Sentence comprehension in monolingual and bilingual aphasia: Evidence from behavioral and eye-tracking methods.

Miren Arantzeta-Pérez

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CHAPTER 1:

1. General introduction

1.1. Introduction

The mechanisms and strategies involved in sentence processing depend partially on the morphosyntactic properties of the language. Typologically, the more morphology a language has (e.g., case and agreement), the greater the freedom it displays when it comes to the word order of the sentence. Previous studies have shown that word order strongly impacts on the sentence comprehension abilities of people with aphasia (PWA). However, it is not clear whether it is an epiphenomenon restricted to certain languages with word order restrictions, or whether morphological markers aid the comprehension of sentences with derived word order to a varying degree across languages.

The current thesis focuses on sentence processing in PWA and non-brain-damaged (NBD) speakers of a free word order language (Basque) and/or a flexible word order language (Spanish). It includes a series of studies on bilingual and monolingual speakers with the goal being to consider a) how language-specific properties influence accuracy and real time processing within sentence comprehension (Chapters 2 and 3); b) the cross-linguistic transferability of sentence parsing mechanisms in bilingual speakers (Chapter 3); c) the potential bilingual advantage in sentence comprehension abilities due to enhancement of executive functions (Chapter 3); and d) self-monitoring abilities and consequent error awareness in sentence comprehension (Chapter 4).

The following dissertation makes four novel contributions to the field of sentence comprehension in PWA and NBD participants. First, it introduces a study on speakers of a language with a unique morphosyntactic pattern; that is, Basque. This pattern pertains to the ergative case in Basque, as well as its free word order. Second, it examines early bilingual speakers of typologically distant languages, namely Basque and Spanish. Third, it merges behavioral and eye-tracking data in order to provide insight into real time sentence processing in both correct and impaired sentence comprehension. Lastly, it transfers a well-established paradigm in the field of consciousness and cognition research into the study of sentence comprehension error awareness in PWA.

1.2. Psycholinguistic aspects of sentence comprehension

1.2.1. Brief characterization of comprehension impairments

People with non-fluent aphasia (in this thesis PWA) frequently show difficulties in comprehending sentences, even when they have spared lexical comprehension abilities. This is the case because sentence comprehension in natural languages goes beyond the cumulative meaning of lexical items; it requires computing the relationships between its parts. In order to successfully interpret a sentence, listeners need to process the structural relationship between the verb and its arguments, by identifying the thematic roles that each argument plays in the event denoted by the verb. For example, in **(1)** the listener must identify that 'the musician' is the Agent of the verb 'tune', while 'the viola' is the Theme.

(1) The musician tunes the viola.

Previous studies have shown that people with Broca's aphasia have unimpaired lexical access to the verb and its argument structure (Shapiro & Levine, 1990), as well as preserved ability to judge the grammaticality of argument structure violations (Kim & Thompson, 2004). Whether the same pattern is found in other non-fluent aphasic syndromes is largely unknown. Still, PWA are particularly impaired when it comes to the comprehension of semantically reversible sentences presented in derived word order **(2)**, which is likely due to a post-activation process required for the assignment of thematic roles to phrasal arguments. In semantically reversible sentences, both of the determiner phrases (DPs) in the sentence are equally plausible choices for the Agent/Theme of the action described by the verb. Thus, in the absence of semantic constraints, PWA have difficulties knowing *who did what to whom* when the arguments are not presented in the base order of the language (e.g., Subject-Agent Verb Object-Theme in English or Subject-Agent Object-Theme Verb in Japanese).

(2) The fish that the frog is biting is green.

Consequently, PWA have a better preserved comprehension of sentences presented in base word order (e.g., active sentences, subject cleft, subject relative **(3)** constructions in English), because the heuristic information of the word order guides the correct interpretation of the linguistic message. They assume that the first DP of the sentence is the agentive-subject of the verb. However, heuristic strategies do not guide a full parsing routine, but rather an approximation of the thematic role assignment across the arguments of the sentence. Thus, comprehension tends to break down when semantic and word order information (i.e., heuristics) do not provide enough information to disentangle the thematic role assignment, and PWA are forced to conduct a full parsing routine taking into account morphosyntactic markers (e.g., passive, object cleft, object relative **(4)** constructions in English) (e.g., Bastiaanse & Van Zonneveld, 2006; Berndt, Mitchum, Haendiges, 1996; Caplan & Futter, 1986; Caplan & Hildebrandt, 1988; Schumacher et al., 2015; Schwartz, Saffran, & Marin, 1980).

(3) I see the woman who combs the girl.
(4) I see the girl who the woman combs.

The use of heuristic information in sentence processing is not restricted to PWA. Parsing routines based on syntactic information are complex and time-consuming processes. Healthy speakers also use heuristic information (e.g., word order, animacy, plausibility) as a less costly, economic and fairly reliable shortcut to disentangle thematic role assignment (Ferreira, 2003; Ferreira, Anes & Horine, 1996; Ferreira & Patson, 2007; Townsend & Bever, 2001; van Herten, Chwilla, & Kolk, 2006). However, when heuristic strategies do not guide the correct interpretation of the sentence (e.g., in semantically reversible sentences in derived word order), the parsing routine is revised based on the detailed analysis of the morphosyntactic markers. In unimpaired adults, the latter also implies higher cognitive effort in sentences presented in T-A argument order compared to sentences presented in A-T order, as suggested by greater error rates (Bornkessel, Schlesewsky, & Friederici, 2002; Ferreira, 2003), longer reaction times (Del Río et al., 2011; Del Río, López-Higes, & Martín-Arangoneses, 2012), longer reading times (Bentacort, Carreiras, & Sturt, 2009; Erdocia, Laka, Mestres-Missé, & Rodriguez-Fornells, 2009) and different electrophysiological brain activity (Carreiras, Duñabeitia, Vergara, de la Cruz-Pavía, & Laka, 2010; Erdocia et al., 2009). It has been shown that there is a gradual deterioration in sentence processing along life span (e.g., Caplan, DeDe, Waters, Michaud, & Tripodis, 2011; Obler, Fein, Nicholas, & Albert, 1991; Schneider, Daneman, & Murphy, 2005; Sung, 2016; Wingfield, Peelle, & Grossman, 2003).

1.2.2. Cross-linguistic evidence on sentence comprehension deficits

All languages allow a certain degree of variability in the order in which constituents of a sentence may be presented, usually depending on the amount of (agreement and case) morphology of each particular language. The effect of word order on sentence comprehension difficulties has been proven across PWA speakers of many typologically distant languages (e.g., in Dutch, Bastiaanse & Edwards, 2004; in Italian, Garraffa and Grillo, 2008; in English, Meyer, Mack, & Thompson, 2012; in Swahili, Abuom, Shah, and Bastiaanse, 2013; but cf. in Indonesian, Jap, Martínez-Ferreiro, & Bastiaanse, 2016). It has also been shown in PWA speakers of languages with case morphology (e.g., in German, Burchert, De Bleser, & Sonntag, 2003; in Turkish, Duman, Altınok, Özgirgin, & Bastiaanse, 2011). These languages mark each argument of the verb depending on their grammatical function or thematic role, and thereby allow more flexibility in the order in which constituents may be placed into the sentence. Still, some cross-linguistic comparisons have suggested that PWA speakers of languages with case morphology have a less impaired comprehension of sentences in derived word orders (Bastiaanse & van Zonneveld, 2006; see Bastiaanse & Edwards, 2004; Burchert, De Bleser, & Sonntag, 2003). This is likely because PWA retain sensibility towards the highly reliable cues needed to parse sentences in their language (Bates, Friederici, & Wulfeck, 1987).

Yarbay et al. (2011) showed that Turkish speakers with Broca's aphasia had difficulties integrating word order and case information. Participants relied on base word order and/or base case (nom/acc) to aid sentence comprehension, and in the absence of one or both cues comprehension was equivalently impaired. To uncover the interplay between word order and case, Yarbay et al. (2011) included embedded sentences. Thus, it is difficult to tease apart the effect of word order from syntactic complexity. Two questions remain unclear. First, it is unknown how variations solely in word order affect sentence comprehension in PWA speakers of free word order languages. Second, it is still unclear whether the degree of impairment in processing sentences in derived word order depends on the type of morphological marking that PWA need to process (e.g., subject-verb agreement in Dutch vs. case morphology in German). This cross-linguistic comparison in bilingual speakers provides us with a unique opportunity to analyze how distinct types of morphological markers impact sentence comprehension abilities.

The current dissertation addresses these two questions in Chapters 2 and 3, respectively. In Chapter 2, we present a group of bilingual Basque-Spanish PWA and NBD who performed a sentence comprehension task in Basque, a richly inflected, ergative, and free word order language. In Chapter 3, we compare a group of Basque-Spanish bilingual PWA and NBD performing a comparable sentence comprehension task in both Basque and Spanish, taking into account a variety of word orders.

Before continuing, we offer a brief characterization of the languages spoken by the PWA and NBD taking part in a series of experiments, which will be presented along with this thesis.

1.2.2.1. Linguistic background: Basque vs. Spanish.

Basque is an isolated, free word-order language, with SOV as a base word order (De Rijk, 1969, Erdocia et al., 2009). It is a richly inflected and agglutinative language. The subject, direct object and indirect object are case marked, and they all agree with the inflected verb in number, person and case. Because of its highly inflectional nature, all constituents may take any position in the sentence without changing a single inflectional morpheme. Furthermore, Basque is an ergative language. This means that the agentive subject of transitive verbs gets the ergative case (-k), whereas the objects of transitive verbs and subjects of unaccusative verbs get the absolutive case marking (-Ø) **(5)**. Hence, in Basque, case morphology marks the thematic role of each argument of the verb (i.e., Agent/Theme), rather than the syntactic function (i.e., Subject/Object) as in previously studied languages (e.g., German or Turkish).

In line with the ergative alignment of the language, sentences beginning with a DP marked with absolutive case are temporarily ambiguous, because they may be interpreted as the subject of an intransitive/unaccusative verb **(6)**, as a sentence-initial object with a null-subject **(7)**, or as the object in a sentence with OSV word order **(8)** (see also Laka, 2012).

(5)	Nesk-a-k	mutil-a- Ø	bultzatu	d-u-Ø
	girl-det-erg	boy-dat-abs	push	aux.has (3pl.abs-root-3pl.erg)
	The girl has pushed the boy.			
(6)	Nesk-a- Ø	erori	da	
	girl-det-abs	fall	aux.is (3pl.abs)	
	The girl has fallen.			
(7)	(nesk-a-k)	mutil-a- Ø	bultzatzu	d-u-Ø
	girl-det-erg	boy-det-abs	push	aux.has (3pl.abs-root-3pl.erg)
	(the girl) has pushed the boy.			
(8)	mutil-a- Ø	nesk-a-k	bultzatu	d-u-Ø
	boy-det-abs	girl-det-erg	push	aux.has (3pl.abs-root-3pl.erg)
	The girl has pushed the boy.			

Spanish is a Romance language. It has a rather flexible word order, with SVO as its base word order (Gutiérrez-Bravo, 2007; Hickey, 1994). The subject agrees with the verb in number and person, and it displays a rich variety of affixes. Contrary to Basque, case morphology is restricted to personal pronouns and the preposition 'a' marks the animate object, except in passive structures. In the active voice, the subject is the Agent and the object is the Theme, whereas in the passive voice the thematic roles are assigned inversely and the Agent is realized as an adjunct prepositional phrase (*by-phrase*), similar to English. In relative clauses (e.g., subject relative; **9**) and clefts (e.g., object cleft; **10**), the animate object is marked by the preposition 'a' (Leonetti, 2003).

(9) Veo al chico que empuja a la chica
see prep boy rel-pron push prep det girl
I see the boy who pushes the girl.

(10) Es a la chica a la que empuja el chico
be prep det girl prep det rel-pron push det boy
It is the girl who the boy pushes.

Previous studies have shown that healthy speakers rely on word-order information to resolve morphological ambiguities affecting sentence interpretation in both Basque and Spanish. When presented with sentences as in **(8)**, healthy speakers of Basque prefer to interpret the sentence according to the Subject-first bias, and subsequently reanalyse the parsing routine when confronted with the second DP (Carreiras et al., 2010; Erdocia et al., 2009; for a review Laka & Erdocia, 2012). In a similar vein, in temporary ambiguous sentences, healthy Spanish speakers interpret the first DP as an agentive-subject, and subsequently implement a full thematic-parsing routine once they are confronted with the disambiguation point (Del Río et al., 2011; see also Casado et al., 2005).

1.2.3. Theories on sentence comprehension deficits: a snapshot

Two major sets of accounts have been proposed to explain sentence comprehension deficits in aphasia: representational and processing accounts. The former includes the most influential representational theory: the Trace Deletion Hypothesis (TDH; Grodzinsky, 1986; 1995, 2000; Drai & Grodzinsky, 2006ab), which states that the syntactic representations are affected in PWA. The latter includes several theories related to language processing breakdown, such as the derived order hypothesis (DOP-H, Bastiaanse & Van Zonneveld, 2006), slowed syntax hypothesis (e.g., Burkhardt, Avrutin, Piñango, & Ruigendijk, 2008; Burkhardt, Piñango, & Wong, 2003), and other models on reduced resource processing (Caplan, 2006; Caplan, Waters, DeDe, Michaud, Reddy, 2007; Dickey, Choy, & Thompson, 2007; Haarmann, Just, & Carpenter, 1997).

According to the TDH (Grodzinsky, 1986; 1995, 2000; Drai & Grodzinsky, 2006ab), individuals with Broca's aphasia have no representation of the trace left behind by the syntactically displaced argument from its base position. Therefore, they fail to assign the correct thematic role to the constituents that have moved position across the sentential structure. In contrast, theories belonging to the processing accounts claim that individuals with Broca's aphasia have intact representations, but they have a difficulty, rather than an inability, in processing derived argument structures (Bastiaanse & Van Zonneveld, 2006). The disorder is particularly noticeable in semantically reversible sentences where arguments are presented in derived Theme-Agent order (e.g., passives and object relatives in English). According to some studies, PWA occasionally fail to comprehend sentences in derived word order because the cognitive demand imposed by the linguistic stimuli exceeds the capacity of the reduced computational resources in PWA (e.g., Burkhardt, Avrutin, Piñango, & Ruigendijk, 2008; Burkhardt, Piñango, & Wong, 2003; Caplan & Waters, 1999; Caplan, 2006; Caplan, Waters, DeDe, Michaud, Reddy, 2007; Haarmann, Just, & Carpenter, 1997).

There are two key differences between representational and processing accounts that will be addressed in the following chapters. First, we will contrast the language-specific predictions that the TDH (Grodzinsky, 1986; 1995, 2000; Drai & Grodzinsky, 2006ab) and DOP-H (Bastiaanse & Van Zonneveld, 2006) make for SOV languages, such as Basque. We will analyze the extent to which word order variation, in the absence of morphological change, affects sentence comprehension deficits in PWA. Second, both representational and processing accounts diverge in their interpretation of chance-level performance in PWA. The TDH (Grodzinsky, 1986; 1995, 2000; Drai & Grodzinsky, 2006ab) attributes chance-level performance on a comprehension task focusing on semantically reversible sentences to a guessing pattern. Contrarily, processing accounts predict that incorrectly comprehended sentences belong to a stochastic breakdown of the parser (Caplan, Michaud, & Hufford, 2013; Caplan, Waters, DeDe, Michaud & Reddy, 2007), and they claim that correctly comprehended sentences do not result from a random choice. This interpretation has been supported by online sentence processing data (Hanne et al. 2011; see Burchert, Hanne, & Vasishth, 2013, for a review). Following the methodology of Hanne et al. (2011), Chapter 2 focuses on contrasting the processing and representational accounts, combining both behavioral (i.e., accuracy and reaction time) and online (i.e., eye-tracking) data in a group of bilingual Basque-Spanish PWA[1] performing a sentence comprehension task in Basque.

1.3. Sentence processing in bilingual speakers

Whereas at least half the world's population is bilingual (e.g., European Commission, 2012; United States Census Bureau, 2016), little is known about the particularities of sentence processing abilities in bilingual PWA. The current dissertation addresses the topic of bilingualism from two perspectives. The first perspective involves the cross-linguistic transferability of linguistic abilities in bilingual speakers. The second one revolves around the enhancement of executive functions in bilingual speakers, which has already been reported in the literature (e.g., Bialystok, Craik, Klein & Viswanathan, 2004; Costa, Hernández, & Sebastián-Gallés, 2008; Martin-Rhee & Bialystok, 2008; Prior & MacWhinney, 2010; Teubner-Rhodes et al., 2016) and the consequences that this enhancement may have for sentence comprehension in bilingual PWA.

1.3.1. Cross-linguistic transferability

The bilingual mind does not process languages separately, as independent entities. There is compelling evidence supporting a unified lexical-syntactic system in bilingual speakers, as suggested by the cross-linguistic transfer in language processing strategies (Wulfeck, Juarez, Bates, & Kilborn, 1986), therapeutic effects in the untreated language (see Ansaldo & Saidi, 2014), and cross-language syntactic priming effects (Verreyt et al., 2013). When it comes to sentence processing, if heuristic strategies fail to guide the correct interpretation of the sentence, the ability to process morphosyntactic information becomes crucial. Although the processing of morphosyntactic information constitutes a core deficit in agrammatic aphasia (see Thompson, Kielar, & Fix, 2012 for an overview), several authors suggest that PWA remain sensitive to highly reliably cues

[1] Currently Basque speaking monolinguals are rare, since both Spanish and French are required by law, depending on geopolitical territories.

in their language (Bates, Friederici, & Wulfeck, 1987). Under a unified lexico-syntactic system, one may wonder whether bilingual PWA speakers of a richly inflected language (i.e., Basque) may benefit from processing morphosyntax in a poorer inflected second language (i.e., Spanish). This potentially provides Basque-Spanish bilingual PWA with a less severe sentence comprehension impairment in Spanish, compared to monolingual Spanish speakers.

A few studies have addressed this question so far. Some studies have reported equal sentence processing impairment across languages in PWA speakers of both distant languages, such as Swahili and English (Abuom, Shah, & Bastiaanse, 2013) and closely related languages as Spanish-Gallician (Juncos-Rabadán, Pereiro, & Souto, 2009). The role of case morphology and the potential cross-linguistic transferability has been studied in case studies on Basque-Spanish (Munarriz, Ezeizabarrena, & Gutierrez-Mangado, 2016) and Hindi-English bilingual PWA (Venkatesh, Edwards, & Saddy, 2012), reporting contradictory findings. However, none of the previous studies have included a monolingual control group.

1.3.2. Enhancement of executive functions

Some studies on bilingualism suggest that the proficient use of two or more languages boosts executive functions (Bialystok, Craik, Klein & Viswanathan, 2004; Costa, Hernández, & Sebastián-Gallés, 2008; Martin-Rhee & Bialystok, 2008; Prior & MacWhinney, 2010). The rationale is that bilingual speakers need additional mechanisms in order to ignore irrelevant information and avoid conflicts across languages, which are activated simultaneously irrespective of the language in use (e.g., Marian & Spivey, 2003; see Kroll, Bobb, & Wodniecka, 2006 and Kroll & Dussias, 2013).

There is evidence that the enhancement in executive functions may aid sentence processing abilities to some extent. Bilingual speakers are less susceptible to sentence-level interference (Filippi, Leech, Thomas, Green, & Dick, 2012), and outperform their monolingual peers in comprehension of both garden-path and non-ambiguous sentences (Teubner-Rhodes et al., 2016). According to Teubner-Rhodes et al. (2016), bilingualism provides speakers with a greater ability to detect and resolve unpredictable conflict during sentence parsing and interpretation in relation to monolingual speakers. Thus, when confronted with sentences, bilingual speakers outperform monolinguals in inhibiting the reverse interpretation of the sentence.

This is important because some authors have suggested that comprehension deficits in PWA are due to impaired inhibitory processes (Dickey et al., 2007; Hanne et al., 2011; Schumacher et al., 2015). Inhibition is in the domain of executive functions, which are strongly related to working memory (Miyake et al., 2000; Friedman & Miyake, 2004). Thus, the involvement of executive processes in understanding sentence comprehension deficits in PWA is in line with previous studies that have associated sentence comprehension deficits in PWA with working memory limitation (e.g., Haarmann et al., 1997; Miyake, Carpenter, & Just, 1994; Sung et al. 2009; Zakariás, Keresztes, Dementer, & Lukács, 2013; cf. Caplan & Waters, 1999; 2013) and cognitive control limitations (see Novick, Trueswell, & Thompson-Schill, 2005; 2010; for an overview Ardila, 2012).

Altogether, there is evidence suggesting that bilingual aphasic speakers show an advantage over monolingual speakers in processing sentences in the same language. From different angles, both the cross-linguistic transfer and the executive function enhancement predict that bilingual Basque-Spanish speakers outperform monolingual Spanish speakers in sentence comprehension in Spanish. Chapter 3 presents a study on bilingual Basque-Spanish PWA and monolingual Spanish PWA, as well as matched unimpaired participants, performing a sentence comprehension task in Spanish.

1.4. Methodological background: eye-tracking on sentence processing

Most of the studies on sentence comprehension deficits have used off-line methods (i.e., by counting the number of correct/incorrect answers). However, sentence comprehension is a dynamic process. Listeners establish syntactic and semantic relationships between the constituents of the sentence as the linguistic cues are presented, and online methods allow us to monitor language processing in real time.

Using the visual world paradigm, the auditory presentation of the linguistic stimuli, as well as the subsequent processing, is tightly linked to visual attention shifts across the visual display (Cooper, 1974; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995).

Thus, it is possible to infer the cognitive processes involved in language comprehension by aligning the auditory presentation of the stimuli with the timing and pattern of eye-gaze fixations to potential referents in the visual world. It has been shown, within this framework, that healthy listeners do not wait until the end of the sentence to assign thematic roles onto the arguments. The assignment of thematic roles onto the arguments of the verb is done extremely fast. Listeners may build up expectations about potential arguments prior to auditory presentation due to the influence of the visual context. Hence, they display an anticipatory behavior in thematic role assignment, as shown in speakers of languages with case morphology, such as Japanese (Kamide, Altmann, & Haywood, 2003) and German (Kamide, Scheepers & Altmann, 2003; Knoeferle et al., 2005).

The visual world paradigm seems to be a promising way to shed light on how PWA and NBD process different types of linguistic cues during the presentation of linguistic stimuli. It also offers the possibility of exploring the extent to which language processing in PWA diverges from that in NBD. Previous visual world paradigm studies on PWA have shown that in sentence comprehension tasks, correctly and incorrectly answered trials correspond to distinctive gaze fixation patterns (Dickey et al., 2007; followed by Hanne et al., 2011; Meyer, Mack, & Thompson, 2012; Schumacher et al., 2015). This finding shows that PWA do not answer by guessing, contrary to the predictions of the TDH (Grodzinsky, 1986; 1995, 2000; Drai & Grodzinsky, 2006ab), but it also provides real time evidence that PWA are sometimes able to process reversible sentences in derived word orders in a similar way to control participants. So far, findings on the sentence processing speed of PWA compared to NBD have not been consistent (see Dickey et al., 2007; Meyer, Mack, & Thompson, 2012 versus Hanne et al., 2011)

Still, it is unclear what underlying processes are involved in the incorrectly interpreted sentences. Based on gaze fixation data, Hanne et al., (2011) reported that PWA increasingly fixate on the target or foil picture early in the auditory presentation of linguistic stimuli, and they do not switch across pictures even when they are incorrect. According to the authors, such behaviour signals that PWA apply a 'deterministic parsing' routine. That is, they choose a canonical or non-canonical parsing routine during the presentation of a sentence from early on. They also cannot reanalyse the initial routine when it requires revision. In the following dissertation, we aim to shed light onto this topic by applying methodologies similar to those of Hanne et al. (2011) (i.e., sentence-picture matching task in the VWP) in the study of PWA speakers of Basque. Recall that Basque presents syntactic ambiguity in sentences presented in OSV word order when the verb is transitive. Consequently, listeners are forced to reanalyse the parsing routine. Thus, the study of sentence processing in Basque PWA may contribute to the understanding of the potential use of "deterministic parsing" and the failure in reanalysis processes.

In addition, this dissertation takes into consideration the role that compensatory strategies may play in sentence comprehension performance in PWA. Compensatory strategies are conscious tactics to overcome specific difficulties, as shown by PWA in many modalities, such as self-cueing, verbal repetition, and mental associations (e.g., Beeke, Wilkinson, & Maxim, 2009; Oelschlaeger and Damico, 1998; Tompkins, Scharp, & Marshall, 2006; see Simmons-Mackie and Damico, 1997). Behavioural and gaze fixation patterns found in previous studies using sentence-picture matching are compatible with the possibility that PWA use agent-first strategy as the "best guess" to overcome their sentence comprehension difficulties. To shed light onto this topic the fourth and last section of this dissertation addresses the topic of error awareness in sentence comprehension in PWA.

1.5. Error awareness in sentence comprehension deficits

The use of compensatory strategies requires a certain degree of conscious awareness of a specific deficit. In Chapter 4 of this dissertation, we get an insight into metacognitive awareness in sentence processing in PWA, by assessing their error awareness in a sentence comprehension task. Metacognitive awareness is measured using confidence ratings reported by the listener after performing the primary task (i.e., sentence-picture matching). The degree of consistency between the objective performance (i.e., comprehension accuracy) and subjective confidence rating is used to assess the extent to which the sentence comprehension task is mediated by conscious knowledge

(Cheesman & Merikle, 1984, 1986; Dienes, Altmann, Kwan, & Goode, 1995; Overgaard, Timmermans, Sandberg, & Cleeremans, 2010), ergo, by voluntary control.

Dienes et al. (1995) proposed two criteria to use confidence ratings to establish a threshold between conscious and unconscious knowledge: the zero-correlation criterion and the guessing-criterion. Zero-correlation refers to the lack of a relationship between confidence ratings and objective accuracy, while the guessing criterion refers to the observed above chance performance in the primary task when participants reported guessing. So far, comprehension error awareness has never been studied in non-fluent PWA. In the current work, we extend the paradigm of Dienes et al. (1995), previously used on perceptual discrimination and implicit learning (Norman and Price, 2015; Overgaard, 2015, for an overview), into the study of aphasia.

In the sentence comprehension task conducted in Spanish, we introduced a secondary task consisting of a confidence rating, in which participants had to judge the correctness of their previous answer. They were provided with a three-option diagram to perform the rating: a) "sure I answered correctly", b) "I guessed", c) "sure I answered incorrectly". We aimed to study the extent to which people with non-fluent aphasia have conscious knowledge of language processing, and hence, perceive the failure of sentence interpretation. This has important theoretical implications, since it may provide evidence in favour of or against the guessing heuristic that the TDH (Grodzinsky, 1986; 1995, 2000; Drai & Grodzinsky, 2006ab) attributes to PWA when they are confronted with sentences with derived order of the arguments. In addition, it also has important clinical implications, because the presence or absence of error awareness in PWA may influence the need to establish systematic language assessment procedures in these patients, even when they claim to comprehend correctly.

To sum up, in the following chapters we present a series of articles studying the effect of word order on sentence comprehension deficits in PWA. Four groups are studied: bilingual Basque-Spanish PWA and NBD, and monolingual Spanish PWA and NBD. Participants performed sentence picture matching tasks in Basque and/or Spanish in a variety of word orders. Across all the experiments we combined behavioural (i.e., accuracy) and online data (reaction time and gaze fixation) in order to study real time sentence processing based on the accuracy of sentence comprehension tasks. In addition, in the Spanish version of the sentence comprehension task, we included a confidence-rating task, the purpose of which was to investigate the subjective perception of participants' performance in each trial, and consequently, error awareness.

1.6. Research questions

We aim to answer the next research questions in the chapters of the present dissertation:

Chapter 2. Sentence comprehension deficits in a free word order language; Basque.

i. Which theoretical account (TDH vs. DOP-H) predicts the sentence comprehension deficits in PWA speakers of a free word order language, such as Basque?

Chapter 3. Sentence comprehension in Basque-Spanish bilingual aphasia and Spanish monolingual aphasia.

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

iii. Do Basque-Spanish bilingual speakers with aphasia and unimpaired non-brain-damaged speakers perform differently from Spanish monolingual speakers on a sentence comprehension test in Spanish?

Chapter 4. Error awareness in sentence comprehension deficits.

iv. Are PWA aware of their sentence comprehension errors?

v. Is sentence comprehension performance unconsciously mediated in PWA and NBD?

vi. To what extent do PWA answer by guessing when comprehending sentences with derived word order?

Finally, in Chapter 5 the results of the three studies will be taken together and discussed.

CHAPTER 2:

Eye-tracking the effect of word order in sentence comprehension in aphasia: Evidence from Basque, a free word order ergative language[2].

Abstract | *Background:* Some studies have shown that agrammatic speakers of languages with overt grammatical case show impaired use of the morphological cues to establish theta-role relations in sentences presented in non-canonical word orders. To gain insight into the underlying nature of this impairment, we analysed the effect of word order on the sentence comprehension of aphasic speakers of Basque, an ergative, free word-order and head-final (SOV) language.

Ergative languages such as Basque establish a one-to-one mapping of the thematic role and the case marker. We collected behavioural (i.e. accuracy and reaction time) and gaze fixation data while agrammatic speakers performed a picture-matching task with auditorily presented sentences with different word orders. We found that PWA had difficulties in assigning theta-roles in non-canonical Theme-Agent order. The gaze data indicated that in verb final and verb initial sentences, correct and incorrect answers in the PWA group showed distinctive fixation patterns at the second and first arguments. This result is in line with processing accounts. In the correctly answered stimuli, PWA processed case-morphology cues as rapidly as the non-brain-damaged group. Contrary to previous findings, our data do not suggest a systematic delay in the integration of morphological information in the PWA group, but strong reliance on the ergative-case morphology and reduced sensibility to verb morphology.

[2] This chapter was adapted from: Arantzeta, M., Bastiaanse, R., Burchert, F., Wieling, M., Martinez-Zabaleta, M., & Laka, I. (2016). Eye-tracking the effect of word order in sentence comprehension in aphasia: Evidence from Basque, a free word order ergative language. *Language, Cognition and Neuroscience, (In progress).*

2.1. Introduction

Aphasia is a condition present in 21-38% of acute stroke patients, and it frequently persists in chronic stages (Pedersen, Jørgensen, Nakayama, Raaschou, & Olsen, 1995; Pedersen, Vinter, & Olsen, 2004). Although language production impairment is the most noticeable symptom, people with aphasia (PWA) with a variety of different syndromes present persistent sentence comprehension deficits (Caramazza, Basili, Koller, & Berndt, 1981; Vallar, Basso, & Bottini, 1990), independently of production abilities (see Caplan & Waters, 1990; Grodzinsky, 2000 for a review). The deficits that underlie sentence comprehension impairment are still unclear, and the heterogeneity of the clinical profiles increases the research challenges in this area.
In one of the earliest publications on agrammatic sentence comprehension, Caramazza and Zurif (1976) pointed out that PWA make systematic use of heuristic rather than algorithmic strategies to comprehend sentences (e.g. Bayesian computations). That is, PWA infer thematic roles of arguments from semantic and word order information, among other cues. This strategy may be illustrated with reference to the examples **(1-2)** below:

(1) The boy washes the dish.

(2) The nurse calls the doctor.

For correct interpretation of the sentence in **(1)** the listener may rely solely on lexical comprehension, rather than on syntactic relations. This is because a semantic restriction of 'to wash' only allows the animate 'boy' to be the agent of the action and not the inanimate 'dish'. Therefore, it is expected that PWA with spared lexical comprehension will not have problems understanding such a sentence.

However, a sentence such as **(2)** shows that lexico-semantic information is not always sufficient to identify who performs the action, since both 'nurse' and 'doctor' are plausible agents of the action (i.e., 'to call'). Sentences such as **(2)** are hence known as 'semantically reversible constructions'. In such structures in English, word order information plays an important role. It is widely accepted in linguistics that languages have a base word order, which is, generally, the order of declarative active sentences where all information is new (Comrie, 1981; e.g., Subject-Verb-Object in English, and Subject-Object-Verb in Japanese). Sentences with other word orders are assumed to be derived from the base word order. Previous research has shown that PWA retain sensitivity towards the base word order of their language, and that they use this knowledge to infer the thematic roles of sentence constituents (i.e., Agent-Theme; Bates, Friederici, & Wulfeck, 1987), as healthy speakers do (Ferreira, 2003). Conversely, the comprehension of sentences with derived word order involves higher cognitive demands, as suggested by greater error rates and longer reaction times in both PWA and healthy speakers, respectively (Bastiaanse & Van Zonneveld, 2006; Bornkessel, Schlesewsky, & Friederici, 2002; Caplan & Waters, 2003; Erdocia, Laka, Mestres-Missé, & Rodriguez-Fornells, 2009; Hanne, Sekerina, Vasishth, Burchert, & De Bleser, 2011).

When correct comprehension of sentences cannot be achieved by means of lexical guesswork, the hierarchical relations between constituents have to be considered. This is the reason why PWA are prone to misinterpreting reversible sentences with non-base word order (Berndt, Mitchum, & Haendiges, 1996; Caramazza & Zurif, 1976; Caplan & Futter, 1986; Saffran, Schwartz, & Marin, 1980). In sentences such as (3-5), where both animate Determiner Phrases (DPs) are the plausible Agent/Theme of the verb and the thematic roles display a non-canonical order (i.e. Theme-Agent), neither of the heuristic strategies mentioned above leads to the correct interpretation of the sentence. Thus, the listener must necessarily process syntactic structure to infer Agent-Theme roles. In fact, it is precisely disentangling the Agent-Theme roles in these types of structures that is at the core of the impairment in PWA with agrammatic comprehension.

(3) The nurse is called by the doctor.

(4) It is the nurse whom the doctor called.

(5) The nurse who the doctor called is tall.

However, it is not only the position of the arguments which affects sentence comprehension deficits, but also the position of the verb. It is still unclear how PWA process the information contained in the verb, but some studies have pointed out that lexical access to the verb and its argument structure in agrammatic aphasia is unimpaired. Using cross-modal lexical decision tasks, Shapiro and Levine (1990) showed that lexical decision times to visually presented stimuli were higher in the vicinity of the verbs with more argument structure options, in both healthy individuals and individuals with agrammatic aphasia. This indicates that the core impairment of people with agrammatic aphasia eradicates the post-activation process required for the assignment of thematic roles to the phrasal arguments (Grodzinsky, 1986), as suggested by preserved abilities in grammaticality judgement tasks involving argument structure violations (Kim & Thompson, 2004). However, ERP studies have suggested that the receptive processing of argument structure is incomplete and temporally delayed in PWA (Kielar, Meltzer-Asscher, & Thompson, 2012).

Although the underlying cause of the inability to correctly interpret semantically reversible sentences is far from understood, several hypotheses have been proposed. Two sets of theories can be identified from representational and processing related accounts; the Trace Deletion Hypothesis (TDH; Grodzinsky, 1986; 1995, 2000; Drai & Grodzinsky, 2006ab) and the Derived Order Problem Hypothesis (DOP-H; Bastiaanse & Van Zonneveld, 2005; 2006), respectively. The main difference between the two theories is that the TDH, heavily relying on the Government and Binding model of grammar (Chomsky, 1981), claims that aphasic individuals suffer from a representational deficit, whereas the DOP-H is a processing based account, largely neutral as to a specific model of grammar. We discuss the particulars of each proposal in the next section.

Based on the tenants of the Government and Binding (GB; Chomsky, 1981), Grodzinsky proposed the Trace Deletion Hypothesis (TDH; 1986; 1995, 2000; see Drai & Grodzinsky, 2006ab for a later revision). In the Government and Binding model of generative grammar (Chomsky, 1981), upon which Grodzinsky's hypothesis is based, syntactically displaced constituents are assumed to have moved from their based generated position where they leave a trace. Thus, sentence comprehension requires keeping track of both the element in the derived position and the trace left in the base-generated position. The TDH postulates that inability to represent the trace is the underlying cause of the comprehension deficits in PWA when confronted with sentences such as (4-5). According to this hypothesis, since the trace is missing from syntactic representation, individuals with Broca´s aphasia cannot assign a thematic role to the moved argument and can only resort to heuristics. They apply a linear-order based assignment of the thematic roles along the sentence and assign the thematic role of Agent to the first DP encountered in the sentence. The thematic role to the non-moved DP (i.e. 'the doctor' in 4-5) is correctly assigned, leaving the aphasic individual with a structure with two Agents. When the individuals with Broca's aphasia are forced to select one out of two pictures that only differ in the thematic roles of the persons depicted (e.g., a doctor calling to a nurse and a nurse calling to a doctor), they have to guess (see 4-5). Thus, the TDH predicts that PWAs will perform at ceiling level in their comprehension of semantically reversible sentences with base word order, and at chance-level (between 33.3 and 66.6 % correct) in those with derived word orders.

Bastiaanse and Van Zonneveld (2006; 2005) proposed the Derived Order Problem Hypothesis (DOP-H) as a processing account. The DOP-H (Bastiaanse & Van Zonneveld, 2005; 2006) states that the production and comprehension of sentences with a derived word order are harder for individuals with agrammatic aphasia than sentences with base word order. For production, the effect is that PWA tend to produce sentences in base word order (Bastiaanse & Edwards, 2004; Bastiaanse & Van Zonneveld, 2005). For comprehension, the disorder is mainly visible in semantically reversible sentences, when the arguments are in derived position (e.g. passives and object relatives in English). These sentences with derived word order are more complex and, therefore, harder to process for PWA (Bastiaanse & Van Zonneveld, 2006). Notice that Bastiaanse and Van Zonneveld (2005; 2006) do not assume that the syntactic representations are affected; rather, they propose a disorder that makes it hard (but not always impossible) to process derived word order structures. Some studies attribute such processing deficits to an overall cognitive slow-down across executive functions, memory, and attention (e.g. Burkhardt, Avrutin, Piñango, & Ruigendijk, 2008; Burkhardt, Piñango, & Wong, 2003; Caplan & Waters, 1999; Caplan, 2006; Caplan, Waters, DeDe, Michaud, Reddy, 2007; Dickey, Choy, & Thompson, 2007; Haarmann & Kolk, 1991). For the sentences under study, the DOP-H claims that sentences are harder to process when there is no linear Agent-Theme order, regardless of the position of the verb in the sentence. The DOP-H can fully account for comprehension data from agrammatic speakers of languages with rather rigid word order (e.g. English and Dutch; Bastiaanse & Edwards, 2004; English and Swahili; Abuom, Shah, & Bastiaanse, 2013), and flexible word order (e.g. Spanish and Galician; Juncos-Rabadán, Pereiro, & Souto, 2009). Nevertheless, the characterization of aphasic speakers of languages with case morphology seems to be slightly different.

Languages with overt case morphology mark the arguments of the verb depending on their grammatical function or thematic role. Correlated with this, sentences in these languages display a greater variety of word orders and, therefore, the word order cue is not as strong as in more rigid word order languages, such as English. Several studies have shown that the processing of case morphology is impaired in PWA (German; Burchert, De Bleser, & Sonntag, 2003; Russian; Friedmann, Reznick, Dolinski-Nuger, & Soboleva, 2010; Hebrew; Friedmann & Shapiro, 2003; Serbo-Croatian; Smith & Mimica, 1984; Turkish: Duman, Altınok, Özgirgin, & Bastiaanse, 2011). However, some cross-linguistic comparisons suggest that aphasic speakers of languages with case marking have certain advantages when it comes to processing derived order sentences. For example, aphasic speakers of German perform better in the comprehension of passive sentences than Dutch speakers (Bastiaanse & Edwards, 2004; Burchert, De Bleser, & Sonntag, 2003; see also Bates, Friederici, & Wulfeck, 1987).

In conclusion, individuals with agrammatic aphasia have problems comprehending semantically reversible sentences when the order of the arguments is derived. Nevertheless, one could wonder whether this deficit is language dependent or not. To gain insight into this topic, more studies of PWA speaking free word order languages with rich case morphology are necessary.

One of the differences between the TDH (Grodzinsky, 1986, 1995, 2000; Drai & Grodzinsky, 2006ab) and the DOP-H (Bastiaanse & Van Zonneveld, 2006) is the predictions they make regarding the performance of PWA in comprehension tasks. As a representational account, the TDH states that PWA miss the traces of the arguments and, hence, have to guess when they have to choose a picture corresponding to a semantically reversible sentence with non-base order of thematic roles, resulting in chance-level performance. The DOP-H (Bastiaanse & Van Zonneveld, 2006) does not make predictions in terms of chance, but suggests that the processing deficits will result in lower performance on semantically reversible sentences in which the arguments are not in base order (i.e. Theme-Agent order). A growing body of online processing data supports this latter prediction (Dickey, Choy, & Thompson, 2007; Hanne et al., 2011).

The introduction of online techniques in psycholinguistic and neurolinguistic studies has led to significant advancement in research. Studies with neuroimaging and eye-tracking (ET) techniques offer insight in real time language processing to complement the behavioural off-line data. This introduces two main advantages: First, online data permit the disambiguation of different processes involved in the same final result, therefore, offering the possibility of reviewing linguistic symptomatology. Second, it offers the possibility to distinguish brain reactions accompanying correct answers from those accompanying incorrect choices, by comparing the real time language processing of PWAs with healthy non-brain-damaged participants (NBD). This is relevant, because chance-level performance has been interpreted as the expression of guessing (e.g. Grodzinsky, 1986, 2000; see Burchert, Hanne, & Vasishth, 2013, for a review). Dickey et al. (2007), followed by Hanne et al. (2011), report evidence indicating that PWA do not guess. Dickey et al. (2007) studied the online comprehension of PWA with ET while comprehending sentences with wh-movement. They analysed the gaze fixation patterns by convergence analysis and found that PWA showed a similar eye-movement pattern to that of NBD participants in the correct answers, but not so in the incorrect answers. Hanne et al. (2011), using the same technology, tested comprehension in PWA speakers of German by comparing reversible sentences with SVO and OVS word orders. In line with Dickey et al. (2007), results revealed that the fixation patterns of PWA for correct and incorrect answers were qualitatively different. Thus, real time language processing suggests that the chance-level performance of PWA is partly guided by normal patterns of language processing (see also Meyer, Mack, & Thompson, 2012).

The Visual World Paradigm (VWP) is based on the idea that language processing results in attention shifts across the visual display. Hence, cognitive processes involved in language comprehension are analyzed by aligning the timing and pattern of eye-gaze fixations to potential referents displayed on the visual workspace (Cooper, 1974; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). This is feasible because eye fixations are time-locked with the continuous auditory stimuli within a margin of 200 ms (Matin, Shao, & Boff, 1993) and this tight link allows insight into real time sentence processing by inferring from the gaze fixations on the visual stimuli. Healthy listeners fixate to the target referent after the auditory stimulus provides sufficient selectional restrictions to discard competitors. Interestingly, several studies have pointed out that they display an anticipatory behaviour in thematic role assignment while doing a sentence resolution task (Kamide, Scheepers, & Altmann, 2003; Kamide, Altmann, & Haywood, 2003; Knoeferle, Crocker, Scheepers, & Pickering, 2005). That is, they assign thematic roles to critical objects in the scene before the names of the objects have been mentioned in the auditory input. The building up of expectations about elements that have not yet been presented auditorily is due to the influence of the visual context information on incremental thematic role assignment, as has been shown for two case marking languages, German (Kamide, Scheepers & Altmann, 2003; Knoeferle et al., 2005) and Japanese (Kamide, Altmann & Haywood, 2003), although under different selective constraints. Altogether, this suggests that VWP is a useful framework to monitor the language comprehension deficits of PWA and, more specifically, their sensitivity towards word order and case morphology information when it comes to comprehending semantically reversible sentences. The use of the VWP thus seems to be a promising way to study how PWA parse grammatical functions in real time.

To sum up, sentence comprehension deficits in PWA are most noticeable in semantically reversible sentences with derived word order, but TDH (Grodzinsky, 1986; 1995, 2000; Drai & Grodzinsky, 2006ab) and DOP-H (Bastiaanse & Van Zonneveld, 2006) provide different explanations for the underlying causes of such impairments in PWA. The current study aims to further our insight into sentence processing in aphasia by analysing the effect of word order on sentence comprehension by PWA speakers of Basque, a free word order and head-final (SOV) ergative language with rich case morphology.

