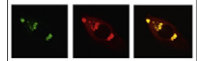


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## Research Report

# Unconscious effects of grammatical gender during object categorisation

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## ABSTRACT

Does language modulate perception and categorisation of everyday objects? Here, we approach this question from the perspective of grammatical gender in bilinguals. We tested Spanish–English bilinguals and control native speakers of English in a semantic categorisation task on triplets of pictures in an all-in-English context while measuring event-related brain potentials (ERPs). Participants were asked to press a button when the third picture of a triplet belonged to the same semantic category as the first two, and another button when it belonged to a different category. Unbeknownst to them, in half of the trials, the gender of the third picture name in Spanish had the same gender as that of the first two, and the opposite gender in the other half. We found no priming in behavioural results of either semantic relatedness or gender consistency. In contrast, ERPs revealed not only the expected semantic priming effect in both groups, but also a negative modulation by gender inconsistency in Spanish–English bilinguals, exclusively. These results provide evidence for spontaneous and unconscious access to grammatical gender in participants functioning in a context requiring no access to such information, thereby providing support for linguistic relativity effects in the grammatical domain.

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## 1. Introduction

Whorf (1956), one of the two fathers of linguistic relativity, famously suggested that the language(s) one speaks shapes the way one thinks. The questions underpinning the linguistic relativity debate are questions such as: does language modulate perception? Is language encapsulated or does it interact with other cognitive processes? If so, what is the nature of these interactions and what properties of language bring these interactions to bear?

Scholars have misinterpreted Whorf's thesis as a formulation close to linguistic determinism, a far stronger claim that language may cause changes in basic physiological processes, e.g., that of visual perception. Pinker (1995), for instance, stated that “no matter how influential language may be, it would seem preposterous to a physiologist that it could reach down into the retina and rewire the ganglion cells (p. 63).” Over the past two decades, however, the linguistic relativity hypothesis has been resurrected in a milder form, perhaps closer to the original thinking of Sapir

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**Table 1 – Example of experimental conditions.**

Picture primes		Targets	Gender congruency	Semantically relatedness
Tomato	Celery	Asparagus	+	+
Tomato	Celery	Carrot	–	+
Tomato	Celery	Truck	+	–
Tomato	Celery	Bike	–	–

and Whorf (Gumperz and Levinson, 1996; Gentner and Goldin-Meadow, 2003). Additionally, interactive models developed by McClelland and Rumelhart (1981), and Humphrey et al. (1997) and a recent, more direct application of these models to linguistic relativity by Lupyan (2012), offer working hypotheses as regards the cognitive mechanisms underpinning language-thought interactions. The label-feedback hypothesis, in particular, proposes that language is highly interconnected with other cognitive processes such as vision and categorisation and influences other functional networks in a top-down fashion.<sup>1</sup>

Several recent studies have highlighted areas where lexical and grammatical information may affect cognitive processes other than language. Lexical characteristics of languages have been shown to affect colour perception in behavioural (Ozgen, 2004; Roberson et al., 2005; Franklin et al., 2008; Athanasopoulos, 2009) and neurophysiological (Thierry et al., 2009; Clifford et al., 2010; Liu et al., 2010) investigations. A number of studies have also reported effects of language in the domain of spatial representation and event conceptualisation where speakers exhibit differences in event description and recollection (Bowermann and Choi, 1991; Majid et al., 2004; Papafragou and Selimis, 2010) or even show different gaze patterns when exploring videos depicting events (Flecken, 2010). Studies investigating differences in grammatical number expression (e.g. languages with classifiers systems) have also suggested alteration of object classification (Lucy, 1992; Zhang and Schmitt, 1998; Athanasopoulos, 2007; Saalbach and Imai, 2007).

One interesting feature of some languages, which offers an appropriate test case for linguistic relativity, is grammatical gender. This feature, present in many of the world's languages, forces all nouns to be assigned to, most commonly, two or three classes: *masculine* and *feminine* and/or *neuter* (Corbett, 1991). Grammatical gender is of particular interest for two reasons: (a) when it is absent, it cannot be replaced by other lexicalisation patterns (unlike classifiers, for instance), and (b) its assignment is arbitrary except in the case of natural gender (male/female distinction).

