needed. (See 13-16. All sentences mean, “The dancer has suddenly become thin.”).

In Spanish, active sentences (17) were formed using the perfect present tense to have a comparable verb length (in ms.) with the counterpart passive sentences (18). In the relative clauses the verbal phrase “I see” introduced the antecedent and the relative pronoun “que” functioned as subject (19) or object (20). In the cleft
sentences, the contrastive element became the complement of the copular verb “ser”, and the relative pronoun “que” introduced the rest of the sentence (21-22). In object-relative constructions, the relative pronoun was preceded by the preposition “a” (gets contracted to “al” when followed by a masculine definite article “el”), as well as the direct object in the cleft constructions.

(17) El árbitro ha empujado al portero.  
The referee has pushed the goalkeeper.

(18) El portero ha sido empujado por el árbitro.  
The goalkeeper has been pushed by the referee.

(19) Veo al árbitro que empuja al portero.  
I see the referee who pushes the goalkeeper.

(20) Veo al portero al que empuja el árbitro.  
I see the goalkeeper who the referee pushes.

(21) Es el árbitro el que empuja al portero.  
It is the referee who pushes the goalkeeper.

(22) Es al portero al que empuja el árbitro.  
It is the goalkeeper who the referee pushes.

The linguistic stimuli were recorded by a female native speaker of standard peninsular Spanish in a soundproof booth (IAC) using a digital microphone (audio-technica AT4022a). An average speech rate was 4.79 syllables/sec, slightly higher than in Basque (i.e., 3.57 syllables/sec; see Arantzeta et al., 2017), but it is still within the parameters for normal speech (3-6 syllables/sec; Levelt, 2001).

In Spanish, the auditory presentation of the linguistic stimuli was segmented into
Regions Of Interest (ROIs) for subsequent gaze data analysis. ROI 1 agreed with the subject/object of the main clause or the antecedent of the relative clause; ROI 2 with the (relative pronoun +) verbal phrase; and ROI 3 with the subject/object of the verbal phrase. A post-offset ROI 4 was included with a length 1120 ms. ROIs of the experimental stimuli were individually measured using the Computerized Language Analysis software (MacWhinney, 2000) and subsequently length duration was pairwise compared. As shown in Table 1, no difference was found across the paired conditions (i.e., active vs. passive, subject vs. object relative, subject vs. object cleft), or across argument orders (i.e., Agent-Theme vs. Theme-Agent), likewise linguistic material in Basque (see Arantzeta et al., 2017).

2.2.2. Visual stimuli:

The visual stimuli consisted of 88 and 44 black-and-white line drawings in Basque and Spanish (see footnote 5). They were presented in 44 and 22 pairs depicting the same action, but with inverse Agent/Theme thematic roles, as illustrated in Figure 1 (see above). The pictures were approximately 15x15 cm. For detailed information about the visual material and corresponding normalization see Arantzeta et al. (2017).

The presentation of the visual stimuli was pseudo-randomized following two criteria. Firstly, no more than two target stimuli could occur in a row on the same side of the screen. Secondly, the direction in which the action was performed was also balanced across the stimuli to avoid left-to-right scanning (Scheepers & Crocker, 2004).

2.3. Procedure

No part of the study procedures was pre-registered prior to the research being conducted. The experiments were conducted using E-Prime 2.0.10 with extensions for Tobii 2.0.2.41 (ClearView; Psychology Software Tools, Pittsburgh, PA). The visual stimuli were presented on a 23 inches wide LED monitor at 1280*720
resolution, while the auditory stimuli were presented through binaural headphones. A Tobii 120 Desktop Eye tracker (sampling rate 120 Hz, accuracy 0.5 degrees) was placed in the low-centre of the screen, set at 15° angle (max. allow 35°) to monitor the gaze-movements of both eyes across the screen. The distance between the participants and the screen was 60-70 cm.

Separate experimental sets were fitted for each language. Each experimental set was divided into four blocks of 40 and 30 items in Basque and Spanish, respectively. No more than two blocks in each language were administered in each experimental session, always preceded by the trial items.

The experiment consisted of a spoken-sentence-to-picture-matching task. Before the presentation of each block of stimuli, a 5-point eye-movement calibration was conducted. Subsequently, participants were given written instructions on the screen, which were also read aloud and explained. A fixation slide, containing a smiley face, centred in the middle of the screen, introduced each trial. Participants had to fixate onto the smiley face for at least 250 ms before being presented with the experimental stimuli. This arrangement ensured that participants were looking at the middle of the screen prior to the presentation of the experimental stimuli. First, the two pictures were presented on the screen for 1000 ms, before the auditory stimulus was presented. Participants had to select the picture that best corresponded to the meaning of the heard sentence by using specific buttons on the keyboard. Both PWA and NBD groups responded using the left hand, with the exception of a participant with crossed aphasia/ left hemiplegia (A2).

Gaze data and auditory stimuli were time aligned with a correction of 200 ms based on the estimated time required to program and execute the saccade beyond the presentation of the linguistic information (Matin, Shao, & Boff, 1993). Fixations with durations shorter than 90ms (11 data points) were rejected from the analysis to exclude ocular artefacts (e.g., blinks and saccades).

