Processing of semantic and grammatical gender in Spanish speakers with aphasia

G. Piazza[a,b]*, M. Calabria[c], C. Semenza[d], C. Poletto[b,e]

[a] *Basque Center on Cognition, Brain and Language (BCBL), Donostia-San Sebastián, Spain;*

[b] *Department of Linguistic and Literary Studies (DiSLL), University of Padova, Padova, Italy;*

[c] *Faculty of Health Sciences, Universitat Oberta de Catalunya (UOC), Barcelona, Spain;*

[d] *Padova Neuroscience Center (PNC), University of Padova, Padova, Italy;*

[e] *Institute of Romance Languages and Literature, Goethe University Frankfurt, Frankfurt am Main, Germany.*

*corresponding author: g.piazza@bcbl.eu

Processing of semantic and grammatical gender in Spanish speakers with aphasia

Abstract

Background. Previous studies have argued that there are two types of linguistic gender: grammatical gender, which is arbitrarily assigned to nouns, and semantic gender, which depends on the gender of the referent.

Aim. We explore the hypothesis that these two types of gender entail distinct cognitive processes by investigating the performance of people with aphasia at the level of sentence processing.

Methods and Procedure. Nine people with aphasia (seven with fluent aphasia) and a control group of thirteen age-matched healthy participants took part in a *constrained completion choice* task. The participants had to complete sentences in a way that made the last word gender congruent. The subjects of the sentences had either Semantic gender (*enfermera*, nurse; indicating the gender of the referent), Grammatical gender (*silla*, chair), or Opaque-Grammatical gender (*tomate*, tomato).

Results. People with aphasia performed more poorly in all gender conditions than healthy controls. They also were less accurate in both the Grammatical and Opaque-Grammatical conditions than in the Semantic gender condition.

Conclusion. We propose that because semantic gender provides more salient information, it is processed faster than grammatical gender.

Keywords: aphasia, agreement, semantic gender, grammatical gender, sentence processing.

1. Introduction

In transparent languages, gender is assigned to every noun (see Corbett, 1991; Picallo, 2008) and, in most cases, is conveyed by information in the final (transparent) morpheme of the noun or through a noun affix. For instance, in Spanish the final morpheme -a usually indicates feminine gender (e.g. *casa*, house.FEM), while -o usually indicates masculine gender (e.g. *casco*, helmet.MASC) (Real Academia Española, 2010). However, there are two types of gender, specifically, 'grammatical' gender, which is arbitrarily assigned to nouns, and 'semantic' gender, which is dictated by the gender of the referent[1]. It seems likely that speakers process these two types of gender in different ways. Indeed, grammatical gender is a purely syntactic property, which is always carried by inanimate nouns (objects) as well as animate nouns without transparent gender morphology. In Spanish, for instance, nouns with the opaque ending (-e) still have grammatical gender, but the -e morpheme does not permit gender identification because it is used for both feminine and masculine nouns (e.g. *puente*, bridge.MASC; *tigre*, tiger.FEM).

Semantic gender, which exclusively applies to animate nouns with final -a or -o, not only comprises grammatical gender but also explicitly indicates information about the referent's gender. Thus, semantic gender provides both syntactic and semantic information (Vigliocco and Franck, 1999). For example, Spanish words such as *enfermero* (nurse.MASC) and *enfermera* (nurse.FEM) bear semantic gender because the -o and -a morphemes reflect the referent's gender.

In Spanish, although both types of gender generally follow the same morphemic rules, there are 'exceptions'. Changing the ending (-o/-a) can create a noun of the opposite gender for some animal names: both *mono* (male monkey) or *mona* (female monkey) have semantic gender. Conversely, changing the ending (-o/-a) of nouns with grammatical gender only does not create nouns with opposite gender, but instead produces non-words or words with a distinct meaning (i.e., *casa*, house.FEM; *caso*, case.MASC)

In the present study, we investigate the hypothesis that sentence processing of semantic gender is reinforced and enhanced because syntactic and semantic features match, whereas grammatical gender processing is driven only by syntax. We explore the assumption that semantic gender carries salient

semantic information – making it easier to process agreement and access meaning – by comparing the performance of people with aphasia (henceforth PWA) with healthy controls. In fact, studies on various patient populations have shown that gender can be preserved, lost or difficult to retrieve in word recognition and sentence comprehension (e.g., Manenti et al., 2009), suggesting possible dissociations between these linguistic processes.

1.1. Semantic vs. grammatical gender

The difference between semantic and grammatical gender is not merely a difference between animate and inanimate nouns. Semantic gender is supplementary semantic information about the gender of the noun referent that is reflected in the noun's morphology. For instance, it is distinct from grammatical gender in words like *silla* (chair.FEM), and *pájaro* (bird.MASC), where the morphology does not convey any information about the gender of the referents; in fact, a chair is an object, while the word *pájaro* does not have a feminine counterpart and is a general term that refers to all birds, both male and female. It is worth underscoring that the gender of an animate referent does not in itself constitute semantic gender if it does not coincide with the morphological expression of gender. For this reason the nouns *pájaro*, which does not have a feminine counterpart, and *tigre* (tiger.MASC), which ends with a morpheme that could be either masculine or feminine, do not have semantic gender.

Comprehension and information retrieval mechanisms operate differently when nouns are encountered in the context of sentences than they do in bare noun recognition. Accordingly, while agreement is optional in word pairs, it is always active and involves a constant process for selection of correct agreement candidates in sentences (Cacciari and Cubelli, 2003; Corbett, 2006). For this reason, our experimental design used an enriched sentence processing context, which ensured gender was activated as participants accessed word meaning and computed agreement at a distance.

4

There are two main accounts that aim to explain how semantic gender influences sentence processing. The first account is known as the *minimal input hypothesis* and derives from theories that claim semantic features have minimal impact on syntactic processing (Bock and Levelt, 1994; Kempen and Hoenkamp, 1987; Levelt, 1989). The *minimal input hypothesis* claims that grammatical gender is a purely syntactic feature that cannot be influenced by conceptual agreement (Chomsky, 1965, 1981); "the committee have decided" is an example of conceptual agreement. In this sentence, the subject-verb agreement is not correct from a grammatical point of view, but it is conceptually acceptable because the meaning is plural. When possible, syntactic agreement is preferred over conceptual agreement; children, for example, autonomously create an agreement system between constituents before they learn rules and irregularities. In this first account, there cannot be different levels (grammatical and semantic) for processing gender, because gender is grammatical and therefore is only processed at the syntactic level. The second account is called the *maximal input hypothesis* and claims that semantic meaning and structures have some influence over agreement and syntactic operations (Barlow, 1993; MacDonald et al., 1994; Pollard and Sag, 1994; Vigliocco, et al., 1996; Vigliocco and Franck, 1999).

Since many linguistic phenomena demonstrate a dichotomy between semantic and grammatical gender, Vigliocco and Franck (1999) postulate that they are processed differently. According to this view, conceptual structures that carry semantic information influence grammatical functions and syntactic processes (such as agreement). This has led to the assumption that gender has a double nature (Vigliocco and Franck, 1999), which allows us to process semantic gender differently from grammatical gender (cf. Van Dyke, 2007; Bates et al., 1995). Linguistic elements create dependencies, even at long distances, which comprehension processes resolve via cue-based retrieval mechanisms (Lewis et al, 2006; Van Dyke and McElree, 2006). Studies on argument hierarchy and feature-sharing showed that if a competing item shares some features with the target, this overlap can interfere with the retrieval process and induce errors (Parker et al., 2017). Conversely, semantic cues could also explain why semantic gender nouns

were produced more accurately than grammatical gender nouns in Vigliocco and Franck's experiment (1999).

In the study by Vigliocco and Franck (1999), participants were first presented with adjectives in both their masculine and feminine forms, then read a preamble sentence. The gender type of the subject (head noun of the sentence) had either semantic or grammatical gender. The participants had to repeat the whole sentence, adding on the correct (gender-matched) adjective at the end. The researchers found that agreement errors were more frequent when the subjects had grammatical gender. They argued that their experimental manipulation led participants to distinguish between gender that carries both syntactic information and semantic properties derived from the gender of the referent (semantic gender) from purely grammatical gender with bare syntactic features (grammatical gender). We still lack evidence for this division of labour in sentence processing, but such results suggest that – at least in speech production – an internal distinction is made between these two types of gender and different processes underpin the assignment of semantic and grammatical gender (see also Vigliocco et al, 1995; Franzon et al., 2013).