2.1.1. Linguistic background: Basque

Basque is a free word-order language, with SOV as base order (De Rijk, 1969, Erdocia et al. 2009). The frequency of usage of each word order varies as quantified by means of written corpora analyses: SOV (56.8%); SVO (14.8%); OVS (13.8%); OSV (9.9%); VOS (3.3%); VSO (1.1%) (Aldezabal et al. 2003). Basque is a richly inflected language in which the inflected verb agrees with the subject, the direct object and the indirect object, which are all case marked. That is, the auxiliary verb presents polypersonal agreement with all the arguments of the sentence. This combination of agreement and morphological case is an infrequent typological pattern. Basque is an ergative language (Levin, 1983; Ortiz de Urbina, 1989; Laka, 2006). Hence, subjects of unaccusative verbs and objects of transitive verbs are morphologically identical (6-7), marked by zero case and called 'absolutive', while the agentive subject of transitive clauses carries ergative case (*-k*) **(1)**.

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

(7)	Txakurr-a- Ø	etorri	da.
	dog-det-abs	arrived	aux.is
	The dog has arrived.		

If a DP marked with absolutive case (Ø) appears at the beginning of a sentence, it can be initially interpreted as the subject of an intransitive/unaccusative verb **(7)**, as a sentence-initial object with a null-subject subject **(8)**, or as a topicalized object in a sentence with OSV word order **(9)** (see also Laka, 2012).

(8)	(katu-a-k)	txakurr-a- Ø	harrapa-tu	du.
	(cat-det-erg)	dog-det-abs	catch-perf.	aux.has
	(the cat) has caught the dog.			

(9)	txakurr-a-Ø	katu-a-k	harrapa-tu	du.
	dog-det-abs	cat-det-erg	catch-perf.	aux.has
	The cat has caught the dog.			

Note that the combination of the singular determiner (-*a*) and the ergative case marker (-*k*) yields a sequence that is homophonous with the plural absolutive marker (-*ak*) in Basque. Consequently, the first DP marked with –*ak* is temporarily ambiguous to the listener, since it may correspond either with a singular agent **(6)** or with a plural object **(10)**.

(10)	Katu-ak-Ø	txakurr-a-k	harrapa-tu	ditu.
	cat-det.pl-abs	dog-det.sg-erg	catch-perf.	aux.has
	The dog has caught the cats.			

Inspired by this free word order property of Basque, Erdocia et al. (2009) compared the online processing of SOV-OSV sentences using self-paced reading and ERP techniques in healthy participants. Both sentence types were either morphologically unambiguous or ambiguous ergative DPs or plural absolutive DPs, as illustrated above in **(10)**. The authors found that Basque speakers employed a 'subject-first' processing strategy and systematically reanalysed OSV sentences at the second DP position. In addition, SOV word order imposed the lowest cognitive demands, as revealed by shorter reading times and a modulation of anterior negativities and P600 components. In another study Carreiras, Duñabeitia, Vergara, de la Cruz-Pavía, and Laka (2010) used the same ambiguous Agent/Theme morphological marking as Erdocia et al. (2009), but in Subject/Object relative clauses (henceforth SRC and ORC, respectively) involving a temporal ambiguity between subject/object-gap that was resolved at the auxiliary verb of the main sentence. Longer reading times and larger amplitudes in the P600 were interpreted by the authors as evidence that ORC are easier to process than SRC in Basque. In agreement with the results of previous studies, speakers deployed an agent-first strategy for the ambiguous sentence-initial DP, yielding lower processing demands for ORC. To sum up, converging evidence shows that healthy speakers of

Basque use word-order information to disentangle morphological ambiguities affecting the interpretation of thematic roles (for an overview, see: Laka & Erdocia, 2012).

2.1.2. Hypothesis and expectations

In the current study, the predictions of the TDH and the DOP-H on sentence comprehension processing in PWAs will be tested with behavioural data (i.e. accuracy and reaction time) and using eye fixations as an online measure of language processing.

The original version of the TDH (Grodzinsky, 1986, 1995, 2000) predicts that behaviourally the PWA group will perform above chance in the comprehension of sentences when the moved argument does not cross the verb in a hierarchical manner **(11)**.

(11) $[_S NP_S [_{VP} NP_O V]]$
(12) $[_{S'} V_i [_S NP_S [_{VP} NP_O t_i]]]$
(13) $[_{S'} NP_{Oi} [_S NP_S [_{VP} t_i V]$
(14) $[_{S'} V_j [_{S'} NP_{Oi} [_S NP_S [_{VP} t_i t_j]$

(See [3] for further clarifications.)

In sentences with VSO word order (12), no argument has moved from its base position and therefore, PWA are expected to present above-chance accuracy. Conversely, in the OSV (13) and VOS (14) there is an additional crossing of the subject by the object and the use of the agent-first strategy will not result in the correct interpretation of the sentence. Therefore, chance-level accuracy is expected. Drai and Grodzinsky (2006ab) laid out some explicit predictions of the TDH for Germanic languages, also with SOV base word order, where they slightly modified the original TDH. According to the authors, the comprehension of passive sentences in Dutch is not impaired in PWA because in this construction the internal argument that becomes the subject of the sentence does not cross the lexical Verb (see Bastiaanse & Van Zonneveld, 2006, for a

[3] Following Kayne (1994) and Fukui and Takano (1998), we assume that there is no rightward movement of the arguments within the sentence. Thus, the only possible derivations for **(12-14)** are the ones shown in this section.

reply). If we assume that this restriction needs to be fulfilled to consider comprehension deficits, neither the OSV nor VOS word order should be impaired according to the TDH, since the Object does not cross the Verb in any of these two constructions. Therefore, PWA speakers of Basque should correctly understand sentences presented in these conditions. Contrary to this, the DOP-H predicts that PWA will score higher in sentences with Agent/Theme linear order (i.e. SOV, VSO) than in sentences with Theme/Agent order (i.e. OSV, VOS). Therefore, these hypotheses on the underlying disorders make different predictions regarding the sentence processing patterns in PWA.

In addition, it should be noted that due to the pluripersonal character of verb agreement in Basque, and regardless of the sensitivity that PWA may have to the argument structure of the lexical verb, the auxiliary will also support thematic-role information by means of agreement with the Agent and Theme of the sentence. That is, the argument structure of the verb will be over-specified at the auxiliary verb in both VSO and VOS conditions. A performance pattern of preserved comprehension in the VSO condition and impaired abilities in the comprehension of VOS support that even when thematic role assignment does not require full access to argument structure information because thematic roles are unambiguously marked by case morphology, there is an impaired assignment of thematic roles onto the DPs. Contrary to this, preserved comprehension of VOS sentences and impaired comprehension in the OSV condition would indicate that PWA assign thematic roles correctly to the DPs when those are offered beforehand by means of agreement morphology on the verb, but they do present impairment in reanalysis processes in verb final constructions.

TDH does not make explicit predictions about reaction times (RTs). The DOP-H predicts that for PWA sentences with derived word order (i.e. OSV, VSO, VOS) will take longer to process due to the increased processing load.

Regarding gaze data, distinct patterns are predicted by TDH and DOP-H. The former predicts that gaze fixation patterns of the sentences for which the PWA have to guess (i.e. OSV and VOS) will be qualitatively different from those of healthy participants, whereas the fixation pattern and timing-window are expected to be similar to those for control participants in conditions with above-chance accuracy (i.e. SOV and VSO). The DOP-H predicts that trials eliciting correct and incorrect answers in PWA should correspond to qualitatively different fixation patterns. Moreover, it is expected that the slow-down of linguistic processing in PWA will cause a temporal delay from the auditory presentation of the stimuli until the fixation to the visual target, as compared to NBD participants.

2.2. Methods

The study obtained the approval of the Basque Clinical Research Ethics Committee (CEIC-E). All participants received written and oral information about the study, rights and implications of their participation, and signed an informed consent form.

2.2.1. Participants

Eight individuals with aphasia (mean age 66.37 years; SD= 14.37; range= 43-83; male/female= 6:2) met the inclusion criteria to take part in this study. They were all L1Basque-L2Spanish bilingual speakers[4] and had experienced a left hemisphere stroke 3-24 months prior to the study. They were right-handed pre-morbidly, as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). The NBD group was composed of eight L1Basque-L2Spanish bilingual speakers without any history of neurological or sensory impairments. They were matched on age range, education level and literacy language with the clinical group (mean age 62.25 years; SD= 13.31; range= 38-80; male/female= 5:3). They all demonstrated normal or corrected-to-normal vision and hearing.

The PWA were Basque-Spanish bilingual speakers whose native language was Basque. They had acquired Spanish at an early age (2-5 years). They were all literate only in Spanish, their language of instruction at school, with the exception A4 who was literate in Basque as well, having used both Spanish and Basque as languages of instruction at school. See **Appendix A1** for detailed individual data.

[4] Currently Basque speaking monolinguals are rare, since both Spanish and French are required by law, depending on geopolitical territories.

Prior to their participation in this study, the PWA had been assessed with the Cognitive Neuroscience Laboratory language screening battery (CNL; Chialant, 2000; adapted to Basque by Erdocia, Santesteban & Laka, 2003) for working memory using the Digit-span task (WAIS-III; Wechsler, 1997), auditory discrimination and comprehension abilities. In the latter test, both word (i.e. nouns and verbs) and sentence comprehension were assessed using picture-matching tasks. Lexical materials were controlled for imageability, animacy as well as frequency; sentences included simple and embedded declaratives presented in both base word order (SOV) and a non-base order (OSV). The sentences were counterbalanced for semantic reversibility, number/person agreement and number of arguments required by the verb, and were marked with ergative, absolutive and dative case morphology, when necessary.

As shown in **Appendix A2**, all eight PWAs had preserved word comprehension abilities for both verbs and nouns, and impaired sentence comprehension abilities. The latter was characterized as chance or below chance performance in the comprehension of semantically reversible sentences in at least one condition (i.e., base SOV versus derived OSV word order). Visual neglect was excluded as a cause of poor performance among all participants using the Behavioural Inattention Test (BIT; Wilson, Cockburn, & Halligan, 1987).

Since no normalized assessment tools are available for PWA speakers of Basque, we analysed samples of spontaneous speech to characterize the clinical participants as non-fluent based on the criteria described below. The samples were taken through spontaneous conversation and elicited language while participants were describing such pictures as the *Cookie Theft* (BDAE; Goodglass, Kaplan & Barresi, 2000) or *Flood Rescue* (Olness, 2006). The analysis was focused on the Mean Length Utterance (MLU), finiteness, grammaticality and speed (i.e. number of words per utterance) in samples of 200 words, unless otherwise indicated. Detailed results are available in **Appendix A3**. Subsequently these samples were compared with the spontaneous language of 10 native Basque speakers matched by age range, dialect and gender using *Ahotsak Ahozko Tradiziozko Korpusa* (*Traditional Oral Language Corpus Ahotsak;* Badihardugu Euskara Elkartea, 2008; see **Appendix A4**). Although the sample materials have not been recorded under similar circumstances, we believe that they offer a rather good picture of language production handicaps shown by the PWA included in the current study.

2.1.2. Design and materials

Materials for the eye tracking study consisted of single sentences presented auditorily, simultaneously with the presentation of pairs of pictures. One of the pictures depicted the action described by the spoken sentence, while the other showed the same action with an Agent-Theme reversal (see **Figure 2.1**). There were 176 trials consisting of 80 experimental items, 80 fillers, and 16 practice items.

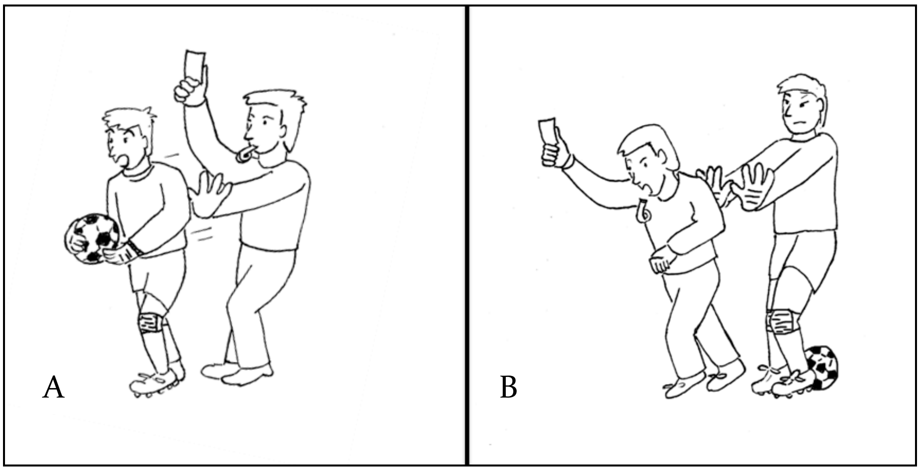

Fig. 2.1. Sample visual display. Target stimulus (Active): "Arbitroak atezaina bultzatu du" (The referee has pushed the goalkeeper). A) Target picture; B) Foil.

2.1.2.1. Linguistic stimuli:

Twenty-two transitive verbs were selected to create the items. Each verb was complemented with two animate, singular DPs to create declarative sentences in the following word orders (a) SOV; (b) OSV; (c) VSO; and (d) VOS. The assignment of the Agent-Theme roles to the DPs in each pair of DPs was randomized and balanced within the four conditions. Hence, each DP was the Agent of the sentence in two out of four conditions. The filler stimuli were created using 22 unaccusative verbs in combination with a single animate DP. In addition, a temporal adverb functioning as an adjunct was added to keep sentence length between target and filler stimuli constant. Filler stimuli were also presented in the four word orders described above, although in this case the adjunct (i.e., temporal adverb) replaced the position of the grammatical object in the sequence. All arguments of both target and filler sentences were highly imageable, had four syllables and comparable lemma frequency (<1000 words/million), as extracted from the *Euskal Hiztegiaren Maiztasun Egitura* ('The Frequency Structure of the Basque Dictionary'; Acha, Laka, Landa & Salaburu, 2013).

In the semantically reversible target sentences, the Agent was overtly marked with the ergative case marker attached to the DP (-*k*), while the Theme was zero-marked for absolutive case, as illustrated in (15-18) below; all sentences mean 'the lady has combed the girl ('s hair).

(15) Subject – object – verb (– aux)

Andere-a-k	neskato-a-Ø	orraz-tu	du
lady-det-erg	girl-det-(abs)	comb-perf.	aux.has

(16) Object – subject – verb (– aux)

Neskato-a-Ø	andere-a-k	orraz-tu	du
girl-det-abs	lady-det-erg	comb-perf.	aux.has

(17) Verb (– aux) – subject – object

Orraz-tu	du	andere-a-k	neskato-a-Ø
comb-perf.	aux.has	lady-det-erg	girl-det-abs

(18) Verb (– aux) – object – subject

Orraz-tu	du	neskato-a-Ø	andere-a-k
comb-perf.	aux.has	girl-det-abs	lady-det-erg

As is the case in ergative languages, the object of the transitive verb carries the same morphological marker (Ø) as the subject of unaccusative verbs. As shown by Erdocia et al. (2009), Basque listeners use a subject-first strategy to resolve this syntactic ambiguity; thus, they assume that the first DP is the subject of an intransitive verb. The processer detects that parsing is incorrect when it reaches the subject marked with the ergative -k as the second DP, and it is forced to reanalyse the sentence. One of the points of interest in the present study was to investigate whether Basque-speaking PWA are able to revise their initial grammatical parsing, and hence, reanalyse the sentences (i.e. OSV). To maintain the syntactic ambiguity filler items with unaccusative verbs were combined with the target stimuli.

Additionally, two of the experimental conditions, VSO and VOS, were selected to test the sensitivity to verb morphology in PWA. We wanted to see whether PWA process verb agreement morphology and, if so, whether this overwrites the impact of word order in the comprehension deficits. Recall that in Basque the inflected verb agrees in case, number and person with all arguments of the sentence, and therefore, the listener may disentangle thematic roles resorting to agreement morphology, with the support of the visual stimuli, as soon as the verb and the first DP are presented (see Ros, Santesteban, Fukumura & Laka, 2015). In such a case, incremental thematic role assignment is expected from the off-set of the first DP, without the need to process the subsequent case markers affixed to the second argument (as shown in Kamide, Scheepers & Altmann, 2003; Knoeferle et al., 2005; Kamide, Altmann & Haywood, 2003 with NBD participants).

In the filler sentences, the subjects were not Agents but Themes, zero-marked for absolutive case, with unaccusative verbs (see 19-22).

Filler sentences:

(19)	Dantzari-a- Ø	bapatean	argaldu	da
	dancer-det-abs	suddenly	become.thin	aux.has
(20)	Bapatean	dantzari-a-Ø	argaldu	da
	suddenly	dancer-det-abs	become.thin	aux.has
(21)	Argaldu	da	dantzari-a- Ø	bapatean
	become thin	aux.has	dancer-det-abs	suddenly
(22)	Argaldu	da	bapatean	dantzari-a- Ø
	become thin	aux.has	suddenly	dancer-det-abs

The dancer has suddenly become thin.

Sentences were recorded by a female native speaker of Basque in a soundproof booth (IAC) using a digital microphone (audio-technica AT4022a). Recordings were normalized using Audacity (v.2.0.3), a cross-platform sound editor. A similar constant prosodic contour was used across all sentence conditions to avoid giving cues biasing one or another interpretation (Weber, Grice, & Crocker, 2006). A rather slow speech rate of 3.57 syllables per second was used, which is still within the parameters for normal speech (3-6 syllables/sec; Levelt, 2001). Since the constituents of the sentences were matched on length (i.e. four syllables/constituent) and speech rate, all constituents and sentences had a duration of 1.12 seconds and 3.36 seconds respectively across all conditions. This fact allowed the subsequent analysis of the longitudinal data (i.e., gaze data) in time windows matched by length across constituents and stimuli.

2.1.2.2. Visual stimuli:

Visual stimuli consisted of 88 black-and-white line drawings divided into 44 pairs separated by a black vertical line in the middle of the screen. Each pair of pictures depicted the same reversible action differing in the role of Agent/Theme. A sample of the visual display is presented in **Figure 2.1** (see above). The pictures were approximately 15x15 cm. and the elements on them were presented at a similar size, while keeping the proportional differences between different elements in the real world (e.g., a child is smaller than an adult). The pictures were controlled for name and comprehension agreement in a norming study with 20 healthy participants. This group was comprised of twenty L1Basque-L2Spanish bilingual speakers (mean age 31.7 years; SD= 2.55; range= 27-38; male-female= 10:10). In the normalization process, the visual stimuli were presented on a 14.1" screen, with a resolution of 1280x800. To test name agreement, the picture was shown and the verb was given to the participants in order to elicit a sentence describing the picture. Attention was focused on the use of nouns and assignment of the Agent-Theme roles in the answers provided by the participants. The use of synonyms or substitution of the nouns was counted as correct as long as they represented the same referent (e.g., the nouns *ama* 'mother' and *anderea* 'lady') and showed unambiguous recognition of the depicted elements. For comprehension agreement, each pair of pictures was shown to the participants simultaneously with an auditory presentation of a sentence. The latter always corresponded to the canonical sentence word order (SOV) and referred to one of the two pictures randomly. Participants were instructed to point to the picture that best depicted the auditory stimuli. After implementing the necessary changes, an agreement of 90.90% and 96.13% was reached in naming and comprehension normalization, respectively.

After normalization, the order of the visual stimuli was pseudo-randomized for the experimental stage based on two criteria. First, the position of the target item on the screen was pseudo-randomized in order to avoid a preference in selecting the drawing depending on its location (i.e., left/right) on the visual display. No more than two target stimuli were displayed in a row on the same side of the screen. Secondly, the direction in which the action was performed in the picture was randomized in order to avoid preferences in left-to-right scanning strategy (Scheepers & Crocker, 2004).

2.2.3. Procedure

The order of both target and filler stimuli was randomized and divided into four blocks of 40 items for presentation. In each experimental session, two blocks of items were administered, preceded by the presentation of eight trial items. No more than two experimental items from the same condition were presented in a row. The experiment was conducted using E-prime 2.0 software with extensions for Tobii 2.1. (Psychology Software Tools, Pittsburgh, PA).

The visual stimuli were presented on a screen of 23 inches with a resolution of 1280x720, and the auditory stimuli were played through stereo headphones (Sony, MDR-XD100). Gaze movements were monitored using a Tobii T120 remote portable eye-tracker (sampling rate: 120 Hz) located below the screen. Participants were placed at 60 to 70 cm distance from the screen, with a visual angle under 15º (max. Allow 35º). Each of the four blocks of stimuli was preceded by a short calibration of the eye-tracker. Such calibration was performed to re-assess the eye position and to ensure that the device correctly detected the eye-gaze of the participants. The participants were required to fixate into five calibration points that appeared in sequence along the screen. Once the initial calibration had been performed successfully, each experimental session started by providing written instructions on the laptop screen to describe the experimental task. The same instructions were verbally explained to all participants before running the experiment.

The participants performed a picture-matching task. Each trial started with the presentation of a fixation smiley face in the centre of the screen. The participants needed to fixate on the image for 250 ms before the presentation of the stimuli was executed. This measure was taken to ensure that the participants did not have a fixation bias at the onset of the stimuli. Subsequently, the visual stimulus was presented on the screen. After 1000 ms of previsualization, the auditory stimulus was presented. The participants' task was to select the picture that best corresponded to the meaning of the presented sentence by pressing specific buttons on the keyboard using the left hand. Trials without answer within a 8000 ms time window from the off-set of the sentence were registered as 'no answer' and the next stimulus was presented automatically.

Non-answered trials were excluded from the data analysis, corresponding to the 2.07% of the total target data. Only fixations lasting more than 90ms (11 data points) were included in the data analysis to avoid blinks and saccades from interfering in the results. In addition, it was checked that there was no trial answered before 500ms from the onset of the auditory presentation since such answers may be due to accidental button press rather than to a conscious answer. Gaze fixation data was switched 200 ms to correct the delay of the gaze fixation in relation to the auditory stimuli (Matin, Shao, & Boff, 1993).

2.3. Data analysis

In addition to standard descriptive statistics, Generalized Linear Mixed-effects Models (GLMM) and Linear Mixed-effects Models (LMM) were used to identify determinants of sentence comprehension across behavioral and gaze data (i.e. GLMMs for the accuracy data, LMMs for the reaction time and gaze data). (G)LMM is a statistical technique assessing the linear effect of both fixed-effects terms (i.e., regression coefficients) and radom-effects terms in a single model (see Bates, 2005). Thus, it simultaneously considers repeatable covariates and the unexplained variation introduced by a specific selection of subject and linguistic stimuli, which are treated as samples from the population of interest. (G)LMMs are suitable to analyze longitudinal and repeated measures studies for a number of reasons. They have been shown to accommodate missing data satisfactorily and to be robust towards outliers (Verbeke & Molenberghs, 2000), which are crucial properties to take into account in the analysis of reduced sample sizes. The difference between a GLMM and LMM is that in the former case, the dependent variable is binary (with 1 indicating a correct answer, and 0 indicating an incorrect answer) and the estimates have to be interpreted with respect to the logit scale (i.e. the log of the odds of observing a correct answer). A positive estimate on this scale indicates that (an increasing value of) the predictor has a positive effect on the probability of observing a correct answer. Similarly, a negative estimate indicates a negative effect on the probability of observing a correct answer. In the latter case (i.e. LMM), the dependent variable is numerical.

Empirical model building was conducted with the off-line (i.e. accuracy and RT) and online (i.e. gaze fixation) data. For that, separate (G)LMMs were fitted by progressively introducing radom-effects, fixed effects and correspondent interactions. Random slopes were not included in the models due to convergence problems, likely due to the limited sample size. Instead, nested random intercepts were used to account for the variability of the subjects and stimuli in relation to some explanatory factorial predictors (e.g., a random intercept for the combination of subject and condition). Model comparison was conducted based on Akaike's Information Criterion (AIC; Akaike, 1974), with a reduction in AIC of 2 indicating a better fitting model (taking into account the complexity of the models). Models with the lowest AIC were kept. When comparing models with a different fixed-effects structure, these were fitted using maximum likelihood estimation (ML). Restricted maximum likelihood estimation (REML; Patterson & Thompson, 1971; Harville, 1974) was used when comparing radom-effects and for our final model (for a detailed review, see McCulloch & Searle, 2000; Verbeke & Molenberghs, 2000). Subsequently, least square means (LSMeans) and 95% confidence intervals (95% CI) were calculated and pairwise comparisons were carried out with a Tukey correction. Effects are considered significant at the $p < .05$ level, unless otherwise indicated. The RT data were log transformed and the numerical predictors Age and Trial number were centred.

In the case of the RT data, the empirical (i.e. best) model did not fully cover the research questions of the study. Therefore, a second model was fitted specifically according to our hypothesis, where the inclusion of fixed-effect predictors was predetermined, and the best radom-effects structure was assessed via AIC comparison. The analysis was conducted using R Statistic software (R Core Team, v.3.1.2.) using the *lme4* package (Bates et al., 2015).

2.4. Results

2.4.1. Comprehension accuracy

General descriptives of accuracy scores at group level are provided in **Table 2.1**. The NBD group did not perform at ceiling level in either of the sentence types, offering a fully sensitive measure to differentiate among the conditions and between groups. See **Appendix A5** for individual participant scores.

Table 2.1: Comprehension accuracy and Standard Error (SE) as a function of group and sentence condition.

Condition	Accuracy % (SE)	
	PWA	**NBD**
SOV	75.81 (3.47)	91.19 (2.25)
OSV	45.80 (4.01)	90.56 (2.32)
VSO	71.14 (3.72)	93.71 (1.93)
VOS	52.28 (4.05)	87.97 (2.59)

NBD= non-brain-damaged; PWA= people with aphasia

A logit link function was used for the GLMM, as indicated previously. The final model obtained for the accuracy data contained two-way interactions for group and condition as fixed effects, and stimuli and subject variables as radom-effects. In addition, the analysis highlighted that the strength of the condition was different between subjects; thus, a nested radom-effect (i.e. for each combination of subject and condition) was added to enable a more precise estimation of the effect of sentence condition in each subject.

There was a significant interaction for group and sentence condition. Overall, the PWA group performed significantly less accurately than NBDs across all sentence conditions. Thus, they presented difficulties comprehending sentences in both canonical word order (i.e. SOV) and non-canonical word order (i.e. OSV, VSO and VOS), although under different significance levels, as presented in **Table 2.2**.

Table 2.2: Comparison of response accuracy between groups across sentence conditions.

	Group	LSMeans (95% CI)	β	SE	z-ratio	p
SOV	**NBD**	2.65(1.80–3.51)	1.315	0.564	2.328	0.0199
	PWA	1.34(0.60–2.08)				
OSV	**NBD**	2.57(1.73–3.42)	2.736	0.553	4.944	<.0001
	PWA	-0.15(-0.87–0.55)				
VSO	**NBD**	3.00(2.09–3.91)	1.946	0.583	3.334	0.0009
	PWA	1.05(0.32–1.79)				
VOS	**NBD**	2.23(1.42–3.03)	2.102	0.534	3.932	0.0001
	PWA	0.12(-0.58–0.84)				

NBD= non-brain-damaged; PWA= people with aphasia; Significance level p<.05

Within-group comparisons in the PWA group uncovered significant differences in the comprehension abilities across sentence conditions. In this group, stimuli were significantly better comprehended when presented in conditions SOV and VSO than in OSV and VOS (see **Table 2.3**). The NBD group did not present accuracy differences across sentence conditions.

Table 2.3: Comprehension accuracy differences between sentence conditions in PWA and NBD groups.

	LSMeans (95% CI)	OSV				VSO				VOS			
		β	SE	z-ratio	p	β	SE	z-ratio	p	β	SE	z-ratio	p
PWA group													
SOV	-0.15(-0.87–0.55)	-1.502	0.360	-4.170	**0.0002**	-0.286	0.344	-0.829	0.8403	-1.217	0.356	-3.419	**0.0035**
OSV	1.34(0.60–2.08)	-	-	-	-	1.216	0.359	3.384	**0.0040**	0.285	0.368	0.774	0.8658
VSO	0.12(-0.58–0.84)	-	-	-	-	-	-	-	-	-0.931	0.355	-2.621	**0.0435**
VOS	1.05(0.32–1.79)	-	-	-	-	-	-	-	-	-	-	-	-
NBD group													
SOV	2.57(1.73–3.42)	-0.081	0.468	-0.174	0.9981	0.347	0.447	0.777	0.8649	-0.428	0.495	-0.864	0.8233
OSV	2.65(1.80–3.51)	-	-	-	-	0.429	0.451	0.949	0.7781	-0.346	0.499	-0.693	0.8998
VSO	2.23(1.42–3.03)	-	-	-	-	-	-	-	-	-0.775	0.478	-1.620	0.3671
VOS	3.00(2.09–3.91)	-	-	-	-	-	-	-	-	-	-	-	-

PWA= people with aphasia; NBD= non-brain-damaged; Significance level p<.05

2.4.2. Response reaction time

Two separate LMMs were fitted for the RT data. The first one was built following the empirical procedure described previously, where variables that better explained the observed data were included in the model. The second one was a hypothesis-driven model that included the variables required to answer the research question of the current study, also including predictors which were excluded (due to lack of explanatory power) from the other model.

Table 2.4: Mean Reaction Time (RT) and Standard Error (SE) as function of group and sentence condition.

Condition	Mean RT (SE) in ms.	
	PWA	**NBD**
SOV	4635.64 (161.96)	3619.69 (102.58)
OSV	4898.85 (174.77)	3953.67 (100.91)
VSO	4921.31 (168.28)	3891.77 (107.44)
VOS	5022.03(173.55)	4125.95 (90.58)

PWA= people with aphasia; NBD= non-brain-damaged.

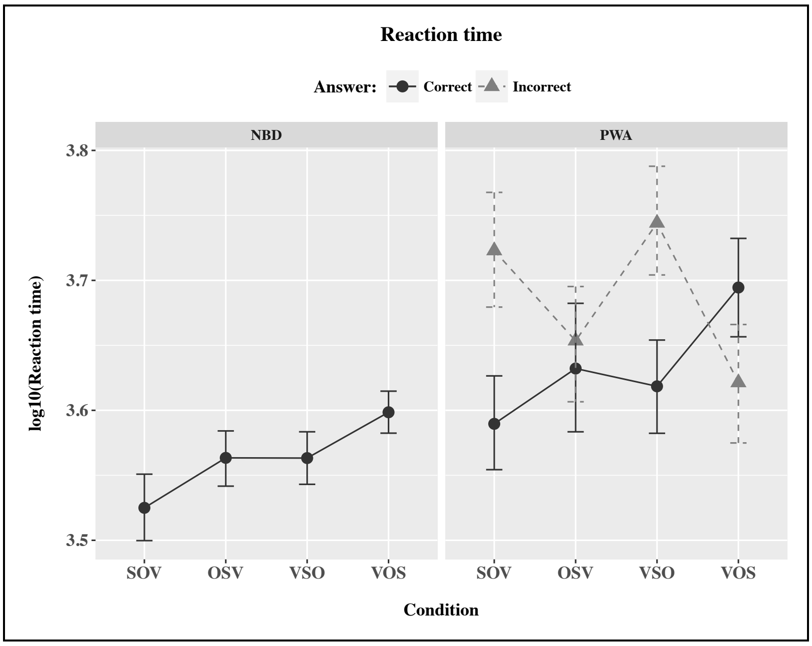

Fig. 2.2. (Log) reaction times as a function of group, sentence condition and correctness of the response. PWA= people with aphasia; NBD= non-brain-damaged.

The empirical model consisted of three-way interactions between the group, sentence condition and trial number, in addition to random intercepts for subject and stimulus and the nested random intercepts of subject with condition and stimulus with condition (i.e. specified in *lmer* as "(1|Subject/Condition) + (1|Stimulus/Condition)"). As presented in **Table 2.5**, this model showed no significant RT differences between groups across any of the conditions. Pairwise comparisons were conducted by condition within each group and the results are presented in **Table 2.6**. The aphasic group did not show differences in RTs in the different conditions, but NBDs showed significantly longer RTs in OSV and VOS conditions when compared to SOV (base order of the arguments), but not when compared to VSO condition (base order of the arguments).

Table 2.5: Reaction time differences between groups across sentence condition.

		LSMeans (95% CI)	β	SE	z-ratio	p
SOV	**NBD**	8.11(7.86–8.36)	-0.233	0.163	-1.433	0.1719
	PWA	8.35(8.10–8.59)				
OSV	**NBD**	8.23(7.98–8.48)	-0.168	0.163	-1.031	0.3184
	PWA	8.40(8.15–8.65)				
VSO	**NBD**	8.22(7.97–8.47)	-0.216	0.163	-1.326	0.2042
	PWA	8.43(8.19–8.68)				
VOS	**NBD**	8.29(8.04–8.54)	-0.145	0.163	-0.893	0.3857
	PWA	8.43(8.18–8.68)				

NBD= non-brain-damaged; PWA= people with aphasia; Significance level p<.05

Moreover, there was a significant interaction between group, condition and trial number. That is, NBD participants became faster along the experiment, but this was not the case for the PWA group. Detailed information is provided in **Table 2.7**. The PWA group did not show an effect of trial number across any of the sentence conditions, while in the NBD group trial number significantly influenced both SOV and OSV conditions, but not VSO and VOS conditions.

Table 2.6: Reaction time differences between sentence conditions in PWA and NBD groups.

	LSMeans (95% CI)	OSV				VSO				VOS			
		β	SE	z-ratio	p	β	SE	z-ratio	p	β	SE	z-ratio	p
PWA group													
SOV	8.35(8.10–8.59)	-0.050	0.042	-1.207	0.6252	-0.089	0.042	-2.101	0.1652	-0.087	0.042	-2.076	0.1738
OSV	8.40(8.15–8.64)	-	-	-	-	-0.038	0.042	-0.914	0.7975	-0.036	0.041	-0.876	0.8171
VSO	8.43(8.19–8.68)	-	-	-	-	-	-	-	-	0.002	0.042	0.048	1.0000
VOS	8.43(8.19–8.68)	-	-	-	-	-	-	-	-	-	-	-	-
NBD group													
SOV	8.11(7.86–8.36)	-0.116	0.041	-2.786	**0.0360**	-0.106	0.042	-2.547	0.0640	-0.175	0.041	-4.203	**0.0006**
OSV	8.23(7.98–8.48)	-	-	-	-	0.009	0.041	0.228	0.9958	-0.059	0.041	-1.421	0.4919
VSO	8.22(7.97–8.47)	-	-	-	-	-	-	-	-	-0.068	0.041	-1.642	0.3641
VOS	8.29(8.04–8.54)	-	-	-	-	-	-	-	-	-	-	-	-

PWA= people with aphasia; NBD= non-brain-damaged; Significance level p<.05

Table 2.7: Trial number effect on the reaction time across sentence conditions in PWA and NBD groups.

		LSMeans (95% CI)	β	SE	z-ratio	p
PWA group						
SOV	**≈1**	8.37(8.12–8.63)	0.053	0.074	0.716	0.4751
	≈80	8.32(8.06–8.58)				
OSV	**≈1**	8.42(8.16–8.67)	0.038	0.073	0.524	0.6009
	≈80	8.38(8.12–8.63)				
VSO	**≈1**	8.45(8.19–8.72)	0.038	0.074	0.522	0.6022
	≈80	8.42(8.16–8.67)				
VOS	**≈1**	8.44(8.19–8.70)	0.022	0.077	0.297	0.7671
	≈80	8.42(8.16–8.68)				
NBD group						
SOV	**≈1**	8.30(8.04–8.56)	0.373	0.072	5.143	<.0001
	≈80	7.93(7.67–8.19)				
OSV	**≈1**	8.33(8.07–8.58)	0.198	0.068	2.888	0.0043
	≈80	8.13(7.87–8.39)				
VSO	**≈1**	8.25(8.00–8.51)	0.072	0.069	1.045	0.2975
	≈80	8.18(7.93–8.44)				
VOS	**≈1**	8.33(8.07–8.58)	0.078	0.073	1.059	0.2905
	≈80	8.25(7.99–8.51)				

≈1= initial Trials; ≈80= final Trials; NBD= non-brain-damaged; PWA= people with aphasia; Significance level $p<.05$

The hypothesis-driven-model consisted of a three-way interaction between group, sentence condition and accuracy of the response as fixed effects, in addition to the same radom-effects structure as for the exploratory model. The results of the comparisons between the groups and sentence conditions were close to the previous model and results are reported in **Tables 2.8-2.9** (find them as additional materials in Appendix A6 and A7). The main interest of developing this new model was to test whether the accuracy of the answers had an effect on the RT of the participants. We compared correct and incorrect answers solely for the PWA group, since the number of incorrect answers within the NBD group was too small. As presented in **Table 2.10**, the results showed that the accuracy of the answer (i.e. correct, incorrect) did not have any effect on the RT.

Table 2.10: Hypothesis driven model. PWA group: reaction time differences between correct and incorrect responses.

		LSMeans (95% CI)	β	SE	z-ratio	p
SOV	**I**	8.41(8.15–8.66)	0.078	0.043	1.782	0.0751
	C	8.33(8.08–8.58)				
OSV	**I**	8.40(8.15–8.65)	0.000	0.039	0.024	0.9813
	C	8.40(8.15–8.65)				
VSO	**I**	8.46(8.21–8.71)	0.041	0.043	0.957	0.3386
	C	8.42(8.17–8.67)				
VOS	**I**	8.40(8.15–8.65)	-0.060	0.039	-1.518	0.1292
	C	8.46(8.21–8.71)				

PWA= people with aphasia; C= Correct answers; I= Incorrect answers; Significance level $p<.05$

2.4.3. Gaze data analysis

To conduct the gaze data analysis, the difference in the proportion of fixations between the correct and incorrect visual stimuli was computed from the onset of the first argument (ROI1) to 1120ms after the offset of the third argument (ROI4). Therefore, a temporal frame of 4480 ms was analysed, divided into four windows (i.e., ROIs). As described in the method section, each of the four ROIs had the same length across all stimuli and conditions (i.e., 1120 ms). ROIs 1, 2 and 3 corresponded to the first, second and third constituents of the sentence, while ROI 4 corresponded to the post-offset silence. Missing gaze data motivated by answers provided before the offset of ROI4 (i.e. RT<4480ms) were treated by logical imputation based on the accuracy of the response. Positive values indicated a margin of difference of fixations towards the correct picture: negative values indicated the inverse pattern. For hypothesis testing, an LMM was fitted with a four-way interaction between the group, sentence condition, ROI and accuracy of the response as fixed effects. In addition, random intercepts for subject and stimuli were included, as well as nested random intercepts for subject together with condition and accuracy, and nested random intercepts for stimulus with condition.

The analysis focused on two distinct aspects. First, we compared the fixation pattern of the NBD and PWA groups in the correctly responded stimuli. Pairwise comparisons of each ROI across the sentence conditions were conducted between groups (see **Table 2.11**). The results revealed that there were no differences between the groups for the fixation pattern for the visual stimuli in each ROI across the different sentence conditions, with the exception of the post-offset region in the VOS condition (see **Figure 2.3**). In this case, there were significantly fewer fixations to the correct picture for the PWA group than for the NBD group. Apart from that, in the correctly answered trials, the gaze data of NBD and PWA groups were indistinguishable based on the progressive increase in fixations towards the correct stimulus over time.

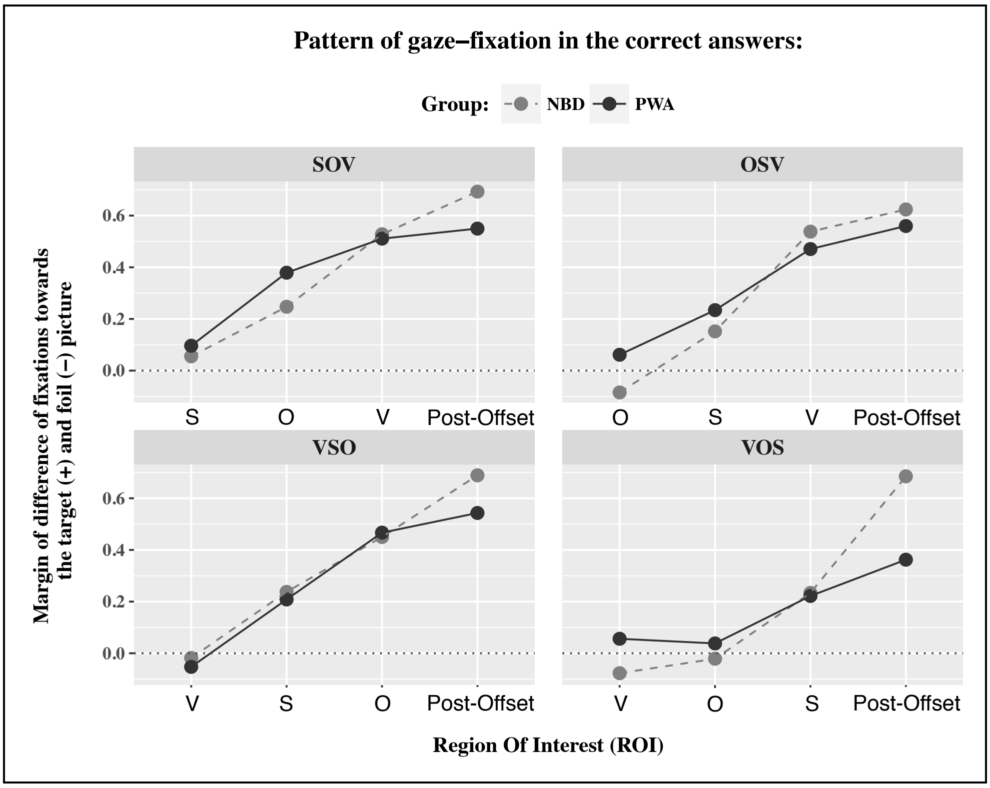

Fig. 2.3. Gaze fixation pattern across the visual stimuli during the auditory presentation of the sentence. Between group comparison in the correct answers. PWA= people with aphasia; NBD= non-brain-damaged

Table 2.11: Between group comparison of the gaze fixation patterns in the correct answers as a function of ROI and sentence conditions.

		SOV						OSV				
		LSMeans (95% CI)	β	SE	z-ratio	p		LSMeans (95% CI)	β	SE	z-ratio	p
ROI1	**NBD**	0.04(-0.10–0.18)	-0.022	0.107	-0.210	0.8335	**NBD**	-0.09(-0.24–0.05)	-0.117	0.117	-1.00	0.3166
	PWA	0.06(-0.09–0.22)					**PWA**	0.02(-0.16–0.20)				
ROI2	**NBD**	0.23(0.08–0.38)	-0.110	0.107	-1.027	0.3040	**NBD**	0.14(-0.00–0.28)	-0.048	0.117	-0.412	0.6799
	PWA	0.34(0.18–0.50)					**PWA**	0.18(0.00–0.37)				
ROI3	**NBD**	0.51(0.36–0.66)	0.034	0.107	0.324	0.7456	**NBD**	0.52(0.37–0.67)	0.094	0.118	0.800	0.4233
	PWA	0.47(0.32–0.63)					**PWA**	0.43(0.24–0.61)				
ROI4	**NBD**	0.67(0.52–0.82)	0.160	0.108	1.482	0.1382	**NBD**	0.611(0.46–0.75)	0.094	0.117	0.802	0.4225
	PWA	0.51(0.35–0.67)					**PWA**	0.51(0.33–0.69)				
		VSO						**VOS**				
		LSMeans (95% CI)	**β**	**SE**	**z-ratio**			**LSMeans (95% CI)**	**β**	**SE**	**z-ratio**	**p**
ROI1	**NBD**	-0.01(-0.16–0.12)	0.068	0.109	0.624	0.5324	**NBD**	-0.08(-0.23–0.06)	-0.136	0.115	-1.177	0.2388
	PWA	-0.08(-0.24–0.07)					**PWA**	0.05(-0.12–0.22)				
ROI2	**NBD**	0.236(0.09–0.38)	0.065	0.109	0.601	0.5478	**NBD**	-0.02(-0.17–0.12)	-0.061	0.116	-0.523	0.6009
	PWA	0.17(0.00–0.33)					**PWA**	0.03(-0.14–0.21)				
ROI3	**NBD**	0.45(0.30–0.59)	0.019	0.109	0.175	0.8609	**NBD**	0.22(0.07–0.37)	0.008	0.116	0.075	0.9401
	PWA	0.43(0.26–0.59)					**PWA**	0.21(0.04–0.39)				
ROI4	**NBD**	0.68(0.54–0.83)	0.189	0.110	1.71	0.0860	**NBD**	0.67(0.52–0.82)	0.321	0.116	2.755	**0.0059**
	PWA	0.49(0.33–0.66)					**PWA**	0.35(0.18–0.53)				

ROI= Region Of Interest; ROI 1= First constituent of the sentence; ROI 2= Second constituent of the sentence; ROI 3= Third constituent of the sentence; ROI 4= Post-offset region; NBD= non-brain-damaged; PWA= people with aphasia; Significance level p<.05

Second, we compared the fixation patterns of the PWA group between correctly and incorrectly answered stimuli. This yielded significant differences, as illustrated in **Figure 2.4**. Correct and incorrect answers were statistically distinguishable from the ROI 2 onward in the SOV (i.e. Object position), OSV (i.e. Subject position), VSO (i.e. Subject position) and VOS (i.e. Object position) sentence conditions, as detailed in **Table 2.12**.