Gaze data were processed by calculating the proportion of fixations to the distractor picture from ROI 1 to ROI 4 of the auditory stimuli. The proportion of gaze-fixations was computed based on the total duration of looks to the target and distractor pictures, and it ranged between 0 and 1. Values closer to 1 indicated fixations on the distractor picture. As expected, the data showed a u-shape
distribution, with the extreme values (0 and 1) being the most frequent, opposite to the middle class interval. The data were log transformed in order to have a linear scale for analysis. Only answers provided within a time window of 11360 ms from the onset of the linguistic stimuli (i.e., consistent with the 8000 ms post-offset established in Arantzeta et al., 2017) were considered valid across both languages. Trials that were not answered in this time period represented 2.59% and 1.46% experimental items in Basque and Spanish, respectively, and were excluded from further data analysis.

3. Data analysis

No part of the study analyses was pre-registered prior to the research being conducted. Generalized Linear Mixed-effects Models (GLMM) and Linear Mixed-effects Models (LMM) were used to analyse binomial (i.e., accuracy) and longitudinal (i.e., reaction time and gaze fixation) data, respectively.

In the model building, an inclusion of fixed effects predictors was determined by the research questions, and the best random-effects structure was assessed using Akaike’s Information Criterion (AIC; Akaike, 1974). Least square means (LSMeans) were used for comparing LS-mean differences on the basis of the specific mixed model. The RT and gaze data were log transformed and the numerical predictor trial number was centred. Tukey correction was used for multiple comparisons, and p<.05 was considered significant. The statistical software R was used for this analysis (R Core Team, 2015, v.3.3.3). The analysis code will be provided to the reader under request.

Additionally, we conducted an individual case analysis by using an odds ratio in order to assess the size of the association between argument orders (i.e., Agent-Theme versus Theme-Agent) in each language in bilingual PWA. The odds ratio was log transformed in order to calculate the correlations of probabilities of individual performance in Basque and Spanish.

4. Results

4.1. Sentence comprehension in the bilingual group: Basque vs. Spanish
4.1.1. Comprehension accuracy in Basque and Spanish:

Bilingual PWA correctly comprehended 64.89% and 73.74% of the sentences in Basque and Spanish, respectively. Bilingual NBD performed close to ceiling level, correctly comprehending 92.11% of the stimuli in Basque and 95.55% of the stimuli in Spanish. Details of accuracy based on argument order across groups and languages are provided in Figure 2. See Table 2 and Table 3 for individual scores in Basque and Spanish.

\[\text{Figure 2 around here}\]
\[\text{Table 2 around here}\]
\[\text{Table 3 around here}\]

The accuracy data were analysed with GLMM containing a three-way interaction between group (PWA, NBD), argument order (Agent-Theme, Theme-Agent) and language (Basque, Spanish). By means of random effects, we accounted for variability within-participants (i.e., likelihood of each participant to answer correctly) and within stimuli (i.e., degree of difficulty of each stimuli). PWA comprehended the sentences significantly worse than NBD in both Agent-Theme (A-T) and Theme-Agent (T-A) argument orders in Basque (A-T: \(\beta= 1.536; \text{SE}= 0.293; p=<.0001\); T-A: \(\beta= 2.145; \text{SE}= 0.262; p=<.0001\)) and Spanish (A-T: \(\beta= 1.463; \text{SE}= 0.280; p=<.0001\); T-A: \(\beta= 2.559; \text{SE}= 0.285; p=<.0001\)). Sentence comprehension was worse in Basque than in Spanish regardless of the argument order for PWA (A-T: \(\beta= -0.448; \text{SE}= 0.194; p= 0.0212\); T-A: \(\beta= -0.425; \text{SE}= 0.162; p= 0.0088\)). NBD participants also performed worse in Basque than in Spanish in sentences presented in Theme-Agent argument order (\(\beta= -0.839; \text{SE}= 0.324; p= 0.0096\)), but not when the stimuli were presented in Agent-Theme argument order (\(\beta= -0.374; \text{SE}= 0.329; p= 0.2557\)).

In addition, we conducted a single case analysis of the likelihood of each PWA correctly answering sentences presented in Agent-Theme and Theme-Agent argument order, separately in each language. Detailed Odds Ratios (OR) are presented in Table 4. Data showed that the odds of answering sentences correctly as a function of argument order varied significantly between languages across the participants. As illustrated in Figure 2, some participants showed a marginal dissociation between language and argument order (\(r= -0.52; p= 0.054\)). Participant
A1, who had the largest odds ratio between Agent-Theme and Theme-Agent in Basque (OR= 8.92), presented the lowest odds ratio between Agent-Theme and Theme-Agent in Spanish (OR= 1.20). In contrast, participant A4, who had the lowest odds ratio in Basque (i.e., OR= 1.37), had the largest ratio in Spanish (OR= 15.44). For participant A3 argument order had a greater impact in Spanish than in Basque, and A6 showed the reverse pattern. Some participants (A2, A5, A7) did not show cross-linguistic differences in this regard. See Figure 3.

In summary, accuracy data indicated that PWA showed poorer sentence comprehension than NBD participants in both Basque and Spanish, and across all argument orders. PWA comprehend sentences presented in Agent-Theme order better than those presented in Theme-Agent order. This finding is consistent in both Basque and Spanish. Cross-linguistic comparison demonstrates that PWA perform worse in Basque than in Spanish, regardless of the argument order. Also, NBD performed worse in Basque than in Spanish, but only in sentences presented in non-linear Theme-Agent order. However, single case analysis has uncovered that the effect of argument order in the comprehension abilities of individual PWA is different in Basque and Spanish.