Vigliocco and Franck's (1999) experiment also explored whether semantic gender is assigned on the basis of animacy, given that all nouns endowed with semantic gender are also animate nouns. They compared animate nouns with transparent gender morphology, in which gender marking was the same for both genders (as in the *pájaro* example mentioned above) and inanimate nouns. It is worth noting that this allowed them to manipulate animacy in isolation. In this experiment, they did not find any difference between animate nouns with fixed gender – which use a fixed final morpheme regardless of the gender of the reference (such as *pájaro*) – and inanimate nouns. These results strongly suggest that semantic gender does not equal animacy. Moreover, Vigliocco and Franck (1999) investigated whether animate nouns with fixed grammatical gender carry semantic gender but did not find an effect comparable to that seen for proper semantic gender nouns. These results indicating that fixed gender for animate nouns is processed differently than semantic gender.

This dissociation between semantic and grammatical gender has been further demonstrated in studies that use metalinguistic tasks. Schiller et al. (2003) found that during a gender categorisation task the frontal ERP N200 component was larger for nouns marked with semantic gender than for animate nouns with opaque endings. This reinforces the idea that semantic gender arises from a match between gender and morphology. Similarly, Franzon et al.'s (2013) preliminary study detected higher accuracy for semantic gender in noun-adjective grammatical judgments. In a more recent study, Caffarra et al. (2016) reported the semantic gender effect in an experiment with Spanish-Basque bilinguals where participants had to indicate the gender of bare words. Half of the stimuli had opaque endings (i.e., the final -e in Spanish), providing no gender information, while the other half had transparent endings (i.e., final -a/-o), expressing feminine/masculine gender. Within the transparent category, half of the nouns had semantic gender and half had only grammatical gender. They observed facilitation in terms of RTs and accuracy for nouns bearing semantic gender. This finding suggests that semantic gender helps with the categorisation of bare nouns by means of explicit gender knowledge. However, to date, no study has explored how people with aphasia (PWA) compute semantic gender in comprehension or sentence processing and whether it facilitates agreement processing when no declarative knowledge is required (i.e., when deciding whether a noun is masculine or feminine vs. using gender to match a noun and its adjective).

In sum, research has not provided conclusive evidence for the existence of two types of gender processes nor found evidence for it in sentence processing tasks. More importantly, since most previous studies used either production tasks or asked participants to make explicit judgments on single words, it remains unclear whether semantic gender facilitates sentence processing. The present study intends to contribute to clarifying these issues using a cognitive neuropsychology method.

1.2. Aphasia and Gender Processing

Research has found evidence for and against the maintenance of gender knowledge in PWA. Some research has demonstrated that gender knowledge is maintained in people with aphasia. For instance, although Bates et al. (2001) tested both Broca's and Wernicke PWA and failed to observe gender priming effects in any PWA, they also found that both fluent and non-fluent PWA were able to correctly use gender. In contrast, Akhutina et al. (2001) found that fluent and non-fluent PWA had comparable difficulties with recognizing grammatical gender during a grammaticality judgement task. The authors found that patients' gender judgments were only related to aphasia severity not aphasia fluency.

The apparent discrepancy between these results can be explained if we assume that two types of gender knowledge exist: one procedural and the other declarative or metalinguistic (Scarnà and Ellis, 2002). The former is unconscious syntactic gender knowledge that allows for automatic computation of agreement between constituents without the need for explicit recall of gender. The latter is the metalinguistic ability to explicitly indicate the gender of an element without putting any syntactic operations into play (Goodglass, 2000, see also Miceli et al, 2002). Scarnà and Ellis (2002) made this assumption after they found that a bilingual PWA had problems categorising Italian nouns with explicit grammatical gender but was nevertheless able to modify adjectives to ensure agreement with a Noun Phrase (NP). It is likely that in some PWA grammatical gender remains intact when retrieved procedurally and unconsciously employed for agreement but is impaired when consciously recalled.

Despite the evidence reported above, some research on PWA has shown varying results for procedural knowledge. For instance, Mondini et al. (1999) tested an Italian with agrammatism, with serious deficits in producing article-noun gender agreement even for nouns bearing gender information, (e.g., *il madre*, the.MASC mother). We stress that, because of the opaque final -e, cases like *madre* do not allow for direct recall of referent gender (*padre*, father ends with the same final -e), so it may not be possible to observe semantic gender facilitation (Vigliocco and Franck, 1999; Schiller et al., 2003). Friedmann and Biran (2003) employed a picture naming task, which does not require declarative

knowledge since gender is only used to assign the correct morpheme (agreement). The authors reported that Hebrew-speaking fluent PWA did not preserve grammatical gender. This was probably because Hebrew is a language which allows for bare nouns, such that these nouns do not need a determiner to be linguistically legal. Consistent with Cacciari and Cubelli (2003), grammatical gender might only be procedurally accessed if agreement is activated (see Roefols et al., 1998). Again, to make sure that agreement came into play, we decided to use subject-adjective pairs in the sentence processing task. Moreover, congruent with evidence on explicit and procedural gender knowledge distinction (Scarnà and Ellis, 2002), we expected PWA to be able to unconsciously employ gender information in our experiment when adjective and noun gender was procedurally matched, without any need for categorisation.

In sum, evidence from PWA is neither clear-cut nor definitive. In addition, to the best of our knowledge, semantic gender comprehension has never been systematically investigated in aphasic populations (see Semenza and Luzzatti, 2019). It is not known how semantic gender is processed by PWA, that is, whether impairments in gender-explicit knowledge may influence their performance in comprehension, or whether – as we assume – additional semantic information on the gender of the referent will help them complete the task, as we expect to find in control participants. As demonstrated by prior research, cognitive processes in impaired and healthy populations diverge substantially; by pinpointing specific deficits, we can learn more about such processes.

2. The Present Study

This study aimed to verify whether gender is processed differently during sentence processing when the gender of the referent matches morphological gender marking, and whether explicit knowledge impairments differently influence the performance of PWA when restoring grammatical and semantic gender. In a *constrained completion choice* task, participants read a sentence and then saw – in isolation – the masculine and feminine forms of an adjective; they had to decide which form matched the subject

of the previous sentence. We employed three conditions: Grammatical gender, Semantic gender (which shares the morphological transparency of the first condition), and Opaque-Grammatical gender, a condition inserted to prevent participants from basing their strategy solely on morphology and to check whether any of the observed effects could be driven by morphology.

According to the maximal input hypothesis (Vigliocco and Franck, 1999), which proposes that semantic processing exerts an influence on grammatical processing, we expected the following results:

Healthy controls would respond faster when checking agreement between adjectives and subjects bearing semantic compared to grammatical gender. As the task is easy for healthy individuals, we did not expect gender conditions to influence their accuracy. In fact, their performance might show reduced differences between conditions and hide the effect derived from processing semantic gender.

We expected patients to be less accurate and slower in all conditions than healthy controls. We were interested to understand if this impairment would vary with gender type; we expected PWA to be faster and more accurate in the Semantic condition. Specifically, if patients performed better in the Semantic than the other conditions, this would confirm the maximal input hypothesis. Furthermore, unlike healthy controls, they might have difficulty computing agreement for Grammatical and Opaque-Grammatical gender, which would widen the gap between these two grammatical conditions and the Semantic condition. Alternatively, if patients performed similarly in all gender conditions, we would have to conclude that gender types are not dissociated, the maximal input hypothesis could not explain our results, and the two gender types do not follow two distinct processing paths.

3. Method

3.1. Participants

A total of 11 Spanish-speaking people with aphasia were recruited from the Speech Therapy Unit of the San Pau i la Santa Creu Hospital in Barcelona. Ten PWA had suffered a stroke and one had had cerebral cancer (Pt.2). All the PWA had a brain lesion in the left hemisphere, exhibited adequate hearing,

demonstrated stable health status, and were in the chronic stage of language disorders (more than one year after the injury). From the total number of PWA, two were discarded from the analysis due to their high error rate (around 60%), leaving a final cohort of 9 PWA (Female = 7, M_{age} = 50.0 years, SD = 9.6, $M_{education}$ = 13.7 years, SD = 3.6, aphasia severity ranging from mild to moderate). Of the final cohort, 7 PWA were early and balanced Spanish-Catalan bilinguals (2 Spanish dominant).

A control group, comprising 13 participants matched for age and education with the PWA group, also completed both tasks (Female = 10, M_{age} = 50.0, SD = 4.6, $M_{education}$ = 14.3 years, SD = 2.3). Eleven of these participants were early and balanced Catalan-Spanish speakers (2 Spanish dominant), while two were Spanish monolingual. The two groups did not differ in age (t = 0, p = 1) or education (t = 0.78, p = 0.47).

Language profile. Bilingual participants self-rated their language proficiency in the two languages (Catalan and Spanish) on a four-point scale (1 = poor, 4 = perfect). Both PWA and healthy controls were highly proficient in both languages and were considered early bilinguals because, on average, they had first been regularly exposed to their non-dominant language at 4.5 years of age. Finally, both PWA and healthy controls reported nearly equivalent use of Catalan and Spanish and could be considered balanced bilinguals (see Table 1).

Before starting the experimental procedure, both patients and controls signed an informed consent form approved by the 'Parc de Salut MAR' Research Ethics Committee.