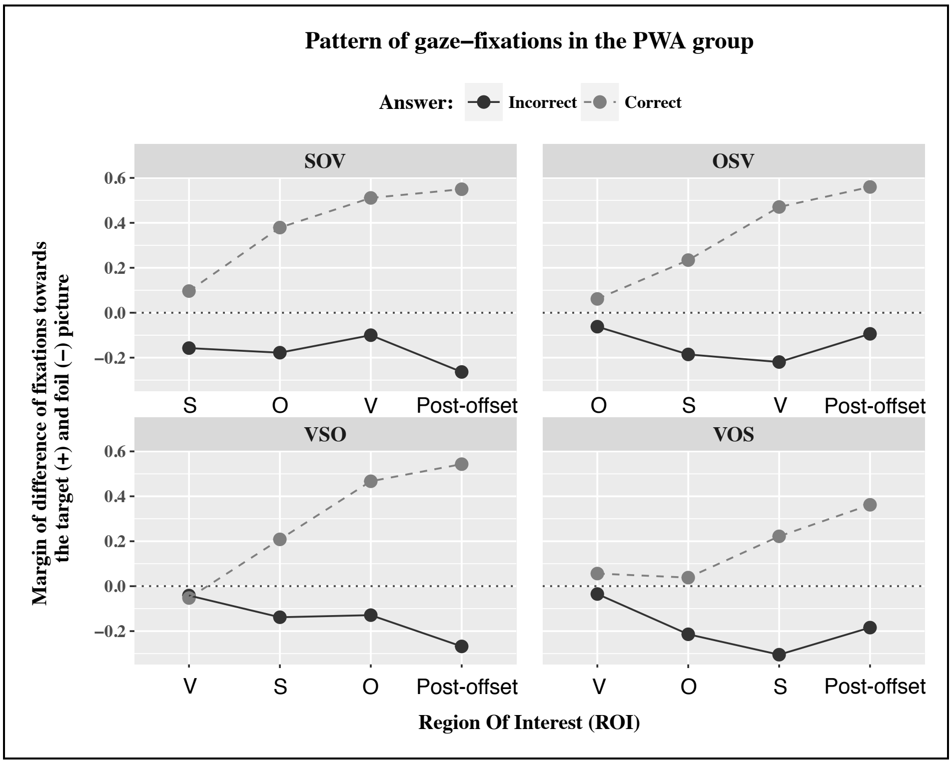

Fig. 2.4. Gaze fixation patterns across the visual stimuli during the auditory presentation of the sentence. Comparison between the correct and incorrect answers in the PWA group. PWA= People With Aphasia.

Table 2.12: Comparison of gaze fixation patterns as a function of ROI and response accuracy in PWA group.

		SOV						OSV				
		LSMeans (95% CI)	**β**	**SE**	**z-ratio**	**p**		**LSMeans (95% CI)**	**β**	**SE**	**z-ratio**	**p**
ROI1	**I**	-0.12(-0.35–0.11)	-0.185	0.131	-1.410	0.1585	**I**	-0.03(-0.21–0.14)	-0.053	0.114	-0.463	0.6432
	C	0.06(-0.09–0.22)					**C**	0.02(-0.16–0.20)				
ROI2	**I**	-0.14(-0.37–0.09)	-0.485	0.131	-3.686	**0.0002**	**I**	-0.15(-0.33–0.02)	-0.344	0.114	-3.005	**0.0026**
	C	0.34(0.18–0.50)					**C**	0.18(0.00–0.37)				
ROI3	**I**	-0.06(-0.29–0.16)	-0.548	0.128	-4.195	**<.0001**	**I**	-0.19(-0.36–-0.01)	-0.622	0.115	-5.39	**<.0001**
	C	0.47(0.32–0.63)					**C**	0.43(0.24–0.61)				
ROI4	**I**	-0.22(-0.45–-0.00)	-0.741	0.130	-5.672	**<.0001**	**I**	-0.06(-0.24–0.11)	-0.584	0.115	-5.047	**<.0001**
	C	0.51(0.35–0.67)					**C**	0.51(0.33–0.69)				
		VSO						**VOS**				
		LSMeans (95% CI)	**β**	**SE**	**z-ratio**			**LSMeans (95% CI)**	**β**	**SE**	**z-ratio**	**p**
ROI1	**I**	0.00(-0.21–0.22)	0.089	0.126	0.710	0.4771	**I**	-0.03(-0.21–0.15)	-0.085	0.115	-0.738	0.4604
	C	-0.08(-0.24–0.07)					**C**	0.05(-0.12–0.22)				
ROI2	**I**	-0.09(-0.31–0.12)	-0.26	0.125	-2.099	**0.0358**	**I**	-0.21(-0.39–-0.02)	-0.244	0.115	-2.118	**0.0341**
	C	0.17(0.00–0.33)					**C**	0.03(-0.14–0.21)				
ROI3	**I**	-0.07(-0.30–0.14)	-0.510	0.126	-4.020	**<.0001**	**I**	-0.30(-0.48–-0.11)	-0.518	0.114	-4.515	**<.0001**
	C	0.43(0.26–0.59)					**C**	0.21(0.04–0.39)				
ROI4	**I**	-0.22(-0.44–0.00)	-0.722	0.129	-5.597	**<.0001**	**I**	-0.17(-0.36–0.00)	-0.534	0.115	-4.61	**<.0001**
	C	0.49(0.33-0.66)					**C**	0.35(0.18–0.53)				

ROI= Region Of Interest; ROI 1= First constituent of the sentence; ROI 2= Second constituent of the sentence; ROI 3= Third constituent of the sentence; ROI 4= Post-offset region; I= Incorrect answer; C= Correct answer; Significance level p<.05

In this section we have analysed behavioural and gaze data from PWA and NBD groups while performing a picture-matching task. Accuracy data have pointed out that the order of the arguments within a sentence has a significant effect on the comprehension deficits of the PWA group. Sentences containing linear Agent-Theme order of arguments were understood significantly better than sentences with the inversed order of constituents. The reaction time data have shown no significant differences between groups, presumably due to high variability in the PWA group. In line with this, within group comparison has uncovered no differences across sentence conditions in the PWA group. Conversely, the NBD group has shorter RTs in base word order (i.e. SOV) in relation to OSV and VOS, contrary to VSO word order. These data converge with the fixation pattern analysed. Comparisons of correctly and incorrectly answered trials in the PWA group show that fixation patterns diverge from the second and first argument in verb final and verb initial sentences, respectively. Fixation patterns shown in correctly answered trials are indistinguishable, in both timing and proportion, between the PWA and NBD group, except in the post-offset region of the VOS condition.

2.5. Discussion

In the current study we aimed to provide further insight into: a) the effect of the order of the arguments on sentence comprehension deficits of PWA in a free-word order language; b) the validity of the Trace Deletion Hypothesis (TDH, Grodzinsky, 1986, 1995, 2000; Drai & Grodzinsky, 2006ab) and Derived Order Problem-Hypothesis (DOP-H, Bastiaanse & Van Zonneveld, 2006) to explain online and off-line sentence comprehension in aphasia. Based on representational and processing perspectives, the TDH and DOP-H have proposed diverging explanations about the underlying deficits that PWA face in sentence processing. This study confronts these hypotheses with results from processing a free word order and morphologically rich language and draws attention to certain cross-linguistic universals in sentence comprehension deficits in PWA.

2.5.1. Sentence comprehension accuracy and reaction times

The findings of this study reveal that the PWA group had a poorer sentence comprehension than the control group, regardless of the word order in which the sentence was presented. Since we demonstrated that the PWA in this study had preserved lexical comprehension, difficulties in the comprehension of sentences presented with base word order (i.e., SOV) indicate difficulties in syntactic processing. The comprehension of sentences presented in SOV and VSO order was not intact, but still above chance. Thus, these results converge with the two hypotheses tested in this paper.

Within group comparisons confirmed differences between conditions. When we compared the results of PWA across conditions, there was no difference between the SOV and VSO order. They turned out to perform worse on OSV and VOS than on SOV and VSO conditions, although OSV and VOS sentences are more frequent than VSO in Basque (Aldezabal et al., 2003). Hence, the error pattern found cannot be explained as a function of frequency of use of the structure in Basque. This finding converges with that of Bornkessel, Schlesewsky, and Friederici (2002), who observed that neurophysiologically distinct responses were observed on the basis of the linguistic properties of the stimuli, but not as a function of the frequency of these structures in a given language. In addition, the NBD group performed equally well on all structures. Thus, differences across conditions support the predictions of the DOP-H and do not support the predictions of the TDH (see Drai & Grodzinsky, 2006ab).

In contrast to previous studies reporting longer RTs for PWA than for healthy listeners (Caplan & Waters, 2003; Hanne et al., 2011), PWA participating in the current study did not show significantly longer latencies to provide an answer than the NBDs. This result does not seem to support the cognitive slow-down as the deficit source of comprehension impairment in PWA. However, exploratory analysis of the data suggests a trend for longer RTs in the PWA group across all sentence types. It is possible that the rather small sample size and large variability in the PWA group may prevent reaching statistical significance. PWA presented a trend for larger RTs than NBD independently of base or derived order of the sentence, a trend that is compatible with the processing account rationale (Burkhardt et al., 2008; Burkhardt, Piñango, & Wong, 2003; Caplan, 2006; Caplan et al., 2007; Dickey et al., 2007; Haarmann & Kolk, 1991).

Contrary to what the DOP-H suggests, the PWA group did not respond quicker to sentences presented in base word order (i.e. SOV) than to the ones with derived order. Meanwhile, the NBD group answered faster to SOV word order sentences than to those in OSV and VOS order. These results converge with previous studies, demonstrating that healthy speakers benefit from sentences with canonical argument order since they use an agent-first strategy to process them (Erdocia et al., 2009). Notice that the requirement for reanalysis in OSV sentences does not imply longer RTs than for VOS sentences, where listeners may assign the thematic roles unambiguously already to the first DP, thanks to the information about grammatical functions on the verb.

Altogether, the behavioural data suggest that PWA have difficulties in assigning thematic roles to DPs in OSV word order sentences, which requires syntactic reanalysis. In addition, they present deficits in making use of the information provided by verbal morphology and case marking to disentangle the thematic role assignment in the case of VOS word order sentences. This may be either because PWA do not fully access the argument structure of the lexical verb and/or inflection information of the verb. An alternative interpretation could be that the application of a linear Agent-Theme strategy overrides the information provided by case and agreement morphology. The trend in RT measurements converges with previous studies, suggesting that PWA do access the argument structure information at the verb position to some extent, but have difficulty processing the case morphology that guides the assignment of the thematic roles to specific DPs (Grodzinsky, 1986; Shapiro & Levine, 1990). Severe impairment in the processing of case morphology was also reported by Burchert, De Bleser, and Sonntag (2003) in a group of German agrammatic speakers. Still, in line with that study, individual analyses of PWA participants in the current study suggest that not all PWA with comprehension impairments have these deficits to the same degree.

In the current experiment, two out of eight participants (A3-A8) performed above chance-level on the experimental task, although they had shown chance-level scores in the pre-test. Working memory limitations may explain these discrepancies depending on the length of the linguistic stimuli. These two participants scored in a rather low percentile of the digit-span task for their age, suggesting poor working memory functioning. This may prevent them from fully comprehending longer sentences such as the ones presented in the Cognitive Neuroscience Laboratory language screening battery (CNL; Chialant, 2000; adapted to Basque by Erdocia, Santesteban & Laka, 2003), while comprehension of the shorter sentences on the experimental task was relatively well-preserved. The other PWA showed variable performance across conditions, but in each case sentences with derived order of the arguments were significantly less well understood than sentences in which the arguments were in base order.

2.5.2. Gaze fixation data

Online language processing data are informative to check the validity of the different theoretical approaches. Using this methodology, we can identify a guessing pattern and diminished grammatical parsing routines that were proposed as potential causes of these deficits by the TDH and DOP-H, respectively. The analysis of the fixation patterns of PWA and NBD across the different sentence types reveals two things: First, there were no different gaze patterns for the correct trials for the two groups. Second, the gaze fixation patterns of PWA in the correct and incorrect answers were different from those as for the correct trials for all word orders.

In the correctly answered trials, all participants fixated into either target or foil picture from early presentation of the sentence, and the proportion of fixations to either option increased along the time line. The fixation pattern along the presentation of each argument of the sentence was indistinguishable between the groups. There was one exception, which corresponds to the post-offset region in the VOS sentence type, where participants from the PWA group fixated less often to the correct picture, although they answered correctly. This may be related to the longer RTs of the PWA to comprehend this word order.

It suggest that PWA wait for the presentation of the ergative case marker of the subject to confirm their choice, and take longer than NBD to integrate the case information into the syntactic structure. When both argument order and verb position are derived, the cost of integrating these information cues may slow down sentence processing on PWA. This is in line with the ERP-findings of Kielar, Meltzer-Asscher, and Thompson (2012), who showed that processing verb arguments in PWA is not always complete. In addition, it converges with the 'Integration Problem Hypothesis' of Duman et al. (2011), which claims that sentence comprehension impairments are related with deficits integrating different types of information cues.

These results show not only that PWA and NBD participants process sentences similarly when they point to the correct picture, but also that they do so time-aligned for each argument of the sentence, contrary to what was found by Hanne et al. (2011). Our findings also contradict the slowdown framework within the processing account. If we assume that the slowing down of basic cognitive functions is the cause of language processing deficits in PWA, a delayed application of the same routines of the NBD group is expected. However, PWA in the current study showed the same rapid, automatic processing of sentences as the NBDs. Interestingly, these results converge with another eye-tracking study on the comprehension of *wh*-questions conducted by Dickey et al. (2007). They concluded that contrary to what representational and processing accounts suggest PWA processed the *wh*-questions like healthy listeners in the correct answers. In line with their claim, we think that it is possible that previous studies implying consciously controlled responses may have slightly biased online measures because of the involvement of a secondary cognitive task, as button press. Still, Hanne et al. (2011), using eye-tracking have shown real time processing delays as measured by gaze fixation patterns. We believe that the procedures used in the current study and in the study of Dickey et al. (2007) may not detect subtle processing delays, because the temporal windows in which the data are analysed are too wide for this purpose. Therefore, we can only conclude that PWA do not present an aberrant processing delay compared to the NBD group.

So far we have shown that correctly interpreted sentences were processed similarly by both PWA and NBD groups. In addition to this, a comparison of the fixation patterns of PWA across correct and incorrect trials supported a non-guessing pattern in PWA (see Burchert et al., 2013, for a review). In line with previous literature (Dickey et al., 2007; Hanne et al., 2011), the fixation advantage towards the target picture was different for the correctly and incorrectly answered trials. For the correctly answered trials, the advantage of fixations on the correct pictures showed a progressive increase, while for incorrectly answered trials the same pattern of looks towards the picture with the reverse interpretations was observed. The time resolution of these divergences was the same across sentence types (i.e., second ROI).

In the SOV condition, the morphological cue is unambiguously provided on the first argument, but correctly and incorrectly answered trials diverge from the second argument onward. This can be explained by the fact that case morphology is presented at the end of each argument DP and the temporal window (i.e., ROI) ends as soon as this information cue is presented. Therefore, it shows that participants need more than 200 ms (i.e., temporal swift applied to gaze data to be aligned with the auditory presented stimuli) to process this information and subsequently fixate on the correct picture. Interestingly, in the VSO and VOS word order, gaze data also diverge from the second ROI onward, which corresponds to the first argument of the sentence. When we analyse VSO and VOS together, data indicate that PWA tend to use an agent-first strategy that leads to the correct interpretation in VSO condition and incorrect interpretation in VOS condition. Note that in the latter the difference of fixations between the correctly and incorrectly answered trials is basically due to the increase of fixations on the incorrect picture in the incorrect answers. The data suggest that PWA rely more strongly on the ergative (i.e., agent) than on the absolutive case markers to disentangle thematic-role assignment, as shown by the slow progression of fixations into the correct picture in VOS. This indicates limited resources to build up expectations in thematic role assignment in agent-second sentences. These results reinforce the trend set by the RT data; that is, they suggest that incorrect answers in the PWA group are motivated by deficits in the thematic role assignment to specific arguments in the sentence, and not by a complete failure to access argument structure information.

In the OSV condition, correctly and incorrectly answered trials diverge again at the subject position, but PWA fixate on the correct picture already while the second argument (i.e., Subject) is being presented. These results do not converge with our expectations of reanalysis in OSV constructions. Recall that OSV structures are temporarily ambiguous. Previous studies have shown that unimpaired Basque speakers interpret the initial DP as the subject of an unaccusative verb, and reanalyse the initial parsing when they encounter the second DP marked with the ergative case (Erdocia et al., 2009). However, we have not found any attempt of such a reanalysis neither on either PWA or NBD groups. The gaze fixation pattern of PWA on correct and incorrect answers differs early, even prior to the disambiguation point on OSV structures (i.e., ergative mark '-k' affixed to the Subject). The proportion of gaze fixations in the foil picture follows an increasing pattern and it does not shift to the target picture, as would be expected in response to the perceived need of reanalysis. In a similar vein, the NBD group fixate into the target picture as soon as they are presented with the Object (marked with Absolutive), and show a steady increase in the proportion of looks to the target increases in the subsequent ROIs. These results do not support the existence of a Subject-first preference in OSV structures, and nor do they therefore show the existence of a reanalysis process in our sample of study.

We believe that the absence of any sign of reanalysis in both PWA and NBD may be related to the methodological constraints of the experiment. In our sentence-picture matching task, the visual material depicting two reverse scenes was present before and during the auditory presentation of the sentence. We included filler sentences with unaccusative verbs to keep constant the need for reanalysis during the task. However, probably the visual stimuli have provided the listeners with enough information about the transitivity of the verb as consolidated by learning effect along the experiment[5]. That is, listeners may develop an inference rationale to know the transitivity of the verb as soon as the image is presented, which overrides the garden path effect on OSV structures.

[5] Most of the visual stimuli on the filler trials depicted one single character, whereas target trials always depicted two characters.

This rationale is related to a broader task-specific influence on sentence processing. The gaze fixation patterns in correctly and incorrectly answered trials have diverged from early on in the presentation of the stimuli across all sentence conditions. This early deviation coincides with previous findings using sentence-picture matching tasks in the visual world paradigm (Hanne et al., 2011; cf. Meyer et al., 2012). In contrast, late emerging differences as a function of response accuracy have been shown in other studies using self-paced listening grammaticality judgment (Caplan & Waters, 2003; Caplan et al., 2007) and the classical visual world paradigm[6] (Dickey et al., 2007).

Such differences are not unequivocally related to the linguistic stimuli, but refer to the online interaction between the syntactic processing and the specific requirements of the task (see Caplan et al., 2006; 2013). In a sentence-picture matching task such as the one used in the current experiment, the visual stimulus depicts the thematic roles that will subsequently be presented in the target sentence, contrary to tasks involving the visual representation of single entities (Caplan & Waters, 2003; Caplan et al., 2007; Dickey et al., 2007). Therefore, the setting on sentence-picture matching tasks provides the listener with some expectations, which may not necessarily benefit PWA. Being visually presented with the target and foil scenes before and during the presentation of the sentence may also impose higher demands inhibiting the representation of the distractor (i.e., foil picture) and, as executive/control requirements vary, it may interfere with comprehension accuracy. This interpretation is consistent with previous findings suggesting that specific linguistic operations are not equally impaired across tasks, because task-related operations also influence or trigger comprehension failure (Caplan et al., 2006; 2013).

2.6. Conclusions

The effect of word order on sentence comprehension in PWA has been a focus of research for decades. This study contributes to the debate by introducing data from a richly inflected ergative language with free word order, and helps to disentangle the

[6] In the classical visual world paradigm, an array of single objects presented in the linguistic stimuli are segregated along visual display, in addition to several distractors (e.g. Dickey et al., 2007; Kamide et al., 2003).

relationship between language properties and the cognitive demand that distinct word orders may impose on PWA.

The current study aimed to investigate the effect of word order on sentence comprehension deficits in PWA speakers of Basque. The results suggest that although the PWA demonstrated preserved lexical comprehension, at group level sentence comprehension is poorer than that of NBDs, both for sentences with base word order and for sentences with derived word orders. This contradicts the predictions made by the TDH (as formulated in Drai & Grodzinsky, 2006ab), but not the original version of this hypothesis (Grodzinsky, 1986, 1995, 2000). That is, PWA were more impaired in their comprehension of sentences in which there was no linear Agent-Theme argument order, regardless of the position of the verb.

For the correct answers, real time fixation patterns during the presentation of the auditory stimuli were indistinguishable from the control group, with a single exception (i.e. post-offset of VOS). However, the pattern diverged for the incorrectly answered trials. This suggests that the correct answers of PWA are due to control-wise language processing and not caused by guessing, as suggested by the TDH. No general delay in sentence processing was found in the PWA group, suggesting that the PWA taking part in this study present a control-wise rapid and automatic processing of linguistic stimuli for sentences they answered correctly. This converges with the findings of Dickey et al. (2007) and suggests that there is inconsistent grammatical parsing, compatible with the DOP-H and other processing accounts. Still, the results need to be interpreted with caution, since they do not necessarily imply that both groups process the stimuli with the same speed; the delay may not have been large enough to be detected with the current methodology and data analysis used in this study.

Altogether, the study suggests that word order has a significant effect on the sentence comprehension abilities of PWA speakers of free word order languages. Thus, the order in which arguments are perceived influences sentence processing, regardless of the morphological information carried by the verb and the DPs. Hence, sentences in which the Theme precedes the Agent are harder to process and comprehend than Agent-Theme sentences, independently of the corpus frequency of the sentences in question. PWA present with serious problems in processing case morphology, even when they are sensitive to the argument structure of the verb; their comprehension performance decreases depending on the demand imposed by the word order, as suggested by the DOP-H.

CHAPTER 3:

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

Abstract | *Background:* The comprehension of semantically reversible sentences presented in derived word order has been proven to be particularly impaired in PWA. It has been suggested that this impairment is related to: a) inconsistent processing of morphological information; and b) difficulties inhibiting the inverse interpretation of the sentence. Studies on bilingual aphasia may offer an important contribution to our understanding of these issues. In relation to the former, it is still not clear whether the processing of different types of morphological cues is equally impaired in PWA. In relation to the latter, some studies suggest that bilingual speakers have enhanced executive and control mechanisms compared to monolingual speakers. Still, it is an open question whether sentence comprehension deficits in PWA can be alleviated in bilingual speakers. To gain insight into these topics, we analyze the effect of word order on sentence comprehension in a group of early Basque-Spanish bilingual PWA and monolingual Spanish PWA, as well as in unimpaired speakers. By using comparable sets of materials in both Basque and Spanish, we have combined off-line (sentence-picture matching) and online (reaction time and gaze data) methods. Results indicate that a) at group level, bilingual speakers perform better in Spanish than in Basque, regardless of the argument order. Still, individual case analysis shows a pattern of weak dissociation between the effect of argument order in Basque and Spanish in four out of seven participants, accompanied by an overall negative correlation across languages; b) bilingual PWA did not outperform monolingual PWA either in comprehension accuracy or gaze fixation pattern. PWA show sentence comprehension differences across languages at both group and individual levels, but performance did not vary discernibly based on bilingualism.

3.1. Introduction

3.1.1. 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 persons 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 (i.e., semantically reversible sentences where all arguments are animate). In this case, sentence interpretation is crucially 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 & Zurif, 1976; Caplan & Futter, 1986; Grodzinsky, 1995, 2000; Mitchum & Berndt, 2008; Schumacher et al., 2015).

PWA show a stochastic deficit in sentence comprehension, with non-systematic or predictable pattern of errors (Caplan, Waters, DeDe, Michaud & Reddy, 2007; Caplan, Michaud, & Hufford, 2013). 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, Michaud, & Hufford, 2013; Caplan et al., 2007; Haarmann, Just, & Carpenter, 1997). This rendering converges with studies on healthy adults that show an age-decline in sentence comprehension abilities related to factors such as syntactic complexity, word order, and processing speed (e.g., Caplan, DeDe, Waters, Michaud, & Tripodis, 2012; Schneider, Daneman, & Murphy, 2005; Sung, 2016; Obler, Fein, Nicholas, & Albert, 1991; Wingfield, Peelle, & Grossman, 2003). Interestingly, eye-tracking studies on PWA have uncovered that, in sentence comprehension tasks, correct and incorrect answers follow distinctive gaze fixation patterns (Dickey et al. 2007; followed by Hanne et al.

2011; Meyer, Mack, & Thompson, 2012; Schumacher et al., 2015; Arantzeta et al., 2016, in Chapter 2). This finding is consistent with the hypothesis that PWA do not answer by guessing, but it also provides real time evidence that PWA are sometimes able to process reversible sentences in derived word orders in a way similar to control participants.

3.1.2. Impact of cross-linguistic differences on sentence comprehension

In the psycholinguistic literature there is an open debate related to the universal character of the parsing routines across languages (see Frazier, 1990; Cuetos & Mitchell, 1988; Cuetos, Mitchell, & Corley, 1996; De Vincenzi & Lombardo, 2000). Be that as it may, processing strategies and mechanisms 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; Ros, Santesteban, Fukumura, & Laka, 2015; Gibson et al., 2013; 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 roles determined by the interplay of the cue validity and cue strength in each language (Competition Model; MacWhinney, Pléh, & Bates, 1985; Bates & MacWhinney, 1989; see also Gibson, 1992). Cues may include language specific properties that modulate agent-identification processes in listeners. Healthy speakers of richly inflected languages such as Italian rely more strongly on morphological information (e.g., subject-verb agreement) to parse the sentence than English speakers who prefer word order information (Bates, Devescovi, & Wulfeck, 2001). Interestingly, some evidence suggests that PWA might remain sensitive to specific informational cues (e.g., morphology or animacy), depending on their reliability in their premorbid language (see Bates, Wulfeck, & MacWhinney, 1991; Vaid & Pandit, 1991). Thus, according to this theory, the comprehension of sentences presented in derived word orders should be less impaired in a PWA speaker of a richly inflected language, such as Italian, than in a PWA speaker of a less inflected language, such as English.

Nevertheless, it is still an open question whether the 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. Recently, 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 might be idiosyncratically affected across languages. The study of early bilinguals offers an alternative approach to the comparison of language-specific morphological properties and their impact on comprehension deficits in PWA.

3.1.3. Sentence comprehension deficits in bilingual speakers

Studies on sentence comprehension abilities in bilingual aphasia are scarce. Abuom, Shah, and Bastiaanse (2013) studied sentence comprehension in a group of bilingual L1Swahili-L2English speakers with agrammatism. They found an equal degree of sentence processing impairment across languages. Thus, these PWA listeners did not benefit from the rich morphological marking system of Swahili to overcome parsing difficulties to a greater degree than in English. Similar results were found in PWA speakers of structurally close languages such as Galician and Spanish (Juncos-Rabadán, Pereiro, & Souto, 2009). There are a few studies on bilingual PWA that allow for contrasting 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 comprehension task using *wh*-questions and relative sentences attending to A-T and T-A 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 very selective impairment in Basque, affecting object-initial *wh*-questions and subject relative sentences[7]. 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 signal the agent overtly with case-morphology, unlike Spanish and English. However, the results showed contradicting findings regarding the role of case-morphology aiding the comprehension of sentences in derived word orders in PWA. Note that in its strict sense, the study of cross-linguistic transfer requires a monolingual study as the baseline (see Khachatryan et al., 2016). However, to the best of our knowledge, such a comparison has not been done in previous studies.

Altogether, sentence processing in bilingual aphasia fully deserves to be researched further for a number of reasons. It offers an opportunity to provide evidence in relation to the cross-language transfer of their linguistic abilities, as it has been suggested for language processing strategies (Wulfeck, Juarez, Bates, Kilborn, 1986), therapeutic outcomes (see Ansaldo & Saidi, 2014), as well as for syntactic priming experiments (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

[7] Because the ergative alienation of the language, subject relative structures arguments follow non-linear T-A order, while object relative structures have A-T argument order. Carreiras, Duñabeitia, Vergara, de la Cruz-Pavía, & Laka, (2010) have shown in an experiment with healthy speakers of Basque, that subject relative sentences are harder to process than object relatives, as suggested by longer self-paced reading times and larger amplitudes in the P600. Speakers deploy an agent-first strategy for the ambiguous sentence-initial DP, yielding the object-gap relative clause making the lowest processing demands.

representations are shared between languages. Turning to the issue at hand, this suggests that a bilingual PWA with spared morphological processing ability in L1 could also show transferable effect on L2, thus enhancing their morphological processing abilities, even though L2 is morphologically poorer.

3.1.4. Sentence comprehension, bilingualism and executive functions

The comprehension of sentences with derived orders using solely morphosyntactic cues requires the inhibition of the dominant interpretation derived via word order. Some studies have suggested that comprehension deficits in PWA might be due to problems in such inhibitory processes (Dickey et al., 2007; Hanne et al., 2011; Schumacher et al., 2015). The executive functions involve inhibitory control processes, mental flexibility and the ability to restore information from working memory (Miyake et al., 2000; Friedman & Miyake, 2004). Hence, executive functions are strongly related to working memory. This is compatible with several studies that have pointed out that syntactic processing deficits in PWA are related to working memory problems (e.g., Haarmann et al., 1997; Caplan & Waters, 2013; Sung et al., 2009; Zakariás, Keresztes, Dementer, & Lukács, 2013), and to cognitive control limitations (see Novick, Trueswell, & Thompson-Schill, 2005; 2010; for an overview Ardila, 2012).

Some evidence suggests that bilingualism enhances executive function. In order to resolve linguistic conflict, bilingual speakers may require a more general inhibitory control system than monolingual speakers, as indicated by better performance and/or lower RTs in several tasks involving verbal and non-verbal executive functions; for example, in children (Martin-Rhee & Bialystok, 2008), young adults (Costa, Hernández, & Sebastián-Gallés, 2008; Prior & MacWhinney, 2010) and older adults (Bialystok, Craik, Klein & Viswanathan, 2004; but cf. 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 & Spivey, 2003; see Kroll & Dussias, 2013 and Kroll, Bobb, & Wodniecka, 2006), as well as comparable patterns of neural activity across languages (Consonni et al., 2013; Díaz, Sebastián-Gallés, Erdocia, Mueller, & Laka, 2011). In summary, in order to ignore irrelevant information and avoid language conflicts, bilingual speakers might require additional control demands relative to monolingual speakers (but cf. Duñabeitia et al., 2014; Paap & Liu, 2014).

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 mechanism across languages (Dussias & Sagarra, 2007) 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 in sentence parsing routines by using object-first garden-path sentences, as well as subject-first non-ambiguous sentences. Crucially, they reported that bilingual speakers outperform monolinguals in their comprehension of both garden-path and non-ambiguous sentences. This suggests that bilingual advantages go beyond the particulars of trials involving conflict in thematic-role assignment. It is associated with a more general conflict-monitoring mechanism. Thus, these results are compatible with the idea that the bilingual advantage is not a consequence of the enhancement of inhibitory processes *per se*, but of a more central executive system. Turning to sentence processing deficits in PWA, if reduced inhibitory abilities cause deficits in interpreting sentences in derived word orders, it is an open question whether such linguistic deficits would be alleviated in bilingual PWA.

3.1.5. The role of online investigation of sentence comprehension

Real time sentence resolution data is essential 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 former motivates attention shifts to the latter (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 (Matin, Shao, & Boff, 1993). Thus, the study of gaze fixation patterns within the visual display allows for inferring how the participant processes specific linguistic information. In the case of sentence processing, healthy listeners assign thematic roles to critical items in the scene prior to their auditory presentation (Kamide, Scheepers, & Altmann, 2003; Kamide, Altmann, & Haywood, 2003; Knoeferle, Crocker, Scheepers, & Pickering, 2005). This phenomenon, called anticipatory thematic role mapping, is due to the influence of the visual stimulus in thematic role assignment.

Studying bilingual aphasia is crucial not only to uncover whether morphological cues are equally impaired in PWA across languages, but also to explore the impact that bilingualism might have on executive functions, and consequently, on sentence processing. 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 control participants. Secondly, the performances of bilingual and monolingual speakers of Spanish in sentence comprehension will be compared.

3.1.6. Linguistic backgrounds

3.1.6.1. Basque:

Basque is an agglutinative language isolate, with very rich inflectional morphology. The subject as well as the direct and indirect objects agree with the inflected verb in person, number, and case. The auxiliary verb presents polypersonal and case agreement with all the arguments of the sentence. It is a free word-order language, with SOV as its base order (De Rijk, 1969; Erdocia et al., 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 correlates with thematic role: ergative case corresponds to agent, absolutive case corresponds to themes, and dative case corresponds to goals.

For example, the objects of transitive verbs and the subjects of unaccusative verbs get the same morphological marking **(1-2)**, called “absolutive” (Ø), while the agentive subject of transitive verbs gets the 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			

Because of the free word order of the language, sentences starting with an absolutive marked (Ø) DP are temporarily ambiguous in Basque. Until disambiguation, the DP can correspond to the subject of an intransitive-unaccusative verb **(2)**, or to a sentence-initial object with a null-subject **(3)**, or as a topicalized object in a sentence with OSV word order **(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).

3.1.6.2. Spanish:

Spanish is a Romance language in which only the subject agrees with the verb in number and person. In addition, nouns, determiners and adjectives are inflected for gender. The base order is SVO, but word order is quite flexible. Animate and semantically definite objects are always 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 can be realized as an adjunct *by-phrase*. The Theme is the object of the active sentence and the subject of the passive sentence. This pattern is consistent in other structures with syntactically-displaced objects, such as relative clauses (subject relative; 7) and clefts (object cleft; 8) where the animate Object is marked by the preposition 'a'.

(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 et al., 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 relation to agent-first structures. Studies using simple structures (Casado et al., 2005; Del Río et al., 2012), as well as embedded structures (Del Río et al., 2011; Bentacort et al., 2009) 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 agent-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).

3.1.7. Research questions

The present study analyses the processes involved in sentence comprehension in bilingual and monolingual speakers combining off-line (accuracy and reaction time) and online (eye-tracking in VWP) methods. Since the goal of this study is twofold, it will be divided into two sections. In the first section, a group of bilingual PWA and NBD perform a sentence comprehension task in Spanish and Basque. In the second section, a group of bilingual and monolingual PWA, and corresponding NBD, will perform a sentence comprehension task in Spanish.

We seek to answer the following research questions:

i. What is the influence of different types of morphological markers (i.e., preposition vs. case-marking) on sentence comprehension deficits in PWA?
ii. Do Basque-Spanish bilingual speakers with aphasia and unimpaired non-brain-damaged speakers perform differently from Spanish monolingual speakers in a sentence comprehension test in Spanish?

3.2. 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.

3.2.1. Participants

Fourteen PWA (11 male; 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 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 aphasia as a consequence of a cerebrovascular accident. Visual neglect was excluded with the Behavioral Inattention Test (BIT; Wilson, Cockburn, & Halligan, 1987). Fourteen healthy control 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 B1** for individual demographic data). All subjects had normal or corrected-to-normal vision and hearing.

The bilingual group consisted of L1Basque-L2Spanish 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 B2**) suggested that all participants were balanced bilinguals. As expected for age reasons, all participants were literate only in Spanish[8].

To assess whether the PWA met inclusion criteria, they were assessed for working memory and linguistic abilities. Bilingual speakers were assessed in both Basque and Spanish, while monolingual speakers were only assessed in Spanish. Working memory was examined using the Forward Digit-span task[9] (WAIS-III; Wechsler, 1997), where bilingual PWA could choose which language to use for counting. 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 B3** 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 suggested by two-sided t-test comparisons conducted in each section (see **Appendix B3**).

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8 Basque Country was under the Francoist dictatorship from the late '30s to the late '70s. During this period, Basque was legally forbidden. The literacy language at schools was only Spanish, and Basque was the family/social language, which was frequently used clandestinely.

9 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 of appearance.

3.2.2. Design and materials

The linguistic and visual materials used in this study were the same as in Chapter 2. They consisted of pairs of pictures offered 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 (see **Figure 3.1**).

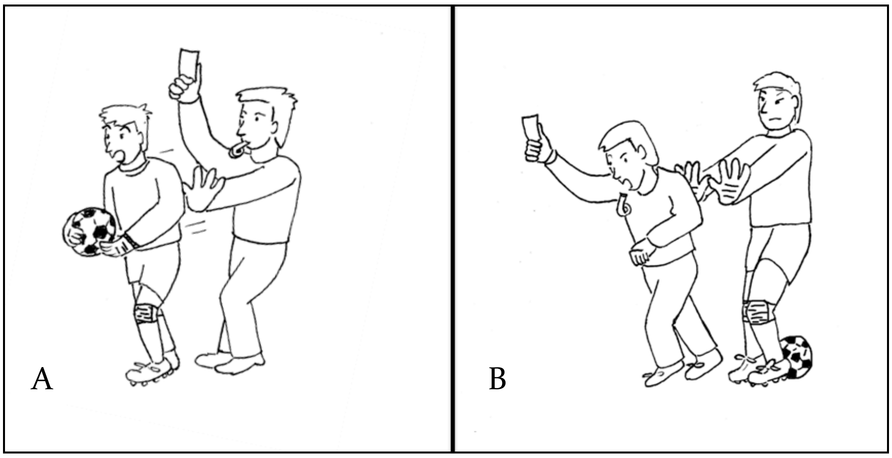

Fig. 3.1. Sample visual display. Target stimulus: (Active~Spanish) "El árbitro ha empujado al portero"/ (SOV~Basque) "Arbitroak atezaina bultzatu du". (The referee has pushed the goalkeeper). A) Target picture; B) Foil.

3.2.2.1. Linguistic stimuli:

Two sets of equivalent linguistic stimuli were used in Basque and Spanish. The original materials used in Chapter 2 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[10] 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 (A-T) and Theme-Agent (T-A). 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 attached to the DP (-k), 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	ehiztaria-a-Ø	zauri-tu	du
Wild boar-det-erg	hunter-det-(abs)	hurt-perf.	aux.has

(10) Object – Subject – Verb (– aux)

ehiztari-a-Ø	basurde-a-k	zauri-tu	du
hunter-det-abs	wild boar-det-erg	hurt-perf.	aux.has

(11) Verb (– aux) – Subject – Object

bultza-tu	du	basurde-a-k	ehiztari-a-Ø

[10] Contrary to Spanish, 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 (Chapter 2) to maintain the syntactic ambiguity implied in OSV constructions due to the case morphology of the language. In its absence in the case of Spanish, no filler stimuli were included.

push-perf. aux.has wild boar-det-erg hunter-det-abs

(12) Verb (– aux) – Object – Subject

butza-tu du ehiztari-a-Ø basurde-a-k

push-perf. aux.has hunter-det-abs wild boar-det-erg

In Spanish, active sentences (13) were formed using the perfect present tense to have a comparable verb length with the counterpart passive sentences (14). In the relative clauses the verbal phrase “I see” introduced the antecedent and the relative pronoun “que” functioned as subject (15) or object (16). 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 (17-18). 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.

(13) El árbitro ha empujado al portero

det referee aux.has push-PTCP prep+det goalkeeper

The referee has pushed the goalkeeper.

(14) El portero ha sido empujado por el árbitro.

det goalkeeper aux.has be-PTCP push-PTCP by det refere

The goalkeeper has been pushed by the referee.

(15) Veo al árbitro que empuja al portero

I see prep+det referee pron-rel push prep+det goalkeeper

I see the referee who pushes the goalkeeper.

(16) Veo al portero al que empuja el árbitro

see prep+det goalkeeper prep+det pron-rel push det referee

I see the goalkeeper who the referee pushes.

(17) Es el árbitro el que empuja al portero

be det referee det rel-pron push prep+det goalkeeper

It is the referee who pushes the goalkeeper.

(18) Es al portero al que empuja el árbitro
be prep+det goalkeeper prep+det rel-pron push det referee
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. 2016, in Chapter 2), 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. ROIs of the experimental stimuli were individually measured using the Computerized Language Analysis software (CLAN; MacWhinney, 2000) and subsequently length duration was pairwise compared. As shown in **Table 3.1**, 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., A-T vs. T-A).

Table 3.1: Regions of Interest (ROI), duration (mean and sd) and comparison of length across paired conditions.

Paired conditions	**ROI (mean duration and SD)**					
	ROI 1 Argument 1 999 ms (46)		ROI 2 Verb 931 ms (12)		ROI 3 Argument 2 852 ms (30)	
	t	p	t	p	t	p
Active vs Passive	0.945	0.350	-0.174	0.863	-1.376	0.177
Subj. vs Obj. Relative	-0.221	0.826	-1.877	0.068	1.268	0.213
Subj. vs Obj. Cleft	1.074	0.290	-0.397	0.693	0.366	0.716
A-T vs T-A	-0.554	0.581	-0.027	0.177	0.077	0.939

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

3.2.2.2. Visual stimuli:

The visual stimuli consisted of 88 black-and-white line drawings. They were presented in 44 pairs depicting the same action, but with inverse Agent/Theme thematic roles, as illustrated in **Figure 3.1** (see above). The pictures were approximately 15x15 cm. For detailed information about the visual material and correspondent normalization, the reader is referred to Chapter 2.

In line with the original experimental setting (see Chapter 2), the presentation of the visual stimuli in Spanish 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).

3.2.3. Procedure

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[11] 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.

[11] Twenty trials were presented in each sentence condition in both Basque and Spanish. Nevertheless, the Spanish version of the experiment did not include filler items and had more sentence conditions than the Basque version. Therefore, the two experimental sets did not have equal number of trials.

The experiment consisted of a spoken-sentence-to-picture-matching task. In the Spanish version we included a secondary task whereby after each sentence comprehension trial, participants were requested to rate their confidence in the accuracy of their previous response. These data are discussed in Chapter 4.

Before the presentation of each block of stimuli, a 5-point 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, a pre-visualisation of the stimuli was offered in the screen for 1000 ms, and subsequently 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 non-dominant hand.

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).

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 Chapter 2) 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.

3.3. Data analysis

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. (G)LMM combine both the fixed and radom-effects of known variables in a single model (see Bates, Maechler, Bolker, & Walker, 2005). Thus, it analyses data in terms of the repeatable covariates and the magnitude of the unexplained variation based on a specific sample of subjects and linguistic stimuli. In addition, (G)LMM are appropriate to address outliers and missing data, a common characteristic of small sample sizes and longitudinal data. For a detailed discussion on these aspects see Verbeke and Molenberghs (2000) and Diggle, Heagerty, Liang and Zeger (2002).

In the model building, an inclusion of fixed effects predictors was determined by the research question, and the best radom-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 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, unless otherwise indicated.

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., A-T versus T-A) in each language in bilingual PWA. The odds ratio was log transformed in order to be used in the correlations of probabilities of individual performance in Basque and Spanish.

The statistical software R was used for this analysis (R Core Team, v.3.2.3.) with the lme4 package (Bates et al., 2015).

Prior to the analysis, in Spanish gaze data was processed by calculating the proportion of fixations in the target and foil pictures from ROI 0 (i.e., previsualization) to the ROI 4 of the auditory stimuli. As described previously, the ROIs 1, 2 and 3 corresponded to the first, second and third arguments of the sentence, while ROI 4 corresponded to a post-offset silence of 1120 ms. Missing gaze data motivated by answers provided before the offset of ROI4 (i.e. on average, RT<3902ms) were treated by logical imputation based on the accuracy of the response.

The proportion of fixations in ROI 1, 2, and 3 of the auditory stimuli was compared to ROI 0 (i.e., previsualization). In the previsualization, the proportion of fixation across the two pictures was random, since the auditory stimuli had not been presented. Thus, changes in the proportion of fixations to the visual stimuli during the presentation of the auditory stimuli (i.e., ROIs 1, 2, and 3) and post-offset period (i.e., ROI 4) were compared pairwise with random/chance fixation patterns (i.e., pre-visualization, ROI 0) across sentence conditions. We aimed to identify the time point at which the fixation proportion to the target or foil picture became significantly different from random in order to infer which information cue across the linguistic stimuli guided the thematic-role resolution. This analysis was conducted separately for correctly and incorrectly answered trials. Bonferroni correction for multiple comparisons was applied by dividing the p level by the number of comparisons (i.e., 4); thus, an α level of 0.0125 was used.