4.2. Sentence comprehension in Spanish: Bilingual vs. Monolingual speakers

4.2.1. Comprehension accuracy: bilingual vs. monolingual speakers

Bilingual and monolingual PWA comprehended 73.74% and 70.51% of the sentences, respectively. NBD performed at ceiling level; bilingual speakers had 95.55% accuracy and monolingual speakers had 96.65% accuracy. Results of response accuracy regarding the argument order as a function of group and mono/bilingualism are provided in Figure 4.
In the GLMM of the accuracy data the predictors of interest were the group (PWA, NBD), argument order (Agent-Theme, Theme-Agent) and bilingualism (bilinguals, monolinguals) in a three-way interaction. The random effects accounted for the variability across participants and stimuli. Moreover, a nested random-effect was added to enable a more precise estimation of the effect of argument order in each participant and stimuli.

PWA comprehended sentences less well than NBD in both Agent-Theme (\(\beta = -1.817; SE = 0.335; p = <.0001\)) and Theme-Agent (\(\beta = -2.776; SE = 0.335; p = <.0001\)) argument order. In addition, PWA showed better performance in sentences presented in Agent-Theme argument order than in Theme-Agent order (\(\beta = 0.897; SE = 0.261; p = 0.0006\)). The NBD group did not show accuracy differences based on the order in which arguments were presented in the sentence (\(\beta = -0.061; SE = 0.344; p = 0.8584\), probably a ceiling effect. Being monolingual or bilingual did not have an effect on the sentence comprehension accuracy of PWA (\(\beta = 0.077; SE = 0.359; p = 0.8281\)) nor in NBD (\(\beta = -0.313; SE = 0.423; p = 0.4595\)) groups. These results were consistent across sentences presented in Agent-Theme argument orders (PWA; \(\beta = 0.275; SE = 0.425; p = 0.5177\); NBD; \(\beta = -0.302; SE = 0.514; p = 0.5557\)) and Theme-Agent argument orders (PWA; \(\beta = -0.119; SE = 0.407; p = 0.7692\); NBD; \(\beta = -0.323; SE = 0.531; p = 0.5430\)).

4.2.2. Reaction time (RT) in Spanish: bilingual vs. monolingual speakers

Mean RTs and standard error are provided in Table 5. The LMM used to analyse the RTs included a four-way interaction between group (PWA, NBD), argument order (Agent-Theme, Theme-Agent), response accuracy (correct, incorrect) and bilingualism (bilingual, monolingual) as predictors. In addition, the model included random effects for subject (i.e., the likelihood of each participant to answer correctly) and stimuli (i.e., the degree of difficulty that a specific stimulus may impose). In addition, nested random-effects were added to account for differential variability in the effect of argument order and response accuracy in each subject, as well as to account for the effect of trial number (i.e., from 1 to 120, the position of the presentation of a given trial in relation to the others) in each stimulus. Based on this model, outliers beyond ±2.5 SD from the mean were excluded from further analysis, consisting of the 1.90% of the data.
There was a significant two-way interaction between group and argument order. PWA showed longer RTs than NBDs in sentences presented in Agent-Theme ($\beta = 0.301; SE = 0.060; p = <.0001$) and Theme-Agent ($\beta = 0.418; SE = 0.060; p = <.0001$) argument orders. PWA showed significantly shorter RTs in sentences presented in Agent-Theme, than in Theme-Agent argument order ($\beta = -0.058; SE = 0.025; p = 0.0237$), whereas this was not the case in the NBD group ($\beta = 0.058; SE = 0.037; p = 0.1199$).

There was another significant two-way interaction between bilingualism and response accuracy. Bilingual speakers did not show RT differences based on response accuracy ($\beta = 0.030; SE = 0.028; p = 0.2851$), whereas monolingual speakers took significantly longer to react in incorrect than correct answers ($\beta = 0.127; SE = 0.030; p = 0.0001$). RT difference as a function of bilingualism was not significant across groups (PWA; $\beta = -0.056; SE = 0.078; p = 0.4688$; NBD; $\beta = -0.073; SE = 0.083; p = 0.3773$).

### 4.2.3. Gaze data analysis in Spanish: bilingual vs. monolingual speakers

In the LMM the predictors of interest were the ROI (1 to 4), argument order (Agent-Theme, Theme-Agent), response accuracy (correct, incorrect), group (PWA, NBD) and bilingualism (bilingual, monolingual) in a five-way interaction. The random effects accounted for the variability across participants and stimuli. In addition, model comparison uncovered that the effect of sentence condition and response accuracy greatly varied in each participant and stimulus. For example, the presentation of a passive sentence condition had a different effect in the gaze-fixation behaviour in each specific stimulus, or the effect of answering correctly or incorrectly affected in a different manner the gaze-fixation pattern of each participant. Nested random-effects were included to account for this variance.

In the next section we will focus on the statistical outcomes directly related to our research questions. There was a significant two-way interaction between response accuracy and bilingualism. Bilingual speakers fixated less than monolingual speakers towards the distractor picture in the correctly answered trials ($\beta = -0.70$;
SE= 0.237; p= 0.0057), but not in the incorrectly answered ones (β= 0.916; SE= 0.535; p= 0.0876).

There was a significant three-way interaction between ROI, bilingualism and response accuracy (see Figure 5). At the correctly answered trials, bilingual speakers fixated significantly less than monolingual speaker on the distractor in ROI 3 (subject/object of the verbal phrase) (β= -0.788; SE= 0.317; p= 0.0146) and ROI 4 (post-offset) (β= -1.854; SE= 0.350; p= <.0001). There were no significant differences in the previous ROIs (ROI1, β= 0.002; SE= 0.313; p= 0.9926; ROI2; β= -0.174, SE= 0.314; p= 0.5804). In the incorrect answers, bilingual speakers fixated more than monolingual speakers into the distractor picture during the auditory presentation of ROI 3 (subject/object of the verbal phrase) (β= 2.262; SE= 0.929; p= 0.0149). There were not significant differences in the rest of ROIs (ROI1, β= 0.451; SE= 0.885; p= 0.6101; ROI2, β= -0.235; SE= 0.886 p= 0.7907; ROI4, β= 1.186; SE= 1.166; p= 0.3092).