With regard to point (a), for instance, Chinese requires the use of a marker before every quantified noun as in 'yi zhang zhi piao' (a [FLAT OBJECT] bank note), and English can sometimes do the same as in 'a piece of paper' or 'a flock of sheep'. By contrast, grammatical gender, when absent from a language, cannot be replaced by any combination of words.

Regarding point (b), the French word for 'sentry' (*une sentinelle*), for instance, is feminine, but rare must have been women sentries; a toaster is masculine in French (*un grille-pain*) but feminine in Spanish (*una tostadora*); in German a woman is feminine (*die Frau*) but a girl is neuter (*das Mädchen*). Even diachronically, the gender of nouns can change: the old word for girl in Polish used to be feminine (*ta dziewczyna*) but nowadays it is neuter (*to dziewczę*). In other words, both within a language and cross-linguistically, the relation between grammatical gender and word meaning appears to escape logic.

Studies investigating grammatical gender to date, have essentially focused on potential links between grammatical gender and object categorisation using (a) the voice-attribution paradigm (Sera et al., 1994, 2002; Bassetti, 2007; Forbes et al., 2008), (b) common noun–proper noun associations (Boroditsky et al., 2003; Phillips and Boroditsky, 2003), (c) semantic ratings and adjective associations (Flaherty, 2001; Boroditsky et al., 2003), or (d) a combination of the above methods (Vigliocco et al., 2005; Ramos and Roberson, 2010). Unfortunately, in all of these cases, the interpretation falls short of establishing the source of effects at an abstract level, disconnected from language itself. As Pinker (2007) put it: "speakers of different languages tilt in different directions in a woolly task, rather than having differently structured minds" (p. 148). The most recent and perhaps strongest evidence of grammatical gender-driven relativity comes from a study by Cubelli et al. (2011), who minimised the possibility that participants could use language as a strategy by using a non verbal semantic task on pictures. However, not all studies investigating implicit effects of grammatical gender on object categorisation have reported overwhelming evidence for such effects (see Kousta et al., 2008) and several have led to mixed results (Sera et al., 2002; Bassetti, 2007).

The greatest limitation of studies conducted so far in this field is their reliance on behavioural measurements. Indeed, as vigorously argued by Pinker (2007), behavioural evidence is open to contamination by explicit and/or idiosyncratic strategies used by participants to resolve the tasks, a process that is likely to solicit language processing (e.g., inner speech, sub-vocal rehearsal of instructions, covert denomination of objects, lexical access, etc.). If language access is prompted by the task at hand, then nothing can be said of the spontaneity of this effect. What is needed then is a method, which detects spontaneous access to grammatical gender representations without explicit involvement of language and not merely inferred from behavioural observations (Cf. Pinker, 2007).

In the present study, we asked participants to decide whether the third of a series of three objects presented one-by-one on the screen belonged to the same semantic

<sup>1</sup> The label-feedback hypothesis is very recent and has only thoroughly been implemented in the context of label effects on object perception and categorisation. However, there is no reason to believe that the feedback processes it outlines do not arise for grammatical features such as gender.

category as the two first ones. Semantic relatedness amongst the three objects was manipulated along with a covert manipulation of grammatical gender consistency (Table 1). We predicted that semantic incongruence would result in a modulation of the N400 wave, a negative-going potential with an average peak latency of 400 ms post-stimulus and known to reflect semantic integration mechanisms (Kutas and Hillyard, 1980; 1984). On the other hand, and critically, we hypothesised that grammatical gender inconsistency may modulate the Left-Anterior Negativity (LAN), a ERP marker of morphosyntactic processing (Friederici et al., 1993; Friederici and Jacobsen, 1999; Hahne and Friederici, 1999; Thierry, 2003). If such results were obtained, it would mean that grammatical gender is retrieved automatically and unconsciously rather than strategically and consciously during object categorisation.

## 2. Results

**Behavioural data:** Accuracy in the semantic relatedness task was overall high (79%) and was not studied by group or condition for the reason stated in Section 5 Fig. 1.