3.4. Results

3.4.1. Sentence comprehension in the bilingual group: Basque vs. Spanish

3.4.1.1. 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. General descriptive details of accuracy based on argument order across groups and languages are provided in **Table 3.2**. See **Appendix B4 and B5** for individual scores in Basque and Spanish, respectively.

Table 3.2: Sentence comprehension accuracy (%) and Standard Error (SE) in Basque-Spanish bilinguals as a function of language and order of arguments in the sentence.

Order of arguments	Accuracy (%) and SE in Spanish		Accuracy (%) and SE in Basque	
	PWA	NBD	PWA	NBD
Agent-Theme	82.35 (1.88)	95.19 (1.05)	74.90 (2.69)	93.16 (1.51)
Theme-Agent	65.20 (2.35)	95.91 (0.97)	55.22 (3.04)	91.07 (1.70)
Mean (SE)	73.74 (1.53)	95.55 (0.71)	64.89 (2.08)	92.11 (1.14)

PWA= people with aphasia; NBD= non-brain-damaged

The accuracy data were analysed with GLMM containing a three-way interaction between group, argument order and language as fixed effects, and stimulus and subject variables as radom-effects. PWA comprehended the sentences significantly worse than NBD in both A-T and T-A argument orders in Basque (A-T: ß= 1.536; SE= 0.293; p=<.0001; T-A: ß=2.145; SE= 0.262; p=<.0001) and Spanish (A-T: ß= 1.463; SE= 0.280; p=<.0001; T-A: ß= 2.559; SE= 0.285; p=<.0001). Cross-linguistic comparison indicated that overall, the sentence comprehension of PWA was worse in Basque than in Spanish (ß= -0.436; SE= 0.126; p= .0006), as well as the NBD group (ß= -0.606; SE= 0.231; p= .0086). This cross-linguistic difference was consistent regardless of the argument order in the PWA group (A-T; ß= -0.448; SE= 0.194; p= 0.0212; T-A; ß= -0.425; SE= 0.162; p= 0.0088), but not in the NBD group. In the latter, participants performed worse in Basque than in Spanish in sentences presented in T-A argument order (ß= -0.839; SE= 0.324; p= .0096), but not when the stimuli were presented in a linear A-T argument order (ß= -0.374; 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 A-T and T-A argument order, separately in each language. Detailed Odds Ratios (OR) are presented in **Table 3.3**. Data showed that the odds of answering sentences correctly as a function of argument order varied significantly between languages across the participants. Some participants showed dissociation between a language and argument order. Participant A1, who had the largest odds ratio between A-T and T-A in Basque (OR= 8.92), presented the lowest odds ratio between A-T and T-A 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). Participant A3 had a greater impact of argument order in Spanish than in Basque, and A6 showed the inverse pattern. Some participants (A2, A5, A7) did not show cross-linguistic differences in the odds of answering sentences in A-T and T-A argument order. As shown in **Figure 3.2**, single case analysis revealed a negative correlation (r= -0.52) between (log) odds ratios in Basque and Spanish.

Table 3.3: Individual sentence comprehension accuracy scores (%) of the Basque-Spanish bilingual PWA as a function of argument order in the sentence.

Participants	**Basque**			**Spanish**		
	A-T	T-A	Odds Ratio	A-T	T-A	Odds Ratio
A1	81.57	33.15	8.92	76.31	72.80	1.20
A2	76.97	58.68	2.35	81.57	66.66	2.21
A3	78.35	61.11	2.30	94.82	65.26	9.75
A4	46.59	38.88	1.37	96.49	64.03	15.44
A5	78.67	60.52	2.40	81.49	65.61	2.30
A6	81.66	63.94	2.51	81.71	72.80	1.66
A7	78.94	71.05	1.52	61.45	50.87	1.53

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

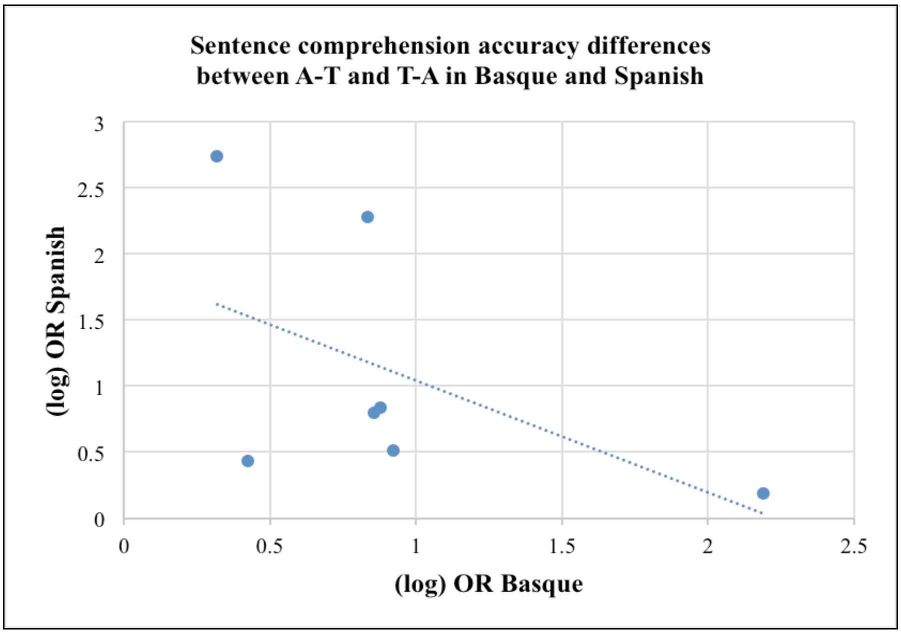

Fig. 3.2. Correlation of (log) Odds Ratio (OR) between A-T and T-A in Basque and Spanish. r= -0.52

3..1.2. Response reaction time in Basque and Spanish:

Detailed reaction time data of bilingual speakers as a function of language, group and argument order are provided in **Table 3.4.**

Table 3.4. Mean reaction time (ms) and Standard Error (SE) in Basque-Spanish bilingual speakers as a function of language and sentence condition.

Spanish	**Reaction time (ms.) (SE)**		**Basque**	**Reaction time (ms.) (SE)**	
Condition	PWA	NBD	**Condition**	PWA	NBD
Active	4641 (170)	3287 (101)	**SOV**	5156 (131)	3430 (81)
Passive	5171 (152)	3155 (74)	**OSV**	5319 (142)	3660 (58)
SbC	4840 (158)	3048 (73)	**VSO**	5309 (130)	3528 (93)
ObC	5169 (148)	3166 (69)	**VOS**	5806 (140)	3765 (77)
SbR	4837 (138)	3390 (93)	-	-	-
ObR	5119 (155)	3609 (74)	-	-	-
Mean (SE)	4963 (64)	3277 (33)		5400 (68)	3596 (39)

PWA= people with aphasia; NBD= non-brain-damaged

As previously mentioned, comparison between RTs in Basque and Spanish could not be conducted, since the length and therefore the resolution point in the linguistic stimuli varied across languages. Hence, separate models were fitted in each language. The models consisted of a three-way interaction between group, condition and response accuracy, and stimulus and subject variables as radom-effects. In addition, in Basque, a nested radom-effect was included to account for a precise estimation of the effect of sentence condition in each subject and stimulus, while in Spanish, nested radom-effects accounted for the variance in the effect of response accuracy in the RT of each subject. Outliers falling beyond ±2.5 standard deviations from the mean were excluded from the model, consisting of 2.11% and 1.75% of the data in Basque and Spanish, respectively.

In Basque, PWA had longer RTs than NBD across all sentence conditions (SOV; ß= -0.380; SE= 0.077; p= .0001; OSV; ß= -0.321; SE= 0.076; p= .0004; VSO; ß= -0.431; SE= 0.079; p<.0001; VOS; ß= -0.512; SE= 0.076; p= <.0001). There were RT differences depending on the response accuracy. In canonical SOV condition, PWA required less time in correctly answered trials than in incorrectly answered ones (SOV; ß= 0.097; SE= 0.040; p= 0.0170). In contrast, in the OSV and VOS conditions, PWA showed longer RTs in correctly answered trials than for incorrectly answered ones (OSV; ß= -0.119; SE= 0.033; p= 0.0003; VOS; ß= -0.113; SE= 0.034; p= 0.0012). There were no RT differences based on response accuracy in sentences presented in VSO word order (ß= -0.007; SE= 0.0384; p= 0.8389).

In Spanish, PWA also showed significantly longer RTs than NBD across all sentence conditions (active; ß= -0.276; SE= 0.120; p= 0.0281; passive; ß= -0.502; SE= 0.114; p= 0.0002; subj. relative; ß= -0.243; SE= 0.110; p= 0.0380; obj. relative; ß= -0.308; SE= 0.109; p= 0.0101; subj. cleft; ß= -0.369; SE= 0.112; p= 0.0032; obj. cleft; ß= -0.512; SE= 0.117; p= 0.0002). RT differences based on response accuracy were restricted to sentences presented in the active condition. In line with the data in Basque, PWA took longer to respond to incorrectly answered trials than to correctly answered ones. There were no RT differences based on response accuracy across the remaining sentence conditions (passive; ß= -0.017; SE= 0.056; p= 0.7591; subj. relative; ß= -0.193; SE= 0.058; p= 0.7414; obj. relative; ß= -0.1025; SE= 0.053; p= 0.0593; subj. cleft; ß= 0.013; SE= 0.063; p= 0.8379; obj. cleft; ß= 0.067; SE= 0.052; p= 0.2042).

In this section, accuracy and RT data have been analysed in a group of bilingual L1Basque-L2Spanish PWA, and corresponding NBD, while performing sentence-picture matching tasks in Basque and Spanish. The accuracy data indicated that 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, case analysis has uncovered that the effect of argument order in the comprehension abilities of individual PWA is different in Basque and Spanish. RT data analysis has shown longer latencies in PWA than in NBD. RT analysis based on response accuracy was different only for simple declarative sentences (i.e., active sentences in Spanish; SOV, OSV, VOS in Basque), suggesting that misinterpretations of sentences with A-T and T-A argument order are guided by incorrectly applied algorithmic and heuristic strategies, respectively.

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

3.4.2.1. 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. General descriptives of response accuracy regarding the argument order as a function of group and mono/bilingualism are provided in **Table 3.5**. See **Appendix B5** for individual scores.

Table 3.5: Sentence comprehension accuracy (%) and Standard Error (SE) in Basque-Spanish bilinguals as a function of language and order of arguments in the sentence.

Order of arguments	Accuracy (%) and SE in Spanish-Bilinguals		Accuracy (%) and SE in Spanish-Monolinguals	
	PWA	NBD	PWA	NBD
Agent-Theme	82.35 (1.88)	95.19 (1.05)	75.73 (2.12)	96.41 (0.91)
Theme-Agent	65.20 (2.35)	95.91 (0.97)	65.27 (2.36)	96.90 (0.84)
Mean (SE)	73.74 (1.53)	95.55 (0.71)	70.51 (1.59)	96.65 (0.62)

PWA= people with aphasia; NBD= non-brain-damaged

In order to analyse the accuracy data a GLMM was fitted with a three-way interaction between group, argument order and bilingualism as fixed effects, and stimuli and subject variables as radom-effects. Moreover, a nested radom-effect was added to enable a more precise estimation of the effect of argument order in each subject and stimuli.

PWA comprehended sentences less well than NBD in both A-T (ß= -1.817; SE= 0.335; p= <.0001) and T-A (ß= -2.776; SE= 0.335; p=<.0001) argument orders. In addition, PWA showed better performance in sentences presented in A-T argument order than in T-A order (ß=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 (ß=-0.061; SE= 0.344; p= 0.8584). A comparison of accuracy scores between monolingual and bilingual speakers showed that there was no difference in PWA (ß= 0.077; SE= 0.359; p= 0.8281) nor in NBD (ß= -0.313; SE= 0.423; p= 0.4595) groups. These results were consistent across sentences presented in A-T argument orders (PWA; ß= 0.275; SE= 0.425; p= 0.5177; NBD; ß= -0.302; SE= 0.514; p= 0.5557) and T-A argument orders (PWA; ß= -0.119; SE= 0.407; p= 0.7692; NBD; -0.323; SE= 0.531; p= 0.5430).

3.4.2.2. Reaction time in Spanish: bilingual vs. monolingual speakers:

Mean reaction times and error rates are provided in **Table 3.6**. The LMM used to analyse the reaction times consisted of a four-way interaction between group, argument order, response accuracy and bilingualism as fixed effects, and subject and stimuli as radom-effects. In addition, nested radom-effects were added to account for subject variability in the effect or argument order and response accuracy, as well as to account for the effect of trial number 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.

Table 3.6: 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.

Order of arguments	Mean RT (SE) in Spanish Bilingual speakers		Mean RT (SE) in Spanish Monolingual speakers	
	PWA	**NBD**	**PWA**	**NBD**
Agent-Theme	4772 (90.23)	3241 (52.33)	4971 (87.92)	3302 (42.62)
Theme-Agent	5153 (87.53)	3312 (43.25)	5281 (96.82)	3386 (49.04)
Mean (SE)	4963 (63.16)	3277 (33.94)	5125 (65.56)	3344 (32.51)

PWA= people with aphasia; NBD= non-brain-damaged

PWA showed longer RTs than NBDs in sentences presented in A-T argument order (ß= -0.301; SE= 0.060; p= <.0001) and T-A argument order (ß= -0.418; SE= 0.060; p= <.0001). In general terms, no RT difference was found between bilingual and monolingual speakers (PWA; ß= -0.056; SE= 0.078; p= 0.4688; NBD; ß= -0.073; SE= 0.083; p= 0.3773). Argument order had an effect on the RT of bilingual PWA (ß= -0.079; SE= 0.033; p= 0.0179), but not on the RT of monolingual PWA (ß= -0.037; SE= 0.033; p= 0.2650), or NBD participants (bilinguals: ß= 0.054; SE= 0.049; p= 0.2715; monolinguals; ß= 0.063; SE= 0.053; p= 0.2397). A three-way interaction was found between response accuracy, argument order and bilingualism, as illustrated in **Figure 3.3**. Monolingual PWA showed significantly longer RTs in incorrectly than correctly answered trials presented in A-T argument order (ß= 0.112; SE= 0.047; p= 0.0180). In sentences presented in T-A argument order, the difference of RT as a function of response accuracy was marginally significant (ß= 0.084; SE= 0.043; p= 0.0530). Contrary to this, bilingual PWA did not show RT differences between correctly and incorrectly answered trials in either argument order (A-T; ß= 0.026; SE= 0.047; p= 0.05835; T-A; ß= -0.010; SE= 0.041; p= 0.8040).

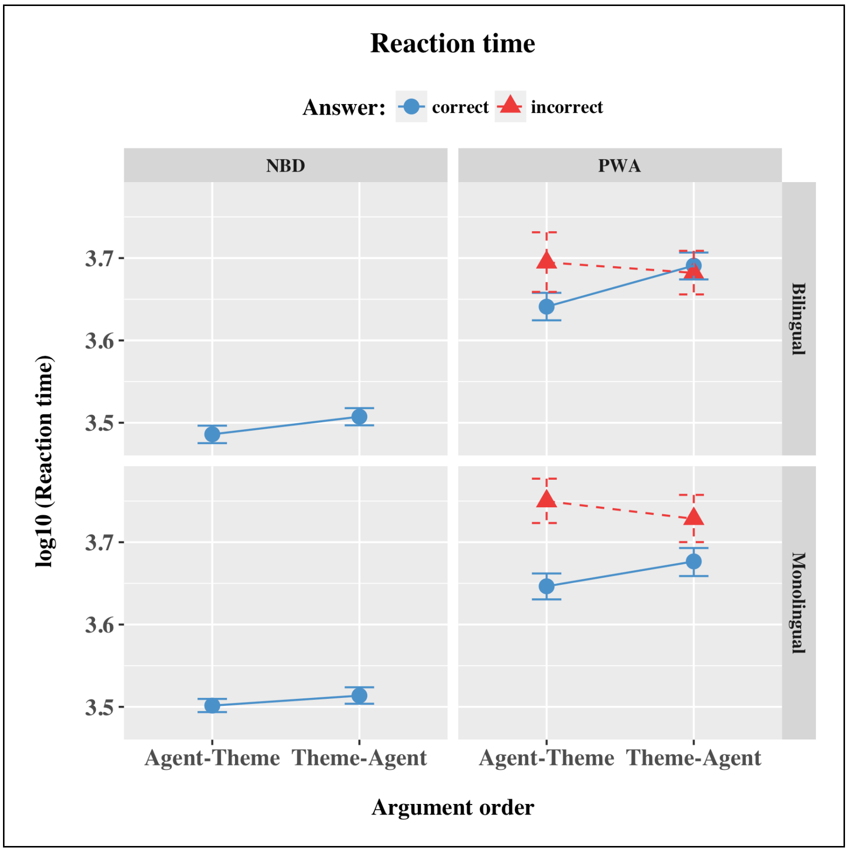

Fig. 3.3. (Log) reaction times (RT) from sentence onset of bilingual and monolingual speakers performing the sentence picture matching task in Spanish. PWA= people with aphasia; NBD= non-brain-damaged

3.4.2.3. Gaze data analysis in Spanish: bilingual vs. monolingual speakers:

The LMM consisted of a four-way interaction between ROI, sentence condition, response accuracy, group and bilingualism as fixed effects and subject and stimuli as radom-effect. In addition, the data analysis uncovered that the strength of sentence condition and response accuracy varied across subjects and stimuli. Nested radom-effects were included to account for this variance.

As illustrated in **Figure 3.4**, correctly and incorrectly answered trials were characterized by different fixation patterns. For the correct responses, participants tended to show an increased proportion of fixations towards the target picture, while in the latter the increase of fixation along the presentation of the auditory stimuli was towards the foil picture.

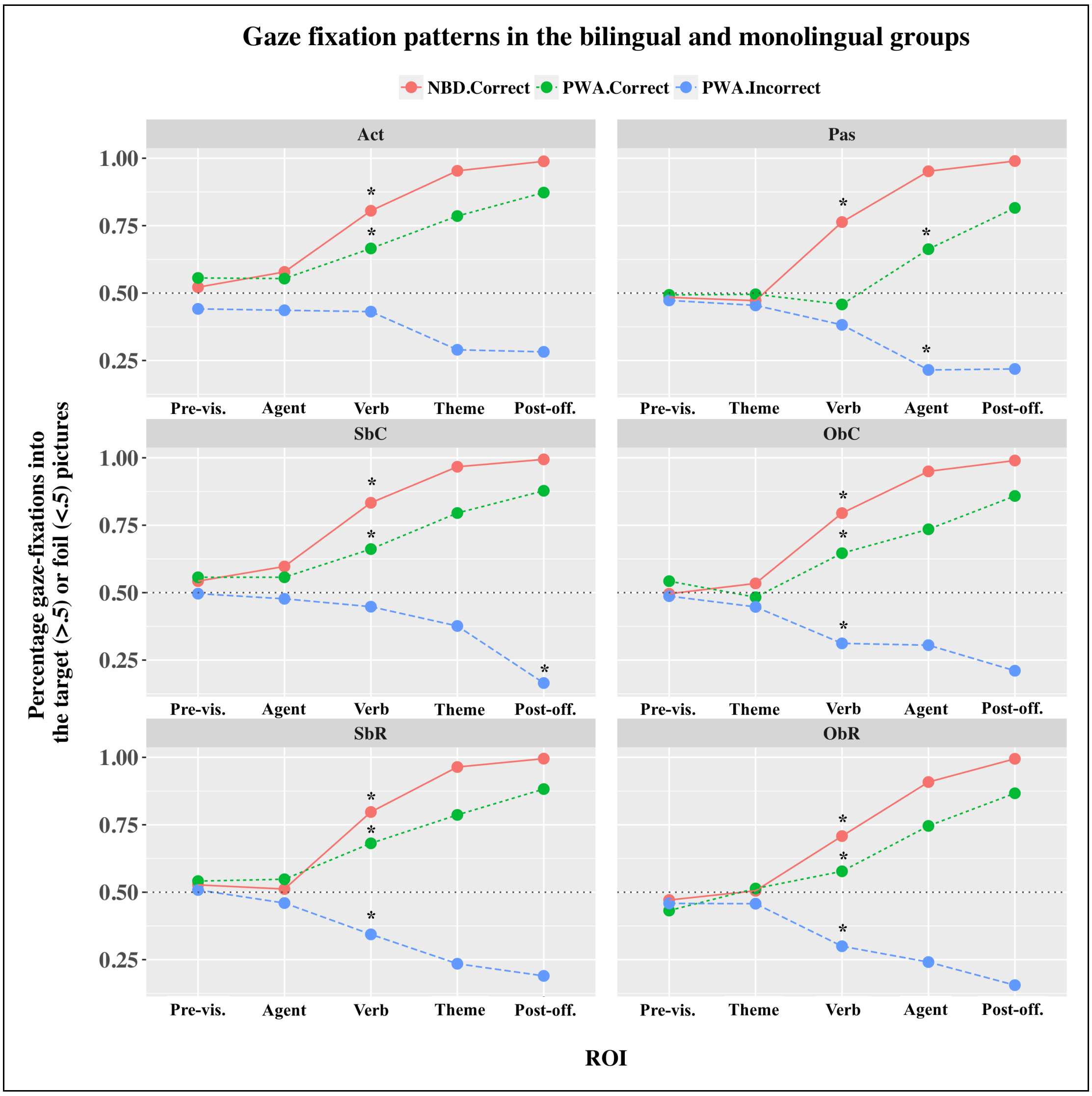

Fig. 3.4. Gaze fixation pattern of monolingual and bilingual speakers of Spanish across the visual display during the auditory presentation of the linguistic stimuli. * signals the first time window in which gaze fixations into target/foil picture are different to random along the presentation of the auditory presentation of the sentence. PWA= People With Aphasia; NBD= non-brain-damaged; Pre-vis.= pre-visualization of the visual display; Post-off= Sentence post-offset (i.e., silence).

Bilingualism was not a significant predictor of gaze data in PWA (ß= -0.017; SE= 0.013; p= 0.2121), nor in the NBD group (ß= -0.001; SE= 0.027; p= 0.9576). Separate comparisons were conducted as a function of group, bilingualism and sentence condition. As shown in **Table 3.7**, a single difference was found limited to correctly comprehended active sentences in the PWA group.

Table 3.7: Gaze data comparison between bilingual and monolingual speakers as a function of sentence condition and group.

	PWA				NBD			
Correct answers								
Condition	**β**	**SE**	**z-ratio**	**p**	**β**	**SE**	**z-ratio**	**p**
Act	-0.011	0.029	-0.406	0.6848	-0.006	0.027	-0.241	0.8099
Pas	0.058	0.030	1.936	0.0529	0.011	0.028	0.397	0.6913
SbR	0.016	0.030	0.549	0.5830	0.025	0.028	0.903	0.3663
ObR	-0.007	0.031	-0.242	0.8087	0.010	0.028	0.378	0.7051
SbC	-0.005	0.029	-0.180	0.8569	0.014	0.027	0.522	0.6015
ObC	-0.030	0.032	-0.934	0.3504	0.003	0.027	0.122	0.9030
Incorrect answers								
Condition	**β**	**SE**	**z-ratio**	**p**	**β**	**SE**	**z-ratio**	**p**
Act	-0.125	0.056	-2.208	0.0273	-	-	-	-
Pas	0.009	0.044	0.200	0.8411	-	-	-	-
SbR	-0.080	0.046	-1.737	0.0824	-	-	-	-
ObR	0.007	0.038	0.188	0.8506	-	-	-	-
SbC	-0.009	0.051	-0.190	0.8490	-	-	-	-
ObC	-0.030	0.037	-0.798	0.4247	-	-	-	-

PWA= People With Aphasia; NBD= Non Brain Damaged; Act= active, Pas= passive; SbR= subject relative; ObR= object relative; SbC= subject cleft; ObC= object cleft

Separate gaze data analysis was conducted for PWA and NBD, based on bilingualism and sentence conditions in order to get insight as to which auditory ROI showed a proportion of fixations that was significantly different to random looks (i.e., ROI 0) for the first time. Such analysis was conducted across correctly and incorrectly answered trials in PWA, and limited to the correctly answered trials in NBD. These data will not be discussed in detail in this paper due to the above-mentioned null-effect for bilingualism.

Henceforth, gaze data analysis will be presented based on group, response accuracy, sentence condition and ROI, but will not discern between monolingual and bilingual speakers.

In the correctly answered trials, the NBD group showed visual resolution at ROI 2 (i.e., verb position). Thus, after the presentation of the first argument of the sentence, and while presented with the verb, participants were already fixating significantly longer onto the target picture across all sentence conditions. PWA and NBD shared the same resolution ROI across all sentence conditions, except in passive constructions. In passive sentences, PWA showed a significant increase of fixations onto the target picture in ROI 3 (i.e., Agent). Detailed data analysis is provided in **Table 3.8**.

Table 3.8: Correctly answered trials in Spanish: Comparison of the proportion of gaze fixations in each ROI with the neutral stage (i.e., ROI0) in both NBD and PWA groups.

Condition	**PWA**				**NBD**			
ACT	**β**	**SE**	**z-ratio**	**p**	**β**	**SE**	**z-ratio**	**p**
ROI1	0.001	0.032	0.059	0.9526	-0.055	0.030	-1.842	0.0654
ROI2	-0.112	0.033	-3.393	**0.0007**	-0.285	0.030	-9.451	**<.0001**
ROI3	-0.226	0.033	-6.825	**<.0001**	-0.432	0.030	-14.362	**<.0001**
ROI4	-0.314	0.033	-9.531	**<.0001**	-0.466	0.029	-15.590	**<.0001**
PAS	**β**	**SE**	**z-ratio**	**p**	**β**	**SE**	**z-ratio**	**p**
ROI1	-0.000	0.034	-0.019	0.9851	0.013	0.030	0.447	0.06552
ROI2	0.038	0.034	1.098	0.2724	-0.277	0.030	-9.186	**<.0001**
ROI3	-0.168	0.034	-4.838	**<.0001**	-0.464	0.030	-15.407	**<.0001**
ROI4	-0.320	0.034	-9.209	**<.0001**	-0.502	0.030	-16.708	**<.0001**
SBR	**β**	**SE**	**z-ratio**	**p**	**β**	**SE**	**z-ratio**	**p**
ROI1	-0.006	0.034	-0.183	0.8548	0.016	0.030	0.527	0.5982
ROI2	-0.138	0.034	-3.961	**0.0001**	-0.269	0.030	-8.768	**<.0001**
ROI3	-0.244	0.034	-7.002	**<.0001**	-0.436	0.030	-14.280	**<.0001**
ROI4	-0.341	0.034	-9.821	**<.0001**	-0.466	0.030	-15.280	**<.0001**
OBR	**β**	**SE**	**z-ratio**	**p**	**β**	**SE**	**z-ratio**	**p**
ROI1	-0.081	0.037	-2.145	0.0320	-0.033	0.030	-1.115	0.2647
ROI2	-0.142	0.038	-3.740	**0.0002**	-0.237	0.030	-7.855	**<.0001**
ROI3	-0.314	0.038	-8.269	**<.0001**	-0.437	0.030	-14.467	**<.0001**
ROI4	-0.434	0.038	-11.442	**<.0001**	-0.523	0.030	-17.339	**<.0001**
SBC	**β**	**SE**	**z-ratio**	**p**	**β**	**SE**	**z-ratio**	**p**
ROI1	-0.001	0.033	-0.055	0.9563	-0.054	0.030	-1.811	0.0702
ROI2	-0.106	0.033	-3.171	**0.0015**	-0.290	0.030	-9.645	**<.0001**
ROI3	-0.238	0.033	-7.047	**<.0001**	-0.424	0.030	-14.144	**<.0001**
ROI4	-0.322	0.033	-9.560	**<.0001**	-0.451	0.030	-15.060	**<.0001**
OBC	**β**	**SE**	**z-ratio**	**p**	**β**	**SE**	**z-ratio**	**p**
ROI1	0.060	0.038	1.551	0.1209	-0.038	0.030	-1.266	0.2056
ROI2	-0.102	0.038	-2.661	**0.0078**	-0.300	0.030	-9.965	**<.0001**
ROI3	-0.190	0.038	-4.935	**<.0001**	-0.454	0.030	-15.071	**<.0001**
ROI4	-0.312	0.038	-8.097	**<.0001**	-0.494	0.030	-16.453	**<.0001**

PWA= people with aphasia; NBD= non-brain-damaged; ROI= Region Of Interest; ROI 0= Pre-visualization face (i.e., neutral stage to the auditory stimuli); ROI 1= first constituent of the sentence; ROI 2= second constituent of the sentence; ROI 3= third constituent of the sentence; ROI 4= Post-offset region; Act= active, Pas= passive; SbR= subject relative; ObR= object relative; SbC= subject cleft; ObC= object cleft; Significance level p<.0125

In the incorrectly answered trials, real time sentence processing varied across conditions. See **Table 3.9**. In sentences presented in active condition, fixation proportions towards the target/foil pictures were not different from random at any auditory ROI. In contrast, in the rest of the conditions PWA progressively increase fixations towards the foil picture. In sentences presented in A-T argument order (i.e., subject relative and subject cleft), PWA showed an increase of fixation towards the foil picture at Verb and Post-offset position (i.e., silence) in subject relative and subject clefts, respectively. In sentences presented in T-A argument order (i.e., passive, object relative and object cleft) PWA visually resolved the sentence at Agent position in passives, and Verb position on object relative and object clefts.

Table 3.9: Incorrectly answered trials in Spanish: Comparison of the proportion of gaze fixations in each ROI with the neutral stage (i.e., ROI0) in the PWA group.

Act	**β**	**SE**	**z-ratio**	**p**	**Pas**	**β**	**SE**	**z-ratio**	**p**
ROI1	0.037	0.075	0.498	0.6186	ROI1	0.017	0.059	0.301	0.7633
ROI2	0.037	0.076	0.488	0.6253	ROI2	0.087	0.059	1.486	0.1372
ROI3	0.183	0.076	2.389	0.0169	ROI3	0.255	0.059	4.312	**<.0001**
ROI4	0.185	0.075	2.443	0.0146	ROI4	0.254	0.059	4.249	**<.0001**
SbR	**β**	**SE**	**z-ratio**	**p**	**ObR**	**β**	**SE**	**z-ratio**	**p**
ROI1	0.049	0.060	0.807	0.4196	ROI1	0.001	0.048	0.041	0.9671
ROI2	0.170	0.061	2.784	**0.0054**	ROI2	0.159	0.048	3.320	**0.0009**
ROI3	0.284	0.060	4.683	**<.0001**	ROI3	0.218	0.048	4.536	**<.0001**
ROI4	0.316	0.060	5.233	**<.0001**	ROI4	0.305	0.048	6.342	**<.0001**
SbC	**β**	**SE**	**z-ratio**	**p**	**ObC**	**β**	**SE**	**z-ratio**	**p**
ROI1	0.010	0.067	0.160	0.8731	ROI1	0.040	0.048	0.850	0.3952
ROI2	0.059	0.067	0.875	0.3815	ROI2	0.173	0.047	3.639	**0.0003**
ROI3	0.131	0.067	1.937	0.0527	ROI3	0.179	0.047	3.759	**0.0002**
ROI4	0.338	0.067	4.985	**<.0001**	ROI4	0.276	0.047	5.782	**<.0001**

PWA= People With Aphasia; NBD= non-brain-damaged; ROI= Region Of Interest; ROI 0= Pre-visualization face (i.e., neutral stage to the auditory stimuli); ROI 1= first constituent of the sentence; ROI 2= second constituent of the sentence; ROI 3= third constituent of the sentence; ROI 4= Post-offset region; Act= active, Pas= passive; SbR= subject relative; ObR= object relative; SbC= subject cleft; ObC= object cleft; Significance level $p<.0125$.

In this section accuracy, RT and gaze data from the bilingual and monolingual PWA and NBD while performing a spoken-sentence-to-picture-matching task in Spanish have been analysed. The accuracy data have revealed that PWA performed significantly worse than NBD in sentence comprehension, regardless of the order of arguments in the sentence. Still, PWA showed more preserved comprehension of sentences presented in A-T argument order than of T-A order, unlike NBD who comprehended both conditions equally well. Accuracy data uncovered no comprehension differences between bilingual and monolingual speakers while performing the same task. RT data revealed that bilingual PWA show an effect of argument order, unlike monolingual PWA. In addition, monolingual PWA show RT differences between correctly and incorrectly answered trials in A-T argument order.

Gaze data analysis has shown that correctly and incorrectly answered trials correspond to a different fixation pattern towards target and foil pictures, respectively. In the correctly answered trials, PWA and NBD resolve the sentence at ROI 2 (i.e., verb position) across all conditions, except in passive sentences. In the latter, PWA require longer presentation of the auditory stimuli (i.e., ROI 3, Agent position) to fixate on the target picture. All sentences except the ones presented in active and subject cleft conditions were resolved at the same ROI across conditions in both correctly and incorrectly answered trials. The crucial difference was that in the correctly comprehended trials, the significant increase of fixations was towards the target picture, while in the incorrectly answered trials it was towards the foil.

3.5. Discussion

By combining behavioral (accuracy and reaction time) and/or eye-tracking data, we examined a group of L1Basque-L2Spanish 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 L1Basque-L2Spanish speakers, in relation to monolingual Spanish speakers, when it comes to processing sentences in derived word orders in Spanish.

3.5.1. Cross-linguistic sentence comprehension processing on bilingual PWA and NBD

3.5.1.1. Sentence comprehension accuracy and reaction times:

PWA showed poorer sentence comprehension than NBD regardless of the order in which the arguments were presented. In both Basque and Spanish, comprehension deficits in PWA were more severe when confronted with sentences with T-A than with A-T argument order, replicating previous results in PWA speakers of these languages (Arantzeta et al. 2016, in Chapter 2; Juncos-Rabadán et al., 2009). NBD did not show accuracy differences depending on the order in which arguments were presented in the sentence, likely due to ceiling level performance. Altogether, accuracy results converge with previous findings, pointing out that sentence comprehension deficits in PWA are strongly related with non-canonical (T-A) linear order of thematic-roles (e.g., Bastiaanse & Van Zonneveld, 2006; Burchert, De Bleser, & Sonntag, 2003; Caramazza & Zurif, 1976; Caplan & Futter, 1986; Grodzinsky, 1995, 2000; Mitchum and Berndt, 2008; Schumacher et al., 2015).

At group level, cross-linguistic comparison revealed that both PWA and NBD performed worse in Basque than in Spanish. With PWA this was found across both argument orders (i.e., A-T and T-A), while the NBD participants had better comprehension in Spanish only with sentences presented in T-A argument order. Asymmetric comprehension performance across languages contradicts previous studies in bilingual Swahili-English PWA (Abuom et al., 2013), where PWA showed equal sentence comprehension impairment in both languages.

Bilingual participants in this study were selected based on early bilingualism and current language exposure; hence, unbalanced bilingual proficiency and/or language attrition do not contribute to these results at group level.

These results can be explained by salience factors, described as the extent to which the acoustic features of the linguistic stimuli impose different degrees of difficulties. Recall that 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 are always preceded by the preposition "a" or the preposition "por", respectively. The morphological marking in Spanish might have more endurance and it is acoustically more perceivable than in Basque (see Ladefoged, 2001), and thereby, can be easier to parse for PWA with reduced processing resources. The comprehension pattern shown in NBD may be also explained within this theory. The effect of the speed of linguistic presentation, as a measure of saliency, has been shown to affect sentence comprehension abilities as a function of age, particularly in sentences requiring non-linear T-A assignment (Wingfield, Peelle, & Grossman, 2003). In our study, the linguistic stimuli were presented at comparable speed in both languages (slightly faster in Spanish than in Basque), but still the phonetic properties of each type of morphological marker (i.e., occlusive consonant vs. open vowel) greatly vary in acoustic prominence. 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, Pléh, & Bates, 1985).

Aside from perceptual factors, single case analysis suggests that the processing of ergative 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 a dissociation between the sentences in A-T and T-A 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. Thus, the odds ratios of answering sentences correctly as a function of argument order in Basque and Spanish showed a negative correlation. These results conciliate previous case studies on agrammatic Basque-Spanish bilingual PWA (Munarriz et al., 2016) and Hindi-English PWA (Vaid & Pandit, 1991), which offered confronting results in relation to the preservation of case morphology in PWA. Individual participant patterns cannot be solely explained by a higher vulnerability of case morphology than prepositional information found at group level. It suggests that processing ergative case morphology and prepositions occupy opposing sides of some computational trade-off. The interpretation of these results is beyond the scope of this dissertation.

At a speculative level, it suggests that the underlying causes of sentence comprehension deficits in PWA may attend to different sources, and consequently present different severities depending on language-specific properties. Note that Basque is an ergative-absolutive language that maps directly thematic roles, whereas Spanish is a nominative-accusative language, which marks syntactic functions. Single case data suggest that similar superficial comprehension disorders may be due to distinctive impairments in higher semantic order and/or syntactic functions. Still, this is based on the interpretation of a small PWA sample, and it needs further theoretical and empirical development.

Age-related decline in syntactic processing and the effect of word order has been reported in languages that guide parsing routines with a variety of morphological cues (Caplan et al., 2012; Sung, 2016; Obler et al., 1991). The current study did not replicate these findings, since the NBD performed at ceiling level in sentences presented in A-T order, not allowing a sensitive comparison of performance as a function of argument orders (A-T vs. T-A). The cross-linguistic asymmetry found in the current study might be compatible with the rendering of higher vulnerability of case-marking morphology in relation to other types of morphological cues (e.g., agreement) as shown in the study of German PWA and healthy controls using a within-language comparison (Hanne et al., 2015). Further research is needed to get insight into the processing dichotomy between case-morphology and prepositional information.

RT data could not be used to contribute to this discussion, since response times could not be compared cross-linguistically due to methodological limitations.

Within-language RT analysis uncovered that PWA required more time to respond to the sentences than NBD across all sentence conditions in both Basque and Spanish. These results do not replicate the findings of Arantzeta et al. (2016) (Chapter 2), who reported no RT differences between groups, likely due to high variability and small sample size. Still, they converge with the general pattern described in PWA group studies supporting processing account theories (e.g., Caplan et al., 2007; 2013; Hanne et al., 2011; Schumacher et al., 2015).

RT differences found between sentence conditions as a function of response accuracy point to the relationship between the type of information to which PWA resort in order to assign thematic roles and the subsequent success rate. Reliance on subject-first preference has been shown to result in shorter RTs for sentence comprehension tasks in healthy speakers (Erdocia et al. 2009; Del Río et al. 2011; 2012). According to this, RT data show that incorrect comprehension of sentences presented in OSV and VOS word order is motivated by a mistaken use of heuristics. In a similar vein, longer RTs in incorrectly answered trials in SOV and active sentences in Basque and Spanish suggest the unsuccessful use of heuristics, and subsequent failure in backtracking to implementation of a full syntactic analysis. The underlying reason why RT differences were not found in Spanish, except for the active condition, might be related to the syntactic complexity of the sentences. The higher cognitive demand involving the processing of embedded sentences might have cancelled the sensitivity of the RTs to the mapping of parsing routines.

In general terms, these data are not compatible with previous studies reporting a negative correlation between accuracy and RT (Caplan et al. 2007). This pattern was only found in SOV/active sentences in Basque and Spanish, respectively. Still, Caplan et al. (2007) conducted per-subject analysis, and we have analyzed RT data at group level, which might influence our results.

3.5.2. Bilingual advantage: comparison of bilingual vs. monolingual speakers of Spanish

3.5.2.1. Sentence comprehension accuracy and reaction times:

As expected, bilingual and monolingual PWA performed significantly worse than matched NBD in both A-T and T-A argument orders. In addition, PWA comprehended sentences presented in linear A-T argument order better than in T-A argument order, replicating the general pattern described in the previous section. The results on the NBD group did not agree with previous literature in sentence comprehension decline in elderly adults (Caplan et al., 2012; Sung, 2016; Obler et al., 1991), since the NBD group did not show comprehension differences regarding argument order. Ceiling level performance in the NBD group covers up potential differences based on argument order.

In relation to our research question, the comparison of accuracy data between bilingual and monolingual speakers did not support the existence of a cross-linguistic transfer nor bilingual advantage in the PWA nor in the NBD group. These two aspects are addressed separately in order to answer our research questions in detail.

The data obtained from the current study on bilingual speakers suggest that preserved sensitivity to morphological information (see Bates, Devescovi, & Wulfeck, 2001; Bates, Wulfeck, & MacWhinney, 1991), in a richly inflected language such as Basque, is not transferable into the processing of a secondary, less inflected language such as Spanish. Contrary to the cross-linguistic transfer argued for in some therapeutic studies (see Ansaldo & Saidi, 2014), our data do not support the existence of a transfer of morphological processing abilities from Basque to Spanish, which has been hypothesized to be able to enhance the comprehension of sentences in non-canonical word orders in Spanish.

Equal comprehension accuracy in both bilingual and monolingual participants in PWA also calls into question the existence of a bilingual advantage in sentence comprehension due to an enhancement of executive functions. This cannot be fully discarded in the NBD group because of ceiling level accuracy. Based on previous literature, we hypothesized that impaired sentence comprehension in PWA might be due to an inability to inhibit conflicting sentence interpretations. The absence of a bilingual advantage found in the current study does not support the view that bilingualism may enhance some aspects of the executive function system (see Costa, Hernández, & Sebastián-Gallés, 2008; Prior & MacWhinney, 2010; Bialystok, Craik, Klein & Viswanathan, 2004; Martin-Rhee & Bialystok, 2008). However, we cannot discard the possibility that diminished executive functions are an important component to explain sentence comprehension deficits in PWA, as suggested by previous studies (Dickey et al., 2007; Hanne et al., 2011; Schumacher et al., 2015). The results of this study suggest that, in any case, if there is an enhancement of executive functions in bilinguals, it does not favour bilingual PWA in sentence comprehension, when compared to monolingual PWA. This might be explained by the fact that impaired executive functions are inherently affected in agrammatic language. It has been widely accepted in the literature that executive functions depend on dynamic networks that might be affected by a variety of lesion locations (see Ardila, 2012). Consequently, the absence of language monitoring abilities due to frontal lobe lesions (see Chapter 4) might override the potential advantage that healthy bilingual speakers show in cognitive control and inhibition processes (Teubner-Rhodes et al., 2016; see also Ardila, 2012).

The analyses of the RTs revealed two main differences as a function of bilingualism, limited to the PWA group. First, bilingual PWAs showed an argument order effect, unlike to monolingual PWAs: they responded faster to sentences presented in A-T argument order than in T-A order. We did not find this effect in Spanish monolingual PWA and NBD groups, who did not show differences based on argument order. The effect of argument order has been widely observed in healthy speakers of Spanish (monolinguals) and Basque (bilinguals) by means of RTs and neurophysiological measures (e.g., Erdocia et al., 2009; Del Río et al., 2011; 2012). The lack of such an effect in our study is probably due to the large variability in the monolingual samples.

Second, unlike bilingual PWA, monolingual PWA showed longer RTs when sentences with T-A order were misinterpreted. Nevertheless, we did not find gaze fixation differences between monolingual and bilingual speakers as a function of bilingualism. It is necessary to keep in mind that this was a comparison conducted with a very reduced number of items. The interpretation of such a processing difference based on bilingualism is not straightforward. The results might converge with previous studies reporting shorter RTs in bilinguals compared to monolingual speakers in tasks involving cognitive control to resolve competition between different sources of information (e.g., Costa et al., 2008; Bialystok et al., 2004). In this fashion, a potential explanation might be that when PWA apply non-canonical parsing routines in sentences with canonical word order[12], bilinguals show shorter RTs than monolingual PWAs due to a better performance of cognitive control that allows them to inhibit the canonical interpretation of the sentence. Be that as it may, we believe that the interpretation of the RT data in the current study must be done cautiously, particularly due to small sample sizes and the reduced number of items in segmented analysis (e.g., based on response accuracy by argument order).