[Figure 5 around here]

In summary, accuracy data uncovered no comprehension differences between bilingual and monolingual speakers while performing the same task. RT data showed that PWA took significantly longer than NBD to provide an answer, in both Agent-Theme and Theme-Agent sentences. Monolingual speakers took longer to answer incorrectly answered trials than correctly answered ones, in contrast to bilingual speakers. Gaze fixation data analysis show that differences between monolingual and bilingual speakers are substantial in the correctly answered trials in which monolingual speakers fixate into the distractor picture more than bilingual speakers. Interestingly, in-depth analysis across the ROIs suggests that monolingual speakers tend to fixate on the distractor more than bilingual speakers from ROI3 (i.e. post-verbal subject/object) onward in the correct trials, whereas bilingual speakers tend to fixate on the distractor significantly more than monolingual speakers exclusively in ROI3, in the incorrectly answered trials. We will interpret these results in the next section.

5. Discussion

By combining accuracy, reaction time and/or gaze-fixation data, we examined a
group of L1 Basque-L2 Spanish bilingual and Spanish monolingual PWA, as well as NBD to get insight into a) the impact of different types of morphological markers (i.e., preposition vs. case-marking) on cross-linguistic sentence comprehension deficits in PWA; b) the potential advantage of bilingual speakers, in relation to monolingual speakers in processing semantically reversible sentences, due to enhances inhibitory control. Data analysis showed that in both the PWA and NBD groups, processing case-marking is more impaired than processing prepositional information, although this pattern does not necessarily apply to all the individual subjects. Also, analysis of gaze-fixation suggested that bilingual speakers show enhanced inhibitory and monitoring abilities compared to monolingual speakers. However, it does not aid sentence comprehension deficits in the bilingual PWA.

5.1. Cross-linguistic sentence comprehension processing in bilingual PWA and NBD

The accuracy results converge with previous findings that show that sentence comprehension deficits in PWA are strongly related to derived (Theme-Agent) order of sentential arguments (e.g., Bastiaanse & Van Zonneveld, 2006; Burchert, et al., 2003; Caramazza & Zurif, 1976; Caplan & Futter, 1986; Grodzinsky, 1995, 2000; Mitchum and Berndt, 2008; Schumacher et al., 2015).

At the group level, the cross-linguistic comparison between bilingual participants showed that both PWA and NBD performed worse in Basque than in Spanish. For PWA this pattern was found for both argument orders (i.e., Agent-Theme and Theme-Agent), while the NBD participants had better comprehension in Spanish only for sentences presented in Theme-Agent argument order. Comparison across groups of PWA speaking different languages is always difficult because of the variability between the participants who make up the groups. The cross-linguistic differences in the NBD group, however, suggest that there may be aspects intrinsic to the languages that impact on sentence comprehension performance. Frequency factors maybe such a factor. However, sentences with Theme-Agent order are more frequent in a free-word-order language such as Basque than in Spanish. Also, corpus analysis suggests that in Basque OVS and VOS word orders are more frequent than VSO (Aldezabal, 2003). Altogether, it is unlikely that the cross-linguistic differences found in this study are motivated by the prevalence of certain
argument orders in the languages spoken by the participants.

Another potential explanation of the cross-linguistic difference relates to the position that the verb takes into the sentence in each language. Recall that the canonical word order in Spanish is SVO, whereas in Basque it is SOV. In our experiment, sentences with Theme-Agent argument order always belong to OVS word order in Spanish, whereas they were presented in OSV or VOS word orders in Basque. According to some authors, sentence processing in verb-final languages requires more memory resources because thematic roles cannot be assigned until the verb is reached (see Gibson 1991, 1998, 2000; Gibson et al. 2013). One could argue that this potentially impacts on sentence comprehension accuracy of adult NBD participants, and results in poorer sentence comprehension in Basque than in Spanish in sentences with Theme-Agent argument order. We believe it is unlikely that this is the case. The gaze-fixation analysis conducted in this same group of participants in Arantzeta et al. (2017) showed that in Basque, both NBD and PWA always resolve sentences (visually) in the vicinity of the subject. That is, participants do not wait till the presentation of the verb to interpret the sentences, because they can establish an interpretative relation between the arguments based on morphological case information. These results converge with previous work on other head-final languages, such as German and Japanese, where listeners show anticipatory thematic role assignment (Kamide, Altmann, & Haywood, 2003), and the position of the verb does not impact on the processing load involved on sentence interpretation (Konieczny, 1996; Nakatani & Gibson, 2010; Sheepers et al. 1999; Yamashita, 1997).