Regarding reaction times, we found a significant main effect of group ( $F(1, 30)=11.4$ ,  $p<0.002$ ,  $\eta_p^2=0.28$ ) but we did not find any significant effect of semantic relatedness ( $F(1, 30)=0.824$ ,  $p>0.1$ ) or gender consistency ( $F(1, 30)=0.010$ ,  $p>0.1$ ) and no significant interactions between factors.

**Electrophysiological data:** N1 and P1 were unaffected by experimental conditions in either of the participant groups. As expected, the N4 was maximal over the centroparietal electrode sites and peaked at 361 ms on average (Fig. 2). There was a significant main effect of semantic relatedness on N400 mean amplitude between 300 and 400 ms ( $F(1, 30)=40.74$ ,  $p<0.0001$ ,  $\eta_p^2=0.576$ ) such that the N400 was less negative in the semantically related than unrelated conditions (Bonferroni,  $p<0.001$ ). There was no interaction between groups and the other experimental factors (Fig. 2A and B)

The LAN was maximal over left frontal regions and peaked at 559 ms on average (Fig. 3). There was a significant main effect of gender consistency ( $F(1, 30)=23.5$ ,  $p<0.0001$ ,

$\eta_p^2=0.439$ ) such that LAN amplitudes were more negative in the gender inconsistent than gender consistent condition (Bonferroni,  $p<0.001$ ). This main effect was qualified by a significant interaction between gender and group ( $F(1, 30)=4.97$ ,  $p<0.05$ ,  $\eta_p^2=0.142$ ). Post-hoc analyses revealed that the effect of gender was present for the Spanish–English bilinguals ( $F(1, 14)=29.5$ ,  $p<0.001$ , Fig. 3A) but not for the English monolinguals ( $F(1, 16)=3.1$ ,  $p>0.05$ , Fig. 3B).

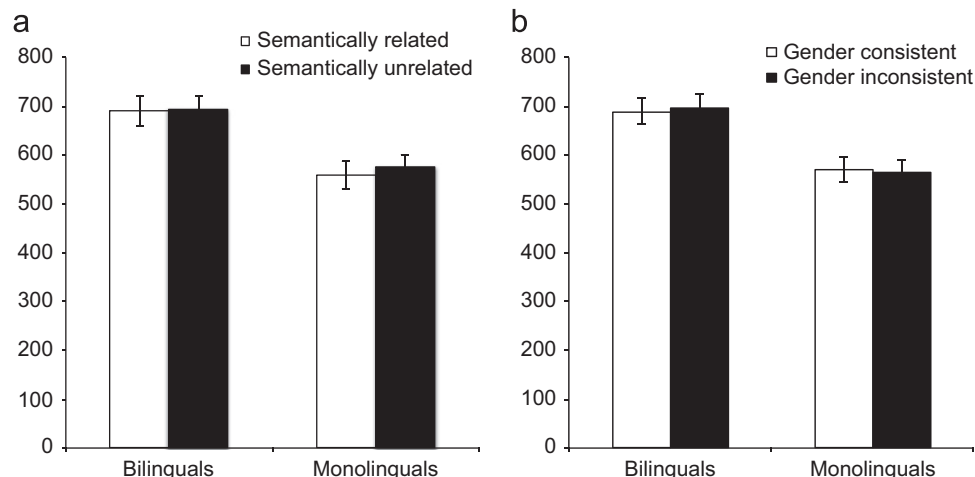
Fig. 4 plots the  $p$ -value (negative log of 10, for presentation purposes) of the  $t$ -tests carried out millisecond by millisecond on the difference between gender consistent and gender inconsistent conditions. The difference between conditions became significant 388 ms after stimulus onset in the Spanish–English bilinguals and remained so until the end of the analysed epoch (700 ms) and was never significant for more than 30 ms in the English monolinguals (Rugg et al., 1995).