3.5.2.2. Gaze-data:

Gaze fixation patterns during the auditory presentation of the linguistic stimuli in Spanish were similar for bilingual and monolingual PWA and NBD speakers. Sentence condition analysis uncovered that only active sentences were distinguishable as a function of bilingualism. No evidence was found for

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[12] The early commitment to parse the sentence either as canonical or non-canonical argument order (i.e., deterministic parsing routine, see Hanne et al. 2011) has been suggested to be related to the sentence-picture matching task. The early presentation of the visual stimuli wherein the two potential interpretations of the sentence are depicted may force listeners to commit to one of the two interpretations from early on in the presentation of the sentence (see Caplan and Waters, 2013).

bilinguals having an advantage over monolinguals in processing sentences in derived word order in terms of processing speed, and subsequent visual resolution timing. Thus, real time sentence processing reinforces the abovementioned interpretation of accuracy data. Henceforth, gaze data will be discussed by taking together bilingual and monolingual speakers.

Gaze data analysis suggested that when comprehending correctly, both PWA and NBD resolve the sentence in the same time window, at the verb position across all sentence conditions, except in the condition involving Spanish passives. Processing passives, PWA waited for the presentation of the *by-phrase* to fixate into the target picture, and resolve agent-identification. These results are compatible with previous eye-tracking studies on passive sentence comprehension in English PWA, reporting late emerging fixation differences at *by-phrase* position as a function of response accuracy (Meyer et al., 2012; Schumacher et al., 2015). Still, contrary to Meyer et al. (2012), time-aligned sentence resolution across correctly and incorrectly answered sentences does not support the idea that successful lexical integration implies a slower processing than its unsuccessful integration.

In the correctly answered trials, sentence processing in PWA is comparable to NBD as far as PWA rely on the preposition "a" to disentangle thematic roles. However, when the Theme is not signalled by a preposition (as in passive constructions), listeners need to wait for the information provided by the *by-phrase*, although verb inflection offers sufficient information to resolve the sentence, as shown by the NBD data. Thus, it seems that PWA have limited access/integration of inflectional information, as suggested previously for Basque PWA processing sentences presented in VOS word order, in Chapter 2.

In the incorrectly answered trials, PWA reached a resolution point towards the foil picture during the presentation of the linguistic stimuli, except in active sentences. In the latter, the proportions of fixations towards target/foil pictures were not different from random at any time-window. This is compatible with the high RTs shown by PWA for the incorrectly answered active trials, as well as with previous studies reporting late-emerging gaze fixation differences as a function of response accuracy (Dickey et al., 2007; Meyer et al., 2012). In the other sentence conditions, except in subject clefts, PWA achieved a significant increase of fixations towards the foil picture in the same time window where they resolved the sentence in the correctly answered trials by looking at the target picture. This time-alignment between correctly and incorrectly answered trials suggests that the parser decides early on for one single routine per sentence, based on either canonical or non-canonical order of thematic roles (see Hanne et al., 2011). Crucially, deterministic parsing does not allow backtracking or parallelism, as indicated by the constant increase of fixations towards the target/foil picture, and therefore, the choice of the incorrect parsing routine frequently fails to provide the correct interpretation of the sentence. Still, the absence/delayed visual resolution point in active/subject cleft sentences suggests that the deterministic parsing following a non-canonical template might involve higher cognitive demand, which might be translated into slower real time parsing routines.

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 morphological processing by bilingual speakers of two typologically distant languages such as 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 have an explanatory value in these data, as suggested by previous results in healthy speakers (Wingfield, Peelle, & Grossman, 2003; MacWhinney, Pléh, & Bates, 1985). These cross-linguistic asymmetries are also compatible with different cognitive demands involving the processing of ergative case-morphology and prepositions (see Hanne et al. 2015). Single case analysis of PWA has suggested 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 in Basque were less impaired in Spanish, and the other way round. The explanation for this negative correlation is not yet clear. We have speculated that different levels of impairment in each individual may yield a distinctive cross-linguistic pattern across participants. This idea deserves further research.

We have also intended to uncover the potential advantage that Basque-Spanish bilingual PWA might show when it comes to comprehending sentences presented in non-canonical word orders compared to monolingual Spanish speakers. Results revealed that bilingual speakers do not outperform monolinguals in sentence comprehension accuracy. From the perspective of the cross-linguistic transfer hypothesis, the data suggest that bilingual PWA do not relocate morphological processing abilities from Basque (a richly inflected language) to Spanish (less inflected language). Consequently, the performance of PWA in processing sentences in derived word orders is indistinguishable as a function of bilingualism. In a similar vein, the alleged enhancement of executive functions and general conflict monitoring system attributed to bilingual speakers (e.g., Teubner-Rhodes et al., 2016) does not obviously appear to help bilingual PWA with sentence comprehension deficits. These results may be also interpreted as agrammatic comprehension being intrinsically related to executive functions, and therefore the bilingual advantage found in healthy speakers might be to a certain extent cancelled in PWA.

The gaze fixation data showed that, in the correctly answered trials, both PWA and NBD resolved the sentence at the verb position. However, in passive sentences PWA were more delayed than NBD, and waited to hear the second argument of the sentence (in the *by-phrase*), suggesting limited lexical access/integration of verbal information (see Arantzeta et al., 2016, in Chapter 2; Meyer et al., 2012; Schumacher et al., 2015). In the PWA group, the significant time-alienation of visual resolution in correctly and incorrectly answered trials supports the idea that PWA rely on a deterministic parsing routine, which is conducted fast and automatically regardless of the success of the interpretation. In line with Caplan and Waters (2013), we believe that this early commitment toward one or the other interpretation may be related to the task-specific demands. However, accuracy data suggest that the parser does not make a random choice when it comes to analyzing the sentence as canonical or non-canonical, but the argument order bias influences parsing decision and speed.

The current study shows that, even when the participant-variability is kept constant, language-specific properties might affect the choice and subsequent success of the parsing routines. In addition, the current study did not find differences between bilingual and monolingual PWA affecting their sentence comprehension deficit. The role of executive functions in the comprehensive approach of sentence processing impairments in PWA deserves further experimental attention.

Chapter 4:

What happens when they think they are right? Error awareness analysis of sentence comprehension deficits in aphasia.

Abstract | *Background:* Comprehension of non-canonical sentences is frequently characterized by chance-level performance in people with aphasia (PWA). Chance-level performance has been interpreted as guessing, but online data does not support this rendering. It is still not clear whether the incorrect sentence processing is guided by the compensatory strategies that PWA might employ to overcome linguistic difficulties. This study combined off-line and online data to investigate the effect of word order and error-awareness on sentence comprehension in a group of PWA and non-brain-damaged (NBD) speakers of Spanish. The off-line tasks involved auditory sentence-picture matching immediately followed by a confidence rating. Participants were asked to judge the perceived correctness of their previous answer. Online data consisted of eye-tracking. NBD participants showed sentence comprehension at ceiling level, while PWA showed comprehension difficulty, with the tendency to perceive as correct both correctly and incorrectly answered trials. Just 6.8% of judgments were classified as "guessing" by PWA. Confidence rating was a poor predictor of response accuracy in PWA, but moderate-good in NBD. Post-hoc gaze data analysis indicated that confidence rating was a predictor of the fixation pattern during the presentation of the linguistic stimuli. Results suggest that PWA were mostly unaware of their sentence comprehension errors and did not consciously employ strategies to compensate for their difficulties.

4.1. Introduction

4.1.1. Word order and sentence comprehension deficits in PWA

Sentence comprehension deficits in agrammatic aphasia have been well established in the literature over the past few decades. In the absence of lexical comprehension deficits, semantically reversible sentences presented in non-canonical[13] word orders are frequently misunderstood by people with non-fluent aphasia (PWA) (e.g., Caplan and Hildebrandt, 1988; Caramazza & Zurif, 1976; Grodzinsky, 2000; Thompson et al. 2013; Schumacher, et al., 2015; see Grodzinsky, Piñango, Zurif, & Drai, 1999 for a review). Both semantic reversibility and word order are key in understanding this difficulty. When both Determiner Phrases (DPs) of a sentence are animate and potential agents of the action (i.e., the sentence is reversible), PWA show better comprehension of sentences presented in Agent-Theme order (henceforth A-T) (e.g., *The girl calls the teacher*) than in Theme-Agent order (henceforth T-A) (e.g., *The teacher has been called by the girl*). This is because in the former, listeners may rely solely on word order information to disentangle the thematic-role assignment, while in the latter they are forced to process morphological information to eventually perform parsing routines and reach the correct interpretation of the sentence.

Typologically, the more (case and agreement) morphology a language has, the greater freedom it displays in sentence word order. Some authors have suggested that PWA are sensitive to language-specific cues and this premorbid awareness may impact their difficulties (Bates, Friederici, & Wulfeck, 1987). This suggests that the strength of word order as a reliable parsing cue varies cross-linguistically. That is, speakers of highly inflected languages may rely on

[13] In the current Chapter, the terms canonical vs. non-canonical refer to the base word order in a certain language (e.g., SVO in Spanish) vs. the rest of word orders allowed in the language (e.g., OVS, VSO, VOS). Aside from this, the terms linear vs. non-linear refer to the order of Agent and Theme in relation to each other; linear Agent-Theme (e.g., SVO, VSO) vs. non-linear Theme-Agent (e.g., OVS, VOS).

morphological cues rather than word order information. Nevertheless, deficits in comprehending sentences in T-A argument order have been found in PWA across languages with more rigid word order (i.e., in English, Schwartz, Saffran, & Marin, 1980; Meyer, Mack, & Thompson, 2012; in Dutch; Bastiaanse & Edwards, 2004), flexible word order (i.e., in Spanish, Juncós-Rabadán, Pereiro, & Souto, 2009; in German, Burchert, De Bleser, & Sonntag, 2003; Hanne et al., 2011; in Italian, Garraffa and Grillo, 2008; in Turkish, Duman, Altinok, Özgirgin, & Bastiaanse, 2011; in Swahili, Abuom, Shah, and Bastiaanse, 2013; cf. in Indonesian, Jap, Martínez-Ferreiro, & Bastiaanse, 2016) and free word order (i.e., in Basque, Arantzeta et al. 2016, in Chapter 2). Nevertheless, a word order effect can be more prominent in some languages than in others (see Munarriz, Ezeizabarrena, and Gutierrez-Mangado, 2014; Vaid and Pandit, 1991), but it points out that the processing of morphosyntactic information is a core deficit in agrammatic aphasia (see Thompson, Kielar, & Fix, 2012 for an overview).

To date, most studies on sentence comprehension have used off-line methods to address the ways in which PWA and non-brain-damaged (NBD) individuals process sentences in order to assign grammatical functions and thematic roles. The sentence-picture matching task has been typically used in both experimental and clinical settings. The participant needs to choose, within a set of two (or more) visual stimuli, the one that best matches the target sentence. Although the results are easy to quantify, it is necessary to consider that the odds of picking the target picture by chance are relatively large. Thus, to compare results against chance, accuracy scores at chance-level (e.g., 33.3%-66.66% accuracy in a binomial choice task) have been traditionally attributed to guessing by the Trace Deletion Hypothesis (TDH; Grodzinsky, 1986, 1995, 2000; see Drai and Grodzinsky, 2006ab for a later revision). Based on the tenets of the Principles and Parameters model of generative grammar[14] (Chomsky, 1981), the TDH states that agrammatism precludes the creation of a chain

[14] According to the Government and Binding model (GB; Chomsky, 1981), the displacement of a sentence constituent leaves behind a trace in its base-generated position. Thus, sentence comprehension requires keeping track of both the element in the derived position and the trace left in the base-generated position.

between the moved element and the trace in its original position. According to the TDH, traces of movement are not available to PWA. Consequently, when presented with passive sentences with non-linear A-T order, PWA cannot assign thematic roles to a moved argument and apply instead a default strategy that assigns the role of Agent to the first DP in the sentence. The argument in the by-phrase gets the correct thematic role, and therefore, the sentence appears to have two agents. Accordingly, the TDH states that PWA resolve this conflict by choosing randomly between the two potential interpretations of the sentence. Thus, the TDH predicts that PWAs will perform at chance-level in the comprehension of sentences with non-canonical A-T word order.

The abovementioned guessing interpretation is related to one important limitation of off-line sentence comprehension tasks. Off-line methods are static in the sense that they measure how participants interpret a sentence once its presentation has concluded, but they do not provide information related to the type of knowledge that listeners tap into to achieve a specific interpretation. The introduction of online methodologies has made an important contribution to aphasiology not only by addressing some of the limitations of off-line methods, but also by suggesting new interpretations of sentence comprehension data in PWA. First, we will briefly introduce the methodological framework.

4.1.2. Eye-tracking studies on sentence comprehension deficits

To examine real time sentence processing, several studies have used eye-tracking (ET) technology in the Visual World Paradigm (VWP). The VWP is based on the idea that the linguistic stimuli mediate visual attention shifts within a visual display due to referentially-driven processes (Cooper, 1974; Eberhard, Spivey-Knowlton, Sedivy, & Tanenhaus, 1995; see Tanenhaus, 2007 and Boland, 2004 for an overview). Participants' eye fixations on pictures in a scene are monitored as participants listen to sentences. Changes in the location and timing of fixations along the time string reveal how visual attention shifts in response to the continuous auditory stimuli. Some findings suggest that language mediated eye gaze tends to be unconscious, but not fully automatic (Mishra, Olivers, & Huettig, 2013). Current data suggest that the VWP provides a sensitive measure of word order processing in sentence comprehension.

Dickey, Choy and Thompson (2007) introduced the VWP in aphasiology research in a study on *wh*-questions. They found that the comprehension of non-canonical object *wh*-questions was at chance-level in PWA. Interestingly, gaze data analysis did not converge with the traditional interpretation of chance-level accuracy (i.e. guessing) (TDH; Grodzinsky, 1986, 1995, 2000; see Drai and Grodzinsky, 2006ab for a later revision; see Burchert, Hanne, and Vasishth, 2013 for a review). Online sentence processing uncovered different processing routines in PWA as a function of off-line response accuracy. That is, PWA showed distinct fixation patterns in the correctly and incorrectly answered trials. In the correctly answered trials PWA showed the same gaze fixation pattern of NBD participants, indicating rapid and automatic thematic role assignment. In contrast, in the incorrectly answered trials, PWA showed a completely different gaze fixation pattern, characterized by a progressive proportion of fixations towards the foil picture. It constituted the first empirical evidence against the guessing interpretation of chance-level performance in PWA. Similar results have been reported in subsequent studies combining VWP with a sentence-picture matching task in German (Hanne et al., 2011) and Basque (Arantzeta et al., 2016, Chapter 2) PWA. Converging with Dickey et al. (2007), unsuccessful off-line performance in PWA was guided by fixation patterns that diverge from correctly interpreted sentences. Altogether, evidence from online data does not support the existence of a guessing pattern in sentence processing in PWA, but distinctive parsing routines that determine the interpretation of the sentence. In successful interpretations of the sentence, PWA show a processing pattern comparable to NBD, but it is still unclear what processes underlie sentence misinterpretation.

Online data analysis of incorrect answers might provide insights regarding the intermittent and hardly predictable (i.e., stochastic) failure shown by PWA in processing sentences with non-canonical word orders. However, this analysis is often challenging due to the small sample sizes and noisy data (see Caplan et al., 2007, for an alternative across-task/measures approach). Dickey et al. (2007) suggested that PWA fail to comprehend sentences with non-canonical word order due to their inability to inhibit counteractive information; for example, the influence of agent-first heuristics. This refers to the tendency to assign the agent role to the first DP in the sentence (Bever, 1970; Bornkessel-Schlesewsky and Schlesewsky, 2013). This heuristic achieves correct interpretation of sentences presented in the canonical word order, also in healthy speakers (Ferreira and Patson, 2007; van Herten, Chwilla, & Kolk, 2006; Townsend and Bever, 2001), but it fails to correctly assign thematic roles in derived word orders. In those cases, listeners must revise the initial parsing by applying more effortful analytical computations. Hanne et al. (2011) suggested that PWA have an early preference for interpreting sentences as canonical or non-canonical based on a "deterministic parsing", followed by the inability to revise the initial parsing computation, even when they detect the need for reanalysis. Altogether, the failure of PWA to inhibit the antagonist interpretation of a semantically reversible sentence has been pointed out as a potential cause of the inconsistent sentence processing failure in PWA. Still, it is an open question whether the use of heuristics by PWA is a consciously learned and self-initiated procedure to compensate for their linguistic deficits, or whether it reflects an unconscious breakdown of parsing routines.

4.1.3. Consciousness and compensatory strategies in PWA

Provided that PWA do not show anosognosia (i.e., unawareness of the aphasic condition) (see Kertesz, 2010; Vuilleumier, 2004 for an overview), PWA use self-initiated compensatory strategies to overcome their communicative impairments. These might be external (e.g., ask for adaptations to the interlocutor, use of electronic devices) or internal (e.g., self-cuing, verbal repetition, mental association) (e.g., Beeke, Wilkinson, & Maxim, 2009;

Oelschlaeger and Damico, 1998; Tompkins, Scharp, & Marshall, 2006; see Simmons-Mackie and Damico, 1997).

In general, the use of heuristics reduces processing time and effort in parsing routines when compared to analytical processes (Shah and Oppenheimer, 2008). There is evidence suggesting that the PWA have limited resource availability to process the linguistic stimuli (Caplan et al., 2007; Kolk, 1993; Miyake, Carpenter, & Just, 1994). Thus, PWA may adopt a conscious shortcut to diminish the cognitive load involved in the parsing process. Among the languages studied in sentence processing in PWA, none has Theme-Agent order as its canonical structure. Indeed, this is a rare pattern shown by less than 4% of the languages worldwide (Dryer, 2005). The frequency of appearance of structures is a primary criterion to determine word order typology across languages; thus, structures with non-canonical word order tend to be less frequent than structures with canonical word order (Dryer, 2007). Hence, if we consider the above factors, reliance on agent-first strategy may be considered as the "best guess" under an arbitrary degree of success. It is unknown to what extent the adoption of an agent-first strategy by PWA is based on a conscious decision that aids comprehension efficiency on an everyday basis. The focus lies in establishing a threshold between the conscious and unconscious processing of language.

Metacognitive tasks assess self-awareness and, hence, consciousness (Seth, Dienes, Cleeremans, Overgaard, & Pessoa, 2008; see Peña-Ayala and Cárdenas, 2015 for an overview). Metacognitive awareness refers to the subjective perception of one´s own cognitive process. It can be measured by the subjective confidence ratings self-reported by the subject in a given task (see Norman and Price, 2015). Participants perform a primary task (e.g., picture matching) and subsequently are asked to rate their confidence in the validity of their decision. The degree of correspondence between the objective performance (i.e., accuracy) and the subjective confidence rating is used to assess the extent to which the primary task is mediated by conscious knowledge (Cheesman and

Merikle, 1984, 1986; Dienes, Altmann, Kwan, & Goode, 1995; Overgaard, Timmermans, Sandberg, & Cleeremans, 2010). Conscious cognition is strongly associated with voluntary control. However, voluntary actions become automatic with practice (Shiffrin and Schneider, 1977) and consequently, the cognitive control over them decreases (e.g., Langer and Imber, 1979; Schneider, 2009). Hence, it is important to keep in mind that there is some degree of contribution of conscious and unconscious knowledge across most cognitive tasks.

Note that a judgment based on confidence rating is certainly a constituent of conscious awareness, but it may be the product of an unconscious inference. What is important is that once the judgment is built, it may augment self-control, and therefore the degree of personal regulation over processes that would otherwise influence behavior directly (Koriat, 2000). Dienes et al. (1995) suggested two criteria to use confidence rates to discern between conscious and unconscious knowledge; the zero-correlation criterion and the guessing-criterion. The former refers to the lack of relationship between confidence rating and objective accuracy, while the latter refers to the observed above-chance performance in the primary task while participants express themselves to be guessing. According to the authors, the fulfilment of these two criteria is a strong indicator of unconscious processing. This paradigm has been used mostly in perceptual discrimination and implicit learning tasks (Norman and Price, 2015; Overgaard, 2015, for an overview). In the current study it is applied for the first time in an aphasiology study.

Contrary to production experiments (Marshall and Tompkins, 1982; Oomen, Postma, & Kolk, 2001), studies of metacognitive awareness in comprehension deficits have been mainly on jargon aphasia (Marshall, Rappaport, & Garcia-Bunuel, 1985; Shuren et al., 1995; see Rubens and Garret, 1991, for an overview). To the best of our knowledge, the only study on comprehension error awareness in non-fluent PWA was conducted by Kennedy and Chiou (2008), who studied a group of Broca's and anomic PWA regarding metacognitive awareness on discourse-related questions. Kennedy and Chiou (2008) reported that metacognitive awareness was mainly explained by the linguistic abilities of the PWA (discourse comprehension and design fluency repetition score), but also executive functions, such as switching and perseveration, contributed to a lesser extent (see also Stuss, 1991). In line with the perceptual loop theory (Levelt, 1989, 2001), deficits in linguistic abilities relate to an impaired perceptual loop, and consequently a gradient of self-monitoring abilities.

We aimed to study the extent to which people with non-fluent aphasia have conscious knowledge of comprehension processing. Comprehension accuracy and self-reported confidence ratings were considered during a comprehension task involving canonical and non-canonical sentences.

4.1.4. Research questions

Behavioral data were collected by using a sentence-picture matching task, followed by a confidence rating. Moreover, participants were monitored with an eye-tracker while performing the primary task (i.e., sentence-picture matching task) as an online measure of sentence processing. The latter aimed to further explore, in a post-hoc analysis, the interaction between self-awareness and real time sentence processing. This study poses three research questions:

1) Are PWA aware of their sentence comprehension errors?

The confidence rates reported to the incorrectly answered trials were studied to uncover the extent to which PWA performed a correct judgment of their (failed) comprehension accuracy. Correct judgments of incorrectly answered trials were considered as an indicator of error awareness in sentence comprehension. In contrast, incorrect judgments of incorrectly answered trials suggest that PWA were not aware of their comprehension errors.

2) Is sentence comprehension performance unconsciously mediated in PWA and NBD?

Following Dienes et al. (1995), this research question was answered based on the zero-correlation criterion and the guessing-criterion. In relation to the zero-correlation criterion, no correlation between objective comprehension performance and subjective confidence rating is an indicator of unconscious knowledge. The opposite pattern would be indicative of consciously mediated processing, and therefore voluntary control over thematic-role parsing. The latter finding would support that metacognitive tasks are valuable to assess the what extent to which PWA use agent-first heuristics as explicit inference to disentangle thematic roles. Regarding the guessing-criterion, above chance performance in trials wherein participants believed that they were guessing indicate unconscious knowledge (i.e., implicit knowledge) of sentence processing.

3) To what extent do PWA answer by guessing on a task for comprehension of sentences in non-linear argument order?

Descriptive analysis of the data was used to add further evidence on the validity of the Trace Deletion Hypothesis (TDH; Grodzinsky, 1986, 1995, 2000; see Drai and Grodzinsky, 2006ab for a later revision). As described before, the TDH states that PWA answer by guessing when confronted with sentences presented in derived word orders. Based on the definition of guessing as "form(ing) or express(ing) an uncertain estimate or conclusion (about something), based on insufficient information" (Collins English Dictionary, online version), we may establish that it refers to a conscious act. Hence, the "guessing" pattern will be quantified through the self-ratings of PWA on correctly and incorrectly judged sentences, and contrasted with the TDH.

4.2. Methods

This study was approved by the Basque Clinical Research Ethics Committee (CEIC-E). All participants, or legal tutors, gave informed consent according to the declaration of Helsinki.

4.2.1. Participants

Fourteen individuals (mean age 66,07 years; SD= 10,38; range= 55-85; male/female= 11:3) with chronic non-fluent aphasia were tested in this study. Half of them were native Spanish monolingual speakers, whereas the others were L1Basque-L2Spanish bilingual speakers[15]. They were all pre-morbidly right-handed, as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971), and presented with aphasia due to cerebrovascular injury. Visual neglect was excluded using the Behavioural Inattention Test (BIT; Wilson, Cockburn, & Halligan, 1987). Fourteen individuals without any history of neurological or sensory impairments composed the NBD group. They were matched on age range and bilingualism with the clinical group (mean age 62,92 years; SD= 12,04; range= 44-82; male/female= 8:6). Demographic, linguistic and clinical information is provided in **Appendix B1**.

PWA were screened in Spanish for word and sentence comprehension abilities using the extended version of the Boston Aphasia Test (BDAE; Goodglass, Kaplan, & Barresi, 2005; Adapted to Spanish by García-Albea, 2005). The subsection of conversation and language exposition, comprehension of words, commands, complex ideational materials and syntactic processing subsections were used. Furthermore, PWA were also assessed for working memory using the digit-span task of the Wechsler Adult Intelligence Scale (WAIS-III; Wechsler, 1997). Scores from the subtests of the BDAE and the WAIS-III are presented in **Appendix B3**.

[15] All bilingual participants had acquired Spanish at an early age (< 5 years) and were literate only in Spanish, their language of instruction at school.

To be included in the present study PWA showed relatively preserved lexical comprehension (>80%) and impaired sentence processing (<66.66%) as assessed by the "Touch A with B" subtest. This subtest distinguishes a reversible relationship between sentence constituents presented in a variety of word orders.

4.2.2. Design and Materials

The materials used in this study were adapted to standard European Spanish from the experiment presented in Chapter 2. They consisted of single sentences provided auditorily in combination with the presentation of two pictures on the screen. Each of the pictures depicted two people taking part in the performance of the same action, but with reverse Agent-Theme thematic roles (see **Figure 3.1** in Chapter 3). There were 126 trials consisting of 120 experimental items and 6 practice items.

4.2.2.1. Picture-matching task:

Linguistic stimuli:

The same twenty-two transitive verbs used in the original study (Arantzeta et al., 2016), as well as two animate singular DPs assigned to each verb were selected to create declarative sentences in the following structures (a) active; (b) passive; (c) subject relative; (d) object relative; (e) subject cleft; (f) object cleft. Subsequently, sentence conditions were clustered as Agent-Theme (A-T) and Theme-Agent (T-A) for data analysis. The Agent-Theme assignment in the DPs was randomized and balanced within the six conditions. That is, each DP was the Agent of the sentence in three out of six conditions. Regions of interest (ROIs) of the experimental stimuli were individually measured using the Computerized Language Analysis software (CLAN; MacWhinney, 2000). Unlike the original version in Basque (Arantzeta et al., 2016), the constituents of the sentences did not have the same length across experimental items. Nonetheless, t-test comparisons of ROI durations between paired conditions (i.e., active vs. passive, subject vs. object relative, subject vs. object cleft) showed no difference (see **Table 4.1**). This was essential for subsequent comparison of temporal data (i.e. gaze data) across paired conditions.

Table 4.1: Regions of Interest (ROI), duration (mean and SD) and comparison of length across paired conditions.

Paired conditions	**ROI (mean duration and SD)**					
	ROI 1 Argument 1 999 ms (46)		ROI 2 Verb 931 ms (12)		ROI 3 Argument 2 852 ms (30)	
	t	p	t	p	t	p
Active vs. Passive	0.945	0,350	-0.174	0,863	-1.376	0.177
Subj. vs. Obj. Relative	-0.221	0.826	-1.877	0.068	1.268	0.213
Subj. vs. Obj. Cleft	1.074	0,290	-0.397	0,693	0.366	0.716
A-T vs. T-A	-0.554	0.581	-0.027	0.177	0.077	0.939

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

In the linguistic stimuli the active sentences **(1)** were constructed with perfect present tense to keep the length of the verb as equal as possible with the counterpart passive sentences **(2)**. In the relative clauses the antecedent was always introduced by the verbal phrase “I see” and the relative pronoun “que” functioning as subject **(3)** or object **(4)**. In the cleft sentence constructions, the contrastive element became the complement of the copular verb “ser”, and the relativizer pronoun “que” introduced the rest of the sentence (5-6). In both object-cleft and object-relative constructions, the relative pronoun was preceded by the preposition “a”, as well as the direct object in the cleft constructions.

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

(2) 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.

(3) 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.

(4) Veo a la niña a la que peina la mujer
see prep det girl prep det pron-rel comb det woman
I see the girl who the woman combs.

(5) Es la mujer la que peina a la niña
be det woman det rel-pron comb prep det girl
It is the woman who combs the girl.

(6) 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.

A female native speaker of standard peninsular Spanish recorded the linguistic stimuli in a soundproof booth (IAC) using a digital microphone (audio-technica AT4022a). All sentences were recorded with a constant prosodic contour to avoid biased thematic role interpretations based on intonation (Ferreira, Anes, & Horine, 1996; Weber, Grice, & Crocker, 2006).

Visual stimuli:
The 88 black-and-white line drawings used by Arantzeta et al. (2016) were adapted to the current study. The drawings constituted 44 pairs, which were presented together divided by a black vertical line in the middle of the screen. The two pictures within each pair showed the same action with an Agent-Theme reversal. Each drawing measured approximately 15x15 cm. See Arantzeta et al. (2016) for detailed information on the visual stimuli and their corresponding normalization.

The presentation of the experimental items in the visual display (i.e. right vs. left) was pseudo-randomized. No more than two target stimuli could occur in a row on the same side of the screen. The direction in which the action was performed was also balanced across the stimuli to avoid rightward-inclined scanning (Scheepers and Crocker, 2004).

4.2.2.1. Confidence rating:

A three-interval confidence rating was used and visually represented by coloured emoticons. From right to left, a green smiley face, an amber neutral face and a red sad face were presented following a horizontal axis (see **Figure 4.1**). Each emoticon measured approximately 10x10 cm. The first (i.e., green smiley emoticon) and last (red sad emoticon) implied confidence of response to some degree, corresponding to "sure I answered correctly" and "sure I answered incorrectly", respectively. The middle response alternative (i.e., amber neutral) corresponded to having no knowledge to report the accuracy judgment, and it was defined as "I don´t know/guess".

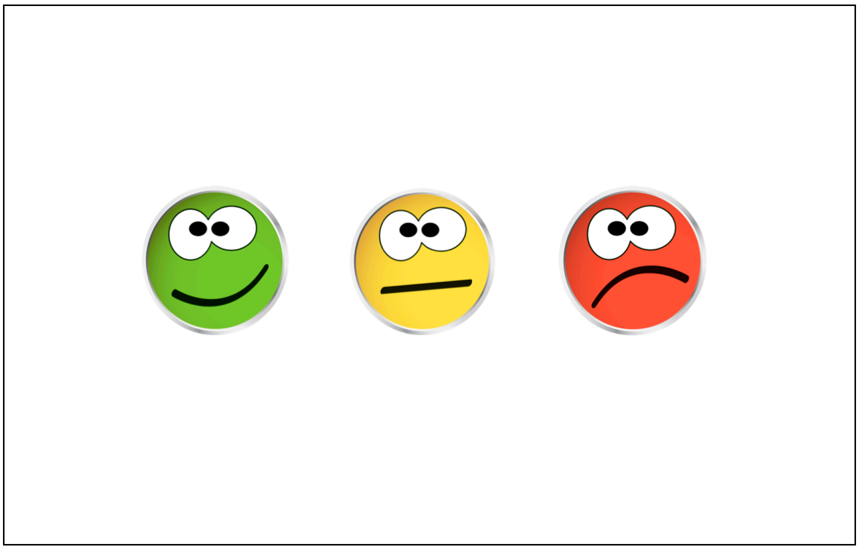

Fig. 4.1. Response grill used to self-report confidence rate on the accuracy of the sentence-picture matching task. The emoticons represented the next confidence rates: green smiley face= "sure I answered correctly"; amber neutral face= "I don´t know/guess"; red sad face= "sure I answered incorrectly".

4.2.3. Procedure

The experiment was programmed using E-Prime 2.0.10 with extensions for Tobii 2.0.2.41 (ClearView; Psychology Software Tools, Pittsburgh, PA). The visual stimulus was presented on a 23" wide screen LED monitor having 1280*720 resolution. The auditory stimuli were delivered binaurally through headphones. Participants were seated 60-70 cm from the screen, with a visual angle under 15° (max. Allow 35°), while their eye movements were captured using a Tobii 120 Desktop Eye Tracker (sampling rate 120 Hz, accuracy 0.5 degrees).

The presentation of the experimental stimuli was divided into four blocks of 30 items. Two blocks were administered in each of the two experimental sessions, after the presentation of six practice items. No more than two consecutive items corresponded to the same linguistic condition.

Prior to the start of the presentation of each block of stimuli, a 5-point calibration sequence was used to calibrate the eye-tracker to each subject. Subsequently, written instructions for the task appeared on the screen. The same instructions were also read aloud and verbally explained to all participants.

The experiment consisted of two consecutive tasks. In the primary task, the participants were asked to perform a picture-matching task, while in the secondary task they were asked to report the perceived correctness of their previous answer using a confidence rate. Trial-by-trial subjective measures were applied, since they have been proven to be more sensitive than post-task reports (Ziori and Dienes, 2006).

At the beginning of each trial, a fixation smiley face was centred in the screen. Participants had to fixate on the image for 250 ms before it was replaced by the display of a pair of pictures corresponding to the experimental stimuli. After 1000 ms of its previsualization, the auditory stimulus was presented. Participants were asked to select the picture that best depicted the auditorily presented sentence by pressing specific keys on the keyboard with the left hand[16]. Trials with no response within 8000 ms from the offset of the sentence were counted as having no response. When the decision was made, the second task was introduced. Participants were asked to make a confidence rating, as an assessment of the accuracy of their response on the previous task (i.e. picture-matching task). To this end, the three colour emoticons appeared on the screen and participants had to select the one that best represented their judgment. They were allowed to make their choice by pressing specific buttons on the keyboard or pointing directly on the screen. Confidence ratings provided by pointing directly on the screen were entered by the researcher using a second keyboard. The participants had a maximum of 12000 ms to answer. After this time, the confidence rating was registered as not being answered and the next trial was started. Trials answered before the onset of the auditory presentation (i.e., previsualization face) were excluded from subsequent data analysis, corresponding to the 0.25% of the total data, since they may correspond to accidental button press.

In both the first and second tasks, trials with no responses were excluded from further analysis, corresponding to 1.28 % and 0.58% of the total data, respectively. Fixations with durations less than 90ms were removed from the analysis to exclude ocular artefacts (e.g., blinks and saccades). We introduced a switch of 200 ms to correct for the time required for planning and executing an eye-movement, and thereby, to time align the gaze fixation data with the linguistic stimuli (Matin, Shao, & Boff, 1993).

4.3. Data analysis

In addition to descriptive statistics, we used regression analyses to examine the relationship between experimental variables and predictors. Different types of

[16] As an exception, a participant with crossed aphasia (A2) answered with the right-hand.

regression analyses were used depending on the type of dataset and the related research questions.

Comprehension accuracy data and post-hoc gaze data analysis were conducted using Generalized Linear Mixed-effects Models (GLMM) with logit function, and Linear Mixed-effects Models (LMM), respectively. As a statistical technique, (G)LMM combines fixed-effects terms (i.e., regression coefficients) and radom-effects terms. The former defines the expected values of the observations, while the latter introduces the variance and covariance of the observations of the subjects and linguistic stimuli (see Bates et al., 2005). Mixed models are resistant to the impact of outlying observations and missing data, common characteristics of small sample sizes and longitudinal data, respectively (see Verbeke and Molenberghs, 2000; Diggle, Heagerty, Liang, & Zeger, 2002). For a detailed description of GLMM and LMM techniques the reader is directed to McCulloch and Searle (2000).

Model building was conducted by progressively introducing radom-effects, fixed effects and corresponding interactions. Akaike's Information Criterion (AIC; Akaike, 1974) was used to measure the goodness of fit and compare models with each other. The model with the lowest AIC value was considered to fit significantly better only when the difference between the two AICs was equal to or higher than two. The numerical predictors Age and Trial number were centred. Least-square means (LSMeans) were used for comparing LS-mean differences on the basis of the mixed model.

Specific procedures were followed to test the zero-correlation and guessing criterions. Zero-correlation criterion was analyzed with simple Logistic Regression Models (LRM) fitted with a logit link function, in addition to the estimation of the area under the receiver operating characteristic (ROC) curve. The area under the curve (AUC) is a measure of the discrimination of the predictors, which ranges from 0.5 indicating random discriminative ability, to 1.0, indicating perfect discrimination. Thus, the area under the curve is the probability that participants correctly rate their accuracy. The ROC curve analysis has been widely used for diagnostic purposes (Zweig and Campbell, 1993; see Streiner and Cairney, 2007 for a review). The nonparametric approach of DeLong (DeLong, DeLong, & Clarke-Pearson, 1988) and bootstrapping methods were used to compare the AUCs between groups. In addition, the analysis was complemented with Spearman's correlation coefficient to measure the strength of the relationship between the objective accuracy and the subjective confidence rate provided by the participants.

The guessing criterion was examined using Linear Regression Models for binary data (i.e., GLMM), by comparing the linear predictor with zero. LSMeans (also called model-adjusted means) and 95% CIs were used for this purpose.

Tukey correction was used for multiple comparisons, and pairwise differences at $p<.05$ were considered significant, unless otherwise indicated. The statistical software R was used for this analysis (R Core Team, v.3.2.3.) with the next packages; lme4 (Bates et al., 2015), rms (Harrell, 2016), and pROC (Robin et al., 2011).

4.4. Results

4.4.1. Comprehension accuracy

Sentence conditions were clustered as Agent-Theme (A-T) and Theme-Agent (T-A). The former included active, subject cleft and subject relative conditions, while the latter included the counter pairs: passives, object clefts and object relatives.

PWA corrently comprehended 79% (Standard Error, SE= 1.42) of the sentences in A-T order and 65% (SE=1.67) of the sentences presented in T-A order. The NBD group performed at ceiling level, obtaining 96% (SE= 0.69) accuracy in A-T and 96% (SE= 0.64) accuracy in T-A argument orders. Detailed statistics on sentence comprehension scores by argument orders are presented in **Table 4.2**. (See **Appendix B5** for individual participants' scores).

Table 4.2. Comprehension accuracy (%) and standard error (SE) as a function of group and sentence condition.

Group	Condition					
	Agent-Theme			Theme-Agent		
	Active	**Subj. Cleft**	**Subj. Rel.**	**Passive**	**Obj. Cleft**	**Obj. Rel**
PWA	81.88%	79.92%	74.81%	74.34%	60.44%	61.62%
	(2.32)	(2.44)	(2.60)	(2.66)	(2.99)	(2.95)
NBD	98.17%	96.05%	93.18%	97.45%	96.78%	95.00%
	(0.80)	(1.16)	(1.51)	(0.95)	(1.05)	(1.30)

PWA= people with aphasia; NBD= non-brain-damaged

The final GLMM obtained for the accuracy data consisted of a three-way interaction for group, argument order and trial number, and stimuli and subject variables as radom-effects.

The PWA performed significantly poorer than the NBD across both A-T (ß= -2.029; SE= 0.324; p=<.0001) and T-A (ß= -2.703; SE= 0.305; p=<.0001) argument orders. The PWA comprehended sentences presented in A-T better than T-A argument order (ß=0.754; SE= 0.120; p= <.0001), while the people with NBD showed no effect regarding word order (ß= 0.080; SE= 0.277; p= 0.7728). In addition, there was an interaction between group, argument order and trial number (i.e., position of the presentation of a given trial in relation to the others). The NBD participants became more accurate in the sentence picture matching task across the course of the experiment, but this improvement was restricted to sentences presented in A-T argument order (A-T; ß=-2.43; SE= 0.704; p= 0.0006. T-A; ß= -0.736; SE= 0.701; p= 0.2942). The PWA did not show any effect of trial number across any of the argument orders (A-T; ß= -0.414; SE= 0.343; p= 0.2278. T-A; ß= -0.327; SE= 0.330; p= 0.3229).

4.4.2. Confidence ratings

Participants expressed their confidence about the correctness of their answer in the sentence-picture matching task by choosing within three options. The distribution of the confidence rates is presented in **Table 4.3**, separately for correctly and incorrectly comprehended trials. See **Figure 4.2** for an overall distribution of responses in each group.

Table 4.3: Distribution of confidence ratings on comprehension accuracy in the primary task (i.e., sentence-picture matching task) as a function of response accuracy and group.

Response accuracy:	**PWA**			**NBD**		
	1	**2**	**3**	**1**	**2**	**3**
Correct answers	90.44%	5.71%	3.83%	98.37%	1.43%	0.18%
	(n=1060)	(n=67)	(n=45)	(n=1576)	(n=23)	(n=3)
Incorrect answers	77.60%	9.53%	12.86%	49.23%	15.38%	35.38%
	(n=350)	(n=43)	(n=58)	(n=32)	(n=10)	(n=23)

PWA= people with aphasia; NBD= non-brain-damaged; 1= "sure I answered correctly"; 2= "I don´t know/guess"; 3= "sure I answered incorrectly".

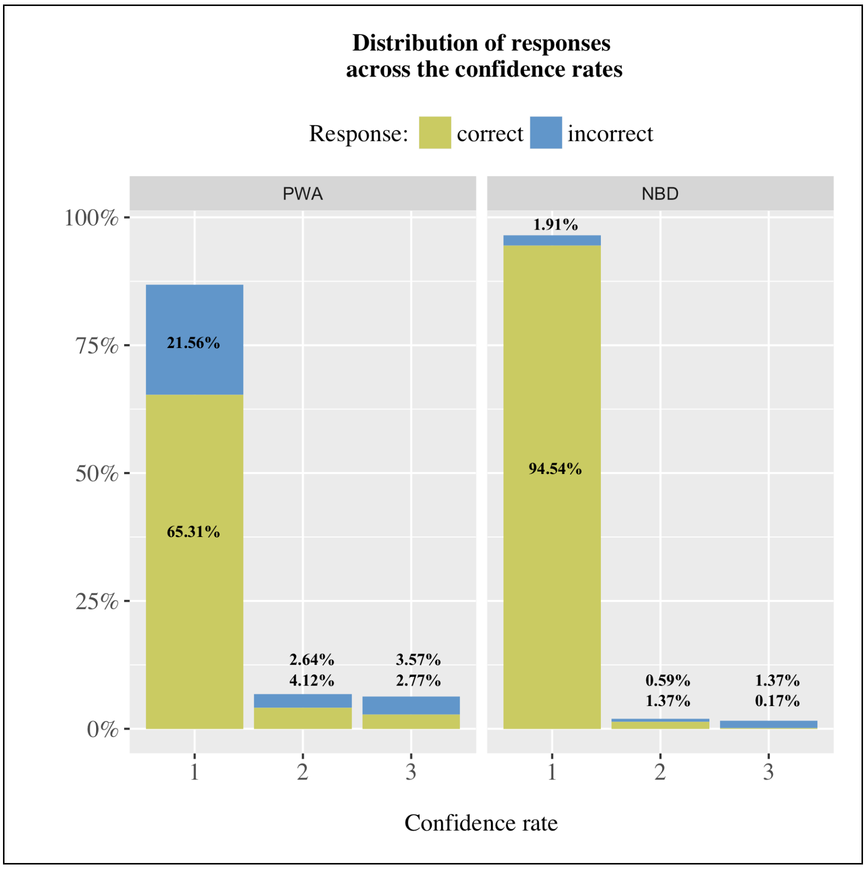

Fig. 4.2. Distribution (%) of the self-reported judgment of the sentence-picture matching task as a function of response accuracy in both NBD and PWA groups. Confidence rate 1= "sure I answered correctly", 2= "I do not know, guessing", 3= "sure I answered incorrectly". NBD= non-brain-damaged; PWA= people with aphasia.

4.4.3. Zero-correlation criterion

Data were arrayed into correct/incorrect judgments (i.e., binary data) for clarification, as provided in **Table 4.4**. Correct judgments refer to the instances in which participants reported as correct the trials answered correctly and reported as incorrect the trials answered incorrectly. Thus, regardless of the accuracy of their response in the primary task (i.e., sentence-picture matching task), participants made a correct judgment of their performance. Incorrect judgments refer to the cases in which participants' subjective self-report (i.e., confidence rating) did not match with the correctness of their answer in the sentence-picture matching task.

Table 4.4: Proportion of correct and incorrect judgments over the trials in which participants expressed themselves as being sure about their answer on the confidence rate (i.e., "sure I answered correctly" and "sure I answered incorrectly"). Calculations across groups and, correctly and incorrectly answered trials.

Response accuracy:	**PWA**		**NBD**	
	C. judgment	**I. judgment**	**C. judgment**	**I. judgment**
Overall	73.89%	26.10%	97.85%	2.14%
Correct answer	95.92% (n=1060)	4.07% (n=45)	99.81% (n=1576)	0.18% (n=3)
Incorrect answer	14.21% (n=58)	85.78% (n=350)	41.81% (n=23)	58.18% (n=32)

PWA= people with aphasia; NBD= non-brain-damaged; C. judgment= correct judgment; I. judgment= incorrect judgment.