We believe that the most parsimonious explanation for the cross-linguistic differences found in NBD participants is related to the acoustic salience of the morphological cues in Basque and Spanish. That is, the extent to which the acoustic features of the linguistic stimuli impose different degrees of difficulty. In Basque the agent of the verb is marked for ergative case by means of a morpheme –k attached at the end of the argument, whereas in Spanish the (animate) theme or the agent of the verb is always preceded by the preposition “a” or the preposition “por”, respectively. The morphological marking in Spanish has more endurance and it is acoustically more perceivable than in Basque (see Ladefoged, 2001), and so, it may be easier to perceive for adult individuals.
NBD participants in our study were older adults (mean age 65 years), with no report of hearing difficulty. No auditory test was conducted prior to their participation into the study. Still, several studies have reported age-related deficits of temporal auditory processing, particularly in gap-detection thresholds, which are not captured by traditional audiometry assessment (Füllgrabe, 2013; Humes, et al. 2010; Snell, 1997). So, even in the absence of peripheral auditory deficits, there is evidence that NBD individuals have increased difficulties to integrate auditory information as they age. Salience factors have also been shown to affect case-marking processing in healthy adult speakers of highly inflected and agglutinative languages such as Hungarian (MacWhinney et al., 1985). With regard to this, one may wonder why NBD participants do not perform worse in Basque than in Spanish, also on sentences with Agent-Theme argument order. We believe that in absence of the information cue necessary to identify the agent of the verb, listeners use the most parsimonious (subject-first) strategy to interpret the sentences. This explanation converges with previous studies showing that the effect of the speed of linguistic presentation (Wingfield et al., 2003) and noise (Wendt et al., 2016), as a measure of saliency, affect sentence comprehension abilities in adult NBD participants, particularly in sentences requiring derived Theme-Agent assignment.

Interestingly, single case analysis suggests that processing of case marking and prepositions may be independently impaired in PWA. The difficulty imposed by the argument order is not always larger in Basque than in Spanish. Some participants showed dissociation between the sentences in Agent-Theme and Theme-Agent argument order across languages. In four out of seven participants, the analysis showed that the larger the effect of argument order was in Basque, the smaller the effect of argument order was in Spanish, and vice versa. These individual differences can offer an explanation for the conflicting results of previous case studies on agrammatic Basque-Spanish bilingual PWA (Munarriz et al., 2016) and Hindi-English PWA (Venkatesh et al., 2012). Our data demonstrate that case morphology does not systematically prevent sentence comprehension deficits in PWA as suggested by Venkatesh et al. (2012). The current data show that processing case morphology is particularly impaired in many PWA, even more than processing other type of morphological markers, such as prepositions. These results are compatible with Abuom et al. (2013), who did not find cross-linguistic
differences in Swahili-English bilingual PWA, since the individual variability may have cancelled a language effect in the results.

The results from individual subjects with aphasia do not always conform to the group results. We believe that there are two potential explanations for the individual variability in sentence comprehension in Basque and Spanish. First, it may be related to the bilingual proficiency and/or dominancy in the group of bilingual participants in our study may be important. All the participants in the bilingual group acquired both Basque and Spanish in early childhood, and they reported a balanced use of the two languages in adulthood. Still, we could not objectively assess the level of proficiency and dominance of each language before and after the injury, nor could we be sure in what language/s and for how long language therapy was delivered. Second, parsing cues are different in Basque and Spanish, and this may also explain the vast individual variability across participants. In Basque, case morphology reliably tags thematic roles (i.e., agent, theme), whereas in Spanish it does not (nominative subjects can be either agents or themes, see Ros (2018) for a discussion on the differential reliability of morphological cues in Spanish and Basque). The individual variability in the processing of sentence in Basque and Spanish suggest that the parser may be distinctively affected at the semantic and the grammatical level, even when participants are agrammatic and do not show evident disruption at the lexico-semantic level in their production.

To sum up, at the group level, the between-language asymmetries are compatible with case-marking morphology being more vulnerable than other types of morphological cues (e.g., agreement) as shown in the study of German PWA and NBD using a within-language comparison (Hanne et al., 2015). However, individual participant patterns require a more complex explanation, which may potentially depend on factors related to bilingual proficiency and dominance, or to specific handicaps related to parsing mechanisms based on semantic versus syntactic functions. These aspects deserve more detailed consideration, which remains beyond the scope of this study.

5.2. Bilingual advantage: comparison of bilingual vs. monolingual speakers of Spanish
Previous studies have suggested that bilingualism enhances some aspects of the executive function system in both NBD (see Bialystok et al., 2004; Costa et al., 2008; Martin-Rhee & Bialystok, 2008; Prior & MacWhinney, 2010) and PWA (Penn et al., 2010). We hypothesized that bilingual PWA may benefit from enhancement of inhibitory control abilities in comprehending semantically reversible sentences, which have been suggested to be difficult for them due to an inability to inhibit conflicting sentence interpretations (Dickey et al., 2007; Schumacher et al., 2015; Vuong & Martin, 2015; see Novick, et al., 2005, 2010; cf. Thothathiri & Mauro, 2018).

In contrast to our expectations, we found equal comprehension accuracy and RT in bilingual and monolingual PWA, calling into question the existence of a bilingual advantage in sentence comprehension due to an enhancement of executive functions (see Teubner-Rhodes et al., 2016). However, the results of close analysis of the RT data, as well as the gaze-data are not fully compatible with a null-effect of bilingualism in sentence processing in either PWA or NBD participants. Although there was no significant difference in accuracy between the bilingual and monolingual PWA, analyses of the RTs revealed that monolingual participants showed an accuracy effect, unlike bilingual participants. The monolingual PWA responded faster on correctly answered sentences than on incorrectly answered ones. This is compatible with the view that for incorrectly answered trials there are difficulties in inhibiting the conflicting interpretations depicted by the distractor picture, and particularly suggests that inhibitory control is more effortful in monolingual speakers.