## 3. Discussion

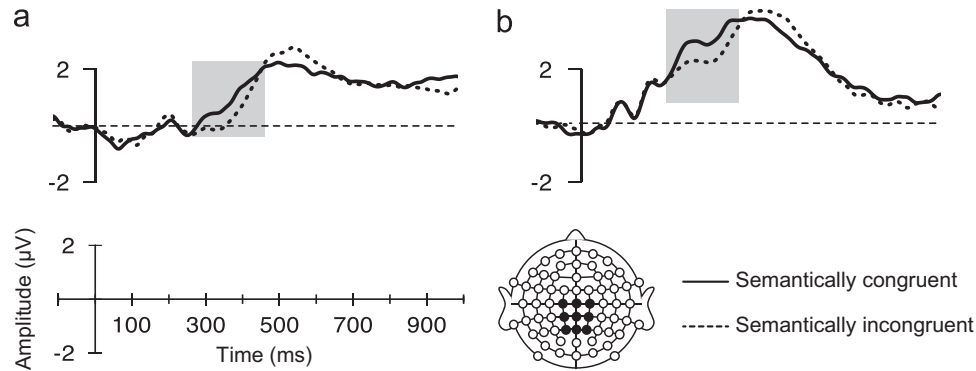
The aim of the present study was to determine whether some features of language affect other cognitive processes such as object categorisation. Grammatical gender is a feature of some languages that has received considerable amounts of attention in linguistics and psycholinguistics but to our knowledge its effect on object categorisation has never been established based on measures of brain activity.

Unlike Cubelli et al. (2011) who used a similar experimental design, we found no behavioural effect of semantic relatedness of grammatical gender in Spanish–English bilingual participants. However, Cubelli et al. (2011) (a) used pairs rather than triads of pictures and (b) tested their participants in an Italian-speaking or Spanish-speaking environment (Italian and Spanish students tested at the university of Padova and Granada, respectively):

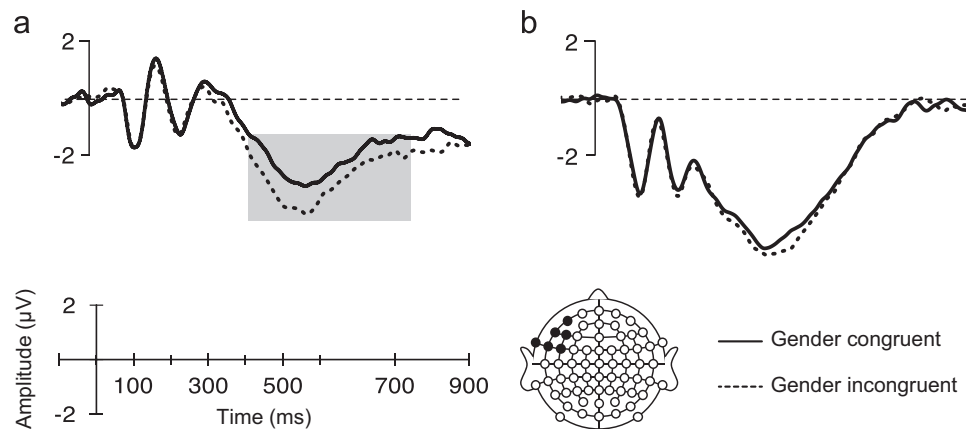
- (a) We used three pictures instead of two in order to (1) load participants' working memory, thereby increasing task difficulty and therefore reducing the likelihood of participants having enough executive resources to work out the



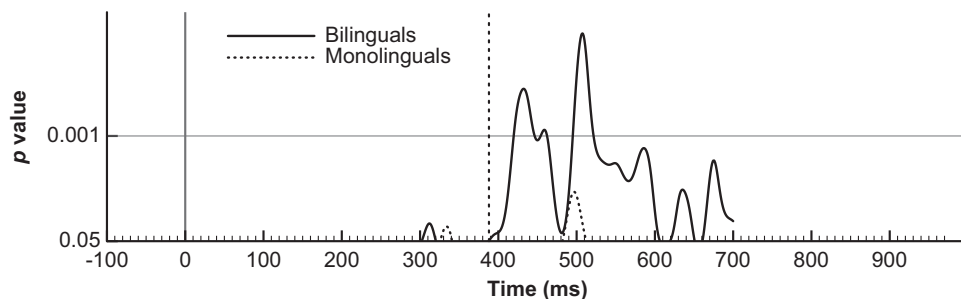
**Fig. 1 – Plot of reaction times on correct trials only for the Spanish–English bilinguals and English monolinguals, showing no effect of condition. (A) Semantic conditions, (B) gender conditions. Error-bars depict s.e.m.**