Simple Logistic Regression Model (LRM) analysis was conducted to explore the relationship between the outcome of sentence comprehension accuracy and the confidence rating provided by the participants. Separate logit models were fitted for each group of participants. ROC analysis considered together the sensitivity (percentage of correctly identified incorrect answers) and the specificity (percentage of incorrectly identified correct answers) across a range of values for the ability to predict the sentence accuracy outcome. The results are illustrated in **Figure 4.3**. The area under the curve (AUC) for the confidence rating that perfectly predicts comprehension accuracy would be 1. In our sample data, the confidence rating had an AUC of 0.56 (95% CI: 0.54-0.58) in the PWA group, just better than random (i.e., 0.50), while the group with NBD had an AUC of 0.74 (95% CI: 0.68-0.81). A comparison of AUCs conducted by DeLong's method uncovered significant differences between the groups (p=<.0001), which was confirmed by bootstrapping analysis (100,000 samples; p= <.0001). Spearman's correlation coefficient between comprehension accuracy and confidence rating was 0.1747 in the PWA group and 0.5175 in the NBD group. The former corresponded to a very weak effect size, while the latter was moderate.

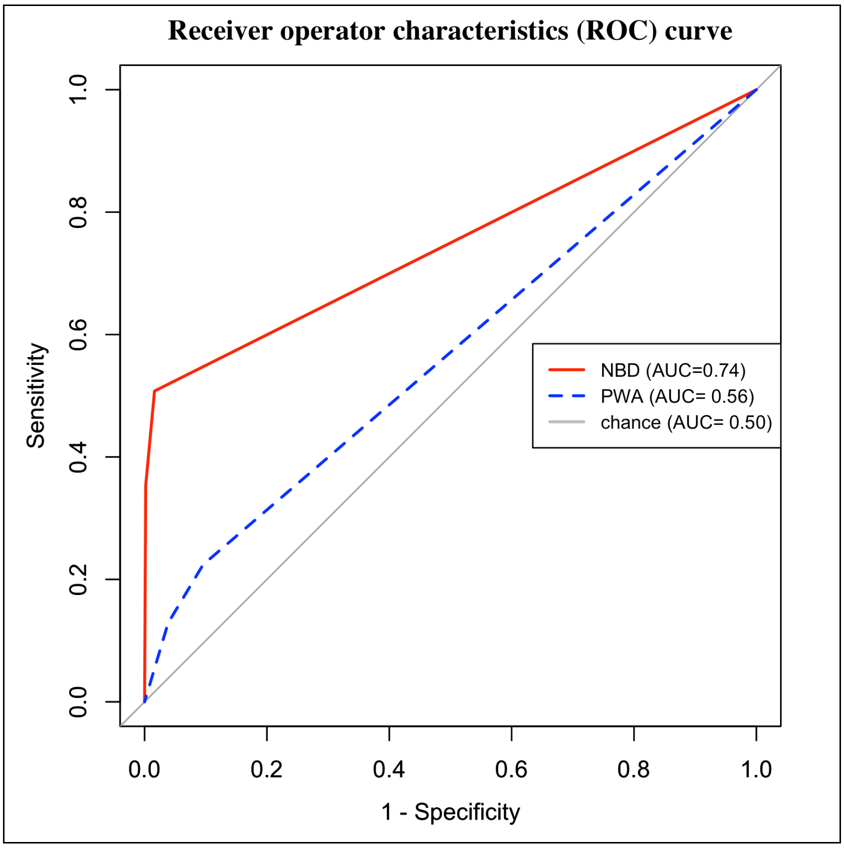

Fig. 4.3: Predicted probability of the confidence rating on the comprehension accuracy, illustrated by the sensibility (i.e., true positive rate) against 1-Specificity (i.e., false positive rate). NBD= non-brain-damaged; PWA= people with aphasia. The area under the ROC curve (AUC) is a measure of how well confidence ratings can distinguish between correctly and incorrectly answered trials.

4.4.4. Guessing-criterion

The proportion and distribution of the instances in which participants reported having guessed are presented in the contingency table in **Table 4.5**. Participants in this study seldom reported they were guessing. Nonetheless, when both PWA and people with NBD reported answering randomly, without enough information, the response accuracy was above the chance baseline (i.e., 50%).

Table 4.5: Distribution of the instances in which participants declared themselves to be guessing, across correctly and incorrectly answered trials in both PWA and NBD groups.

Response accuracy:	PWA		NBD	
	Num. trials (n=110)	%	Num. trials (n=33)	%
Correct answer	67	60.90%	23	69.69%
Incorrect answer	43	39.09%	10	30.30%

PWA= people with aphasia; NBD= non-brain-damaged.

The empirical model consisted of a two-way interaction between the group and confidence rating and a two-way interaction between group and argument order, in addition to radom-effects for subject and stimulus. A nested radom-effect was included to account for the effect of sentence condition and argument order in each stimulus and subject, respectively.

The guessing criterion was studied by comparing the linear predictor with zero. The regression intercept was significantly positive in PWA (LSMean= 0.640; SE= 0.305; 95% CI= 0.04-1.23; t(109)= 2.098; p= 0.0382) and those with NBD (LSMean= 1.254; SE= 0.490; 95% CI= 0.29-2.21: t(32)= 2.557; p= 0.0155), indicating above-chance accuracy. The same analysis was conducted separately as a function of argument order, as illustrated in **Figure 4.4**. In the PWA group, the lower limit of the 95% CI was significantly positive in sentences presented in A-T argument order (LSMean= 1.085; SE= 0.336; 95% CI= 0.42-1.74; t(44)= 2.339; p= 0.0239), but not in sentences presented in T-A argument order (LSMean= 0.196; SE= 0.325; 95% CI= -0.44-0.833; t(64)= 0.605; p= 0.5469). In the group of people with NBD, the intercept was significantly positive across sentence presented in A-T argument order (LSMean= 1.150; SE= 0.532; 95% CI= 0.10-2.19; t(14)= 2.16; p= 0.0486), as well as in T-A argument order (LSMean= 1.358; SE= 0.526; 95% CI= 0.32-2.39; t(17)= 2.579; p= 0.0195).

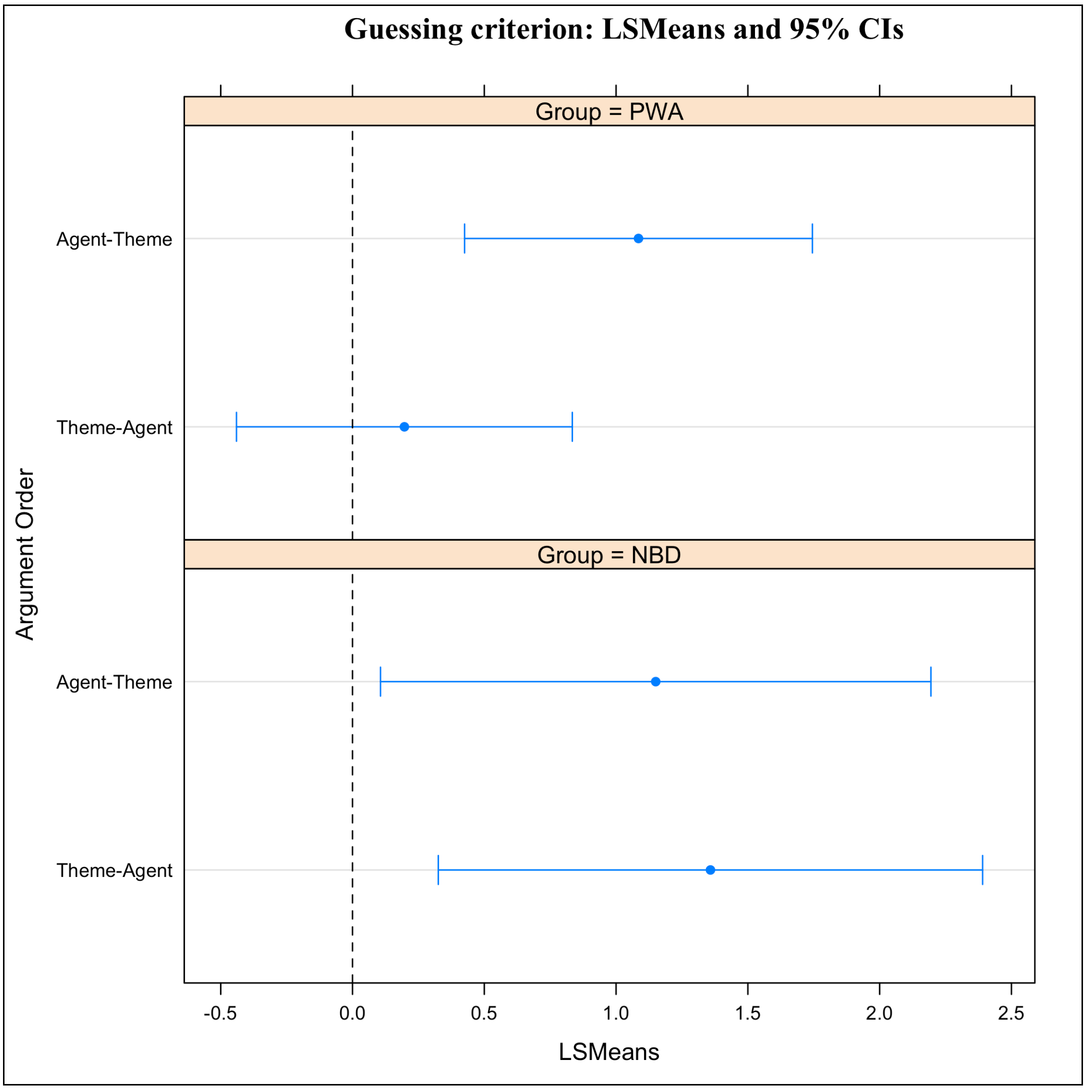

Fig. 4.4. Illustration of the least-square means (LSMeans) and 95% confidence intervals across groups and argument orders in trials where participants declared themselves to be answering by guessing. PWA= people with aphasia; NBD= non-brain-damaged.

4.4.5. Gaze data analysis

The difference in the proportion of fixations between the target and foil pictures was computed across different temporal Regions Of Interest (ROIs). ROIs 1, 2 and 3 corresponded to the presentation of the first, second and third constituents of the sentence. In addition, a post-offset ROI 4 with a duration of 1120 ms was included in the data analysis to account for gaze fixation following the end of the auditory presentation of the stimuli. As detailed in **Table 4.1**, the duration of the ROIs did not differ across pairs of sentence conditions, nor across A-T and T-A argument orders. This property of the experimental design provided the possibility to merge the gaze data across sentence conditions to gain statistical power to analyse the effect of response accuracy and confidence rate in real time sentence processing. Missing gaze data were imputed in the trials answered before the offset of ROI4 (i.e. mean RT<3902 ms) based on the accuracy of the response.

Post-hoc analysis of the gaze data was conducted exclusively on the PWA, since the accuracy and confidence rating data were almost completely confounded in the NBD group, as shown in **Table 4.3**. The empirical model consisted of a three-way interaction between the response accuracy, ROI and confidence rating, in addition to radom-effects for subject and stimulus. A Bonferroni procedure was used to control the error rate in testing multiple comparisons. The adjustment was applied, dividing the p level by the number of levels of the confidence rating (i.e., 3). Thus, an α level of 0.016 was used.

The interaction between the independent variables is illustrated in **Figure 4.5**. Note that in all of the sentences, the target picture could in principle be determined on the basis of the first constituent (i.e, ROI 1) in subject/object cleft structures, and on the basis of the second constituent (i.e., ROI 2) in the rest of the sentence conditions. In line with previous studies, gaze fixation patterns along the visual display differed depending on the correctness of the answer from ROI 2 (see Arantzeta et al., 2016; Hanne et al., 2011). In correctly comprehended sentences, PWA showed an incremental proportion of fixations towards the target picture through the presentation of the sentence, while in the incorrectly answered trials PWA showed the opposite pattern. In addition to this, in the current study the confidence rating uncovered a distinctive gaze fixation pattern as a function of response accuracy.

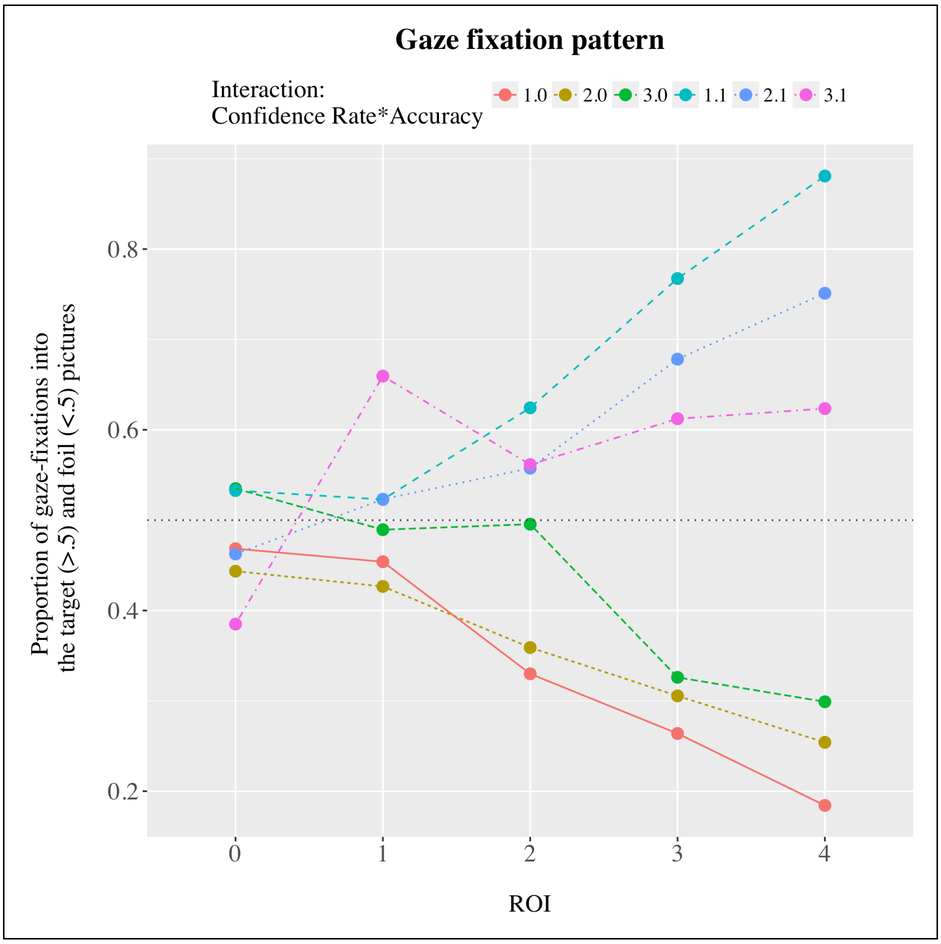

Fig. 4.5. Fixation pattern of PWA across the visual display along the presentation of the auditory stimuli. The gaze data is presented as a function of confidence rate (1,2,3) and accuracy (0,1). Confidence rate, 1= "sure I answered correctly", 2= "*I do not know, guessing*", 3= "sure I answered incorrectly". Accuracy, 0= incorrectly answered trials; 1= correctly answered trials.

The following results are based on gaze fixation differences along the visual display during the presentation of the linguistic stimuli as a whole. A detailed comparison of gaze data along specific ROIs is available in **Table 4.6**. In the correctly answered trials, the gaze fixation pattern for sentences that PWA reported to have answered correctly (i.e., confidence rating (CR)= 1) and sentences that PWA reported to have answered incorrectly (i.e., CR= 3) were distinctive (ß=0.084; SE= 0.030; p= 0.0060). Trials rated with CR= 1 (i.e., "sure I answered correctly") also corresponded to a different fixation pattern compared to trials in which PWA reported to answer by guessing (i.e., CR= 2) (ß=0.071; SE= 0.024; p= 0.0033). Nonetheless, the fixation pattern of the latter was indistinguishable from incorrectly judged trials (i.e., CR= 3) (ß=0.013; SE= 0.038; p= 0.7305). In the incorrectly answered trials, gaze fixation pattern was significantly different between trials rated as correctly understood (i.e., CR= 1) and trials rated as incorrectly understood (i.e., CR= 3) by PWA (ß=-0.93; SE= 0.028; p= 0.0008). There was no difference in the fixation patterns of the trials where PWA declared themselves to have guessed (i.e., CR= 2) versus trials answered with certainty (perceived as correct; ß=-0.027; SE= 0.031; p= 0.3847; perceived as incorrect; ß=-0.066; SE= 0.039; p= 0.0959).

Gaze fixation patterns for correctly and incorrectly answered trials were more-or-less mirror images. The data suggest that regardless of whether PWA answered correctly or not, when they were confident about the correctness of their answer (i.e., “sure I answered correctly”), they usually looked towards the target or foil picture from ROI 2. As soon as they were provided with an information cue that might guide thematic role parsing, they chose an interpretation and stayed with it. There is no indication that PWA doubt their choice when they get to the trace position.

Table 4.6: Comparison of gaze data per each ROI across the confidence rates provided by the PWA group.

	β	SE	z-ratio	p	β	SE	z-ratio	p
Correct answers:								
C.R.			**ROI1**			**ROI2**		
1-2	-0.000	0.048	-0.013	0.9897	0.066	0.048	1.366	0.1719
1-3	-0.137	0.061	-2.238	0.0252	0.062	0.061	1.020	0.3074
2-3	-0.136	0.076	-1.792	0.0732	-0.003	0.076	-0.051	0.9596
C.R.			**ROI3**			**ROI4**		
1-2	0.088	0.048	1.841	0.0656	0.1293	0.047	2.696	**0.0070**
1-3	0.154	0.061	2.520	**0.0117**	0.2567	0.060	4.236	**<.0001**
2-3	0.065	0.076	0.861	0.3895	0.1274	0.075	1.688	0.0914
Incorrect answers:								
C.R.			**ROI1**			**ROI2**		
1-2	0.028	0.064	0.437	0.6618	-0.028	0.063	-0.446	0.6550
1-3	-0.034	0.055	-0.626	0.5310	-0.165	0.056	-2.940	**0.0033**
2-3	-0.062	0.079	-0.787	0.4307	-0.136	0.079	-1.716	0.0862
C.R.			**ROI3**			**ROI4**		
1-2	-0.040	0.062	-0.649	0.5161	-0.069	0.062	-1.103	0.2700
1-3	-0.061	0.056	-1.099	0.2718	-0.114	0.056	-2.017	0.0437
2-3	-0.020	0.079	-0.264	0.7918	-0.044	0.079	-0.564	0.5726

C.R.= Confidence rate; 1= "sure I answered correctly"; 2= "I don´t know/guess"; 3= "sure I answered incorrectly". ROI= Region Of Interest; ROI 1= first constituent of the sentence; ROI 2= second constituent of the sentence; ROI 3= Third constituent of the sentence; ROI 4= Post-offset region; Significance level p<.016

We have analysed a group of PWA and NBD performing a sentence-picture matching task followed by a confidence rating. The accuracy data show that PWA were more likely to be correct in understanding sentences presented in A-T than in T-A argument order. NBD showed ceiling accuracy across all argument orders. The analysis of the response accuracy and confidence rating has shown that PWA tend to judge as correct both correctly and incorrectly comprehended trials; they were sure that they were correct on 90% of correct responses and 78% of incorrect responses. That is, PWA have shown little awareness of their comprehension errors. Confidence rating was a very weak predictor of comprehension accuracy in PWA; it was worse than in the NBD group. Both PWA and NBD participants reported guessing in a small number of cases (6.8% and 2.0% of trials, respectively). In terms of the guessing criterion, when participants reported that they were guessing, the comprehension accuracy was above chance in both PWA and NBD groups. This pattern was not consistent in sentences presented in T-A order to the PWA group. Post-hoc analysis showed that both response accuracy and confidence rating were significant predictors of the gaze fixation data. Participants showed distinct fixation patterns depending on the confidence rating subsequently given to the trial.

4.5. Discussion

The questions addressed in this study are: a) Are PWA aware of their sentence comprehension errors?; b) Is sentence comprehension performance unconsciously mediated in PWA and NBD?; and c) Do PWA guess in the comprehension of sentences with derived word orders?. In addition, we conducted a gaze data analysis to explore the relationship between real time sentence processing and the metacognitive awareness reported by PWA. This section will initially discuss sentence comprehension accuracy data to contextualize the subsequent discussion.

As expected, PWA taking part in this study performed worse than NBD in the sentence comprehension task. PWA comprehended sentences with a linear A-T order, better than the derived T-A order. The NBD group comprehended sentences in both A-T and T-A argument orders equally well. Altogether, the present findings converge with those of Chapter 2, whose linguistic and visual materials were adapted for the present study, as well as with previous studies involving Spanish speakers with aphasia (Juncós-Rabadán et al., 2009), and other languages (Swahili, Abuom, Shah, and Bastiaanse, 2013; German, Burchert et al., 2003; Turkish, Duman, Altinok, Özgirgin, & Bastiaanse, 2011; Italian, Garraffa and Grillo, 2008; English, Meyer et al., 2012; Schwartz et al., 1980; cf. in Indonesian, Jap, Martínez-Ferreiro, & Bastiaanse, 2016).

Metacognitive awareness of sentence comprehension accuracy differed significantly between correct and incorrect responses. In the former, both NBD and PWA usually made a correct judgment of their answer. That is, they perceived as correct the trials answered correctly. PWA frequently rated incorrect trials as correct. They failed to detect the error (i.e., false negative detection). Hence, PWA were generally not aware of their sentence comprehension difficulties. NBD made few comprehension errors, but similarly only a reduced part of these errors were correctly rated (i.e., 35% of the incorrectly answered trials). This indicates that not even NBD participants are always aware of comprehension failure, suggesting that it is not only the neurological injury in PWA that is impacting awareness of error. This is a potentially interesting experimental question, but it is beyond the immediate scope of this study.

4.5.1. Zero-correlation criterion

Following Dienes et al. (1995), the degree of correspondence between the accuracy and the confidence rating was used to assess the conscious versus unconscious threshold in sentence comprehension. The consistency between the measures varied across the two groups, suggesting that the extent to which sentence comprehension is mediated by conscious knowledge varies as a consequence of neurological injury. In the PWA group, the strength of the subjective perception (i.e., confidence ratings) in predicting the comprehension accuracy was slightly above chance, while in the NBD it was significantly larger, although not perfect. This result was confirmed by a very low correlation between the accuracy and confidence rating measures in the PWA group, and a moderate correlation in the NBD group.

The results suggest that PWA and NBD do not share the same consciousness threshold in sentence processing. In the PWA group, sentence comprehension is mainly mediated by unconscious knowledge, suggesting little voluntary control (i.e., dominance of automatic control). Consequently, PWA do not consciously perceive failure in the parsing routine. In contrast, in the NBD group, a moderate relationship between accuracy and confidence rating suggests that conscious and unconscious knowledge equally interplay in sentence processing. Thus, voluntary and automatic control appear to function together in thematic-role mapping in NBD, who appear to self-monitor, contrary to PWA. Note that the lack of control shown in the PWA group cannot be explained by practice (Shiffrin and Schneider, 1977; Langer and Imber, 1979), since agent-first heuristics have also been proven to be deployed in healthy speakers (Bornkessel-Schlesewsky and Schlesewsky, 2013; Ferreira and Patson, 2007; van Herten et al., 2006). Still, NBD show a moderate-good perception of the parsing mechanism, and reanalyze the sentence based on analytical routines (i.e., by processing morphological cues) when the use of heuristics fails to correctly interpret the sentence. It is not clear whether PWA do not perceive the need to reanalyze or whether the impairment lies in the reanalysis process *per se*. We first need to introduce the guessing-criterion to address this question.

4.5.2. Guessing-criterion

The analysis of the instances in which participants said they were guessing uncovered two main things. First, both PWA and NBD rarely reported that their answer in the comprehension task was based on uncertainty. This finding does not support the TDH (TDH; Grodzinsky, 1986, 1995, 2000; see Drai and Grodzinsky, 2006ab for a later revision), which states that PWA choose randomly when thematic roles need to be assigned in non-linear order. In contrast to the predictions of the TDH, PWA nearly always tended to provide confidence rates (correct or incorrectly) based on certainty (i.e., "sure I answered right/wrong") – they did not report they were guessing. Second, according to the guessing-criterion (Dienes et al., 1995), the two groups performed above baseline in the trials in which they said they had guessed, indicating unconscious knowledge of sentence processing. This effect was found in the NBD group across all argument orders and in the PWA group in sentences presented in A-T order. It suggests that PWA lack the required unconscious knowledge, or access to it, to guide the processing of sentences presented in T-A argument order.

Taken together, the data demonstrate that PWA show reduced metacognitive awareness of sentence processing, and hence little voluntary control over their assignment of thematic roles. Overall, there is no evidence that PWA use internal compensatory strategies to overcome their comprehension difficulties, as proposed for other linguistic domains; for example, word retrieval (see Tompkins et al. 2006) or conversational efficiency (Beeke et al., 2009). Thus, the data show that PWA do not systematically overuse an explicit (i.e., conscious) strategy such as agent-first heuristics to disentangle thematic roles to a higher degree than NBD, as the best probabilistic guess to reach the correct interpretation of the sentences. Indeed, the data show that PWA are mostly unaware of their comprehension failures.

4.5.3. Gaze fixation data

Gaze fixation data were collected as a measure of online language processing to get insight into the parsing routines in Spanish speakers with aphasia and corresponding NBD participants. In line with previous findings (Arantzeta et al., 2016; Dickey et al., 2007; Hanne et al., 2011), the gaze data show that sentence comprehension accuracy in PWA was underlined by distinctive parsing routines. Correctly and incorrectly answered sentences corresponded to distinctive fixation patterns along the visual display. Gaze data analysis showed that the confidence rating provided by the participants trial-by-trial was a significant predictor of the gaze fixation pattern. PWA showed different gaze fixation proportions to the target and foil pictures in correctly and incorrectly judged trials. Trials answered by guessing consistently showed a midpoint in the proportion of fixations into the target/foil picture in relation to correctly and incorrectly judged trials.

The data suggest that there is a relationship between real time sentence processing and the subjective perception of correctness in sentence comprehension. Nonetheless, it is not possible to identify the causal direction of this relationship. That is, we do not know whether the gaze fixations have an effect on the subsequent individual perception of the correctness of the answer, or whether different parsing routines, corresponding to different degrees of confidence, are reflected distinctively in the gaze data of PWA. So far, the data show that confidence ratings are a sensitive measure of metacognitive awareness.

4.5.4. Error awareness and revision of parsing routines

So far, we have shown that PWA have little conscious knowledge of sentence processing, and probably, therefore, reduced voluntary control of thematic role assignment. For NBD both conscious and unconscious knowledge interplay in the parsing routines, as indicated by a moderate relationship between sentence accuracy and confidence ratings. It suggests that a degree of self-monitoring is crucial in sentence processing. These findings are compatible with the perceptual loop theory (Levelt, 1989; 2001), which states that the comprehension system regulates the internal speech as well as the self-produced overt speech. Thus, deficits in the perceptual feedback loop are responsible for the misdetection of speech errors. PWA analyzed in the current study were characterized by having agrammatic language. Thus, the perceptual loop theory would predict that the impaired feedback system would provide PWA with deficits in language comprehension monitoring.

Language monitoring is involved in repair and reanalysis when the linear Agent-Theme thematic role assignment (perhaps determined by an agent-first heuristic) does not guide the correct interpretation of the sentence. In PWA, the reduced metacognitive awareness (i.e., conscious knowledge) shown in the current study might be related to the inability to perceive the need for revision. Both the behavioral and the gaze data partially converge with the "deterministic parsing" suggested by Hanne et al. (2011), and support the view that PWA adopt either a canonical or a non-canonical sequence of thematic-role assignment from early on during the presentation of the sentence[17]. Nevertheless, contrary to Hanne et al. (2011), we have no evidence that PWA are occasionally aware of the need for revision, but fail to backtrack. Rather, we argue that PWA do not perceive the need to revise the initial parsing. We will defend this interpretation from two different perspectives.

First, PWA showed a tendency to look at either the target or foil picture from the presentation of the verb, while progressively increasing the proportion of fixations towards the selected picture. Contrary to Hanne et al. (2011), but in line with our previous findings in Basque speakers with aphasia (Chapter 2) and Spanish speakers with aphasia (Chapter 3), PWA did not shift fixations to the counterpart picture at any point of the presentation of the sentence. Based on the gaze fixation data, they did not show any attempt to revise the initial parsing routine.

Second, in healthy speakers, the psychological experience of revising the parsing routine is sometimes conducted by conscious problem-solving mechanisms (see Townsend and Bever, 2001). The heavy processing costs of certain constructions require increased conscious attention. If we consider the diminished cognitive processing abilities reported for PWA (Caplan et al. 2007; Kolk, 1993; Miyake et al., 1994), we expect that their conscious threshold in revising routines is significantly lower than in healthy controls. The need to revise parsing routines, and eventually their failure, might be available to conscious knowledge in sentence constructions that healthy speakers can revise unconsciously. PWA may feel the need to reanalyze when their initial parsing routine does not match with the presence/absence of the accusative

[17] This pattern fits with task-specific demands and their influence on sentence comprehension accuracy in PWA, as described by the across-task analysis of Caplan, Michaud, & Hufford (2013). As opposed to other tasks such as self-paced listening (Caplan & Waters, 2003; Caplan et al., 2013) or classical visual word paradigms (Dickey et al., 2007; Meyer et al., 2012) in sentence-picture matching tasks the scenes of the full representation of the oncoming linguistic stimuli are presented slightly before or at the same time as the linguistic stimuli. This may influence listeners to make an early commitment to interpret the sentence according to one or other visual representation, likely due to processing resource reduction (see Caplan et al., 2013)

preposition or verbal morphology. However, if they failed to revise, we expect them to have an intuitive judgment of processing difficulty (i.e., "not sure/guess"). On the contrary, PWA in our study seldom reported uncertainty in the sentence comprehension task, but incorrectly judged the incorrectly comprehended sentences (i.e., false negative detection). Altogether, these data suggest that PWA chose to parse the sentences following either linear or non-linear thematic role assignment essentially from the first thematic role determining component. They do not revise the parsing routine when it results in incorrect interpretation of the sentence. There is no evidence to suggest that PWA have a specific difficulty in reanalysis processes *per se*. Instead, data advocate that PWA do not perceive the need to revise the parsing routine in the absence of self-monitoring abilities.

A potential way to shed light on this debate would be to test the processing of fully ambiguous sentences presented auditorily, similar to the ones used by Erdocia et al. (2009) in Basque. Providing PWA with the option to match a fully ambiguous sentence with one and/or other visual representation of the stimuli would assess their ability to parse the sentence following a canonical or non-canonical template, as well as their ability to revise their initial parsing routine.

4.6. Conclusions

The study of metacognitive awareness, and hence consciousness has been widely neglected in aphasiology research regarding comprehension deficits. The current study introduced behavioral and online methods in consciousness research of PWA to get insight into the extent to which the participants' responses are mediated by conscious versus unconscious knowledge.

We aimed to investigate whether PWA consciously used compensatory strategies as agent-first heuristics, as the best probabilistic guess to overcome their limitation in the comprehension of semantically reversible sentences in non-canonical word orders. The study was conducted with a group of PWA and NBD speakers of Spanish; a language that allows a relatively flexible word order in sentential structures. Participants performed a sentence-picture matching task of sentences presented in linear (i.e., A-T) and derived (T-A) argument order, followed by a subjective rating of their awareness of the accuracy in the primary task. As expected, PWA comprehended significantly less well than NBD across all argument orders (i.e., A-T and T-A). Moreover, PWA were more impaired in their comprehension of sentences with a derived T-A argument order.

The relationship between comprehension accuracy and confidence rating was studied to get insight into the degree to which sentence processing was unconsciously mediated (i.e., zero-correlation criterion; Dienes et al., 1995). In the PWA group, the confidence rating was a very poor predictor of sentence comprehension accuracy, indicating reduced metacognitive awareness of comprehension failure. In contrast, confidence rating was a moderate-good predictor in the NBD group. Regarding the guessing-criterion (Dienes et al., 1995), PWA had above-chance performance in the comprehension of sentences presented in A-T order, even when they claimed to be guessing, but not in sentences presentenced in T-A order. This suggests that unlike NBD participants, PWA do not show signs of the implicit knowledge required for correct thematic role assignment. Note that participants believed themselves to be guessing in very few responses. On the one hand, this indicates that cautious interpretation of the guessing criterion is needed. On the other hand, the pattern of responses is not compatible with the predictions of the TDH (Grodzinsky, 1986, 1995, 2000; see Drai & Grodzinsky, 2006ab for a later revision), which claims that PWA answer by guessing when confronted with reversible sentences in non-canonical word orders. By replicating previous findings (Arantzeta et al., 2016, in Chapter 2; Hanne et al., 2011), gaze data analysis also contradicts this by showing that gaze fixation patterns diverge between correctly and incorrectly comprehended trials and the divergence starts at the first constituent to which a thematic role can be assigned. That is, PWA assign the role of either agent or theme to the first possible constituent, and (mostly, although not always) proceed on that basis.

In addition, gaze analysis showed that PWA look at the visual stimuli in a distinctive way depending on the confidence with which the trials were rated. Although the causal direction of this relationship cannot be determined in the current study, it demonstrates the validity of confidence rating for obtaining insight into unconscious processes in PWA.

In summary, PWA showed anosognosic behavior towards sentence comprehension deficits, even when they were aware of their aphasic condition. These results converge with previous studies in jargon aphasia (see Rubens and Garret, 1991). The lack of conscious cognition, which is strongly linked with voluntary control, does not suggest that they use compensatory strategies to overcome their comprehension difficulties. Thus, awareness cannot be taken as a self-regulatory mechanism for therapeutic applications in PWA, as suggested for healthy individuals (Koriat, 2000). We have speculated that the lack of conscious control might be congruent with the inhibition problems suggested by some authors to understand sentence comprehension deficits in PWA (Dickey et al., 2007; Hanne et al., 2011). Further research is required to determine the relationship between executive functions in relation to sentence comprehension deficits in PWA.

CHAPTER 5

General discussion

The goal of this dissertation was to study the effect of word order on sentence processing in people with agrammatic aphasia (PWA) and non-brain-damaged participants (NBD) who are speakers of Basque and/or Spanish. In the last three chapters, a series of experiments has been presented on a) sentence comprehension deficits in a free word order language (Basque); b) cross-linguistic transferability of sentence parsing mechanisms in bilingual speakers; c) potential bilingual advantage in sentence comprehension abilities due to the enhancement of executive functions; d) self-monitoring abilities, and consequently, error awareness in sentence comprehension. All experiments have combined off-line (i.e., accuracy) and online (reaction time and gaze fixation) data to shed light on the underlying processes guiding sentence comprehension and its occasional failure. Experiments in both Basque and Spanish have shown that word order strongly affects sentence comprehension abilities in PWA, and occasionally also in NBD. Cross-linguistic differences have been shown to be explanatory of sentence comprehension performance, but not bilingualism. In addition, we have provided evidence that PWA are not aware of their sentence comprehension errors. In this chapter, we re-visit the research questions raised across each experimental chapter to discuss the findings and their implications.

5.1. Research questions addressed in this dissertation

The following six research questions have been addressed in the three experimental chapters presented in this dissertation:

i. Which theoretical account (TDH vs. DOP-H) predicts the sentence comprehension deficits in PWA speakers of a free word order language, such as Basque?

ii. What is the influence of different types of morphological markers (i.e., preposition vs. case-marking) on sentence comprehension deficits in PWA?
iii. Do Basque-Spanish bilingual speakers with aphasia and unimpaired non-brain-damaged speakers perform differently from Spanish monolingual speakers in a sentence comprehension test in Spanish?
iv. Are PWA aware of their sentence comprehension errors?
v. Is sentence comprehension performance unconsciously mediated in PWA and NBD?
vi. To what extent do PWA answer by guessing when comprehending sentences with derived word order?

The accompanying sections introduce the fundamental conclusions drawn from the studies that constitute this dissertation, as well as directions for further research.

5.2. General conclusions

5.2.1. Sentence comprehension deficits in a free word order language: The case of Basque

It is widely accepted in the literature that semantically reversible sentences in which the arguments are in derived order are particularly impaired in PWA, even when they have preserved lexical comprehension (e.g., Bastiaanse & Edwards, 2004; Bastiaanse & Van Zonneveld, 2006; Berndt, Mitchum, Haendiges, 1996; Burchert, De Bleser & Sonntag, 2003; Caplan & Futter, 1986; Caplan & Hildebrandt, 1988; Schumacher et al., 2015). However, it is not clear whether the difficulty is language-independent or whether morphological markers aid the comprehension of sentences with derived word order to a varying degree across languages. To gain insight into this topic, in Chapter 1 we have studied a group of PWA and NBD speakers of Basque - a free word order language with ergative case morphology.

(i) **In line with the predictions of the DOP-H, comprehension of sentences where the Theme precedes the Agent is more impaired than Agent-Theme sentences in PWA speakers of Basque, regardless of the position of the verb in the sentence.**

The first research question asked which theoretical approach – the DOP-H (Bastiaanse & Van Zonneveld, 2006) or TDH (Grodzinsky, 1986; 1995, 2000; Drai & Grodzinsky, 2006ab) – is more explanatory of sentence comprehension deficits found in the PWA speakers of a free word order language such as Basque. The results of our first experiment show that, regardless of word order, Basque PWA comprehended sentences less accurately than NBDs. In addition, PWA were more impaired in their comprehension of sentences in which there was no linear Agent-Theme argument order, regardless of the position of the verb. Altogether, the findings are in favour of the DOP-H, and are not compatible with the predictions made in the latest version of the TDH (see Drai & Grodzinsky, 2006ab).

The gaze fixation pattern during the presentation of the linguistic stimuli showed distinctive patterns for correct and incorrect answers. The results closely replicate previous findings (Dickey et al., 2007; Hanne et al., 2011). This suggests that the correct answers of PWA are due to control-wise language processing, and not caused by guessing, as suggested by the TDH (Grodzinsky, 1986; 1995, 2000; Drai & Grodzinsky, 2006ab). The processing speed of the linguistic stimuli in PWA was as rapid and automatic as in NBD in the correctly answered trials. The incorrect answers of PWA were consistent with a stochastic breakdown in the parsing routine, compatible with the DOP-H (Bastiaanse & Van Zonneveld, 2006) and other processing accounts (e.g., Burkhardt, Avrutin, Piñango, & Ruigendijk, 2008; Burkhardt, Piñango, & Wong, 2003; Caplan, 2006; Caplan & Waters, 1999; Caplan, Michaud, & Hufford, 2013; Caplan, Waters, DeDe, Michaud, Reddy, 2007). PWA showed severe problems in processing case morphology, even when data suggest that, to a certain extent, they were sensitive to the argument structure of the verb (e.g., in verb-initial sentences). Consequently, sentence comprehension increases depending on the processing demands imposed by the argument order, as suggested by the DOP-H.

To sum up, the effect of word order on the sentence comprehension deficits in PWA extends to speakers of free word order languages such as Basque. These results provide evidence of the importance of word order in sentence parsing routines, as well as a universal characteristic of sentence comprehension deficits in some PWA.

5.2.2. The role of cross-linguistic variability and bilingualism in sentence processing in PWA and unimpaired speakers

(ii) At group level, processing case morphology in Basque imposes higher demands than processing prepositional information in Spanish, in both PWA and NBD bilingual participants.

The second research question was whether the different types of morphological markers have varying degrees of impact on sentence comprehension deficits in PWA. In Chapter 3, the study of Basque-Spanish early bilingual PWA provided evidence that thematic role assignment is more impaired when PWA need to process the ergative case '-k' (in Basque) than when they are guided by the parsing routine of the 'by-phrase' or preposition 'a' (in Spanish). Thus, comprehension difficulties are more severe in Basque than in Spanish.

These results are not easy to reconcile with the idea that PWA remain sensitive to highly reliable cues needed to parse sentences in their language (Bates, Friederici, & Wulfeck, 1987), since ergative case marking in Basque is the unique and strongly reliable mark to signal the agent of the verb. Moreover, the results do not converge with previous cross-linguistic findings, which suggest that the comprehension of passive sentences is better preserved in PWA speakers of languages with case morphology such as German, as opposed to Dutch (Bastiaanse & Van Zonneveld, 2006; see Bastiaanse & Edwards, 2004; Burchert, De Bleser, & Sonntag, 2003). Apart from the role of case morphology, there seem to be other factors involved in the degree to which PWA preserve their ability to process sentences in derived word orders.

Sentence processing in bilingual PWA is not aided by the rich morphology of Basque but, contrarily, it seems to be better preserved in a poorer inflected language such as Spanish. Interestingly, cross-linguistic difference was not only reduced to PWA. The NBD participants also performed better in Spanish than in Basque when sentences were presented in Theme-Agent order rather than with derived orders. These results may be explained by two factors. First, the perceptual salience of the specific morphemes in Basque and Spanish may impact sentence comprehension (see Wingfield, Peelle, & Grossman, 2003; MacWhinney, Pléh, & Bates, 1985), in combination with age-related factors (see Caplan et al., 2011; Sung, 2016; Obler et al., 1991). Secondly, different cognitive demands involving the processing of ergative case-morphology and prepositions (see Hanne et al., 2015) may also influence comprehension capacity. Interestingly, individual case analysis has shown that a considerable number of participants show dissociation between the effect of argument order and language. Altogether, the effect of argument order shows a negative correlation between Basque and Spanish, which suggests the existence of distinct underlying causes of sentence comprehension deficits. These issues are beyond the scope of the current study, and they are considered in further research on the topic described below.

(iii) Basque-Spanish early bilinguals (whether PWA or NBD) do not outperform monolingual Spanish speakers in their comprehension of sentences in Spanish.

The third research question raised in this dissertation was whether Basque-Spanish bilingual speakers show an advantage when processing sentences in Spanish, compared to monolingual Spanish speakers. The results showed that sentence processing abilities are indistinguishable as a function of bilingualism, as suggested by behavioral, reaction time, and gaze fixation data.

According to the rationale of cross-linguistic transfer, we expected PWA to relocate morphological processing abilities from a richly inflected language (i.e., Basque) to a less inflected language (i.e., Spanish). In Chapter 3, the findings of our experiment indicated the opposite, which is in line with the answer to our previous research question. The PWA who took part in this study showed worse sentence comprehension in Basque than in Spanish. Although the underlying causes of this result are still unclear, it shows that PWA are more impaired when processing ergative case morphology than when processing prepositional information. Therefore, it cannot be claimed that there is a cross-linguistic transfer of morphosyntactic abilities from Basque to Spanish, since the PWA studied in our experiment did not show more retained ability to process morphological marks in the richly inflected language (i.e., Basque; see Bates, Friederici, & Wulfeck, 1987; Bates, Wulfeck, & MacWhinney, 1991). These data suggest that cross-linguistic transfer may be based on the premise that PWA have preserved or enhanced (e.g., by treatment) morphological processing abilities in the richly inflected language, which is not the case in our studies. Study of the potential predictors of cross-linguistic transfer in sentence comprehension abilities deserves more experimental attention.

The null-effect of bilingualism on sentence comprehension abilities in PWA and NBD also fails to support claims of better executive functions and general conflict monitoring systems in bilingual speakers (e.g., Teubner-Rhodes, et al. 2016). The results must be interpreted with caution. They do not provide evidence against the enhancement of executive functions in bilingual speakers (e.g., Costa, Hernández, & Sebastián-Gallés, 2008; Filippi, et al., 2012; Teubner-Rhodes et al., 2016; Prior & MacWhinney, 2010) and they are still compatible with the potential role that diminished executive functions may play in the underlying causes of sentence comprehension deficits in PWA (see Dickey et al., 2007; Hanne et al., 2011; Schumacher et al., 2015). A core deficit in executive functions in PWA may override the increase of executive functions and widespread control system shown in healthy bilingual speakers. That is, if diminished abilities in executive functions are involved in sentence comprehension abilities in PWA, this same deficit may cancel the potential benefit that bilingualism may provide. The latter calls into question how reduced "bilingual advantage" in executive functions impacts bilingual PWA in language suppression and code-switching, amongst others.

5.2.3. Error awareness in sentence comprehension deficits

(iv) PWA are not aware of their sentence comprehension errors.