This interpretation is partly reinforced by the gaze-data. In line with our predictions, successful sentence interpretation in bilingual speakers is coupled by an enhanced inhibitory control system in relation to monolingual speakers, who look significantly more at the conflicting interpretation of the sentence. The absence of online processing differences between sentences with Agent-Theme argument order and Theme-Agent argument order in terms of ROIs is in line with Teubner-Rhodes et al.’s., (2016) findings. It suggests that bilingual speakers have a monitoring capacity that goes beyond sentences involving conflict. We are aware that the sentence-to-picture task used in this study imposes certain degree of conflict, since the counterpart interpretations of the semantically reversible sentence are visually
represented to the participant. However, keeping this variable constant, bilingual participants showed similar inhibitory abilities towards the competitor representation on sentences with Agent-Theme and Theme-Agent argument order, although only in the latter the default parsing routine (i.e. agent first) conflicts with the linguistic target, and therefore imposes the need for revision. Overall, the online data favour the idea of bilingual PWA and NBD participants displaying an inhibitory advantage, in line with previous studies (Bialystok et al., 2004; Costa et al., 2008; Martin-Rhee & Bialystok, 2008; Penn et al., 2010; Prior & MacWhinney, 2010).

Unexpectedly, we found that the role of bilingualism in the fixation behaviour towards the competitor picture is reversed in the incorrectly answered trials. In the instances in which sentences are misinterpreted, bilingual speakers fixate more often than monolingual speakers on the distractor.

Note that in both correct and incorrect answers, the difference between the proportion of fixations towards the competitor picture as a function of bilingualism does not appear throughout the whole presentation of the auditory stimulus, but it depends on the timing of the comprehension. That is, differences are clear once the sentence can be unambiguously interpreted (i.e., at the verbal phrase). Thus, they are not related to random noise. In the correctly answered trials, the gaze-fixation difference between bilingual and monolingual speakers starts after the presentation of the verbal phrase, and continues until the post-offset of the sentence. In contrast, in the incorrect answers, it is limited to the post-verbal subject/object.

Unlike the fixation pattern observed in the correctly-answered trials, the greater inclination of bilingual speakers to fixate on the distractor in the incorrectly answered trials cannot be explained by better inhibitory abilities. However, this gaze-fixation pattern, which is limited to incorrect answers right after the sentence resolution point, is compatible with the monitoring behaviour as described in Thibaut & French (2016). According to these authors, participants frequently look back into the non-target picture in an attempt to revise their choice, particularly on incorrect answers. This interpretation accords with the results of previous studies suggesting that monitoring takes places only in items with high difficulty and uncertainty (Howie & Roebers, 2007). Enhanced ability to monitor the correctness
in the incorrect answers has been attributed to strengthen development of executive functioning in adults versus children (Thibaut & French, 2016), and it goes along with the enhanced inhibitory abilities shown by bilingual speakers in the correctly answered trials. However, the error awareness analysis performed in this group of participants in Arantzeta et al. (2018) has shown that PWA are usually unaware of their sentence misinterpretation. Thus, a boosted monitoring ability in the incorrectly answered trials in bilingual speakers is simply speculative, and warrants further research.

At this point, the question is why the advantage in inhibitory abilities shown by bilingual speakers does not provide bilingual speakers with a better sentence comprehension capacity or overall increased speed. In the case of NBD participants, this effect may not be apparent because of ceiling level performance. In relation to PWA, we find no transfer of the potential enhancement of executive functioning to sentence comprehension outcomes. One potential explanation is in the same vein as Thothathiri & Mauro (2018), who have recently reported case studies of PWA with slower sentence processing but accurate comprehension, and the other way around. Thus, we suggest that sentence comprehension deficits in PWA are not necessarily related to deficits in monitoring, and, therefore, that the advantage in inhibiting the distractor picture found in bilingual speakers does not prevent them from comprehension failure.

It is worth mentioning that unlike Thothathiri & Mauro (2018) and Penn et al. (2010), we have not used formal tests to assess executive functioning in PWA. We suggested that online sentence processing within a particular experimental setting (i.e. sentence-picture-matching task with binomial choice) has uncovered differences between bilingual and monolingual speakers, which we could interpret as a sign in favour of enhanced executive functioning in terms of inhibition in bilingual speakers. However, there is equal sentence comprehension accuracy in bilingual and monolingual speakers. This mismatch between inhibitory behaviour towards the distractor picture and the sentence comprehension accuracy does not mean that other aspects of inhibitory control, or executive functioning in general, are damaged in PWA (Hamilton & Martin, 2005; Peristeri, et al., 2011; Purdy, 2002) Also, it does not rule out that impaired executive function could be an important component of sentence comprehension difficulties in PWA (Dickey et al.,
6. Conclusion

Sentence comprehension deficits in PWA with preserved lexical comprehension have been reported in a series of languages, but they have rarely been studied in bilingual populations. We aimed to shed light on cross-linguistic differences in sentence processing, and more specifically on morphosyntactic processing by bilingual speakers of two typologically distant languages, that is, Basque and Spanish. We reported evidence regarding the ways in which language-specific properties affect sentence comprehension performance in both PWA and NBD. At group level, sentence comprehension difficulties were greater in Basque than in Spanish. Salience factors may explain these difficulties, as suggested by previous results in healthy speakers (MacWhinney et al., 1985; Wendt et al. 2016; Wingfield et al., 2003). These cross-linguistic asymmetries are also compatible with different cognitive demands involving the processing of case-morphology and prepositions (Hanne et al., 2015). Single case analysis of PWA showed that the ability to process ergative case marking in Basque and prepositional information in Spanish is negatively correlated. Participants who were more impaired in processing derived word order sentences in Basque were less impaired in Spanish, and the other way round. The explanation for this negative correlation is not yet clear – but it shows that bilingual PWA use different strategies in understanding sentences from typologically very different languages.