INSERT TABLE 1 ABOUT HERE

Language assessment. To define the type and degree of language impairment in PWA participants, a Spanish version of the Western Aphasia Battery test (WAB, Kertesz, 1982; Kertesz and Pascual-Leone, 2000) was administered by a neuropsychologist with expertise in aphasia. The WAB allows for the

evaluation of the main clinical aspects of language: function, content, fluency, auditory (sentence) comprehension, repetition, naming, reading, writing, and calculation.

According to the WAB assessment (see Table 1 for individual subtest scores) only one PWA exhibited NonFluent aphasia along with scores compatible with Broca's aphasia (Pt. 5); the rest exhibited Fluent aphasia. The subtest scores of three PWA were compatible with Anomic aphasia, two with Wernicke's aphasia, and two with Conduction aphasia. One PWA was not classified (Pt.9).

The degree of language impairment ranged from mild to moderate (WAB AQs of 54.1 to 89.2 out of 100) and the mean values for each subtest were: 13.12/20 (SD = 4.02) for Fluency, 8.23/10 (SD = 1.40) for Comprehension, 6.83/10 (SD = 1.9) for Repetition, and 7.30/10 (SD = 1.43) for Naming.

INSERT TABLE 2 ABOUT HERE

3.2. Material

A set of 78 sentences, comprising 26 sentences for each of the three experimental conditions (Gender Type), was selected (see Appendix A for examples). Sentence subjects (or controllers, see Corbett, 1991, 2006) across the three gender conditions differed as follows:

a) Subjects with *Semantic* gender were nouns that had semantic gender reflecting the gender of the referent (nouns referring to humans, animals, or occupations) and transparent endings (-a/-o; e.g., *esposo*, spouse.MASC).

b) Subjects with *Opaque-Grammatical* (henceforth, *Opaque*) gender were inanimate nouns with grammatical gender and opaque endings (-e; e.g., *puente*, bridge.MASC).

c) Subjects with *Transparent-Grammatical* (henceforth, *Grammatical*) gender were inanimate nouns with grammatical gender and transparent endings (-a/-o; e.g., *cuchara*, spoon.FEM).

We ensured that the gender of the sentence subjects was the same for the Spanish and corresponding Catalan nouns to avoid any potential effects or decision delays resulting from gender incongruency between the bilinguals' two languages (see Paolieri et al., 2020).

Adjectives available for sentence completion were all phonologically transparent with -a or -o endings that clearly indicated feminine or masculine gender. The sentences (e.g., *El esposo en la iglesia está...*, the spouse in the church is...) were formed with a subject that was a full noun-phrase (NP), including an article and a noun, followed by a distractor that always had the opposite gender as the subject (*en la iglesia*, in the church) and the third-person singular of the verbs *ser/estar*[2] (to be; hence, *es* or *está)*. The final part of the sentence was the adjective, which needed to agree with the subject. All adjectives had transparent endings (-a/-o) with relevant features balanced across conditions (see below); all options provided plausible sentence completions (e.g., *emocionado*, excited)[3]. Following Vigliocco and Franck (1999), we used distractors that had the opposite gender as subjects to increase demands on cognitive control and induce a higher error rate; research has shown that target retrieval is slower when other items share some of its features (Van Dyke and McElree, 2006; Parker et al., 2017).

We recruited 5 native Spanish speakers, who did not participate in our experiment, and asked them to rate how natural our sentences were on a Likert scale were (1-5, from not natural at all to completely natural). On average, these native speakers awarded our sentence 3.8 points, indicating that, although our sentences did not sound completely natural, they did not sound highly unnatural. We checked the values of the psycholinguistic variables of interest using Busca-Palabras (B-Pal) software (Davis and Perea, 2006); B-Pal is a free software program that brings together previous databases on various psycholinguistic properties (also subjective ratings) of approximately 31,500 Spanish words. The final number results from the authors' selection of words from the various databases and the Real Academia Española (RAE) dictionary. We used B-Pal scores to balance the subjects of the sentences for average log frequency means, which did not significantly vary across conditions: 1.16 (SD = 0.53) for the Grammatical condition, 1.15 (SD = 0.6) for the Semantic condition, and 1.11 (SD = 0.66) for the Opaque

condition. We did the same for the adjectives and distractors. Adjective average log frequency did not significantly differ across conditions: 1.25 (SD = 0.57) for the grammatical, 1.14 (SD = 0.5) for the semantic, and 1.15 (SD = 0.61) for the opaque gender condition. The average frequency of distractors was, respectively, 1.37 (SD = 0.56), 1.6 (SD = 0.66), and 1.59 (SD = 0.52) for the three conditions.

Imageability was also balanced and did not significantly differ across conditions for either adjectives or distractors. The average imageability score for adjectives was 4.01 (SD = 0.67) for the Grammatical condition, 4.15 (SD = 0.51) for the Semantic condition, and 4.27 (SD = 0.62) for the Opaque condition. The average imageability score of the distractors was 5.59 (SD = 0.91), 5.55 (SD = 0.74), and 5.83 (SD = 0.51), respectively.

Since objects do not have semantic gender, it was impossible to balance the animacy scores of subjects across conditions. To calculate the statistics, we simply assigned -0,5 to inanimate and 0,5 to animate nouns. Subjects with Semantic gender had a significantly higher animacy score than the other conditions ($p < 0.05$), while Opaque and Grammatical gender did not differ. As already mentioned, Vigliocco and Franck (1999) tested whether animacy carries the effect of semantic gender. They found instead that the Semantic gender effect distinguished between conditions with the same level of animacy, indicating that the results from the gender type manipulation could not be attributed to animacy (see Vigliocco and Franck, 1999, for further discussion).

We created 4 different lists to avoid order effects or effects due to random noun-adjective associations. The sentence-adjective pairs were not randomized in order to avoid nonsense sentence-adjective pairs but were varied across the 4 lists. We picked one list of stimuli for every participant in consecutive order. The order of stimulus presentation was randomized.

3.3. Procedure

The experimental software used for the administration of all tasks was DMDX (Forster and Forster, 2003). The experiment was displayed on a 15-inch Toshiba screen with the participant seated approximately 40cm in front of the screen. A fixation cross was presented at the centre of the screen for 700ms, then a sentence appeared for 3500ms. The preamble sentences, for example, *El esposo en la iglesia está…* (The spouse in the church is), appeared in the mid-upper area of the monitor. After sentence presentation (3500ms), two options for the final adjective were presented below (in the mid-lower area of the screen) to the left and right, for example, the masculine (*emocionado*, excited) on one side and the feminine (*emocionada*, excited) on the other. Right and left positions were balanced across participants and trials. The sentence remained on the screen for up to 10 seconds or until a response was provided. The sentences were in black (RGB 0,0,0) size 16 Corbel) font and presented in the centre of the screen with a grey background (RGB 192,192,192). The adjectives were written in all caps and presented in the centre mid-lower area of the screen. Using a standard keyboard (see Damian, 2010, for a discussion on its experimental use), participants had to choose between the two options in order to complete the sentence according to the gender of the subject: pressing 'Z' for the left-sided and 'M' for the right-sided adjective. We substituted keys 'Z' and 'C' for PWA who could only use their left hand. We counterbalanced the side of the correct answer for all participants to reduce any bias on RTs due to hemiplegia. Moreover, participants were asked to initiate responses starting from a neutral position on the keyboard.

3.4. Statistical analysis

Repeated-measure ANOVAs were performed for the analysis of the experimental data, including within-subject and Group factors (PWA vs. control group). The analyses were conducted separately on RTs and accuracy. All missed and overtime responses (exceeding timeout), software malfunctions, and

inaccurate responses were classified as errors and discarded from the analysis. In addition, we removed all responses exceeding 2 standard deviations above or below the individual RT mean.

Given that Broca's aphasia (NonFluent aphasia) can entail issues with grammar, and therefore also issues with processing grammatical gender, we conducted an analysis on the PWA excluding the participant with Broca's aphasia. In addition, we took into consideration the behaviour of Pt.9 who was not classified, and we checked whether their behavioural pattern was in line with that of participants with Fluent aphasia. Since the pattern of results and the analysis without the participant with Broca's aphasia did not change the overall results, here we report only the main analysis conducted. However, individual data from the PWA were analysed and are presented in Figures 2 and 4.

Given the relatively small sample size, we also conducted all analyses using non-parametric analyses. As the pattern of results did not differ, we only report results from the parametric statistics here. When significant effects were found in main analyses, we employed Bonferroni correction for multiple comparisons in post-hoc analyses.

4. Results

Repeated-measure ANOVAs were performed, including Gender Type (Grammatical vs. Opaque vs. Semantic) as within-subject factors and Group as the between-subjects factor.