The fourth question in this thesis was whether PWA with sentence comprehension deficits were aware of their comprehension errors. This question was explored in Chapter 4. The results showed that PWA have a tendency to perceive as correct both correctly and incorrectly answered sentences. Although the PWA taking part in this study have no anosognosia, and therefore were aware of their aphasic condition, they did not accurately perceive their errors in sentence comprehension. Nevertheless, the accuracy and gaze fixation data showed that confidence ratings are a sensitive measure to obtain insight into unconscious processes in PWA. Gaze fixation followed distinctive patterns in the visual display depending on the response accuracy and confidence rate in which the trials were rated, although PWA perceived their answers to the most trials similarly (i.e., as correctly).

Two main conclusions can be drawn from these data. First, *a priori* self-awareness cannot be taken as a self-regulatory mechanism for therapeutic applications in sentence comprehension. A line of investigation would be to test whether self-awareness in PWA is susceptible to training; for instance, by using feedback systems, to eventually use self-awareness in treatment. Second, overall awareness of language deficits in PWA does not necessarily imply awareness of its symptomatology. These data highlight the importance of systematically assessing sentence comprehension capacities in PWA, instead of relying on the subjective perception of PWA regarding their comprehension abilities in both clinical and experimental setting.

(v) In the PWA group, sentence comprehension is mainly mediated by unconscious knowledge, while in the NBD group both conscious and unconscious knowledge equally contribute to sentence processing.

The fifth research question addressed in this dissertation revolves around the degree to which sentence processing was unconsciously mediated in PWA and NBD. This question was explored following the zero-correlation criterion and guessing criterion of Dienes et al. (1995). According to the zero-correlation criterion, the subjective perception on a given answer is a very poor predictor of its objective accuracy in PWA. This is consistent with the conclusions from the previous research question. PWA do not perceive their failures in comprehension, and therefore they overestimate their performance. In contrast, confidence rating is a moderate to good predictor of sentence comprehension accuracy in NBD participants. This suggests that sentence comprehension is mainly mediated by unconscious knowledge in PWA, while it combines both conscious and unconscious knowledge in NBD individuals.

The guessing criterion (Dienes et al., 1995) added evidence that PWA not only lack conscious knowledge in sentence processing, but there is also a loss of unconscious knowledge guiding the processing of sentences presented in Theme-Agent argument order. When PWA report answering by guessing in sentences with non-linear Theme-Agent argument order, their accuracy is not above what is expected by chance, indicating that unconscious knowledge is not involved. In contrast, in sentences with linear Agent-Theme argument order, PWA perform above chance, similarly to the NBD participants, in the occasional trials where they said they were guessing.

In conclusion, PWA have reduced metacognitive awareness, and hence, impaired subjective perception about their sentence comprehension processes.

Metacognitive awareness is involved in self-monitoring in sentence processing, particularly in parsing and revision routines. In combination with the previous research question, we may conclude that there is no evidence suggesting that PWA consciously use compensatory strategies, such as agent-first, to compensate for their comprehension deficits. They are oblivious of the breakdown in the parsing routine.

(vi) PWA reported to answer by guessing just the 6.8% of the sentences.

The sixth and last research question of the current dissertation assessed the extent to which PWA answer by guessing in the comprehension of sentences with derived word orders. The TDH (Grodzinsky, 1986, 1995, 2000; see Drai and Grodzinsky, 2006ab for a later revision) states that PWA choose randomly along the two potential interpretations of sentences presented in non-canonical word order. From the perspective of this dissertation, "guessing"[18] is a conscious act, and therefore PWA should be aware of their proposed guessing behavior. In contrast, the confidence rating in the Spanish version of the sentence comprehension task indicates that PWA rarely declared having answered by guessing; just on 6.8% of the sentences. PWA mainly rated their confidence based on certainty (i.e., "sure I answered correctly/incorrectly"). This result does not support the predictions of the TDH and questions its validity as a theoretical framework to explain sentence comprehension deficits in agrammatic speakers.

There is a unifying theme to this dissertation, which is related to the mechanisms underpinning sentence comprehension and how they can break down in PWA. All three experimental chapters shed light on this topic providing off-line and online data in PWA speakers of Basque (Chapter 2), PWA speakers of Spanish (Chapter 3), and metacognitive awareness of sentence

[18] 'Guessing' is defined as "form(ing) or express(ing) an uncertain estimate or conclusion (about something), based on insufficient information" (Collins English Dictionary, online version).
http://www.collinsdictionary.com/dictionary/english/conclusion

comprehension failure (Chapter 4). In this regard, there are three main conclusions to draw. First, our findings are compatible with the "deterministic parsing" routine suggested by Hanne et al., (2011). Gaze fixation patterns in both Basque and Spanish suggest that PWA parse sentences following a canonical or non-canonical word order template from early on in the auditory presentation of the stimuli. Thus, PWA apply a predetermined parsing routine and do not revise and reanalyse, even in Basque, wherein many sentences are initially ambiguous. This pattern may be influenced by task-specific demands, since the early presentation of the visual scene may engage PWA to an early commitment towards one or other interpretation (Caplan, Michaud, & Hufford, 2013). Second, gaze fixation data in both Basque and Spanish hint that PWA do not perceive the need to revise the initial parsing routine when it guides the incorrect interpretation of the sentence. This does not support the findings of Hanne et al. (2011), who reported that PWA occasionally perceived the need for reanalysis, but they failed to conduct the revision. Third, findings are compatible with diminished metacognitive awareness, and therefore, self-monitoring capacities found in PWA speakers of Spanish. We speculated that in the absence of self-monitoring abilities, PWA are not aware of information incompatible with the initial parsing, and as a result, they do not perceive the need to revise their thematic role assignment.

5.3. Directions for further research

The cross-linguistic results of the early bilingual group have suggested that saliency factors are involved in the sentence comprehension abilities of PWA and NBD. A direction for further research is to test whether acoustic manipulation of salience properties (e.g., length and intensity) impacts on the sentence comprehension deficits of bilingual PWA speakers of Basque and Spanish. Were the outcome positive, it would be possible to control for salience across Basque and Spanish stimuli, and to uncover potential differences in processing ergative case and prepositional information.

Another direction for further research relies on parsing and reanalysis processes in PWA. It is crucial for shedding light on whether PWA have difficulty detecting the need for reanalysis, or whether their reanalysis mechanism is impaired *per se*. Further research should aim to tease these two processes apart. For instance, a study of PWA while processing fully ambiguous sentences in a multiple-choice picture-matching task may contribute to this topic.

Overall, further research needs to be oriented to formulate theories, and describe the relationships between executive functioning and language impairments. Currently there is a conglomerate of constructs assimilated under the notion of executive functions. It is essential to develop a fine-grained description and characterization of their nature, to specify how they interact with language processing. Thus, it will be necessary to work on an operational definition of executive functions, which has not been achieved until now.

References:

Abuom, T. O., Shah, E., & Bastiaanse, R. (2013). Sentence comprehension in Swahili-English bilingual agrammatic speakers. *Clinical Linguistics and Phonetics, 27*, 355–70. doi:10.3109/02699206.2013.775346

Acha, J., Laka, I., Landa, J., and Salaburu, P. (2014). EHME : A new word database for research in Basque Language. *The Spanish Journal of Psychology, 17*, E79. doi: 10.1017/sjp.2014.79

Akaike, H. (1974). A new look at the statistical model identification. *IEE Transactions on Automatic Control AC, 19*, 716–723. doi: 10.1109/tac.1974.1100705

Aldezabal, I., Aranzabe, M., Atutxa, A., Gojenola, K., Sarasola, K., and Zabala, I. (2003). Hitz-hurrenkeren azterketa masiboa corpusean. Department of Language and Informatic Systems. University of Basque Country. *UPV/EHU/LSI/TR 2-2003*. (Manuscript).

Ansaldo, A. I. & Saidi, L. G. (2014). Aphasia therapy in the age of globalization: Cross-linguistic therapy effects in bilingual aphasia. *Behavioural Neurology, 2014*, 1-10. doi: 10.1155/2014/603085

Arantzeta, M., Bastiaanse, R., Burchert, F., Wieling, M., Martinez-Zabaleta, M., & Laka, I. (2016). Eye-tracking the effect of word order in sentence comprehension in aphasia: Evidence from Basque, a free word order ergative language. *Language, Cognition and Neuroscience, (In progress).*

Ardila, A. (2012). The executive functions in language and communication. In R.K. Peach and L. P. Shapiro (Eds.), *Cognition and Acquired Language Disorders: An information processing approach* (pp. 147-166). St. Louis: Elsevier Mosby. ISBN: 978-0-323-07201-4

Avrutin, S. (2006). Weak syntax. In Y. Grodzinsky and K. Amunts (Eds.), *Broca´s Region (pp. 49-62)*. Oxford: Oxford University Press. ISBN: 0195177649

Bader, M. & Lasser, I. (1994). German Verb-final clauses and sentence processing: Evidence for immediate attachment. In C. Clifton, L. Frazier, & K. Rayner (Eds.), *Perspectives on Sentence Processing* (pp. 225-242). New York: Psychology Press. ISBN: 987-0-805-81581-8

Badihardugu Euskara Elkartea. (2008). Ahotsak Ahozko Tradiziozko Korpusa. URL: http://www.ahotsak.eus/corpusa/

Bastiaanse, R., and Edwards, S. (2004). Word order and finiteness in Dutch and English Broca's and Wernicke's aphasia. *Brain and Language, 89*, 91–107. doi: 10.1016/S0093-934X(03)00306-7

Bastiaanse, R., and Van Zonneveld, R. (2005). Sentence production with verbs of alternating transitivity in agrammatic Broca's aphasia. *Journal of Neurolinguistics, 18*, 57-66. doi: doi:10.1016/j.jneuroling.2004.11.006

Bastiaanse, R., and Van Zonneveld, R. (2006). Comprehension of passives in Broca's aphasia. *Brain and Language, 96*, 135–142. doi: 10.1016/j.bandl.2005.06.012

Bates, E., Devescovi, A., & Wulfeck, B. (2001) Psycholinguistics: A cross-language perspective. *Annual Review of Psychology, 52*, 369-296. doi: 10.1146/annurev.psych.52.1.369

Bates, E., Friederici, A., and Wulfeck, B. (1987). Comprehension in aphasia: a cross-linguistic study. *Brain and Language*, *32*, 19–67. doi: 10.1016/0093-934X(87)90116-7

Bates, E. & MacWhinney, B. (1989). Functionalism and the Competition Model. In B. MacWhinney, & E. Bates (Eds.), *The crosslinguistic study* *of sentence processing* (pp. 1-73). New York: Cambridge University Press. ISBN: 0521261961

Bates, D., Maechler, M., Bolker, B., and Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software, 67*, 1-48. doi: 10.18637/jss.v067.i01

Bates, E., Wulfeck, B., & MacWhinney, B. (1991). Crosslinguistic research in aphasia: An overview. *Brain and Language, 41*, 123-148. doi: 10.1016/0093-934x(91)90149-u

Beeke, S., Wilkinson, R., & Maxim, J. (2009). Prosody as a compensatory strategy in the conversations of people with agrammatism. *Clinical Linguistics & Phonetics, 23*, 133-155. doi:10.1080/02699200802602985

Bentacort, M., Carreiras, M., & Sturt, P. (2009). The processing of subject and object relative clauses in Spanish: An eye-tracking study. *The Quarterly journal of Experimental Psychology, 62*, 1915-1929. doi: 10.1080/17470210902866672

Berndt, R. S., Mitchum, C. C., and Haendiges, A. N. (1996). Comprehension of reversible sentences in 'agrammatism': A meta-analysis. *Cognition*, *58*, 289–308. doi: 10.1016/0010-0277(95)00682-6

Bever, T. G. (1970). The influence of speech performance on linguistic structure. In G. B. Flores d'Arcais, W. J. M. Levelt (Eds.), *Advances in Psycholinguistics* (pp. 4-30). Amsterdam: North-Holland Publishing Co. ISBN: 072046031X

Bialystok, E., Craik, F. I. M., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology and Aging,* 19, 290-303. doi: 10.1037/0882-7974.19.2.290

Birdsong, D., Gertken, L.M., & Amengual, M. (2012). *Bilingual Language Profile (BLP): An Easy-to-Use Instrument to Assess Bilingualism.* Basque adaptation: M. Arantzeta (2016). COERLL, University of Texas at Austin. URL: https://sites.la.utexas.edu/bilingual/using-the-blp/access-testing-materials/

Boland, J. (2004). Linking eye movements to sentence comprehension in reading and listening. In M. Carreiras and C. Clifton (Eds.), *The On-line Study of Sentence Comprehension: Eyetracking, ERPs and Beyond* (pp. 51-76). Hove, US: Psychology Press. ISBN: 1-84169-400-2

Bornkessel, I., Schlesewsky, M., and Friederici, A. D. (2002). Grammar overrides frequency: Evidence from the online processing of flexible word order. *Cognition*, *85*, 21–30. doi: 10.1016/S0010-0277(02)00076-8

Bornkessel-Schlesewsky, I. & Schlesewsky M. (2013). Neurotypology: Modeling crosslinguistic similarities and differences in the neurocognition of language comprehension. In M. Sanz, I. Laka, & M. K. Tanenhaus (Eds.) *Language Down the Garden Path. The cognitive and biological basis for linguistic structures* (pp. 241-252). Oxford: Oxford University Press. ISBN: 978-0-19-967713-9

Burchert, F., De Bleser, R., & Sonntag, K. (2003). Does morphology make the difference? Agrammatic sentence comprehension in German. *Brain and Language, 87*, 323–42. doi: 10.1016/S0093-934X(03)00132-9

Burchert, F., Hanne, S., and Vasishth, S. (2013). Sentence comprehension disorders in aphasia: The concept of chance performance revisited. *Aphasiology*, *27*, 112–125. doi: 10.1080/02687038.2012.730603

Burkhardt, P., Avrutin, S., Piñango, M., and Ruigendijk, E. (2008). Slower-than-normal syntactic processing in agrammatic Broca's aphasia: Evidence from Dutch. *Journal of Neurolinguistics*, *21*, 120–137. doi: 10.1016/j.jneuroling.2006.10.004

Burkhardt, P., Piñango, M., and Wong, K. (2003). The role of the anterior left hemisphere in real-time sentence comprehension: Evidence from split intransitivity. *Brain and Language, 86*, 9–22. doi: 10.1016/S0093-934X(02)00526-6

Caramazza, A., Basili, A. G., Koller, J. J., and Berndt, R. S. (1981). An investigation of repetition and language processing in a case of conduction aphasia. *Brain and Language*, *14*, 235–271. doi: 10.1016/0093-934X(81)90078-X

Caramazza, A., and Zurif, E. B. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language*, *3*(4), 572–582. doi: 10.1016/0093-934X(76)90048-1

Carreiras, M., Duñabeitia, J. A., Vergara, M., de la Cruz-Pavía, I., & Laka, I. (2010). Subject relative clauses are not universally easier to process: Evidence from Basque. *Cognition*, *115*, 79–92. doi: 10.1016/j.cognition.2009.11.012

Casado, P.; Fernández Frías, C.; Martín-Loeches, M. & Muñoz, F., Fernández-Frías, C. (2005). Are semantic and syntactic cues inducing the same processes in the identification of word order? *Cognitive Brain Research, 24*, 526-543. doi: 10.1016/j.cogbrainres.2005.03.007

Caplan, D. (2006). Aphasic deficits in syntactic processing. *Cortex, 42*, 797-804. doi: 10.1016/s0010-9452(08)70420-9

Caplan, D., DeDe, G., Waters, G., Michaud, J., & Tripodis, Y. (2011). Effects of age, speed of processing, and working memory on comprehension of sentences with relative clauses. *Psychology and Aging, 26*, 439-450. doi: 10.1037/a0021837

Caplan, D., and Futter, C. (1986). Assignment of thematic roles to nouns in sentence comprehension by an agrammatic patient. *Brain and Language*, *27*, 117–134. doi: 10.1016/0093-934X(86)90008-8

Caplan, D. and Hildebrandt, N. (1988). *Disorders of Syntactic Comprehension*. Cambridge, MA: MIT Press. ISBN: 0-262-03132-9

Caplan, D., Michaud, J., and Hufford, R. (2013). Dissociations and associations of preformance in syntactic comprehension in aphasia and their implications for the nature of aphasic deficits. *Brain and Language, 127*, 21-33. doi: 10.1016/j.bandl.2013.07.007

Caplan, D., and Waters, G. S. (1990). Short-term memory and language comprehension: A critical review of the neuropsychological literature. In G. Vallar & T. Shallice (Eds.), *Neurosychological impairments of short-term memory* (pp. 337-389). Cambridge: Cambridge University Press. ISBN: 9780521370882

Caplan, D., and Waters, G. (1999). Verbal working memory and sentence comprehension. *Behavioural And Brain Sciences*, *22*, 77–126. doi: 10.1017/s0140525x99001788

Caplan, D., and Waters, G. (2003). On-line syntactic processing in aphasia: Studies with auditory moving window presentation. *Brain and Language*, *84*, 222–49. doi: 10.1016/S0093-934X(02)00514-X

Caplan, D. & Waters, G. (2013). Memory mechanisms supporting syntactic comprehension. *Psychonomic Bulletin & Review, 20*, 243-268. doi: 10.3758/s13423-012-0369-9

Caplan, D., Waters, G., DeDe, G., Michaud, J., and Reddy, A. (2007). A study of syntactic processing in aphasia I: Behavioral (psycholinguistic) aspect. *Brain and Language, 101*, 103-150. doi: 10.1016/j.bandl.2006.06.225

Cheesman, J. and Merikle, P. M. (1984). Priming with and without awareness. *Perception and Psychophysics, 36*, 387-395. doi: 10.3758/BF03202793

Cheesman, J. and Merikle, P. M. (1986). Distinguishing conscious from unconscious perceptual processes. *Canadian Journal of Psychology/Revue Canadienne de Psychologie, 40*, 343. doi: 10.1037/h0080103

Chialant, D. (2000). Cognitive Neuropsychology Laboratory (CNL) *Language Screening Battery*. (Manuscript). Basque adaptation: Erdocia, K., Santesteban, M., & Laka, I. (2003). Elebilab Psycholinguistic Laboratory. University of Basque Country.

Collins English Dictionary (2012). Retrieved July 27th, 2016, from: http://www.collinsdictionary.com/dictionary/english/guess

Comrie, B. (1981). *Language universals and linguistic typology: syntax and morphology*. Oxford: Blackwell. ISBN: 978-0226114330

Consonni, M., Cafiero, R., Marin, D., Tettamanti, M., Iadanza, A., Fabbro, F., & Perani, D. (2013). Neural convergence for language comprehension and grammatical class production in highly proficient bilinguals is independent of age of acquisition. *Cortex, 49*, 1252-1258. doi: 10.1016/j.cortex.2012.04.009

Cooper, R. M. (1974). The control of of eye spoken fixation by the meaning language. *Cognitive Psychology*, *107*, 84–107. doi: 10.1016/0010-0285(74)90005-x

Costa, A., Hernández, M., & Santián-Gallés, N. (2008). Bilingualism aids conflict resolution: Evidence from the ANT task. *Cognition, 106*, 59-86. doi: 10.1016/j.cognition.2006.12.013

Costa, A. & Santesteban, M. (2004). Lexical access in bilingual speech production: Evidence from language switching in highly proficient bilinguals and L2 learners. *Journal of Memory and Language, 50*, 491-511. doi: 10.1016/j.jml.2004.02.002

Cuetos, F. & Mitchell, D. C. (1988). Cross-linguistic differences in parsing: Restrictions on the late-closure strategy in Spanish. *Cognition, 30*, 73-105. doi: 10.1016/0010-0277(88)90004-2

Cuetos, F., Mitchell, D. C., & Corley, M. M. B. (1996). Parsing in different languages. In M. Carreira, J. E., García-Albea, & N. Sebastián-Gallés (Eds.), *Language processing in Spanish* (pp. 145-187). Mahwah, NJ: Lawrence Erlbaum Associates. ISBN: 0805817212

DeLong, E. R., DeLong, D. M., and Clarke-Pearson, D. L. (1988). Comparing the areas under two or more receiver operating characteristic curves: A nonparametric approach. *Biometrics, 44*, 837-845. doi: 10.2307/2531595

De Rijk, R. (1969). Is Basque an SOV language? *Fontes Linguae Vasconum 1*, 319-351.

De Vincenzi, M. and Lombardo, V. (2000). *Cross-linguistic perspective on language processing*. Dordrecht: Springer. ISBN: 978-94-011-3949-6

Del Río, D., López-Higes, R., & Martín-Aragoneses, M. T. (2012). Canonical word order and interference-based integration costs during sentence comprehension: The case of Spanish subject- and object-relative clauses. *The Quarterly Journal of Experimental Psychology, 65*, 2108-2128. doi: 10.1080/17470218.2012.674951

Del Río, D., Maestú, F., López-Higes, R., Moratti, S., Gutiérrez, R., Maestú, C., & del-Pozo, F. (2011). Conflict and cognitive control during sentence comprehension: Recruitment of a frontal network during the processing of Spanish object-first sentences. *Neuropsychologia, 49*, 382-391. doi: 10.1016/j.neuropsychologia.2010.12.005

Díaz B., Sebastián-Gallés N., Erdocia K., Mueller J.L., & Laka I. (2011). On the cross-linguistic validity of electrophysiological correlates of morphosyntactic processing: A study of case and agreement violations in Basque. *Journal of Neurolinguistics, 24*, 357-373. doi: 10.1016/j.jneuroling.2010.12.003

Dickey, M. W., Choy, J. J., and Thompson, C. K. (2007). Real-time comprehension of wh- movement in aphasia: evidence from eyetracking while listening. *Brain and Language*, *100*, 1–22. doi: 10.1016/j.bandl.2006.06.004

Dienes, Z., Altmann, G. T. M., Kwan, L., and Goode, A. (1995). Unconscious knowledge of artificial grammars is applied strategically. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 1322-1338. doi: 10.1037/0278-7393.21.5.1322

Diggle, P., Heagerty, P., Liang, K., & Zeger, S. (2013). *Analysis of longitudinal data*. Oxford: Oxford University Press. 2nd edition. ISBN: 978-0-19-852484-7

Drai, D., and Grodzinsky, Y. (2006a). A new empirical angle on the variability debate: Quantitative neurosyntactic analyses of a large data set from Broca's Aphasia. *Brain and Language*, *96*, 117–128. doi: 10.1016/j.bandl.2004.10.016

Drai, D., and Grodzinsky, Y. (2006b). The variability debate: More statistics, more linguistics. *Brain and Language*, *96*, 157–170. doi: 10.1016/j.bandl.2005.05.004

Duman, T. Y., Altınok, N., Özgirgin, N., and Bastiaanse, R. (2011). Sentence comprehension in Turkish Broca's aphasia: An integration problem. *Aphasiology, 25*, 908–926. doi: 10.1080/02687038.2010.550629

Duñabeitia, J. A., Hernández, J. A., Antón, E., Macizo, P., Estévez, A., Fuentes, L. J., Carreiras, M. (2014). The inhibitory advantage in bilingual children revisited: Myth or reality?. *Experimental Psychology, 61*, 234-251. doi: 10.1027/1618-3169/a000243

Dussias, P. & Sagarra, N. (2007). The effect of exposure on syntactic parsing in Spanish-English bilinguals. *Bilingualism: Language and Cognition, 10*, 101-116. doi: 10.1017/s1366728906002847

Dryer, M. S. (2005). Order of Subject, Object, and Verb. In M. Haspelmath, M. Dryer, D., Gil, & B. Comrie (Eds.), *The World Atlas of Language Structures* (pp. 330-333). Oxford: Oxford University Press. ISBN: 0-19-925591-1

Dryer, M. S. (2007). Word order. In Timothy Shopen (Ed.), *Clause Structure, Language Typology and Syntactic Description*, Vol. 1. (pp. 61-131). Cambridge: Cambridge University Press.

Eberhard, K. M., Spivey-Knowlton, M. J., Sedivy, J. C., & Tanenhaus, M. K. (1995). Eye movements as a window into real-time spoken language comprehension in natural contexts. *Journal of Psycholinguistic Research, 24*, 409-435. doi: 10.1007/bf02143160

Erdocia, K., Laka, I., Mestres-Missé, A., & Rodriguez-Fornells, A. (2009). Syntactic complexity and ambiguity resolution in a free word order language: behavioral and electrophysiological evidences from Basque. *Brain and Language, 109*, 1–17. doi: 10.1016/j.bandl.2008.12.003

European Commission Special Eurobarometer. (2012). Europeans and their languages. Retrieved October 1, 2016, from http://ec.europa.eu/public_opinion/archives/ebs/ebs_386_en.pdf

Ferreira, F. (2003). The misinterpretation of noncanonical sentences. *Cognitive Psychology*, *47*, 164–203. doi: 10.1016/S0010-0285(03)00005-7

Ferreira, F., Anes, M. D., & Horine, M. D. (1996). Exploring the use of prosody during language comprehension using the auditory moving window technique. *Journal of Psycholinguistic Research, 25*, 273-290. doi: 10.1007/BF01708574

Ferreira, F. and Patson, N. D. (2007). The good enough approach to language comprehension. *Language and Linguistic Compass, 1*, 71-83. doi: 10.1111/j.1749-818X.2007.00007.x

Filippi, R., Leech, R., Thomas, M. S. C., Green, D. W., & Dick, F. (2012). A bilingual advantage in controlling language interference during sentence comprehension. *Bilingualism: Language and Cognition, 15*, 858-872. doi: 10.1017/s1366728911000708

Frazier, L. (1990). Exploring the architecture of language system. In G. Altmann (Ed.), *Cognitive models of speech processing: Psycholinguistic and computational perspectives* (pp. 409-433). Cambridge, MA: MIT Press. ISBN: 978-0262510844

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology General, 133,* 101-135. doi: 10.1037/0096-3445.133.1.101

Friedmann, N., Reznick, J., Dolinski-Nuger, D., and Soboleva, K. (2010). Comprehension and production of movement-derived sentences by Russian speakers with agrammatic aphasia. *Journal of Neurolinguistics*, *23*, 44–65. doi: 10.1016/j.jneuroling.2009.08.002

Friedmann, N., and Shapiro, L. P. (2003). Agrammatic comprehension of simple active sentences with moved constituents: Hebrew OSV and

OVS structures. *Journal of Speech, Language, and Hearing Research : JSLHR*, *46*, 288–297. doi: 10.1044/1092-4388(2003/023)

Fukui, N. and Takano, Y. (1998). Symmetry in syntax: Merge and demerge. *Journal of East Asian Linguistics, 7*, 27-86. doi: 10.1023/A:1008240710949

Futter, C. (1986). Assignment of thematic roles to nouns in sentence comprehension by an agrammatic patient. *Brain and Language*, *27*, 117–134. doi: 10.1016/0093-934X(86)90008-8

Garraffa, M. and Grillo, N. (2008). Canonicity effects as grammatical phenomena. *Journal of Neurolinguistics, 21*, 177-197. doi: 10.1016/j.jneuroling.2007.09.001

Gibson, E. (1992). On the adequacy of the Competition Model. *Language, 68*, 812-830. doi:10.1353/lan.1992.0024

Gibson, E., Piantados, S., Brink, K., Bergen, L., Kim, E., & Saxe, R. (2013). A noisy-channel account of crosslinguistic word-order variation. Psychological Science, 24, 1079-88. doi: 10.1177/0956797612463705

Goodglass, H., Kaplan, H., & Barresi, B. (2005). The assessment of aphasia and related disorders (3rd edition). Spanish adaptation: J. E. García-Albea. Madrid: Médica Panamericana. ISBN: 9788479037857

Grodzinsky, Y. (1986). Language deficits and the theory of syntax. *Brain and Language*, *27*, 135–159. doi: 10.1016/0093-934X(86)90009-X

Grodzinsky, Y. (1995). A restrictive theory of agrammatic comprehension. *Brain and Language, 50*, 27-51. doi: 10.1006/brln.1995.1039

Grodzinsky, Y. (2000). The trace deletion hypothesis and the tree-pruning hypothesis: Still valid characterizations of Broca's aphasia. *The Behavioral and Brain Sciences*, *23*, 1–21; discussion 55-64. doi: 10.1017/S0140525X00002399

Grodzinsky, Y., Piñango, M., Zurif, E., and Drai, D. (1999). The critical role of group studies in neuropsychology: Comprehension regularities in Broca's aphasia. *Brain and Language. 67*, 134–147. doi: 10.1006/brln.1999.2050

Gutiérrez-Bravo, R. (2007). Prominence scales and unmarked word order in Spanish. *Natural Language & Linguistic Theory, 25*, 235-271. doi: 10.1007/s11049-006-9012-7

Haarmann, H. J., Just, M. A., & Carpenter, P. A. (1997). Aphasic sentence comprehension as a resource deficit: A computation approach. *Brain and Language, 59*, 76-120. doi: 10.1006/brln.1997.1814

Haarmann, H. J., and Kolk, H. H. (1991). A computer model of the temporal course of agrammatic sentence understanding: The effects of variation in severity and sentence complexity. *Cognitive Science, 15*, 49–87. doi: 10.1207/s15516709cog1501_2

Hanne, S., Burchert, F., De Bleser, R., & Vasishth, S. (2015). Sentence comprehension and morphological cues in aphasia: What eye-tracking reveals about integration and prediction. *Journal of Neurolinguistics, 34*, 83-111. doi: 10.1016/j.jneuroling.2014.12.003

Hanne, S., Sekerina, I. A., Vasishth, S., Burchert, F., & De Bleser, R. (2011). Chance in agrammatic sentence comprehension: what does it really mean? Evidence from eye movements of German agrammatic aphasic patients. *Aphasiology, 25*, 221–244. doi: 10.1080/02687038.2010.489256

Harrell F. E. J. (2016). rms: Regression Modeling Strategies. R package version 4.5-0. URL: https://CRAN.R-project.org/package=rms

Hartsuiker, R. J., and Kolk, H. H. J. (1998). Syntactic facilitation in agrammatic sentence production. *Brain and Language, 62*, 221-254. doi: 10.1006/brln.1997.1905

Harville, D. A. (1974). Bayesian inference for variance components using only error contrasts. *Biometrika, 61*, 383-385. doi: 10.2307/2334370

Hickey, L. (1994). Word order in Spanish: Four perspectives. Bristol: Department of Hiypanic, Portuguese and Lation American Studies. Occasional papers n° 14.

Jap, B. A., Martinez-Ferreiro, S., & Bastiaanse, R. (2016). The effect of syntactic frequency on sentence comprehension in standard Indonesian Broca's aphasia. *Aphasiology, 11*, 1325-1340. doi: 10.1080/02687038.2016.1148902

Juncos-Rabadán, O., Pereiro, A. X., & Souto, M. (2009). Manifestaciones de la afasia en gallego. Datos preliminaries de pacientes bilingües Gallego-Castellano. *Revista de Logopedia, Foniatría y Audiología, 29*, 21-29. doi: 10.1016/s0214-4603(09)70140-8

Kamide, Y., Altmann, G. T. M., and Haywood, S. L. (2003). The time-course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory and Language, 49,* 133–156. doi: 10.1016/S0749-596X(03)00023-8

Kamide, Y., Scheepers, C., and Altmann, G. T. M. (2003). Integration of syntactic and semantic information in predictive procesing: Cross-linguistic evidence from German and English. *Journal of Psycholinguistic Research*, *32*, 37–55. doi: 10.1023/A:1021933015362

Kayne, R. (1994). *The antisymmetry of syntax*. Cambridge, Mass.: MIT Press. ISBN: 9780262611077

Kennedy, M.R.T. & Chiou, H.H. (2008). What explains metacomprehension in adults with aphasia? Clinical Aphasiology Conference, Jackson, WY. URL: http://aphasiology.pitt.edu/archive/00001937/01/viewpaper.pdf

Kertesz, A. (2010). Anosognosia in Aphasia. In Prigatano, G. P. (Ed.), *The study of anosognosia* (pp.113-122). New York: Oxford University Press. ISBN: 978-0-19-537909-9

Khachatryan, E., Vanhoof, G., Beyens, H., Goeleven, A., Thijs, V., & Van Hulle, M M. (2016). Language processing in bilingual aphasia: a new insight into the problem. *WIREs Cognitive Science, 7*, 180-196. doi: 10.1002/wcs.1384

Kielar, A., Meltzer-Asscher, A., and Thompson, C. K. (2012). Electrophysiological responses to argument structure violations in healthy adults and individuals with agrammatic aphasia. *Neuropsychologia*, *50*, 3320–3337. doi: 10.1016/j.neuropsychologia.2012.09.013

Kim, M., and Thompson, C. K. (2004). Verb deficits in Alzheimer's disease and agrammatism: Implications for lexical organization. *Brain and Language*, *88*, 1–20. doi: 10.1016/S0093-934X(03)00147-0

Knoeferle, P., Crocker, M. W., Scheepers, C., & Pickering, M. J. (2005). The influence of the immediate visual context on incremental thematic role-assignment: evidence from eye-movements in depicted events. *Cognition*, *95*, 95–127. doi: 10.1016/j.cognition.2004.03.002

Kolk, H. H. J. (1993). A time-based approach to agrammatic production. *Brain and Language, 50*, 282-303. doi: 10.1006/brln.1995.1049

Koriat, A. (2000). The feeling of knowing: Some metatheoretical implications for consciousness and control. *Consciousness and Cognition, 9*, 149-171. doi: 10.1006/ccog.2000.0433

Kroll, J. F., Bobb, S. C., & Wodniecka, Z. (2006). Language selectivity is the exception, not the rule: Arguments against a fixed locus of language selection in bilingual speech. *Bilingualism: Language and Cognition, 9*, 119-135. doi: 10.1017/s1366728906002483

Kroll J. F. & Dussias P. E. (2013). The comprehension of words and sentences in two languages. In T. Bhatia and W. Ritchie (Eds.), *The Handbook of Bilingualism and Multilingualism* (2nd ed.) (pp. 216–43). Malden, MA: Wiley-Blackwell. ISBN: 978-1-4443-3490-6

Ladefoged, P. (2001). *Vowels and consonants: An introduction to the sounds of language*. Oxford: Blackwell. ISBN: 0631214127

Laka, I. (2006). On the nature of case in Basque: structural or inherent?. In H. Broekhuis, N. Corver, J. Koster, R. Huybregts, & U. Kleinhenz (Eds.). *Organizing Grammar: Linguistic Studies in Honor of Henk van Riemsdijk* (pp. 374-382). Berlin/New York: Mouton de Gruyter. ISBN: 3110188503 / 3-11-018850-3.

Laka, I. (2012). Merging from the temporal input: on subject-object asymmetries and an ergative language. In R. Berwick R. & M. Piattelli-Palmarini (eds.) *Rich Grammars from Poor Inputs* (pp. 127-246), Oxford: Oxford University Press. doi: http://dx.doi.org/10.1093/acprof:oso/9780199590339.003.0009

Laka, I. and Erdocia, K. (2012). Linearization preferences given "free word order"; subject preferences given ergativity: A look at Basque. In Torrego E. (ed.). *Festschrift for Professor Carlos Piera*. Oxford: Oxford University Press.

Langer, E. J. and Imber, L. G. (1979). When practice makes imperfect: debilitating effects of overlearning. *Journal of Personality and Social Psychology, 37*, 2014-2024. doi: 10.1037/0022-3514.37.11.2014

Leonetti, M. (2003). Specificity and object marking: The case of Spanish a. In K. von Heusinger, & G. A. Kaiser (Eds.), *Proceedings of the workshop semantic and syntactic aspects of specificity in romance languages* (pp. 67-101). Konstanz: Fachbereich Sparachwissenchaft.

Levelt, W. J. M. (1989). *Speaking: From Intention to Articulation*. Cambridge, Massachusetts: MIT Press. ISBN: 9780262121378

Levelt, W. J. M. (2001). Spoken word production: a theory of lexical access. *Proceedings of the National Academy of Sciences of the United States of America*, *98*, 13464–71. doi: 10.1073/pnas.231459498

Levin, B. C. (1983). *On the nature of ergativity,* PhD dissertation, MIT.

MacWhinney, B. (2000). The CHILDES project: Tools for analyzing talk. Mahwah: Erlbaum. . URL: http://childes.talkbank.org/clan/

MacWhinney, B., Pléh, C., & Bates, E. (1985). The development of sentence interpretation in Hungarian. *Cognitive Psychology, 17*, 178-209. doi: 10.1016/0010-0285(85)90007-6

Marian, V. & Spivey, M. (2003). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition, 6*, 97-115. doi: 10.1017/s1366728903001068

Mariën, P., Engelborghs, S., Vignolo, L. A., and De Deyn, P. P. (2001). The many faces of crossed aphasia in dextrals: report of nine cases and review of the literature. *European journal of Neurology, 8*, 643-658. doi: 10.1046/j.1468-1331.2001.00319.x

Mariën, P., Paquier, P., Cassenaer, S., and De Deyn, P. P. (2003). The history of crossed aphasia: confluence of concepts. *Journal of Neurolinguistics, 16*, 1-12. doi: 10.1016/s0911-6044(01)00026-4

Marshall, R. C., and Tompkins, C. A. (1982). Verbal self-correction behaviours of fluent and nonfluent aphasic subjects. *Brain and Language, 15*, 292-306. doi: 10.1016/0093-934X(82)90061-X

Marshall, R. C., Rappaport, B. Z., and Garcia-Bunuel, L. (1985). Self-monitoring behavior in a case of auditory agnosia with aphasia. *Brain and Language, 24*, 297-313. doi: 10.1016/0093-934x(85)90137-3

Martin-Rhee, M. M. & Bialystok, E. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition, 11*, 1-13. doi: 10.1017/s1366728907003227

Matin, E., Shao, K. C., and Boff, K. R. (1993). Saccadic overhead: Information-processing time with and without saccades. *Perception and Psychophysics, 53*, 372–380. doi: 10.3758/BF03206780

McCulloch, C. E. and Searle, S. R. (2000). *Generalized, Linear and Mixed Models*. New York: Wiley. ISBN: 978-0-470-07371-1

Meyer, A. M., Mack, J. E., & Thompson, C. K. (2012). Tracking passive sentence comprehension in agrammatic aphasia. *Journal of Neurolinguistics, 25*, 31-43. doi: 10.1016/j.jneuroling.2011.08.001

Mishra, R. K., Olivers, C. N. L., and Huettig, F. (2013). Spoken language and the decision to move the eyes: To what extent are language-mediated eye movements automatic? In V. S. C. Pammi, & N. Srinivasan (Eds.), *Progress in Brain Research: Decision making - Neural and behavioural approaches* (pp. 135-149). New York: Elsevier. doi: 10.1016/B978-0-444-62604-2.00008-3

Mitchum, C. C. & Berndt, R. S. (2008). Comprehension and production of sentences. In R. Chapey (Ed.), *Language intervention strategies in aphasia and related neurogenic communication disorders* (5th ed.) (pp. 632-653). Philadelphia: Wolters Kluwer. ISBN: 0781769817

Miyake, A., Carpenter, P. A., and Just, M. A. (1994). A capacity approach to syntactic comprehension disorder: Making normal adults perform like aphasic patients. *Cognitive Neuropsychology, 11*, 671-717. doi: 10.1080/02643299408251989

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contribution to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49-100. doi: 10.1006/cogp.1999.0734

Munarriz, A., Ezeizabarrena, M., & Gutierrez-Mangado, J. (2016). Differential and selective morpho-syntactic impairment in Spanish-Basque bilingual aphasia. *Bilingualism: Language and Cognition, 19*, 810-833. doi: 10.1017/s136672891400042x

Norman, E. and Price, M. C. (2015). Measuring consciousness with confidence ratings. In M. Overgaard (Ed.), *Behavioral methods in consciousness research* (pp. 159-180). Oxford: Oxford University Press. ISBN: 978-0-19-968889-0

Novick, J. M., Trueswell, J. C., & Thompson-Schill, S. L. (2005). Cognitive control and parsing: Reexamining the role of Broca's area in sentence comprehension. *Cognitive, Affective, & Behavioral Neuroscience, 5*, 263-281. doi: 10.3758/cabn.5.3.263

Novick, J. M., Trueswell, J. C., & Thompson-Schill, S. L. (2010). Broca´s area and language processing: Evidence for the cognitive control connection. *Language and Linguistic Compass, 4*, 906-924. doi: 10.1111/j.1749-818x.2010.00244.x

Obler, L. K., Fein, D., Nicholas, M., & Albert, M. L. (1991). Auditory comprehension and aging: Decline in syntactic processing. *Applied Psycholinguistics, 12*, 433-452. doi: 10.1017/s0142716400005865

Oelschlaeger, M. and Damico, J. S. (1998). Spontaneous verbal repetition: A social strategy in aphasic conversation. *Aphasiology, 12*, 971–988. doi: 10.1080/02687039808249464

Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia*, *9*, 97–113. doi: 10.1016/0028-3932(71)90067-4

Olness, G. S. (2006). Genre, verb, and coherence in picture-elicited discourse of adults with aphasia. *Aphasiology*, *20*, 175–187. doi: 10.1080/02687030500472710

Ortiz de Urbina, J. (1989). *Parameter in the Grammar of Basque*. Foris, Dordrecht. ISBN: 978-9067653374

Oomen, C. C. E, Postma, A., & Kolk, H. H. J. (2001). Prearticulatory and postarticulatory sef-monitoring in Broca's aphasia. *Cortex, 37*, 627-641. doi: 10.1016/S0010-9452(08)70610-5

Overgaard, M. (2015). *Behavioral methods in consciousness research*. Oxford: Oxford University Press. ISBN: 978-0-19-968889-0

Overgaard, M., Timmermans, B., Sandberg, K., and Cleeremans, A. (2010). Optimizing subjective measures of consciousness. *Consciousness and Cognition, 19*, 682-684. doi: 10.1016/j.concog.2009.12.018

Patterson, H. D., and Thompson, R. (1971). Recovery of inter-block information when block sizes are unequal. *Biometrika*, *58*, 545–554. doi: 10.1093/biomet/58.3.545

Pedersen, P. M., Jørgensen, H. S., Nakayama, H., Raaschou, H. O., and Olsen, T. S. (1995). Aphasia in acute stroke: Incidence, determinants, and recovery. *Annals of Neurology*, *38*, 659–666. doi: 10.1002/ana.410380416

Pedersen, P. M., Vinter, K., and Olsen, T. S. (2004). Aphasia after stroke: type, severity and prognosis. *Cerebrovascular Diseases*, *17*, 35–43. doi: 10.1159/000073896

Peña-Ayala, A. and Cárdenas (2015). A conceptual model of metacognitive activity. In A. Peña-Ayala (Ed.), *Metacognition: Fundaments, applications, and trends* (pp. 39-72). Springer International Publishing. ISBN: 978-3-319-11061-5

Prior, A. & MacWhinney, B. (2010). A bilingual advantage in task switching. *Bilingualism: Language and Cognition, 13*, 253-262. doi: 10.1037/e520562012-021

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/.

Robin, X., Turck, N., Hainard, A., Tiberti, N., Lisacek, F., Sanchez, J. C., and Müller, M. (2011). pROC: an open-source package for R and S+ to analyze and compare ROC curves. *BMC Bioinformatics, 12*, p. 77. doi: 10.1186/1471-2105-12-77

Ros, I., Santesteban, M., Fukumura, K. and Laka, I. (2015). Aiming at shorter dependencies: the role of agreement morphology. *Language, Cognition and Neuroscience, 30, 1156-1174.* doi: 10.1080/23273798.2014.994009

Rubens, A. B. and Garrett, M. F. (1991). Anosognosia of linguistic deficits in patients with neurological deficits. In Prigatano, G. P. & Schacter, D. L. (Eds.), *Awareness of deficit after brain injury: Clinical and theoretical issues* (pp. 40-52). New York: Oxford University Press. ISBN: 0-195-05941-7

Saffran, E. M., Schwartz, M. F., and Marin, O. S. M. (1980). The word order problem in agrammatism 2: Production. *Brain and Language*, *10*, 249–262. doi: 10.1016/0093-934X(80)90055-3

Santesteban, M., Pickering, M. J., Laka, I., & Branigan, H. P. (2015). Effects of case-marking and head position on language production? Evidence from an ergative OV language. *Language, Cognition and Neuroscience, 30, 1175-86*. doi: 10.1080/23273798.2015.1065335

Scheepers, C. and Crocker, M. (2004). Constituent Order Priming from Reading to Listening: A Visual-World Study. In: M. Carreiras and C.