Overall, the data do not suggest that bilingual PWA transfer morphosyntactic processing abilities from Basque (a richly inflected language) to Spanish (a less inflected language). This pattern is not in line with the findings of Santesteban and Costa (2006), who analysed Noun-Determiner agreement in Basque-Spanish and Catalan-Spanish healthy bilingual speakers, and found that the syntactic properties of L1 (word order) influence processing of Noun-Determined agreement in L2. This may be due to the vast individual differences found in our study. We have speculated that different levels of impairment in each individual in our study may yield a distinctive cross-linguistic pattern across participants (see Caramazza et al., 2007; Schumacher et al., 2015; Vuong & Martin, 2015; see Novick, et al., 2005, 2010).
2001; Caramazza & Miceli, 1991). This idea deserves further research.

We also intended to explain the potential advantage that Basque-Spanish bilingual PWA show in semantically reversible sentences compared to monolingual Spanish speakers. Online sentence processing has uncovered drifts compatible with enhanced inhibitory abilities as a function of bilingualism in both PWA and NBD groups, in line with previous studies (e.g., Costa et al., 2009; Martin-Rhee & Bialystok, 2008; Teubner-Rhodes et al., 2016), but it has been shown that they do not aid sentence comprehension abilities in bilingual PWA. The reasons for the online sentence processing differences between monolingual and bilingual speakers in sentence misinterpretations are unclear. We have speculated that it can be related to better monitoring abilities in bilingual speakers, but this issue should be targeted in future research. All together, the data do not provide sufficient evidence for bilingual advantage on inhibitory control as a support of linguistic performance in terms of sentence comprehension, opposite to the findings of Penn et al. (2010) on conversational management.

The current study shows that, even when the participant-variability is kept constant, language-specific properties affect the choice and subsequent success of the parsing routines. In addition, it showed enhanced inhibition abilities towards the competitor interpretation of the sentence, although it did not diminish their sentence comprehension deficit. A more operational definition of executive functions, as well as the combination of formal testing on conflict monitoring and online sentence processing is necessary to shed light into this topic.

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Acknowledgements:
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References:


Arantzeta, M., Bastiaanse, R., Burchert, F., Wieling, M., Martínez-Zabaleta, M., & Laka, I. (2017). Eye-tracking the effect of word order in sentence comprehension in aphasia: Evidence from Basque, a free word order


Del Río, D., López-Higes, R., & Martín-Aragoneses, M. T. (2012). Canonical word order and interference-based integration costs during sentence


TABLES:

**Table 1.** Regions of Interest (ROI), duration (mean and sd) and comparison of length across paired conditions.

<table>
<thead>
<tr>
<th>Paired conditions</th>
<th>ROI 1 (mean duration and SD)</th>
<th>ROI 2 (mean duration and SD)</th>
<th>ROI 3 (mean duration and SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>999 ms (46)</td>
<td>931 ms (12)</td>
<td>852 ms (30)</td>
</tr>
<tr>
<td>Active vs Passive</td>
<td>t</td>
<td>p</td>
<td>t</td>
</tr>
<tr>
<td>Subj. vs Obj. Relative</td>
<td>-0.221</td>
<td>0.826</td>
<td>-1.877</td>
</tr>
<tr>
<td>Subj. vs Obj. Cleft</td>
<td>1.074</td>
<td>0.290</td>
<td>-0.397</td>
</tr>
<tr>
<td>A-T vs T-A</td>
<td>-0.554</td>
<td>0.581</td>
<td>-0.027</td>
</tr>
</tbody>
</table>

ROI= Region Of Interest; A-T= Agent-Theme; T-A= Theme-Agent

**Table 2.** Individual scores of the PWA and NBD group on sentence comprehension accuracy in the experimental task in Basque.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Condition</th>
<th>Subject</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWA</td>
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<td>OSV</td>
<td>VSO</td>
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<td>40</td>
<td>84.21</td>
</tr>
<tr>
<td>A2</td>
<td>78.94</td>
<td>47.36</td>
<td>75</td>
</tr>
<tr>
<td>A3</td>
<td>78.94</td>
<td>50</td>
<td>77.77</td>
</tr>
<tr>
<td>A4</td>
<td>57.89</td>
<td>36.84</td>
<td>35.29</td>
</tr>
<tr>
<td>A5</td>
<td>75</td>
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<tr>
<td>A6</td>
<td>83.33</td>
<td>57.89</td>
<td>80</td>
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<tr>
<td>A7</td>
<td>84.21</td>
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<td>73.68</td>
</tr>
<tr>
<td>Mean (SE)</td>
<td>76.74</td>
<td>51.11</td>
<td>73.07</td>
</tr>
</tbody>
</table>