Reaction times (RTs). The main effect of Gender Type was significant [$F_{(2, 40)} = 6.256$, $p = 0.004$, $\eta p^2 = 0.238$]. The post-hoc analysis showed that participants were faster in the Semantic (2006ms) than the Grammatical (2063ms, $p = 0.006$) and Opaque (2043ms, $p = 0.01$) conditions (Fig. 2). The interaction between Gender Type and Group did not reach significance [$F_{(2, 40)} = 2.590$, $p = 0.08$], while the Group effect did [$F_{(1, 20)} = 16.546$, $p = 0.001$, $\eta p^2 = 0.453$], revealing that PWA overall were slower (2943ms) than the control group (1084ms).

In order to control for bilingualism as a possible confounding factor, we conducted a further analysis including only bilingual participants from both groups. This revealed that the Gender Type effect was

still significant [F (2, 34) = 5.090, p = 0.01, ηp² = 0.230] as was a Gender Type*Group interaction [F (2, 34) = 3.287, p = 0.050, ηp² = 0.162], possibly suggesting that the two groups carried out the task differently. To explain this interaction, we performed further analyses by comparing the magnitude of the effects of the conditions in the two groups of participants. The magnitude of the effects was calculated as follows: for the Semantic condition, we calculated the difference in RTs between the Semantic and the Grammatical conditions, divided by the RTs of the Semantic condition and multiplied by 100 (as in Calabria et al., 2012). For the Opaque condition, we calculated the difference in RTs between the Opaque and the Grammatical conditions, divided by the RTs of the Grammatical condition and multiplied by 100. Despite the interaction, the magnitude of the Semantic gender effect (Semantic-Grammatical) did not differ between the two groups [F (1, 17) = 0.009, p = 0.92]. The interaction effect was more likely driven by the Opaque condition. In the control group, the Opaque condition resulted in slower RTs (1076ms) than the Grammatical (1044ms) and the Semantic (989ms) conditions, whereas in the PWA group the Grammatical condition was the slowest (3233ms), followed by the Opaque (3039ms) and Semantic (2986ms) conditions. Nevertheless, the magnitude of the Opaque-Grammatical effect did not differ for the two groups [F (1, 17) = 1.133, p = 0.3].

Individual level analysis. Given that variability of performance in the PWA group might reflect different types of aphasia, we ran an individual level analysis to assess whether there was a substantial difference in the magnitude of the effect in PWA compared to the control group. We used the magnitude of the Semantic gender effect (vs. the Grammatical condition) – as explained above – and applied the modified t-test described by Crawford and Howell (1998) for independent samples. The t values were calculated as follows:

$$t = \frac{X_1 - X_2}{s_2 \sqrt{\dfrac{N_2 - 1}{N_2}}}$$

where X_1 represents individual performance, X_2 represents the mean of the control group, s_2 is the standard deviation of the control group, and N_2 is the sample size of the control group. The analysis showed that 2 PWA had proportionally shorter RTs in the Semantic condition (vs. the Grammatical condition) in comparison to the mean score of the control group, Pt.4 -13,7% [t = 2.5, df = 12, p = 0.03], Pt.5 -13,3% [t = 2.45, df = 12, p = 0.03], suggesting that this group benefitted most from the Semantic condition. In contrast, the Semantic condition slowed down Pt.1's responses, as shown by the proportional difference between the Semantic and Grammatical conditions [t = 2.25, df = 12, p = 0.04].

INSERT FIGURE 1 ABOUT HERE

INSERT FIGURE 2 ABOUT HERE

Accuracy. The main effect of Group was significant [F (1, 20) = 33.893, p < 0.001, ηp^2 = 0.629] suggesting that PWA (74.92%) performed more poorly than controls (98.32%). The main effect of Gender Type was significant [F (2, 40) = 6.950, p = 0.003, ηp^2 = 0.258] and the post-hoc analysis showed that performance on Semantic (92,31%) was significantly more accurate than Opaque (85,67%, p = 0.01), and marginally better than Grammatical (88,29%, p = 0.07) gender, while the difference between the latter conditions was not significant (p = 0.14) (Fig. 3). The interaction between Gender Type*Group was also significant [F (2, 40) = 4.272, p = 0.02, ηp^2 = 0.176]. To explore this interaction, we conducted further post-hoc analyses and found that the magnitude of the Semantic-Grammatical effect (Semantic gender effect) was significantly greater in PWA [F (1, 20 = 4.542, p = 0.04, ηp^2 = 0.185], whereas the Opaque-Grammatical effect was not significantly different between groups [F (1, 20) = 0.905, p = 0.3]. This indicated that participants had more difficulty processing agreement in the Opaque and Grammatical conditions than controls, whereas the way in which they processed semantic gender was more similar to the control group, therefore more preserved in the Semantic condition. The Analysis on bilingual

participants confirmed the above reported results: the main effect of Gender Type was significant [$F_{(2, 34)}$ = 4.940, p = 0.01, ηp^2 = 0.225], and there was a Gender Type*Group interaction [$F_{(2, 34)}$ = 4.097, p = 0.02, ηp^2 = 0.194]. Post-hoc analysis indicates that the Semantic condition significantly differed from both the Grammatical (p = 0.009) and Opaque (p = 0.04) conditions, which did not differ from each other (p = 1).

Individual level analysis. We ran an individual level analysis on the magnitude of the Semantic gender effect (Semantic-Grammatical) found in PWA to compare each individual's performance to the control group mean. The analysis showed that 6 PWA had a larger magnitude Semantic gender effect compared to the control group mean (Fig. 4): Pt.1 +21% [t = 5.75, df = 12, p < 0.0001], Pt.2 +60% [t = 16.75, df = 12, p < 0.0001], Pt.7 + 13% [t = 3.57, df = 12, p = 0.004], Pt.8 +21% [t = 5.75, df = 12, p < 0.0001], Pt.9 +18% [t = 4.94, df = 12, p = 0.0003]. By contrast, Pt.5 showed the reverse pattern of effects with a significantly lower magnitude Semantic gender effect [t = 6.15, df = 12, p < 0.0001]. Pt.3 and Pt.4, which did not significantly differ from the controls', nevertheless showed clear directionality in the effect (a Semantic gender advantage).

INSERT FIGURE 3 ABOUT HERE

INSERT FIGURE 4 ABOUT HERE

5. Discussion

We investigated whether grammatical and semantic gender are processed in different ways in sentence processing as proposed by the maximal input hypothesis (Barlow, 1993; Pollard and Sag, 1994; Vigliocco and Franck, 1999). According to this hypothesis, we should expect fewer errors in the Semantic gender Condition because its morpho-syntactic and semantic features matched, making sentence processing easier. We used experimental material similar to that in Vigliocco and Franck (1999),

including a distractor with the opposite gender to that of the sentence subject to induce higher cognitive demand. The distractor nouns did not c-command the adjectives so they did not directly interfere in syntactic processing, nor hamper detection of the two gender types. Our experiment differed in four key respects from Vigliocco and Franck's (1999) study: we chose to employ Spanish, we explored sentence processing, we measured RTs, and we tested PWA, a group that is more likely to show sharper differences in processing the two types of gender.

Our main finding was that the Semantic gender Condition was processed faster and more accurately than both the Grammatical and Opaque conditions, by both the control group and PWA. This supports the hypothesis that gender type influences semantic processing. Crucially, we found a substantial difference in the magnitude of the Semantic gender effect in the PWA compared to the control group. The individual analysis highlighted that this effect was significantly larger for the majority of PWA than for controls. This finding further confirms our assumption that semantic gender provides salient information that supports both lexical processing and the computation of agreement. By contrast, although accuracy was above chance, grammatical gender agreement processing was impaired in PWA compared to controls (consistently with the cue-based retrieval model for sentence processing, Lewis and Van Dyke, 2003; Van Dyke and McElree, 2006; Parker et al., 2017). The fact that the effect was of larger magnitude in PWA than controls supports our hypothesis that semantic gender helps PWA by making sentence processing easier; in contrast, computing grammatical gender requires greater cognitive resources. Below, we discuss this PWA Semantic gender effect in the context of our hypothesis and consider the role of cognitive control in sentence processing.

Since semantic gender reflects the gender of its referent, it facilitates gender agreement tasks. This is because semantic information is retrieved during lexical access (see Friedmann et al., 2013) and strictly bound to meaning, two factors that facilitate lexical processing. We assume that semantic gender originates at the level of the conceptual representations that underpin lexical concepts, in line with studies that have demonstrated the existence of semantic priming (Masson, 1995; Ortells et al., 2006).