**Fig. 2 – ERPs elicited in the semantic related and semantic unrelated conditions. (A) Spanish–English bilinguals, (B) English monolinguals. Linear derivation of electrodes C1, CZ, C2, CP1, CPZ, CP2, P1, PZ, P2.**



**Fig. 3 – ERPs elicited in the gender consistent and gender inconsistent conditions. (A) Spanish–English bilinguals, (B) English monolinguals. Linear derivation of electrodes FT9, FT7, FC5, F7, F5, AF7.**



**Fig. 4 – Plot of the p-value ms by ms for the LAN (negative log of 10). Dashed vertical line at 388 ms indicates when the effect becomes reliably significant.**

hidden manipulation and (2) maximise the explicit and implicit priming effects (i.e., experimental sensitivity) due to the more consistent baseline produced by the first two pictures;

- (b) The speaking environment has been shown to have a tangible impact on the language mode of individuals (Grosjean, 1998; Elston-Guttler et al., 2005). Our participants were tested in an all-in-English context during and outside the experimental session. It must be noted that Welsh is also spoken in the region of North-Wales but that exposure to Welsh is rare to very rare if individuals are not

actively seeking it, the medium of conversation being essentially English.

Nevertheless, we found the predicted semantic priming effect on N400 ERP amplitude (Kutas and Hillyard, 1980, 1984), showing that semantic priming amongst the picture triads was present even though it did not manifest itself behaviourally.

Critically, in addition to the semantic relatedness effect, we found a grammatical gender consistency effect in the ERP

data exclusively in the Spanish–English bilinguals, manifesting itself as a LAN modulation and showing that these participants extracted gender information while engaged in a semantic categorisation task requiring no such information. Since participants were tested in an all-in-English context, were never made aware of the gender manipulation, never reported being aware of it after debriefing, and since gender consistency had no behavioural effect, we interpret this result as evidence that access to gender information was implicit and unconscious (see [Thierry and Wu, 2007](#); [Wu and Thierry, 2010](#)). This result indicates that grammatical gender is spontaneously retrieved during semantic processing of pictures even though lexical-semantic processing was not explicitly required ([Strijkers et al., 2011](#)).

This result could be interpreted in terms of mere spreading of activation leading to the activation of grammatical gender representation even though accessing gender was irrelevant. Similarly, grammatical gender has been shown to affect picture naming cross-linguistically in bilingual word production ([Lemhöfer et al., 2008](#)) and there is good evidence that it is transferred in bilingualism ([Ganushchak et al., 2011](#)). However, we note that most studies having brought to light such spontaneous effects of grammatical gender retrieval have used tasks that rely heavily on language activation. This was not the case in the current study since participants were not required to name pictures or retrieve any verbal information to perform semantic categorisation. In addition, the absence of a behavioural effect in our study suggests that spreading activation alone is not sufficient to account for the pattern of results obtained.

Irrespective of the fact that we did not find any behavioural effects, our conclusions are similar to those of [Cubelli et al. \(2011\)](#) with the added dimension that such effect is probably encountered on an unconscious level. Altogether our results suggest that object conceptual retrieval and categorisation are unconsciously affected by language-specific syntactic information, such as grammatical gender, even when such information is task-irrelevant. Similar results of access to task-irrelevant semantic features were obtained by [Yee et al. \(2012\)](#). The demonstration of this phenomenon in the grammatical domain supports the view that language substantially interacts with other cognitive processes, and further highlights the critical role of language in shaping the way humans process reality and the world around them.