PWA= people with aphasia; NBD= non-brain damaged
**Table 3.** Individual scores (%) of both IWA and NBD group on sentence comprehension accuracy in the experimental task in Spanish.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>A1</td>
<td>Bilingual</td>
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<td>75</td>
<td>75</td>
<td>75</td>
<td>68.42</td>
<td>78.94</td>
<td>75</td>
</tr>
<tr>
<td>A2</td>
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<td>89.47</td>
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<tr>
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</tr>
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<td>68.42</td>
<td>76.47</td>
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<tr>
<td>A7</td>
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<tr>
<td>A8</td>
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<td>A9</td>
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<td>55</td>
<td>55.55</td>
<td>55.55</td>
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<td>44.44</td>
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<td>94.73</td>
<td>100</td>
<td>85</td>
<td>95</td>
<td>80</td>
</tr>
<tr>
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<td>47.36</td>
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</tr>
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<td>A13</td>
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<td>87.47</td>
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<td>80</td>
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<tr>
<td><strong>NBD</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>94.73</td>
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<td>100</td>
<td>95</td>
<td>100</td>
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<td>100</td>
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<td>C5</td>
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<tr>
<td>C6</td>
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<td>94.73</td>
<td>90</td>
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<td>95</td>
</tr>
<tr>
<td>C7</td>
<td>Bilingual</td>
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<td>94.11</td>
<td>90</td>
<td>100</td>
<td>94.73</td>
<td>95</td>
</tr>
<tr>
<td>C8</td>
<td>Monolingual</td>
<td></td>
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<td>100</td>
<td>95</td>
<td>100</td>
<td>95</td>
<td>100</td>
</tr>
<tr>
<td>C9</td>
<td>Monolingual</td>
<td></td>
<td>100</td>
<td>100</td>
<td>95</td>
<td>100</td>
<td>95</td>
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</tr>
<tr>
<td>C10</td>
<td>Monolingual</td>
<td></td>
<td>95</td>
<td>100</td>
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<td>95</td>
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<td>95</td>
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<tr>
<td>C11</td>
<td>Monolingual</td>
<td></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>95</td>
<td>90</td>
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<tr>
<td>C12</td>
<td>Monolingual</td>
<td></td>
<td>100</td>
<td>95</td>
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<tr>
<td>C13</td>
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<tr>
<td>C14</td>
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<td>100</td>
<td>100</td>
<td>95</td>
<td>95</td>
<td>85</td>
</tr>
</tbody>
</table>

PWA= people with aphasia; NBD= non-brain-damaged; Act= active; Pass= passive; Subj.Cl= Subject cleft; Obj.Cl= Object cleft; Subj.Rl= Subject relative; Obj.Rl= Object relative.
**Table 4:** Individual sentence comprehension accuracy scores (%) of the Basque-Spanish bilingual PWA as a function of argument order in the sentence.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Basque</th>
<th>Spanish</th>
<th>A-T</th>
<th>T-A</th>
<th>Odds Ratio</th>
<th>A-T</th>
<th>T-A</th>
<th>Odds Ratio</th>
</tr>
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<tbody>
<tr>
<td>A1</td>
<td>81.57</td>
<td>33.15</td>
<td>8.92</td>
<td></td>
<td></td>
<td>76.31</td>
<td>72.80</td>
<td>1.20</td>
</tr>
<tr>
<td>A2</td>
<td>76.97</td>
<td>58.68</td>
<td>2.35</td>
<td></td>
<td></td>
<td>81.57</td>
<td>66.66</td>
<td>2.21</td>
</tr>
<tr>
<td>A3</td>
<td>78.35</td>
<td>61.11</td>
<td>2.30</td>
<td></td>
<td></td>
<td>94.82</td>
<td>65.26</td>
<td>9.75</td>
</tr>
<tr>
<td>A4</td>
<td>46.59</td>
<td>38.88</td>
<td>1.37</td>
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<td>96.49</td>
<td>64.03</td>
<td>15.44</td>
</tr>
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<td>A5</td>
<td>78.67</td>
<td>60.52</td>
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<td>81.49</td>
<td>65.61</td>
<td>2.30</td>
</tr>
<tr>
<td>A6</td>
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<td>63.94</td>
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<td></td>
<td></td>
<td>81.71</td>
<td>72.80</td>
<td>1.66</td>
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<td>61.45</td>
<td>50.87</td>
<td>1.53</td>
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</tbody>
</table>

A-T= Agent-Theme; T-A= Theme-Agent

**Table 5:** Mean reaction time (ms) and Standard Error (SE) in bilingual and monolingual speakers of Spanish as a function of group and order of arguments in the sentence.

<table>
<thead>
<tr>
<th>Order of arguments</th>
<th>Mean RT (SE) in Spanish Bilingual speakers</th>
<th>Mean RT (SE) in Spanish Monolingual speakers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PWA</td>
<td>NBD</td>
</tr>
<tr>
<td>Agent-Theme</td>
<td>4772 (90.23)</td>
<td>3241 (52.33)</td>
</tr>
<tr>
<td>Theme-Agent</td>
<td>5153 (87.53)</td>
<td>3312 (43.25)</td>
</tr>
<tr>
<td><strong>Mean (SE)</strong></td>
<td><strong>4963 (63.16)</strong></td>
<td><strong>3277 (33.94)</strong></td>
</tr>
</tbody>
</table>

PWA= People With Aphasia; NBD= Non Brain Damaged
FIGURES:

Figure 1. Sample visual display. Target stimulus: (Active-Spanish) “El árbitro ha empujado al portero”/ (SOV-Basque) “Arbitroak atezaina bultzatu du”. (The referee has pushed the goalkeeper). A) Target picture; B) Foil.
Figure 2. Sentence comprehension accuracy (%) and Standard Error (SE) in Basque-Spanish bilinguals as a function of language and order of arguments in the sentence. PWA= People With Aphasia; NBD= Non Brain Damaged
Figure 3. Correlation between Odds Ratio (OR) between Agent-Theme (AT) and Theme-Agent (TA) in Basque and Spanish. $r = -0.52; p = 0.054$. 
Figure 4. Sentence comprehension accuracy (%) and Standard Error (SE) in Spanish in bilingual and monolingual speakers as a function of group and order of arguments in the sentence.
Figure 5. Mean gaze-fixations and standard error towards the distractor picture as a function of bilingualism, response accuracy and Region Of Interest (ROI).
Author statement

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