Importantly, our results suggest that the two gender types were processed differently, and that semantic gender plays an active role in lexical access. Compatible with cue-based retrieval models, which assume that cue weights (or salience) determine dependency retrieval (Lewis et al., 2006; Van Dyke and McElree, 2006; Parker et al., 2017), our results support the idea that semantic gender is a more salient feature than grammatical gender and that it enhances sentence processing by conveying both semantic and syntactic information. The interference we observed was limited to (both) the grammatical gender conditions, although they shared the same gender feature as sentence distractors. Conversely, semantic gender facilitated computation of agreement because more salient information was accessible during the retrieval process. For this reason, semantic gender was preserved in the memory of PWA, reducing the influence of grammatical gender candidates; by contrast, PWA's processing of both transparent and opaque grammatical gender was impaired. This cue-based retrieval model could also explain the lack of statistical difference between the Opaque and Grammatical conditions, since both had equally low salient features.

This result also confirms that the effect we observed was not driven by the degree of morphological transparency. If this had been the case, the Opaque condition would have been slower and less accurate. Caffarra et al., (2016) showed a difference between nouns with opaque and transparent grammatical gender, which we failed to observe in both groups. We assume this discrepancy is due to task differences: Caffarra et al.'s task entails explicit use of gender (gender categorisation of bare nouns), while ours elicits procedural knowledge of gender in sentence processing. In fact, Gollan and Frost (2001) found that Hebrew bare nouns with irregular gender morphemes (which do not indicate noun gender) are processed less accurately and more slowly than bare transparent nouns, but this difference was eliminated when these same nouns were computed together with the article to form a full noun phrase (procedural knowledge).

Impairment of inhibition and cognitive control (Faroqi-Shah et al., 2016) may play a role in the larger Semantic effect observed in PWA. In the context of sentence processing, PWA were overall able

to process agreement at distance. However, their adjective choice mostly echoed the distractor's grammatical gender in the Grammatical and Opaque gender conditions, presumably because they were unable to inhibit this irrelevant but recent gender cue. This indicates that in PWA non-relevant information (the gender of the distractor) tends to reverberate and becomes more difficult to inhibit. Such findings are also in line with Lewis et al.'s (2006) computational principles of sentence comprehension, which describe how rapid retrieval of word is hindered by interference from similar items ('similarity-based interference', see also Van Dyke and Johns, 2012).

Alongside deficits in cognitive control, previous research has shown that limits in short-term and working memory can explain poor performance in sentence processing related to syntactic complexity and the amount of semantic information available (Martin and Romani, 1994; Martin and He, 2004; Pettigrew and Hillis, 2014). Semantic and grammatical gender processing may entail two distinct paths one of which may be more taxing for WM and cognitive control. Processing agreement for grammatical gender relies more heavily on working memory (WM) – as Sagarra and Herschensohn's (2010) results suggest – while the salient information in semantic gender facilitates lexical processing, probably requiring a smaller contribution from WM. PWA have weaker working memory than controls when processing sentences, and this may lead to the difficulties they displayed in the Grammatical and Opaque conditions relative to controls (see Minkina et al., 2018; Varkanitsa and Caplan, 2018 for a discussion on short-term/working memory in aphasia). In fact, PWA were deceived by the distractor noun presented in the sentence and were apparently unable to disregard this distracting feature (i.e., the opposite gender) such that this irrelevant cue influenced their adjective choice for gender agreement. Even though this task put some demands on PWAs' WM, which could have influenced their performance, we do not believe that WM overload was so complete as to have invalidated their results. If this had been the case, WM overload would have been reflected by drastic decreases in PWA's accuracy scores. They would have performed the task with such low accuracy that there would have been no differences observed between gender types.

In sum, we confirmed our hypothesis that semantic gender and grammatical gender are processed but incur different levels of difficulty for PWA and healthy participants. We also found that the Semantic gender effect was of greater magnitude in most PWA than controls. This suggests that semantic gender is retained in this impaired population, whereas agreement for grammatical gender – of both transparent and opaque morphology – is partially disrupted. PWA's procedural knowledge of gender, although worse than that of controls, was generally spared. This may be the skill they employ during post-lexical processes when agreement is required (Cacciari and Cubelli, 2003, see also Roelofs et al., 1998). If so, it was the additional semantic feature exhibited by semantic gender that allowed PWA to perform similarly to the control group only in the semantic condition.

We had a heterogeneous group of PWA, although seven out of nine PWA had fluent aphasia. We analysed individual PWA performances and the results demonstrated that participants' responses most likely did not depend on the type or origin of their aphasias. Even Pt.2, who had had a cerebral cancer removed, behaved similarly to most other PWA. Nevertheless, we hesitate to generalize this effect to brain tumour patients due to the limited evidence (a single patient) and the variability across participants. In fact, Akhutina et al.'s (2001) work, which reported a gender priming effect in PWA, acknowledged that such an effect did not correlate with any aphasia factor score, symptom, or classification. In addition, some research has been conducted on heterogeneous groups of PWA. Kulke and Blanken (2001), for example, grouped patients with various types of aphasia to study the preservation of grammatical gender. They discovered that in participants with fluent and non-fluent aphasias the level of gender preservation was significantly above chance, with no significant difference between the two groups.

Moreover, the tasks we employed did not involve speaking or naming, which could have been more impaired in some participants than in others. Despite possible impairments, the PWA we analysed were able to complete the experiments and obtain a good accuracy score. It is known that a given brain lesion may produce a recognizable pattern of errors across different tasks (Whitworth et al., 2006). Together with neurological evidence, this supports the classification of aphasia types. Nevertheless, there is

23

considerable variability across patients with similar lesions or types of aphasia. Two patients with the same lesion or diagnosis may not perform similarly, even on the same language tasks (Whitworth et al. 2006). Assigning PWA to particular types of aphasia cannot precisely predict linguistic performance. Consistently, Grunden et al. (2020) explored voluntary language switching in bilingual aphasia and demonstrated that PWA with the same aphasia diagnosis have varied and sometimes even opposite types of language control issues. We compared PWA's performance to non-brain-damaged controls and showed that, in most cases, PWA performance was in line with that of the control participants (see Fig.2 and Fig.5). In addition, Pt.5 (the only non-fluent PWA), who produced the opposite pattern of accuracy to the other PWA, showed a significant Semantic gender advantage in RT results like the other PWA. Conversely, the Semantic gender effect produced significantly slower RTs for Pt.1 (fluent aphasia), who nevertheless clearly benefitted from higher accuracy in the same Semantic condition. We conclude that the presence of different aphasia types did not compromise our results.

The results reported by Vigliocco and Franck (1999) suggest that the animacy of nouns does not influence the semantic gender effect. Indeed, they showed that if morphology does not match the gender of the referent (in animate nouns) the advantage or the effect derived from semantic gender does not arise. This suggests that animacy does not play a major role and is not equivalent to semantic gender. However, since our findings cannot be conclusive on this point, it remains possible that the animacy of subject-NPs is responsible for eliciting the effect we observed.

Moreover, we do not consider bilingualism to be a concern for our experiment because we found no substantial difference between bilinguals and monolinguals in the analysis of the sub-set of bilinguals. Note that both groups of participants had monolinguals and bilinguals in similar proportion and the gender of the stimuli was the same in both Spanish and Catalan. Future investigations should probe effects in bilinguals whose languages differ in the ascription of gender to check whether bilingualism is a confounding factor.

6. Conclusion

Semantic gender is assumed to be the first type of gender retrieved because this retrieval happens concurrently with lexical access at an early stage of processing. Semantic gender may also enhance word recognition in a sentence and – since it is bound to noun meaning – induce longer-lasting effects than grammatical gender, which is retrieved later. This viewpoint is also supported by evidence from PWA, who were slower to inhibit irrelevant stimuli when processing agreement at distance. Further research using declarative knowledge of semantic gender in PWA will shed light on the nature of semantic gender processing.

Disclosure of interest

The authors report no conflict of interest.

References

Akhutina, T., Kurgansky, A., Kurganskaya, M., Polinsky, M., Polonskaya, N., Larina, O., Bates, E., & Appelbaum, M. (2001). Processing of Grammatical Gender in Normal and Aphasic Speakers of Russian. *Cortex*, *37*(3), 295–326. https://doi.org/10.1016/S0010-9452(08)70576-8

Balota, D. A. (1992). Visual word recognition: The journey from feature to meaning. In M. Gernsbacher (ed.), *Handbook of psycholinguistics*, 303-357. New York: Academic Press.

Barlow, D. H. (Ed.). (1993). *Clinical handbook of psychological disorders: A step-by-step treatment manual, 2nd ed* (pp. x, 534). The Guilford Press.