This conclusion is inconsistent with the modularity of language hypothesis ([Fodor, 1975](#); [Chomsky, 2000](#); [Fodor, 2008](#)) and rather suggests that the organisation of information at the cortical level relies heavily on interconnectivity and interactions amongst distributed cell assemblies

([McClelland and Rumelhart, 1981](#); [Humphreys et al., 1997](#); [Pulvermüller, 1999](#); see [Martin, 2007](#) for review). The data also lend support to the linguistic relativity hypothesis, and its newest development ([Lupyan, 2012](#)), by showing that semantic features of objects are spontaneously retrieved together with semantically irrelevant information such as syntactic gender and this information likely contributes to participants' mental representations of these objects.

#### 4. Conclusion

While language does not necessarily determine thoughts, and while thinking may be possible without the aid of language, it nonetheless provides a ready basis of information for the purposes of classifying the world into meaningful categories ([Lucy, 1997](#)). To date, this observation has been empirically demonstrated primarily in the domain of colour ([Regier and Kay, 2009](#); [Thierry et al., 2009](#); [Clifford et al., 2010](#); [Liu et al., 2010](#)). The current study shows that humans may automatically utilise grammatical categories such as gender when asked to make judgements about semantic relationships unrelated to the grammatical categories in question. The fact that we have found such effects in the domain of grammatical gender is particularly important, since previous empirical attempts to address the Whorfian question in this domain used methods and task instructions, mostly based on behavioural measures, that might promote strategic use of grammatical gender categories. Future studies will shed more light on the locus of this effect as well as patterns of brain connectivity, and establish whether it generalises to other language-specific properties, e.g., compound words, classifiers, and highly grammaticised language features, such as tense and aspect.

#### 5. Experimental procedures

**Participants:** Participants were 16 Spanish native speakers with English as a second language (L2) (henceforth Spanish–English bilinguals). One participant was eliminated due to insufficient data quality. The 15 remaining participants (9 female, age:  $32.6 \pm 1.981$ ; 6 male, age:  $29.3 \pm 2.028$ ) were included in the final analyses. All the participants learned English at least in primary and secondary school in Spanish speaking countries and were living in the UK at the time of testing. [Table 2](#) summarises participants' language experience and self-assessed proficiency in L1 and L2. At the time of testing, the participants were using L2 slightly more

**Table 2 – Characteristics of Spanish–English participants.**

Measure	Mean	Standard error
L1 self-rating (10 pt scale)	9.7	(0.1)
L2 self-rating (10 pt scale)	8.5	(0.4)
Daily L1 usage (%)	44.6	(6.5)
Daily L2 usage (%)	55.4	(6.5)
Age of L2 acquisition (years)	10.2	(1)
Length of immersion (months)	52.6	(12.3)



than L1, due to their immersion context but the difference in self-reported use was not significant. Proficiency was however significantly higher in L1 than L2 ( $z = -2.49$ ,  $p < 0.05$ ).

Twenty native speakers of English who all reported that they were monolingual also took part in the experiment as a control group. Three of them were eliminated due to insufficient data quality. The 17 remaining participants (9 female, age:  $19.57 \pm 0.53$ ; 8 male, age:  $19.25 \pm 0.16$ ) were included in the final analyses. All the participants were right-handed and had normal or corrected-to-normal vision.

**Materials:** We selected 288 black-and-white line drawings from Snodgrass and Vanderwart (1980) and Szekely et al. (2004). Pictures were grouped in 96 triads, such that the name of two first pictures had the same gender and they belonged to the same semantic category and the third picture was either from the same or a different semantic category and their name either had the same or the opposite gender as the two others. The 96 triads could therefore be split into 48 semantically related and 48 semantically unrelated associations, or 48 gender consistent and 48 gender inconsistent associations, providing 24 triads per individual experimental conditions.

**Procedure:** After participants filled out a questionnaire about their language learning background and self-assessed proficiency in L1 and L2, they were tested individually in a quiet room. They were seated in front of a computer monitor (CRT make 19", 100 cm from the screen) on which picture stimuli were displayed within a viewing angle of  $8^\circ$  and handed a response box. The participants were instructed to press a given button if the three pictures of a triad belonged to the same semantic category and another button if not. Participants were never told about the covert gender manipulation. On each trial, a fixation cross was presented for 1000 ms, followed immediately by the first prime for a duration of 600 ms, then the second picture appeared after a blank screen of 250 ms duration, for a duration 600 ms. Then the target (third picture) appeared after a variable interval randomly selected between 300 and 500 ms in steps of 50 ms, in order to cancel offset effects. The target remained on screen until participants responded. Five practice trials preceded the experimental trials. All experimental instructions were provided in English. The order of blocks was counterbalanced across participants and the presentation of items was randomised within each block.