Clifton, Jr. (eds), *The On-line Study of Sentence Comprehension: Eyetracking, ERP and Beyond*. United Kidgdom: Psychology Press. ISBN: 978-0415655781

Schneider, W. (2009). Automaticity and consciousness. In W. P. Banks (Ed.), *Encyclopedia of Consciousness* (pp. 83-92). Amsterdam: Elsevier. ISBN: 978-0-12-373873-8

Schneider, B. A., Daneman, M., & Murphy, D. R. (2005). Speech comprehension difficulties in older adults: Cognitive slow-down or age-related changes in hearing?. *Psychology and Aging, 20*, 261-271. doi: 10.1037/0882-974.20.2.261

Schumacher, R., Cazzoli, D., Eggenberger, N., Preisig, B., Nef, T., Nyffeler, T., Gutbrod, K., Annoni, J., & Müri, R. (2015). Cue recognition and integration – Eyetracking evidence of processing differences in sentence comprehension in aphasia. *PloS ONE, 10*, (11): e0142853. doi: 10.1371/journal.pone.0142853

Schwartz, M. F., Saffran, E., and Marin, O. S. M. (1980). The word order problem in agrammatism. *Brain and Language, 10*, 249-262. doi: 10.1016/0093-934X(80)90055-3

Seth, A. K., Dienes, Z., Cleeremans, A., Overgaard, M., and Pessoa, L. (2008). Measuring consciousness: relating behavioral and neurophysiological approaches. *Trends in Cognitive Sciences, 12*, 314-321. doi: 10.1016/j.tics.2008.04.008

Shah, A. K., and Oppenheimer, D. M. (2008). Heuristic made easy: An effort-Reduction framework. *Psychological Bulletin, 134*, 207-222. doi: 10.1037/0033-2909.134.2.207

Shapiro, L. P., and Levine, B. A. (1990). Verb processing during sentence comprehension in aphasia. *Brain and Language, 38*, 21–47. doi: 10.1016/0093-934X(90)90100-U

Shiffrin, R. M. and Schneider, W. (1977). Controlled and automatic human information precessing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84*, 127-190. doi: 10.1037/0033-295X.84.2.127

Shuren, J. e., Hammond, C. S., Maher, L. M., Rothi, L. J., and Heilman, K. M. (1995). Attention and anosognosia: The case of a jargon aphasic patient with unawareness of language deficit. *Neurology, 45*, 376-378. doi: 10.1212/wnl.45.2.376

Simmons-Mackie, N. N., and Damico, J. S. (1997). Reformulating the definition of compensatory strategies in aphasia. *Aphasiology, 11*, 761-781. doi: 10.1080/02687039708250455

Smith, S. D., and Mimica, I. (1984). Agrammatism in a case-inflected language: Comprehension of agent-object relations. *Brain and Language, 21*, 274–290. doi: 10.1016/0093-934X(84)90052-X

Streiner, D. L., and Cairney, J. (2007). What's under the ROC? An introduction to Receiver Operating Characteristics Curves. *The Canadian journal of Psychiatry, 52*, 121-128.

Stuss, D. T. (1991). Disturbance of self-awareness after frontal system damage. In G.P. Prigatono & D.L. Schacter (Eds.), Awareness of deficits after brain inkury (pp. 64-83). New York: Oxford University Press. ISBN: 0-195-05941-7

Sung, J. E. (2016). Age-related decline in case-marker processing and its relation to working memory capacity. *The Gerontological Society of America, 0*, 1-8. doi: 10.1093/geronb/gbv117

Sung, J. E., McNeil, M. R., Pratt, S. R., Dickey, M. W., Hula, W. D., Szuminsky, N. J., & Doyle, P. J. (2009). Verbal working memory and its relationship to sentence-level reading and listening comprehension in persons with aphasia. *Aphasiology, 23*, 1040-1052. doi: 10.1080/02687030802592884

Tanenhaus, M. K. (2007). Eye movements and spoken language processing. In R.P.G. van Gompel, M. H. Fischer, W.S. Murray and R.L. Hill (Eds.), *Eye Movements: A window on Mind and Brain* (pp. 443-469). Amsterdam; Boston : Elsevier. ISBN: 0-080-44980-8

Tanenhaus, M. K., Spivey-Knowlton, M., Eberhard, K., and Sedivy, J. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science*, *268*, 1632–1634. doi: 10.1126/science.7777863

Teubner-Rhodes, S. E., Mishler, A., Corbett, R., Andreu, L., Sanz-Torrent, M., Trueswell, J. C., & Novick, J. M. (2016). The effects of bilingualism on conflict monitoring, cognitive control, and garden-path recovery. *Cognition, 150*, 213-231. doi: 10.1016/j.cognition.2016.02.011

Thompson, C. K., Kielar, A., and Fix, S. (2012). Morphological aspects of agrammatic aphasia. In R. Bastiaanse and C. K. Thompson (Eds.), *Perspectives on Agrammatism* (pp. 75-105). Hove: Psychology Press. ISBN: 978-0-203-12037-8

Thompson, C. K., Meltzer-Asscher, A., Cho, S., Lee, J., Wieneke, C., Weintraub, S., and Mesulam, M. M. (2013). Syntactic and morphosyntactic processing in stroke-induced and primary progressive aphasia. *Behavioural neurology, 26*, 35-54. doi: 10.1155/2013/749412

Tompkins, C. A., Scharp, V. L., and Marchall, R. (2006). Communicative value of self cues in aphasia: A re-evaluation. *Aphasiology, 20*, 684-704. doi: 10.1080/02687030500334076

Townsend, D. J. and Bever, T. G. (2001). *Sentence comprehension: the integration of rules and habits*. Cambridge, MA: MIT Press. ISBN: 978-0-262-70080-1

Paap, K. R. & Greenberg, Z. I. (2013). There is no coherent evidence for a bilingual advantage in executive processing. *Cognitive Psychology, 66*, 232-258. doi: 10.1016/j.cogpsych.2012.12.002

Paap, K. R. & Liu, Y. (2014). Conflict resolution in sentence processing is the same for bilinguals and monolinguals: The role of confirmation bias in testing for bilingual advantage. *Journal of Neurolinguistics, 27*, 50-74. doi: 10.1016/j.jneuroling.2013.09.002

Prior, A. & MacWhinney, B. (2010). A bilingual advantage in task switching. *Bilingualism: Language and Cognition, 13*, 253-262. doi: 10.1017/s1366728909990526

United States Census Bureau (ASCB). Retrieved October 1, 2016, from http://www.census.gov/acs/www/

Vaid, J. & Pandit, R. (1991). Sentence interpretation in normal and aphasic Hindi speakers. *Brain and Language, 2*, 250-274. doi: 10.1016/0093-934x(91)90155-t

van Herten, M., Chwilla, D. J., and Kolk, H. H. J. (2006). When heuristics clash with parsing routines: ERP evidence for conflict monitoring in sentence perception. *Journal of Cognitive Neuroscience, 18*, 1181-1197. doi: 10.1162/jocn.2006.18.7.1181

Vallar, G., Basso, A., and Bottini, G. (1990). Phonological processing and sentence comprehension. A neuropsychological case study. In G. Vallar & T. Shallice (Eds.), *Neuropsychological impairments of short-term memory* (pp. 448-476). Cambridge: Cambridge University Press. ISBN: 978-0521370882

Venkatesh, M., Edwards, S., & Saddy, J. D. (2012). Production and comprehension of English and Hindi in multilingual transcortical aphasia. *Journal of Neurolinguistics, 25*, 615-629. doi: 10.1016/j.jneuroling.2011.10.003

Verbeke, G. & Molenberghs, G. (2000). *Linear Mixed Models for Longitudinal data*. New York: Springer. ISBN: 978-1-4419-0299-3

Verreyt, N., Bogaerts, L., Cop, U., Bernolet, S., De Letter, M., Hemelsoet, D., Santens, P., & Duyck, W. (2013). Syntactic priming in bilingual patients with parallel and differential aphasia. *Aphasiology, 27*, 867-887. doi: 10.1080/02687038.2013.791918

Vuilleumier, P. (2004). Anosognosia: The neurology of beliefs and uncertainties. *Cortex, 40*, 9-17. doi: 10.1016/S0010-9452(08)70918-3

Weber, A., Grice, M., and Crocker, M. W. (2006). The role of prosody in the interpretation of structural ambiguities: a study of anticipatory eye movements. *Cognition*, *99*, B63–72. doi: 10.1016/j.cognition.2005.07.001

Wechsler, D. A. (1997). *Wechsler Adult Intelligence Scale-III (WAIS-III*). San Antonio: The Psychological Corporation. ISBN: 0-158-98104-9

Wingfield, A., Peelle, J. E., & Grossman, M. (2003). Speech rate and syntactic complexity as multiplicative factors in speech comprehension by young and older adults. *Aging Neuropsychology and Cognition, 10*, 310-322. doi: 10.1076/anec.10.4.310.28974

Willmes, K. & Poeck, K. (1993). To what extent can aphasic syndromes be localized?. *Brain, 116*, 1527-1540. doi: 10.1093/brain/116.6.1527

Wilson, B. A., Cockburn, J., and Halligan, P.W. (1987). *Behavioral Inattention Test (BIT)*. England: Thames Valley Test Company. ISBN: 978-0-749-12997-2

Wulfeck, B. B., Juarez, L., Bates, E. A., & Kilborn, K. (1986). Sentence interpreation strategies in healthy and aphasic bilingual adults. In J. Vaid (Ed.), *Language processing in bilinguals: Psycholinguistic and*

Neuropsychological Perspectives, (pp. 199-219). Hillsdale, NJ: Lawrence Erlbaum Associates. ISBN: 9780415724005

Zakariás, L., Keresztes, A., Demeter, G., & Lukács, Á. (2013). A specific pattern of executive dysfunctions in transcortical motor aphasia. *Aphasiology, 27*, 1426-1439. doi: 10.1080/02687038.2013.835783

Ziori, E. and Dienes, Z. (2006). Subjective measures of unconscious knowledge of concepts. *Mind & Society, 5*, 105–122. doi: 10.1007/s11299-006-0012-4

Zweig, M. H., and Campbell, G. (1993). Receiver-Operating Characteristic (ROC) Plots: A fundamental evaluation tool in clinical medicine. *Clinical Chemistry, 34*, 561-577.

Appendix

A. Appendices to Chapter 2

Appendix A1. Participants' demographic and clinical information: 1) people with aphasia (A); and 2) *non-brain-damaged* participants (C).

Participant	Age	Gender	Education level	Literacy language	Months post-onset	Location
A1	80	M	1	Spanish	18	Ischaemic, LMCA
A2	70	M	2	Spanish	9	Ischaemic, LMCA
A3	53	M	2	Spanish	12	Ischaemic, LMCA
A4	43	F	3	Basque	23	Ischaemic, LMCA
A5	80	M	1	Spanish	10	Ischaemic, LMCA
A6	62	M	1	Spanish	13	Ischaemic, LMCA
A7	83	F	1	Spanish	20	Ischaemic, LMCA
A8	60	M	2	Spanish	3	Ischaemic, LMCA
C1	80	M	1	Spanish	n/a	n/a
C2	62	M	2	Spanish	n/a	n/a
C3	54	M	3	Spanish	n/a	n/a
C4	38	F	3	Basque	n/a	n/a
C5	74	F	1	Spanish	n/a	n/a
C6	60	F	1	Spanish	n/a	n/a
C7	77	M	1	Spanish	n/a	n/a
C8	53	M	2	Spanish	n/a	n/a

F= Female; M= Male; 1= Elementary; 2= Technical; 3=University; LMCA= Left Middle Cerebral Artery; n/a= not applicable

Appendix A2. Summary of the individual scores obtained on the relevant subtests of the Cognitive Neuroscience Laboratory language screening battery (CNL; Chialant, 2000; adapted to Basque by Erdocia, Santesteban & Laka, 2003).

Partici-pant	Digit-span (pCTL)	Auditory discr. [0-1]	Lexical compr. [0-1]	Sentence comprehension [0-1]			
				SOV	**(R-)SOV**	**OSV**	**(R-)OSV**
A1	70	.97	.71	.55	.53	.50	.40
A2	14	1.00	.93	.70	.53	.68	.60
A3	14.7	1.00	.97	1.00	1.00	.75	.60
A4	14.7	1.00	1.00	1.00	1.00	.68	.50
A5	14	1.00	.89	.75	.69	.68	.60
A6	-	.70	.71	.55	.47	.56	.60
A7	52	.85	.91	.40	.30	.50	.50
A8	6.8	1.00	1.00	.90	.92	.75	.60

pCTL = percentile by age range; Auditory discr.= auditory discrimination; Lexical compr.= lexical comprehension; (R-)= Semantically reversible

Appendix A3. Analysis of spontaneous speech samples of participants with aphasia.

Subject	MLU	Finiteness (%)	Grammaticality (%)	N°.words/min.
A1	5.05	69.44	64	25
A2	5.16	62.16	56.52	39
A3*	4.68	86.36	57.89	28
A4**	6.39	69.56	68.75	63
A5	3.52	65.45	77.77	52
A6***	-	-	-	-
A7	4.22	71.11	43.75	27
A8	5.90	74.19	60.86	39

MLU= Mean Length of Utterance; *120words; **160 words; ***spontaneous language sample collection was not possible due to Global aphasia.

Appendix A4. Analysis of spontaneous speech samples of non-brain-damaged (NBD) participants from *Ahotsak Ahozko Tradiziozko Korpusa* (*Traditional Oral Language Corpus Ahotsak;* Badihardugu Euskara Elkartea, 2008).

Subject	Gender	Age	MLU	Finiteness (%)	Grammaticality (%)	Num.words/min.
C1	male	79	6.67	85.71	95.83	102
C2	female	81	8.5	95.45	95.43	84
C3	male	74	7.33	88	100	92
C4	male	66	8.8	95.23	95	105
C5	male	77	7.91	91.66	95.45	117
C6	female	82	8.52	91.30	100	95
C7	male	70	11.8	93.33	100	120
C8	male	65	9.73	100	94.73	116
C9	male	65	8.22	90.47	100	122
C10	female	66	10.79	94.11	100	94
x̄		72.5	8.83	92.53	97.64	104.70
se		(sd 6.91)	0.49	1.28	0.79	4.24

MLU= Mean Length of Utterance

Appendix A5. Sentence comprehension accuracy (%) in the experimental task.

PWA					NBD				
Group	**Sentence condition**				**Sentence condition**				
PWA	**SOV**	**OSV**	**VSO**	**VOS**	**NBD**	**SOV**	**OSV**	**VSO**	**VOS**
A1	75	27	61	72	C1	90	75	100	84
A2	60	20	70	35	C2	100	95	90	90
A3	95	95	95	85	C3	95	100	94	90
A4	95	15	95	10	C4	95	95	100	89
A5	75	57	82	63	C5	75	90	90	85
A6	57	36	35	38	C6	94	100	100	95
A7	63	45	50	42	C7	100	95	90	95
A8	84	68	73	73	C8	80	73	85	75
$\bar{x}$	75.81	45.80	71.14	52.28	**$\bar{x}$**	91.19	90.56	93.71	87.97
se	3.47	4.01	3.72	4.05	**se**	2.25	2.32	1.93	2.59

PWA= people with aphasia; NBD= non-brain-damaged

Appendix A6. Additional materials.

Table 2.8 Hypothesis driven model. Reaction time differences between groups across sentence conditions.

		LSMeans (95% CI)	**β**	**SE**	**z-ratio**	**p**
SOV	**NBD**	8.10(7.85–8.35)	-0.269	0.163	-1.641	0.1201
	PWA	8.37(8.12–8.62)				
OSV	**NBD**	8.29(8.04–8.54)	-0.105	0.163	-0.645	0.5282
	PWA	8.40(8.15–8.64)				
VSO	**NBD**	8.26(8.00–8.51)	-0.184	0.165	-1.117	0.2800
	PWA	8.44(8.19–8.69)				
VOS	**NBD**	8.27(8.02–8.52)	-0.162	0.162	-1.000	0.3325
	PWA	8.43(8.18–8.68)				

NBD= non-brain-damaged; PWA= people with aphasia; Significance level p<.05

Appedix A7. Additional materials.

Table 2.9 Hypothesis driven model. PWA and NBD groups: reaction time differences between sentence conditions.

LSMeans (95% CI)		OSV				VSO				VOS			
		β	SE	z-ratio	p	β	SE	z-ratio	p	β	SE	z-ratio	p
SOV	8.37(8.14–8.60)	-0.027	0.043	-0.636	0.9200	-0.071	0.044	-1.610	0.3792	-0.063	0.043	-1.446	0.4756
OSV	8.40(8.17–8.63)	-	-	-	-	-0.044	0.043	-1.022	0.7375	-0.035	0.042	-0.839	0.8355
VSO	8.44(8.21–8.67)	-	-	-	-	-	-	-	-	0.008	0.043	0.202	0.9970
VOS	8.43(8.20–8.66)	-	-	-	-	-	-	-	-	-	-	-	-
		β	**SE**	**z-ratio**	**p**	**β**	**SE**	**z-ratio**	**p**	**β**	**SE**	**z-ratio**	**p**
SOV	8.10(7.86–8.33)	-0.191	0.055	-3.435	**0.0042**	-0.156	0.059	-2.628	**0.0453**	-0.169	0.053	-3.139	**0.0109**
OSV	8.29(8.06–8.53)	-	-	-	-	0.034	0.059	0.589	0.9353	0.022	0.053	0.413	0.9762
VSO	8.26(8.02–8.49)	-	-	-	-	-	-	-	-	-0.012	0.057	-0.223	0.9961
VOS	8.27(8.04–8.50)	-	-	-	-	-	-	-	-	-	-	-	-

PWA= people with aphasia; NBD= non-brain-damaged; Significance level $p<.05$

B. Appendices to Chapter 3 and 4.

Appendix B1. Demographic and clinical information about the participants with aphasia (A) and non-brain-damaged participants (C).

Participant	Age	Gender	Educ.	Bilingualism	Post-onset (Y:M)	Location
A1	68	F	1	Biling.	0:10	I- LMCA
A2	55	M	2	Biling.	7:4	I-RMCA[19]
A3	57	M	2	Biling.	9:10	I- LMCA
A4	61	M	2	Biling.	1:5	I- LMCA
A5	82	M	1	Biling.	2:8	I- LMCA
A6	85	M	2	Biling.	0:9	I- LMCA
A7	64	M	1	Biling.	2:5	I- LMCA
A8	58	M	2	Monoling.	>8:00	AEP
A9	79	F	1	Monoling.	2:9	I-LMCA
A10	59	M	1	Monoling.	2:11	I-LMCA
A11	77	M	2	Monoling.	2:10	I-LMCA
A12	57	F	2	Monoling.	1:00	I-LMCA
A13	65	M	2	Monoling.	5:7	I- LMCA
A14	58	M	1	Monoling.	2:6	I- LMCA
C1	67	M	2	Biling.	n/a	n/a
C2	54	M	2	Biling.	n/a	n/a
C3	63	F	1	Biling.	n/a	n/a
C4	58	F	1	Biling.	n/a	n/a
C5	77	F	1	Biling.	n/a	n/a
C6	82	M	2	Biling.	n/a	n/a
C7	73	M	1	Biling.	n/a	n/a
C8	79	M	2	Monoling.	n/a	n/a
C9	53	F	2	Monoling.	n/a	n/a
C10	44	F	2	Monoling.	n/a	n/a
C11	44	M	2	Monoling.	n/a	n/a
C12	64	F	1	Monoling.	n/a	n/a
C13	65	M	1	Monoling.	n/a	n/a

[19] Crossed-aphasia: presence of aphasia due to right hemisphere injury in a dextral participant (Mariën, et al. 2001; 2003; see also Willmes & Poeck, 1993)

C14	58	M	3	Monoling.	n/a	n/a

F= Female; M= Male; 1= Elementary; 2= Technical; 3=University; I-LMCA= Ischemic-Left Middle Cerebral Artery; I-RMCA= Ischemic-Right Middle Cerebral Artery n/a= not applicable.

Appendix B2. Summarized data on linguistic background and use of languages across different context/modalities in bilingual PWA and NBD. Data collected with the Bilingual Language Profile: Spanish-Basque (BLP; Birdsong, Gertken, & Amengual, 2012; adapted by Arantzeta, 2016).

	AoA		**Use of languages**									
			Friends		**Family**		**Work**		**Self-talk**		**Count**	
	S	**B**	S	B	S	B	S	B	S	B	S	B
A1	birth	birth	50%	50%	50%	50%	50%	50%	50%	50%	80%	20%
A2	4	birth	40%	60%	10%	90%	50%	50%	30%	70%	70%	30%
A3	3	birth	60%	40%	60%	40%	30%	70%	50%	50%	70%	30%
A4	3	birth	20%	80%	10%	90%	30%	70%	10%	90%	50%	50%
A5	4	birth	10%	90%	0%	100%	20%	80%	10%	90%	80%	20%
A6	3	birth	50%	50%	70%	30%	30%	70%	30%	70%	90%	10%
A7	5	birth	20%	80%	0%	100%	40%	60%	10%	90%	10%	90%
C1	3	birth	40%	60%	20%	80%	60%	40%	50%	50%	60%	40%
C2	2	birth	60%	40%	30%	70%	50%	50%	60%	40%	60%	40%
C3	4	birth	20%	80%	10%	90%	60%	40%	10%	90%	70%	30%
C4	4	birth	10%	90%	10%	90%	30%	70%	10%	90%	80%	20%
C5	5	birth	10%	90%	0%	100%	30%	70%	0%	100%	70%	30%
C6	4	birth	40%	60%	20%	80%	40%	60%	20%	80%	60%	40%
C7	5	birth	20%	80%	0%	100%	50%	50%	10%	90%	50%	50%

AoA= age of acquisition; S= Spanish; B= Basque.

Appendix B3. Individual scores on the Wechsler Adult Intelligence Scale (WAIS-III; Wechsler, 1997), in the extended version of the Boston Aphasia Test (BDAE; Goodglass, Klapla, & Barresi, 2005; Adapted to Spanish by García-Albea, 2005) and in the Cognitive Neuroscience Laboratory Language screening battery (CNL; Chialant, 2000; adapted to Basque by Erdocia, Santesteban, & Laka, 2003)

Participant	WAIS	BDAE (Spanish)					CNL (Basque)		
	Digit-span (pCTL)	Word compr.	Commands	Complex Ideational Material	Syntactic processing		Auditory discrimination	Lexical comprehension	Sentence comprehension
					Touching A with B	Embedded sentences			
A1	68.8	100	86.66	41.66	58.33	60	100	92	72.22
A2	14.7	100	86.66	83.33	66.66	80	92	100	72.22
A3	68.8	94.59	100	75	58.33	60	100	96	69.44
A4	6.8	91.89	80	58.33	33.33	30	100	93	66.66
A5	14	86.48	66.66	41.66	16.66	70	95	90	63.88
A6	14	94.59	86.66	66.66	50	40	92.5	92	72.22
A7	-	91.89	73.33	50	25	50	95	86	55
A8	68.8	94.59	100	75	66.66	60	n/a	n/a	n/a
A9	0.7	94.59	80	83.33	33.33	90	n/a	n/a	n/a
A10	0	89.1	66.66	50	66.66	60	n/a	n/a	n/a
A11	14	94.59	86.66	91.66	33.33	90	n/a	n/a	n/a
A12	0	91.89	80	58.33	33.33	30	n/a	n/a	n/a
A13	-	81.08	-	50	16.66	60	n/a	n/a	n/a
A14	37.1	97.29	100	66.66	41.66	90	n/a	n/a	n/a
***t-Test*[20]**		***0.4107***	***0.6944***	***0.3566***	***0.8170***	***0.2566***	-	-	-

pCTL = percentile by age range; Word compr.= word comprehension.

[20] Two-sample t Test with unequal variance comparing task performance between bilingual and monolingual speakers. Sign. level at $p<.05$

Appendix B4. Individual scores of the PWA and NBD groups on sentence comprehension accuracy in the experimental task in Basque.

Subject	Condition				Subject	Condition			
PWA	**SOV**	**OSV**	**VSO**	**VOS**	**NBD**	**SOV**	**OSV**	**VSO**	**VOS**
A1	78.94	40	84.21	26.31	**C1**	94.73	100	100	95
A2	78.94	47.36	75	70	**C2**	95	90	94.73	85
A3	78.94	50	77.77	72.22	**C3**	95	70	100	100
A4	57.89	36.84	35.29	38.88	**C4**	95	95	80	75
A5	75	57.89	82.35	63.15	**C5**	75	90	90	85
A6	83.33	57.89	80	70	**C6**	95	100	100	100
A7	84.21	68.42	73.68	73.68	**C7**	100	95	90	95
Mean	76.74	51.11	73.07	59.39	**Mean**	92.80	91.42	93.52	90.71
(SE)	(3.73)	(4.31)	(3.90)	(4.27)	**(SE)**	(2.19)	(2.37)	(2.09)	(2.46)

PWA= people with aphasia; NBD= non-brain damaged

Appendix B5. Individual scores (%) of both IWA and NBD groups on sentence comprehension accuracy in the experimental task in Spanish.

Subject	Bilingualism	Condition:					
PWA		**Act**	**Pass**	**Subj.Cl**	**Obj.Cl**	**Subj.Rl.**	**Obj.Rl.**
A1	Bilingual	75	75	75	68.42	78.94	75
A2	Bilingual	94.73	90	80	45	70	65
A3	Bilingual	95	80	100	47.36	89.47	68.42
A4	Bilingual	100	63.15	100	78.94	89.47	50
A5	Bilingual	85	78.94	89.47	57.89	70	60
A6	Bilingual	95	80	73.68	68.42	76.47	70
A7	Bilingual	70	52.63	55.55	47.36	58.82	52.63
A8	Monolingual	100	94.44	100	80	95	81.25
A9	Monolingual	55	55.55	55.55	41.17	40	64.70
A10	Monolingual	94.73	90	85	44.44	90	15.78
A11	Monolingual	95	94.73	100	85	95	80
A12	Monolingual	50	47.68	64.70	47.36	55.55	60
A13	Monolingual	55	50	44.44	40	52.63	45
A14	Monolingual	85	87.47	85	90	85	80
Mean (SE)		82.18 (2.31)	74.62 (2.66)	79.85 (2.45)	60.44 (2.99)	75 (2.64)	61.85 (2.96)
NBD							
C1	Bilingual	95	94.73	100	100	95	100
C2	Bilingual	95	100	95	95	90	95
C3	Bilingual	100	100	100	100	90	95
C4	Bilingual	100	95	100	95	100	85
C5	Bilingual	100	95	89.47	95	95	95
C6	Bilingual	100	94.73	90	95	90	95
C7	Bilingual	90	94.11	90	100	94.73	95
C8	Monolingual	100	100	95	100	95	100
C9	Monolingual	100	100	95	100	95	100
C10	Monolingual	95	100	100	95	90	95
C11	Monolingual	100	100	100	95	90	95
C12	Monolingual	100	95	95	100	95	95
C13	Monolingual	100	95	95	90	90	100
C14	Monolingual	100	100	100	95	95	85
Mean (SE)		98.18 (0.80)	97.46 (0.94)	96.05 (1.16)	96.78 (1.05)	93.18 (1.51)	95 (1.30)

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.

C. Linguistic stimuli in Basque

Experimental items (Chapter 2 & 3; target items, N=80, filler items, N=80)

Target items:

The stimuli correspond to the following conditions: a) SOV; b) OSV; c) VSO; and d) VOS.

1. Beldurtu (*to frighten*)
   a) Marinelak arratoia beldurtzen du.
   b) Marinela arratoiak beldurtzen du.
   c) Beldurtzen du arratoiak marinela.
   d) Beldurtzen du arratoia marinelak.
2. Bultzatu (*to push*)
   a) Arbitroak atezaina bultzatzen du.
   b) Atezaina arbitroak bultzatzen du.
   c) Bultzatzen du atezainak arbitroa.
   d) Bultzatzen du arbitroa atezainak.
3. Esnatu (*to wake up*)
   a) Neskameak abadea esnatzen du.
   b) Abadea neskameak esnatzen du.
   c) Esnatzen du abadeak neskamea.
   d) Esnatzen du neskamea abadeak.
4. Estali (*to cover*)
   a) Gurasoak mutikoa estaltzen du.
   b) Gurasoa mutikoak estaltzen du.
   c) Estaltzen du gurasoak mutikoa.
   d) Estaltzen du gurasoa mutikoak.
5. Filmatu (*to record*)
   a) Poliziak txinatarra filmatzen du.
   b) Polizia txinatarrak filmatzen du.
   c) Filmatzen du poliziak txinatarra.
   d) Filmatzen du polizia txinatarrak.
6. Gelditu (*to stop*)

a) Gaizkileak agurea gelditzen du.
b) Gaizkilea agureak gelditzen du.
c) Gelditzen du agureak gaizkilea.
d) Gelditzen du agurea gaizkileak.

7. Kolpatu (*to hit*)
    a) Kamioiak autobusa kolpatzen du.
    b) Autobusa kamioiak kolpatzen du.
    c) Kolpatzen du autobusak kamioia.
    d) Kolpatzen du kamioia autobusak.
8. Laztandu (*to caress*)
    a) Mutikoak agurea laztantzen du.
    b) Mutikoa agureak laztantzen du.
    c) Laztantzen du agureak mutikoa.
    d) Laztantzen du agurea mutikoak.
9. Marraztu (*to draw*)
    a) Soldaduak mutikoa marrazten du.
    b) Soldadua mutikoak marrazten du.
    c) Marrazten du soldaduak mutikoa.
    d) Marrazten du soldadua mutikoak.
10. Orraztu (*to comb*)
    a) Neskatoak anderea orrazten du.
    b) Anderea neskatoak orrazten du.
    c) Orrazten du andereak neskatoa.
    d) Orrazten du neskatoa andereak.
11. Saritu (*to reward*)
    a) Alkateak dantzaria saritzen du.
    b) Dantzaria alkateak saritzen du.
    c) Saritu du dantzariak alkatea.
    d) Saritu du alkate dantzaria.
12. Tiratu (*to pull*)
    a) Furgonetak traktorea tiratu du.
    b) Furgoneta traktoreak tiratu du.
    c) Tiratu du furgonetak traktorea.
    d) Tiratu du furgoneta traktoreak.

13. Sendatu (*to treat*)
    a) Medikuak erizaina sendatu du.
    b) Medikua erizainak sendatu du.
    c) Sendatu du erizainak medikua.
    d) Sendatu du erizaina medikuak.
14. Txalotu (*to applaude*)
    a) Erregeak dantzaria txalotu du.
    b) Dantzaria erregeak txalotu du.
    c) Txalotu du dantzariak erregea.
    d) Txalotu du erregea dantzariak.
15. Ukitu (*to touch*)
    a) Andereak eskalea ukitu du.
    b) Anderea eskaleak ukitu du.
    c) Ukitu du andereak eskalea.
    d) Ukitu du anderea eskaleak.
16. Zapaldu (*to tread*)
    a) Emazteak postaria zapaldu du.
    b) Emaztea postariak zapaldu du.
    c) Zapaldu du postariak emaztea.
    d) Zapaldu du postaria emazteak.
17. Zauritu (*to hurt*)
    a) Basurdeak ehiztaria zauritu du.
    b) Basurdea ehiztariak zauritu du.
    c) Zauritu du ehiztariak basurdea.
    d) Zauritu du ehiztaria basurdeak.
18. Salbatu (*to rescue*)
    a) Suhiltzaileak tximinoa salbatu du.
    b) Tximinoa suhiltzaileak salbatu du.
    c) Salbatu du tximinoak suhiltzailea.
    d) Salbatu du suhiltzailea tximinoak.
19. Lehortu (*to dry*)
    a) Mutikoak neskatoa lehortu du.
    b) Mutikoa neskatoak lehortu du.
    c) Lehortu du mutikoak neskatoa.

d) Lehortu du mutikoa neskatoak.

20. Zikindu (*to dirty*)

a) Andereak pintorea zikindu du.
b) Pintorea andereak zikindu du.
c) Zikindu du pintoreak anderea.
d) Zikindu du anderea pintoreak.

Practice target items:

- Agurtu (*to wave*)
  a) Neskatoak saltzailea agurtzen du.
  b) Saltzailea neskatoak agurtzen du.
  c) Agurtzen du saltzaileak neskatoa.
  d) Agurtzen du neskatoa saltzaileak.
- Babestu (*to protect*)
  a) Udaltzainak suhiltzailea babestu du.
  b) Suhiltzailea udaltzainak babestu du.
  c) Babesten du suhiltzaileak udaltzaina.
  d) Babesten du udaltzaina suhiltzaileak.

Filler items (Chapter 2, N=80)

The stimuli correspond to the following conditions: a) S-Adv-V, b) Adv-S-V, c) V-S-Adv, d) V-Adv-S.

1. Mugitu (*to move*)
   a) Basurdea bapatean mugitu da.
   b) Bapatean erizaina mugitu da.
   c) Mugitu da basurdea bapatean.
   d) Mugitu da bapatean erizaina.
2. Etorri (*to come*)
   a) Marinela azkenean etorri da.
   b) Azkenean arbitroa etorri da.
   c) Etorri da arbitroa azkenean.
   d) Etorri da azkenean marinela.

3. Gaixotu (*to get sick*)
    a) Erizaina bapatean gaixotu da.
    b) Bapatean erizaina gaixotu da.
    c) Gaixotu da mutikoa bapatean.
    d) Gaixotu da bapatean mutikoa.
4. Garbitu (*to clean*)
    a) Ehiztaria berehala garbitu da.
    b) Berehala suhiltzailea garbitu da.
    c) Garbitu da suhiltzailea berehala.
    d) Garbitu da berehala ehiztaria.
5. Harritu (*to surprise*)
    a) Polizia bapatean harritu da.
    b) Bapatean polizia harritu da.
    c) Harritu da neskamea bapatean.
    d) Harritu da bapatean neskamea.
6. Hondatu (*to break*)
    a) Kamioia bapatean hondatu da.
    b) Bapatean kamioia hondatu da.
    c) Hondatu da traktorea bapatean.
    d) Hondatu da bapatean traktorea.
7. Hotzitu (*to cool*)
    a) Anderea berehala hotzitu da.
    b) Berehala agurea hotzitu da.
    c) Hotzitu da agurea berehala.
    d) Hotzitu da berehala agurea.
8. Hurbildu (to come nearer)
    a) Tximinoa azkenean hurbildu da.
    b) Azkenean mutikoa hurbildu da.
    c) Hurbildu da tximinoa azkenean.
    d) Hurbildu da azkenean mutikoa.
9. Iritsi (*to arrive*)
    a) Soldadua honezkero iritsi da.
    b) Honezkero marinela iritsi da.
    c) Iritsi da soldadua honezkero.

d) Iritsi da honezkero marinela.

10. Jesarri (*to sit down*)
    a) Gaizkilea azkenean jesarri da.
    b) Azkenean gaizkile jesarri da.
    c) Jesarri da txinatarra azkenean.
    d) Jesarri da azkenean txinatarra.
11. Jostatu (*to play*)
    a) Atezaina azkenean jostatu da.
    b) Azkenean atezaina jostatu da.
    c) Jostatu da mutikoa azkenean.
    d) Jostatu da azkenean mutikoa.
12. Zutitu (*to stand up*)
    a) Polizia berehala zutitu da.
    b) Berehala polizia zutitu da.
    c) Zutitu da eskalea berehala.
    d) Zutitu da berehala eskalea.
13. Loditu (*to gain weight*)
    a) Dantzaria bapatean loditu da.
    b) Bapatean arbitroa loditu da.
    c) Loditu da dantzaria bapatean.
    d) Loditu da bapatean arbitroa.
14. Lokartu (*to fall asleep*)
    a) Medikua honezkero lokartu da.
    b) Honezkero neskamea lokartu da.
    c) Lokartu da medikua honezkero.
    d) Lokartu da honezkero medikua.
15. Mintzatu (*to express*)
    a) Emaztea azkenean mintzatu da.
    b) Azkenean emaztea mintzatu da.
    c) Mintzatu da alkatea azkenean.
    d) Mintzatu da azkenean alkatea.
16. Nekatu (*to tire*)
    a) Postaria berehala nekatu da.
    b) Berehala postaria nekatu da.

c) Nekatu da gaizkilea berehala.
d) Nekatu da berehala gaizkilea.

17. Tristetu (*to sadden*)
    a) Neskatoa bapatean tristetu da.
    b) Bapatean gurasoa tristetu da.
    c) Tristetu da gurasoa bapatean.
    d) Tristetu da bapatean neskatoa.
18. Altxatu (*to awaken*)
    a) Alkatea azkenean altxatu da.
    b) Azkenean neskatoa altxatu da.
    c) Altxatu da alkatea azkenean.
    d) Altxatu da azkenean neskatoa.
19. Labaindu (*to slide*)
    a) Suhiltzailea bapatean labaindu da.
    b) Bapatean suhiltzailea labaindu da.
    c) Labaindu da dantzaria bapatean.
    d) Labaindu da bapatean dantzaria.
20. Agertu (*to appear*)
    a) Basurdea honezkero agertu da.
    b) Honezkero tximinoa agertu da.
    c) Agertu da basurdea honezkero.
    d) Agertu da honezkero tximinoa.

Practice filler items:

- Argaldu (*to lose weight*)
    a) Udaltzaina berehala argaldu da.
    b) Berehala erregea argaldu da.
    c) Argaldu da erregea berehala.
    d) Argaldu da berehala udaltzaina.
- Aspertu (*to bore*)
    a) Neskatoa honezkero aspertu da.
    b) Honezkero pintorea aspertu da.
    c) Aspertu da neskatoa honezkero.
    d) Aspertu da honezkero pintorea.

D. Linguistic stimuli in Spanish

Experimental items (Chapter 3 & 4; target items, N=120)

Target items

The stimuli correspond to the following conditions: a) Active, b) Passive, c) Object cleft, d) Subject cleft, e) Subject relative, f) Object relative.

1. Acariciar (*to caress*)
    a) El chico ha acariciado al abuelo.
    b) El chico es acariciado por el abuelo.
    c) Es el abuelo el que acaricia al chico.
    d) Es al abuelo al que acaricia el chico.
    e) Veo al abuelo que acaricia al chico.
    f) Veo al abuelo al que acaricia el chico.
2. Aplaudir (*to applaude*)
    a) El rey ha aplaudido a la bailarina.
    b) El rey es aplaudido por la bailarina.
    c) Es la bailarina la que aplaude al rey.
    d) Es a la bailarina a la que aplaude el rey.
    e) Veo al rey que aplaude a la bailarina.
    f) Veo al rey al que aplaude la bailarina.
3. Arrastrar (*to pull*)
    a) El tractor ha arrastrado la furgoneta.
    b) La furgoneta es arrastrada por el tractor.
    c) Es la furgoneta la que arrastra el tractor.
    d) Es al tractor al que arrastra la furgoneta.
    e) Veo la furgoneta que arrastra el tractor.
    f) Veo la furgoneta a la que arrastra el tractor.
4. Asustar (*to frighten*)
    a) El ratón ha asustado al marinero.
    b) El marinero es asustado por el ratón.

c) Es el marinero el que asusta al ratón.
d) Es al ratón al que asusta el marinero.
e) Veo al marinero que asusta al ratón.
f) Veo al marinero al que asusta el ratón.

5. Curar (*to treat*)
    a) El médico ha curado a la enfermera.
    b) El médico es curado por la enfermera.
    c) Es la enfermera la que cura al médico.
    d) Es a la enfermera a la que cura el médico.
    e) Veo al médico al que cura la enfermera.
    f) Veo al médico que cura a la enfermera.
6. Despertar (*to wake up*)
    a) El cura ha despertado a la sirvienta.
    b) El cura es despertado por la sirvienta.
    c) Es el cura el que despierta a la sirvienta.
    d) Veo al cura que despierta a la sirvienta.
    e) Es al cura al que despierta la sirvienta.
    f) Veo al cura al que despierta la sirvienta.
7. Detener (*to stop*)
    a) El delincuente ha detenido al abuelo.
    b) El abuelo es detenido por el delincuente.
    c) Es el delincuente el que detiene al abuelo.
    d) Es al delincuente al que detiene el abuelo.
    e) Veo al abuelo que detiene al delincuente.
    f) Veo al delincuente al que detiene el abuelo.
8. Dibujar (*to draw*)
    a) El chico ha dibujado al soldado.
    b) El chico es dibujado por el soldado.
    c) Es el chico el que dibuja al soldado.
    d) Es al chico al que dibuja el soldado.
    e) Veo al chico que dibuja al soldado.
    f) Veo al chico al que dibuja el soldado.
9. Empujar (*to push*)
    a) El árbitro ha empujado al portero.

b) El árbitro es empujado por el portero.

c) Es el portero el que empuja al árbitro.

d) Es al portero al que empuja el árbitro.

e) Veo al árbitro que empuja al portero.

f) Veo al árbitro al que empuja el portero.

10. Ensuciar (*to dirty*)

a) El pintor ha ensuciado a la señora.

b) El pintor es ensuciado por la señora.

c) Es la señora la que ensucia al pintor.

d) Es al pintor al que ensucia la señora.

e) Veo al pintor que ensucia a la señora.

f) Veo a la señora a la que ensucia el pintor.

11. Golpear (*to hit*)

a) El camión ha golpeado el autobús.

b) El camión es golpeado por el autobús.

c) Es el autobús el que golpea al camión.

d) Es al autobús al que golpea el camión.

e) Veo el autobús que golpea al camión.

f) Veo el autobús al que golpea el camión.

12. Grabar (*to record*)

a) El policía ha grabado al chico.

b) El policía es grabado por el chico.

c) Es el policía el que graba al chico.

d) Es al chico al que graba el policía.

e) Veo al chico que graba al policía.

f) Veo al policía al que graba el chico.

13. Herir (*to hurt)*

a) El cazador ha herido al jabalí.

b) El cazador es herido por el jabalí.

c) Es el jabalí el que hiere al cazador.

d) Es al jabalí al que hiere el cazador.

e) Veo al cazador que hiere al jabalí.

f) Veo al cazador al que hiere el jabalí.

14. Peinar (*to comb*)
    a) La chica ha peinado a la mujer.
    b) La chica es peinada por la mujer.
    c) Es la mujer la que peina a la chica.
    d) Es a la chica a la que peina la mujer.
    e) Veo a la chica que peina a la mujer.
    f) Veo a la mujer a la que peina la chica.
15. Pisar (*to tread*)
    a) El cartero ha pisado a la mujer.
    b) La mujer es pisada por el cartero.
    c) Es el cartero el que pisa a la mujer.
    d) Es al cartero al que pisa la mujer.
    e) Veo a la mujer que pisa al cartero.
    f) Veo al cartero al que pisa la mujer.
16. Premiar (*to reward*)
    a) La bailarina ha premiado al alcalde.
    b) La bailarina es premiada por el alcalde.
    c) Es la bailarina la que premia al alcalde.
    d) Es al alcalde al que premia la bailarina.
    e) Veo al alcalde que premia a la bailarina.
    f) Veo a la bailarina a la que premia el alcalde.
17. Salvar (*to save*)
    a) El mono ha salvado al bombero.
    b) El mono es salvado por el bombero.
    c) Es el mono el que salva al bombero.
    d) Es al mono al que salva el bombero.
    e) Veo al bombero que salva al mono.
    f) Veo al bombero al que salva el mono.
18. Secar (*to dry*)
    a) La chica es secada por el chico.
    b) El chico ha secado a la chica.
    c) Es la chica la que seca al chico.
    d) Es al chico al que seca la chica.
    e) Veo a la chica que seca al chico.

f) Veo a la chica a la que seca el chico.

19. Tapar (*to cover*)
    a) La madre ha tapado al chico.
    b) La madre es tapada por el chico.
    c) Es la madre la que tapa al chico.
    d) Es a la madre a la que tapa el chico.
    e) Veo al chico que tapa a la madre.
    f) Veo al chico al que tapa la madre.
20. Tocar (*to touch*)
    a) El mendigo ha tocado a la señora.
    b) La señora es tocada por el mendigo.
    c) Es la señora la que toca al mendigo.
    d) Es al mendigo al que toca la señora.
    e) Veo a la señora que toca al mendigo.
    f) Veo a la señora a la que toca el mendigo.

Practice items:

- Saludar (*to wave*)

  Es la chica la que saluda al vendedor.

  Es a la chica a la que saluda el comerciante.

  Veo al vendedor al que saluda la chica.
- Proteger (*to protect*)

  El bombero es protegido por el municipal.

  El bombero ha protegido al municipal.

  Veo al bombero que protege al municipal.