Bates, E. (1999). Language and the infant brain. *Journal of Communication Disorders*, *32*(4), 195–205. https://doi.org/10.1016/S0021-9924(99)00015-5

Bates, E., Devescovi, A., Pizzamiglio, L., D'Amico, S., & Hernandez, A. (1995). Gender and lexical access in Italian. *Perception and Psychophysics*, *57*(6), 847-862. https://doi.org/10.3758/BF03206800

Bates, E., Marangolo, P., Pizzamiglio, L., & Dick, F. (2001). Linguistic and Nonlinguistic Priming in Aphasia. *Brain and Language*, *76*(1), 62–69. https://doi.org/10.1006/brln.2000.2391

Berg, T., & Levelt, W. J. M. (1990). Speaking: From Intention to Articulation. *The American Journal of Psychology*, *103*(3), 409. https://doi.org/10.2307/1423219

Bock, K., & Levelt, W. J. M. (1994). Language Production: Grammatical Encoding. In M. A. Gernsbacher (Ed.), *Handbook of Psycholinguistics*. pp. 945-984. San Diego, CA: Academic Press.

Cacciari, C., & Cubelli, R. (2003). The Neuropsychology of Grammatical Gender: An Introduction. *Cortex*, *39*(3), 377–382. https://doi.org/10.1016/S0010-9452(08)70254-5

Caffarra, S., Zimnukhova, S., & Mancini, S. (2016). What usage can do: The effect of language dominance on simultaneous bilinguals' morphosyntactic processing. *Linguistics Vanguard*, *2*(s1). https://doi.org/10.1515/lingvan-2016-0020

Chomsky, N. (1965). *Aspects of the Theory of Syntax*. Cambridge: MIT press.

Chomsky, N. (1981). *Lectures on government and binding: the Pisa lectures*. Holland: Foris Publications.

Corbett, G. G. (1991). *Gender*. Cambridge University Press. https://doi.org/10.1017/CBO9781139166119

Corbett, G. G. (2006). *Agreement*. Cambridge University press.

Crawford, J. R., & Howell, D. C. (1998). Comparing an Individual's Test Score Against Norms Derived from Small Samples. *The Clinical Neuropsychologist*, *12*(4), 482–486. https://doi.org/10.1076/clin.12.4.482.7241

Damian, M. F. (2010). Does variability in human performance outweigh imprecision in response devices such as computer keyboards? *Behavior Research Methods*, *42*(1), 205–211. https://doi.org/10.3758/BRM.42.1.205

Davis, C. J., & Perea, M. (2005). BuscaPalabras: A program for deriving orthographic and phonological neighborhood statistics and other psycholinguistic indices in Spanish. *Behavior Research Methods*, *37*(4), 665–671. https://doi.org/10.3758/bf03192738

Faroqi-Shah, Y., Sampson, M., Pranger, M., & Baughman, S. (2016). Cognitive control, word retrieval and bilingual aphasia: Is there a relationship? *Journal of Neurolinguistics*. https://doi.org/10.1016/j.jneuroling.2016.07.001

Forster, K. I., & Forster, J. C. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, & Computers*, *35*(1), 116–124. https://doi.org/10.3758/BF03195503

Franzon, F., Peressotti F., Arcara G., & Semenza C. (2013). Gender Agreement: a comparate psycholinguistic and aphasia case study. Academy of Aphasia-52nd Annual Meeting. *Frontiers in Psychology*, 5-7. https://doi.org/conf.fpsyg.2014.64.00056

Friedmann N., Biran, M., & Dotan, D. (2013). Lexical retrieval and its breakdown in aphasia and developmental language impairment. In Boeckx, C., & Grohmann, K.K. (Eds.), *The Cambridge Handbook of Biolinguistics*. Cambridge: Cambridge University Press. https://doi.org/doi:10.1017/CBO9780511980435.021

Friedmann, N., & Biran, M. (2003). When is Gender Accessed? A Study of Paraphasias in Hebrew Anomia. *Cortex*, *39*(3), 441–463. https://doi.org/10.1016/S0010-9452(08)70258-2

Friedmann, N., Biran, M., & Dotan, D. (2013). Lexical retrieval and its breakdown in aphasia and developmental language impairment. In C. Boeckx & K. K. Grohmann (Eds.), *The Cambridge Handbook of Biolinguistics* (pp. 350–374). Cambridge University Press. https://doi.org/10.1017/CBO9780511980435.021

Gollan, T. H., & Frost, R. (2001). Two routes to grammatical gender: Evidence from Hebrew. *Journal of Psycholinguistic Research*, *30*(6), 627–651. https://doi.org/10.1023/A:1014235223566

Goodglass, H. (2000). Grammatical gender is not always syntactic. In Grodzinsky, Y., Shapiro, L.P., & Swinney, D. (Eds), Language and the brain: representation and processing. San Diego: Academic Press. https://doi.org./10.1016/B978-012304260-6/50015-3

Grunden, N., Piazza, G., García-Sánchez, C., & Calabria, M. (2020). Voluntary Language Switching in the Context of Bilingual Aphasia. *Behavioral Sciences*, *10*(9), 141. https://doi.org/10.3390/bs10090141

Kempen, G., & Hoenkamp, E. (1987). An Incremental Procedural Grammar for Sentence Formulation. *Cognitive Science*, *11*(2), 201–258. https://doi.org/10.1207/s15516709cog1102_5

Kertesz, A. (1982). *The Western Aphasia Battery:* Test Manual, Stimulus Cards, Test Booklets (Test Kit). New York: Grune and Stratton. https://doi.org/10.1080/01688638508401277

Kertesz, A., Pascual, Á. P.-L., & García, A. P.-L. (1990). *Batería de afasías "Western": (The western aphasia battery en versión y adaptación castellana). Manual del test*. Nau Llibres. https://dialnet.unirioja.es/servlet/libro?codigo=90650

Kulke, F., & Blanken, G. (2001). Phonological and syntactic influences on semantic misnamings in aphasia. *Aphasiology*, *15*(1), 3–15. https://doi.org/10.1080/02687040042000070

Levelt, W. J. M. (1989). *Speaking: From Intention to Articulation*. Cambridge, MA: MIT Press. https://doi.org/10.2307/1423219

Lewis, R. L., Vasishth, S., & Van Dyke, J. A. (2006). Computational principles of working memory in sentence comprehension. *Trends in Cognitive Sciences*, *10*(10), 447–454. https://doi.org/10.1016/j.tics.2006.08.007

MacDonald, M. C., Pearlmutter, N. J., & Seidenberg, M. S. (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review*, *101*(4), 676–703. https://doi.org/10.1037/0033-295X.101.4.676

Manenti, R., Repetto, C., Bentrovato, S., Marcone, A., Bates, E., & Cappa, S.F. (2004). The effects of ageing and Alzheimer's disease on semantic and gender priming. *Brain*, *127*(10), 2299–2306. https://doi.org/10.1093/brain/awh264

Martin, R.C., & He, T. (2004). Semantic short-term memory and its role in sentence processing: A replication. *Brain and Language*, *89*(1), 76–82. https://doi.org/10.1016/S0093-934X(03)00300-6

Martin, R.C., & Romani, C. (1994). Verbal working memory and sentence comprehension: A multiple-components view. *Neuropsychology*, *8*(4), 506–523. https://doi.org/10.1037/0894-4105.8.4.506

Masson, M. E. J. (1995). A distributed memory model of semantic priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(1), 3–23. https://doi.org/10.1037/0278-7393.21.1.3

Miceli, G., Turriziani, P., Caltagirone, C., Cappaso, R., Tomaiuolo, F., Caramazza, A. (2002). The neural correlates of grammatical gender: An fMRI investigation. *Journal of Cognitive Neuroscience*, 14: 618-628, 2002. https://doi.org/10.1162/08989290260045855

Minkina, I., Salis, C., & Martin, N. (2018). Short-term and working memory deficits in aphasia: Current issues in theory, evidence, and treatment. *Journal of Neurolinguistics*, *48*, 1–3. https://doi.org/10.1016/j.jneuroling.2018.07.001

Mondini, S., Luzzatti, C., & Semenza, C. (1999). Grammatical gender knowledge in an Italian agrammatic patient. *Brain and Language*, 69(3), 278–281.

Ortells, J. J., Vellido, C., Daza, M. T., & Noguera, C. (2006). Efectos de priming semántico con y sin conciencia perceptiva. [Semantic priming effects with and without perceptual awareness.] *Psicológica*, *27*(2), 225–242.

Paolieri, D., Demestre, J., Guasch, M., Bajo, T., Ferré, P. (2020). The gender congruency effect in Catalan–Spanish bilinguals: Behavioral and electrophysiological evidence. *Bilingualism: Language and Cognition,* 1–11. https://doi.org/10.1017/S1366728920000073

Parker, D., Shvartsman, M., & Van Dyke, J. A. (2017). The cue-based retrieval theory of sentence comprehension: New findings and new challenges. In L. Escobar, V. Torrens, & T. Parodi (Eds.) *Language Processing and Disorders* (pp. 121-144). Newcastle: Cambridge Scholars Publishing.

Pettigrew, C. & Hillis, A. E. (2014) Role for memory capacity in sentence comprehension: Evidence from acute stroke. *Aphasiology*, 28:10, 1258-1280, https://doi.org/10.1080/02687038.2014.919436

Picallo, C. (2008). Gender and Number in Romance. *Lingue e Linguaggio*, 1, 47–66.