**Electrophysiological recording:** The EEG was continuously recorded at a rate of 1 kHz from 64 Ag/AgCl electrodes placed according to the extended 10–20 convention. Two additional electrodes were attached above and below the left eye and on either side of the left and right eye in order to monitor for eye-blinks and horizontal eye movements. Cz was the reference electrode during acquisition. Impedances were maintained below 5 k $\Omega$  for all 64 electrodes and below 10 k $\Omega$  for vertical electrooculogram electrodes. EEG signals were filtered off-line using a 30 Hz low pass zero phase shift digital filter.

**Behavioural data analysis:** Given that the task performed by participants was a semantic relatedness task, accuracy was not informative regarding access to gender information, especially if we consider that some semantic associations were farfetched due to the necessity of creating a fully counter-balanced experimental design. Indeed, some of the triads may have seemed unrelated to the participant when they were considered related by the experimenters

and vice versa. Therefore, we considered reaction times irrespective of response accuracy and we did not consider potential differences in accuracy arising between groups or conditions. However, RTs shorter than 250 ms and differing by more than 2.5 standard deviations from the average RT in each condition and participant were individually discarded. A two-way ANOVA by participant was conducted on the RTs with semantic relatedness (related, unrelated), grammatical gender consistency (consistent, inconsistent) as within-subject factors and group (Spanish–English bilinguals, English monolinguals) as between-subject factor.

**Electrophysiological data analysis:** Eye-blink artefacts were mathematically corrected using the algorithm provided in Scan 4.4<sup>TM</sup>. The algorithm is derived from the method advocated by Gratton et al. (1983). Note that eye-blink occurred mostly after the response was made as a consequence of special instruction given to the participants. ERPs were then computed by averaging EEG epochs ranging from  $-100$  to  $1000$  ms after stimuli onset. Baseline correction was applied in relation to  $100$  of pre-stimulus activity and individual averages were re-referenced to the global field power produced over the entire scalp. ERPs time-locked to the onset of target pictures were visually inspected and mean amplitudes were measured in temporal windows determined based on variations of the mean global field power measured across the scalp (Picton et al., 2000). Four components were identified as expected. The P1 and N1 were maximal at parietal sites and were measured in the  $100$ – $150$  ms range for the P1 and  $170$ – $230$  ms for the N2, the N400 was maximal on central sites (Cz) and was measured in the  $300$ – $400$  ms window. Finally, the left anterior negativity, strongest at left anterior recording sites, was measured in the  $380$ – $600$  ms window. Peak latencies were measured at sites of maximal amplitude (PO8 for the P1 and N1, CZ for the N4; FT9 for the LAN) and mean ERP amplitudes were measured in regions of interest around the sites of maximal amplitude (O1, PO3, PO7, O2, PO4, PO8 for the P1 and N1; C1, CZ, C2, CP1, CPZ, CP2, P1, PZ, P2 for the N4; FT9, FT7, FC5, F7, F5, AF7 for the LAN). Note that we did not conduct a full-scalp analysis because the modulation of the ERP components were predicted to occur in the regions of interest and therefore statistical analyses of ERP mean amplitude were conducted in sets of electrodes determined *a priori* based on the LAN and N400 literature (cf. introduction). Mean amplitudes and peak latencies were subjected to a mixed repeated-measures ANOVA with semantic relatedness (related, unrelated), grammatical gender consistency (consistent, inconsistent) and electrode (6 or 9 levels) as within-subject factors and group (Spanish–English bilinguals, English monolinguals) as between-subject factor. In addition, paired sample t-tests were conducted between the gender consistent and gender inconsistent conditions millisecond-by-millisecond to determine the onset of differences between conditions (using a linear derivation of the 6 electrodes used in the mean amplitude analysis).

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