Pollard, C., & Sag, I. A. (1994). *Head-Driven Phrase Structure Grammar*. Chicago: The University of Chicago Press.

Real Academia Española (2010). *Nueva gramática de la lengua española* [New gramar of Spanish] (1° Edition). Planeta (Ed.). ISBN: 978-84-670-3281-9

Repetto, C., Manenti R., Cappa S.F., Miniussi C., & Riva G. (2009). Semantic and gender priming in frontotemporal dementia. *Annual Review of Cybertherapy and Telemedicine,* 237-239. https://doi.org/10.3233/978-1-60750-017-9-237

Roelofs, A., Meyer, A.S., & Levelt, W. J. M. (1998). A case for the lemma/lexeme distinction in models of speaking: Comment on Caramazza and Miozzo (1997). *Cognition,* 69, 219-230. https://doi.org/10.1016/s0010-0277(98)00056-0

Sagarra, N., & Herschensohn, J. (2010) The role of proficiency and working memory in gender and number agreement processing in L1 and L2 Spanish. *Lingua,* 120(8), 2022-2039. https://doi.org/10.1016/j.lingua.2010.02.004

Scarnà, A., & Ellis, A. W. (2002). On the assessment of grammatical gender knowledge in aphasia: The danger of relying on explicit, metalinguistic tasks. *Language and Cognitive Processes*, *17*(2), 185–201. https://doi.org/10.1080/0169096014300038

Schiller, N. O., Munte, T. F., Horemans, I., & Jansma, B. M. (2003). The influence of semantic and phonological factors on syntactic decisions: An event-related brain potential study. *Psychophysiology*, 40, 869–869. https://doi.org/10.1111/1469-8986.00105

Schiller, N. O., Schuhmann, T., Neyndorff, A. C., & Jansma, B. M. (2006). The influence of semantic category membership on syntactic decisions: A study using event-related brain potentials. *Brain Research*, *1082*(1), 153–164. https://doi.org/10.1016/j.brainres.2006.01.087

Semenza, C., & Luzzatti, C. (2019) Disturbi lessicali nell'afasia. In Denes et al. (Eds), *Manuale di Neuropsicologia*, Zanichelli, Bologna.

Van Dyke, J. A. (2007). Interference effects from grammatically unavailable constituents during sentence processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(2), 407–430. https://doi.org/10.1037/0278-7393.33.2.407

Van Dyke, J. A., & Johns, C. L. (2012). Memory Interference as a Determinant of Language Comprehension: Interference in Comprehension. *Language and Linguistics Compass*, *6*(4), 193–211. https://doi.org/10.1002/lnc3.330

Van Dyke, J. A., & McElree, B. (2006). Retrieval interference in sentence comprehension. *Journal of Memory and Language*, *55*(2), 157–166. https://doi.org/10.1016/j.jml.2006.03.007

Varkanitsa, M., & Caplan, D. (2018). On the association between memory capacity and sentence comprehension: Insights from a systematic review and meta-analysis of the aphasia literature. *Journal of Neurolinguistics*, 48, 4–25. https://doi.org./10.1016/j.jneuroling.2018.03.003

Vigliocco, G., Butterworth, B., & Semenza, C. (1995). Constructing Subject-Verb Agreement in Speech: The Role of Semantic and Morphological Factors. *Journal of Memory and Language*, *34*(2), 186–215. https://doi.org/10.1006/jmla.1995.1009

Vigliocco, Gabriella, & Franck, J. (1999). When Sex and Syntax Go Hand in Hand: Gender Agreement in Language Production. *Journal of Memory and Language*, *40*(4), 455–478. https://doi.org/10.1006/jmla.1998.2624

Vigliocco, Gabriella, Butterworth, B., & Garrett, M. F. (1996). Subject-verb agreement in Spanish and English: Differences in the role of conceptual constraints. *Cognition*, *61*(3), 261–298. https://doi.org/10.1016/S0010-0277(96)00713-5

Whitworth, A, Webster J, & Howard D. (2006). *A Cognitive neuropsychological approach to assessment and intervention in aphasia*. Hove and New York: Psychology Press. https://doi.org/10.4324/9781315852447

Footnotes

[1] Throughout this paper we will refer to the *gender* of the referent as the source for semantic gender. When referring to animal nouns, *sex* could be used instead. Without doubt, gender and sex have two substantially different meanings. Nevertheless, for the purpose of this paper, it is not always easy to determine which is the more appropriate term, because semantic gender pertains to both animals and humans. When referring to the semantic gender of human nouns, it is probably more correct to say it originates from gender, although (but this is not the aim of the paper) we do not know how semantic gender would be conceptualized in the case of non-correspondence between gender and sex.

[2] In Spanish the verb *to be* can be expressed using two forms, derived from different roots, depending on the context.

[3] The whole sentences, composed of the preamble + (correct gender choice) adjective, were similar to this example: *El esposo en la iglesia está emocionado* ("The spouse in the church was excited").

	PWA		Healthy controls		
	n = 9		n = 13		
	M	SD	M	SD	*p-values*
Age (years)	50.0	9.6	50.0	4.6	*1*
Education (years)	13.7	3.6	14.3	2.3	*0.47*
Age of regular dominant language use	2.2	0.3	2.0	0	*0.24*
Age of regular non-dominant language use	4.7	1.7	4.3	3.6	*0.76*
Language proficiency (1-4)					
Dominant language					
Speaking	4.0	0	4.0	0	*1*
Comprehension	4.0	0	4.0	0	*1*
Reading	4.0	0	4.0	0	*1*
Writing	3.7	0.5	4.0	0	*0.08*
Non-dominant language					
Speaking	3.9	0.4	3.95	0.1	*0.45*
Comprehension	3.9	0.4	4.0	0	*0.22*
Reading	3.9	0.4	4.0	0	*0.22*
Writing	3.9	0.4	4.0	0	*0.22*
% Language use	51.7	13.3	58.3	0.5	*0.46*

Table 1. Socio-demographic and linguistic characteristics of the samples.

PWA	Severity	Type of aphasia	Aphasia quotient (max.100)	Fluency (max 20)	Sentence Comprehension (max. 10)	Repetition (max. 10)	Naming (max10)
Pt.1	MODERATE	**ANOMIC**	71.4	12	8.5	8.1	8.1
Pt.2	MILD	**CONDUCTION**	84.5	18	9.25	6.4	8.6
Pt.3	MODERATE	**WERNICKE**	75.7	16	6.75	6.2	8.9
Pt.4	MILD	**ANOMIC**	79.9	14	9.55	8.6	7.3
Pt.5	MODERATE	**BROCA**	55.6	8	6.9	7.1	5.8
Pt.6	MODERATE	**WERNICKE**	56.3	13	6.25	3.2	5.7
Pt.7	MODERATE	**CONDUCTION**	54.1	7	8.75	5.8	5.5
Pt.8	MILD	**ANOMIC**	89.2	17	9.9	9.2	8.5
Pt.9		**N.C.**					

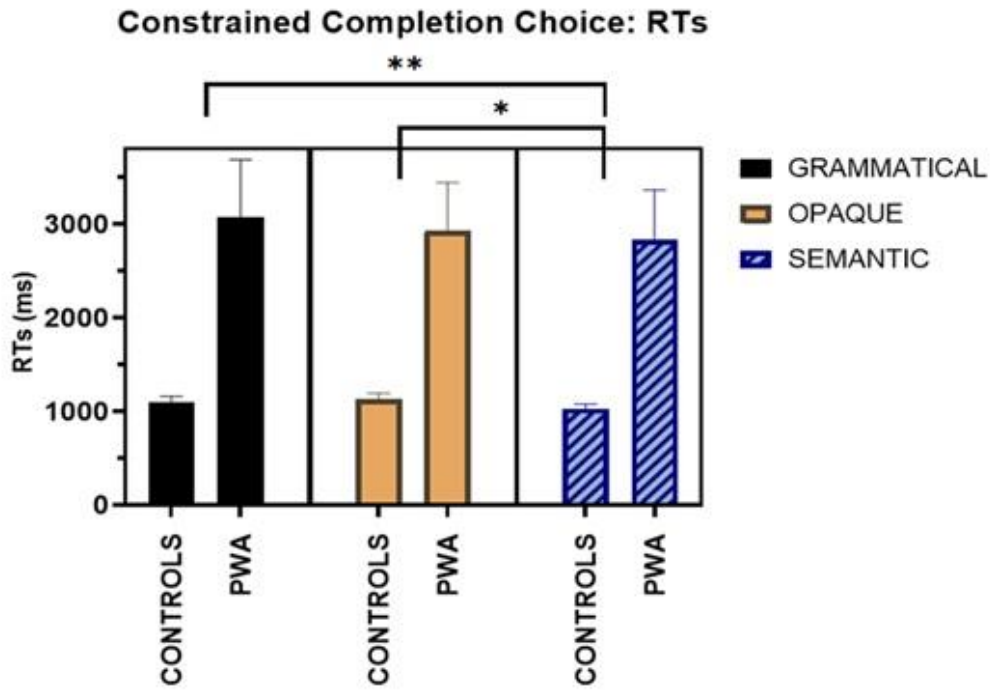**Table 2.** Individual scores for the Western Aphasia Battery.

Fig. 1. RTs broken down by Gender Type and participant group (control group and PWA). The error bars indicate SE. The effect of Group is not reported, even though it is significant.
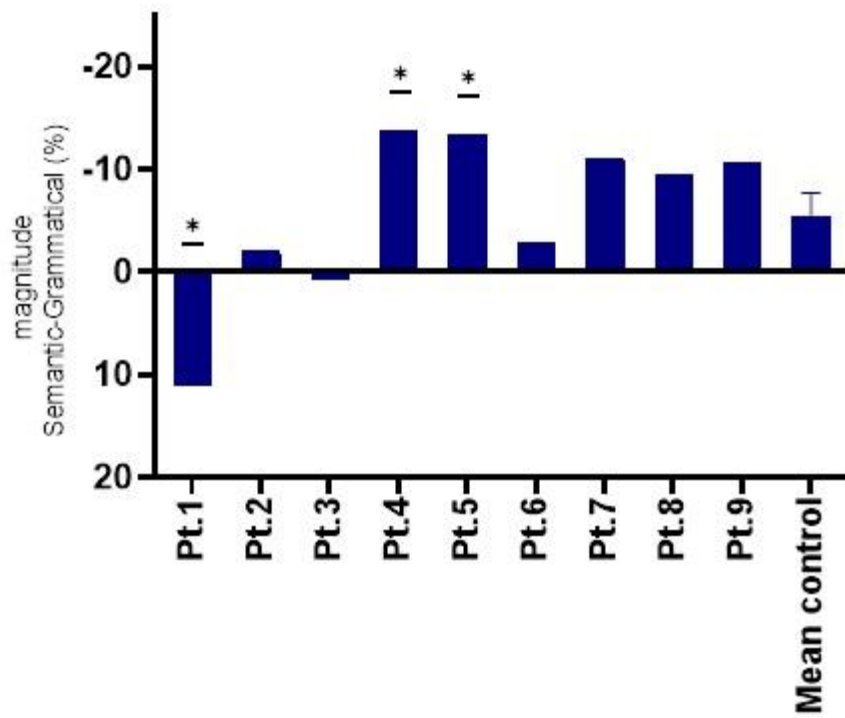
Fig. 2. Magnitude of the Semantic gender effect based on RT differences between the Semantic and the Grammatical conditions. Individual PWA scores (stars indicate where individual performance significantly differed from the controls). More negative values indicate (proportionally) faster responses in the Semantic condition.
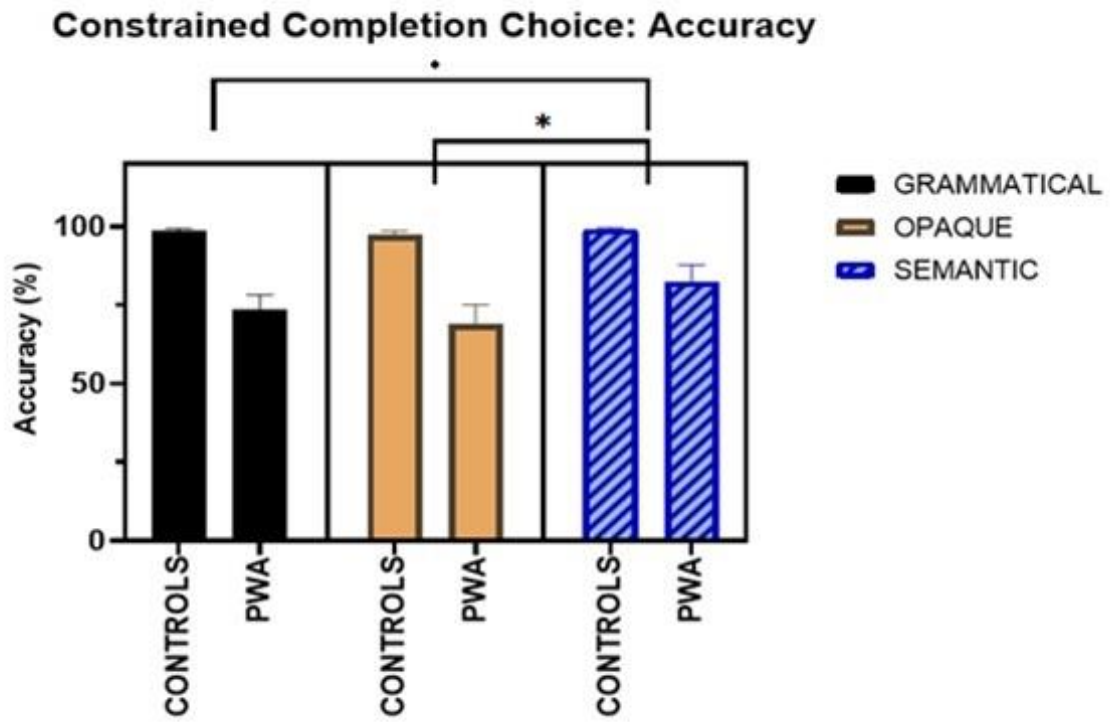
Fig. 3. Accuracy broken down by Gender Type and participant group (control group and PWA). The error bars indicate SE. The effect of Group is not reported, even though it is significant.
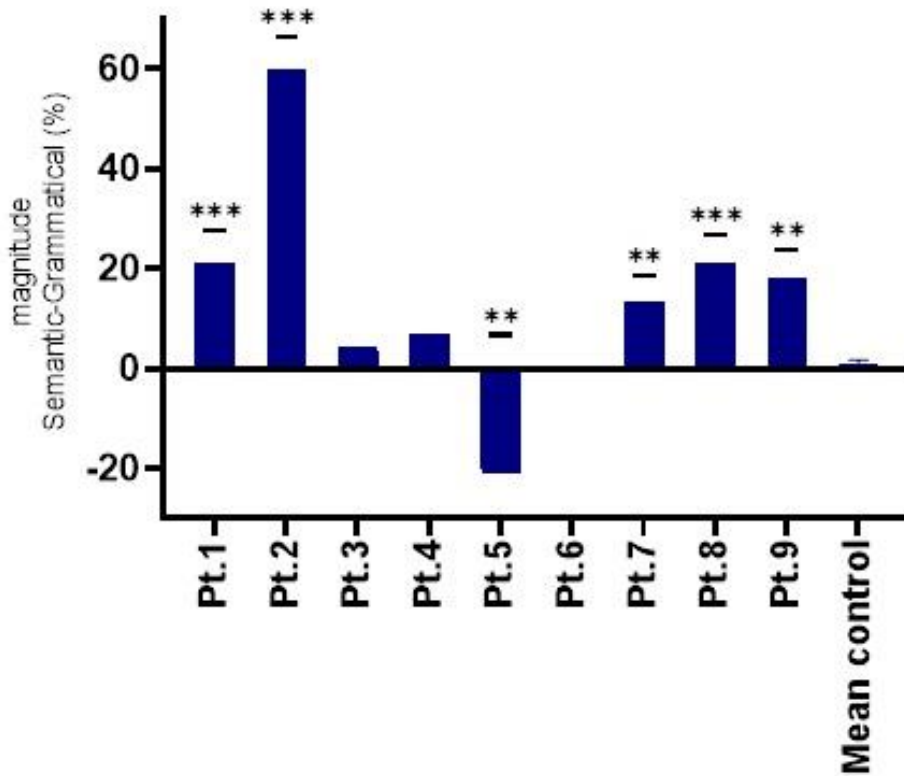
Fig. 4. Magnitude of the Semantic gender effect based on accuracy difference between the Semantic and the Grammatical conditions as described in the main text. Individual PWA scores (stars where the individual performance significantly differed from the controls). More positive values indicate (proportionally) more accurate responses.

El esposo en la iglesia está *The spouse in the church is*	Semantic condition	EMOCIONADA *EXCITED*	EMOCIONADO
El mono en la clínica está *The monkey in the clinic is*	Semantic condition	NERVIOSO *NERVOUS*	NERVIOSA
La cuchara en el suelo está *The spoon on the ground is*	Grammatical condition	SUCIA *DIRTY*	SUCIO
La comida en el plato está *The food on the dish is*	Grammatical condition	SABROSA *TASTY*	SABROSO
La fuente del suelo está *The fount on the ground is*	Opaque condition	SECA *DRY*	SECO

APPENDIX A. Examples of sentences & predicative adjectives.