NeuroImage 57 (2011) 1243–1250

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

Electrophysiological effects of semantic context in picture and word naming

Niels Janssen [a,*], Manuel Carreiras [b,c], Horacio A. Barber [a]

[a] Universidad de La Laguna, Tenerife, Spain
[b] Basque Center on Cognition, Brain, and Language, Donostia-San Sebastián, Spain
[c] IKERBASQUE, Basque Foundation for Science, Bilbao, Spain

ARTICLE INFO

Article history:
Received 17 January 2011
Revised 30 March 2011
Accepted 5 May 2011
Available online 12 May 2011

ABSTRACT

Recent language production studies have started to use electrophysiological measures to investigate the time course of word selection processes. An important contribution with respect to this issue comes from studies that have relied on an effect of semantic context in the semantic blocking task. Here we used this task to further establish the empirical pattern associated with the effect of semantic context, and whether the effect arises during output processing. Electrophysiological and reaction time measures were co-registered while participants overtly named picture and word stimuli in the semantic blocking task. The results revealed inhibitory reaction time effects of semantic context for both words and pictures, and a corresponding electrophysiological effect that could not be interpreted in terms of output processes. These data suggest that the electrophysiological effect of semantic context in the semantic blocking task does not reflect output processes, and therefore undermine an interpretation of this effect in terms of word selection.

Introduction

Current language production models generally assume that the production of speech is a multi-staged process, encompassing at least a semantic processing stage where communicative intentions are formed, a linguistic processing stage where words are selected and ordered, and an articulation stage where the speech sounds corresponding to words are retrieved (e.g., Caramazza, 1997; Dell, 1986; Levelt, 1989). This view of the production system is primarily based on evidence from behavioral studies (e.g., Dell and Reich, 1981; Schriefers et al., 1990; Janssen and Caramazza, 2009). Recently, however, a number of studies have started to investigate language production processes from an electrophysiological perspective. Two of these studies have used the effect of semantic context in the semantic blocking task to make claims about the time course of the word selection mechanism (Aristei et al., 2011; Maess et al., 2002). On the basis of the onset of the effect of semantic context in this task, these authors concluded that word selection starts around 200 ms post-stimulus onset. Here we wanted to further establish that the effect of semantic context in the semantic blocking task arises at the output stages of word production.

Word selection is generally assumed to be a process in which a target word must be selected from a set of alternative, non-target candidates (Caramazza, 1997; Dell, 1986; Levelt, 1989). This view is based on the assumptions of spreading activation and a network view of semantic memory (e.g., Collins and Loftus, 1975). Word production involves the initial activation of representations in semantic memory, which in turn lead to the activation of the target word. In addition, besides the target, non-target word representations that are semantically related to the target also become activated. Word selection is viewed as a decision process that must ensure the selection of the target word in the context of the activated non-target words. One way to ensure that the correct word is selected is to assume that word selection only takes place when a word's level of activation is sufficiently greater than the activation levels of the other activated words. This can be implemented by assuming that the selection process is competitive in nature (e.g., Roelofs, 1992), or that there are lateral inhibitory links between word representations (e.g., Snyder et al., 2010). This particular mechanism of word selection makes a clear prediction about the time it should take to select a target word: Word selection times should increase with increasing activation of non-target competitors.

In order to provide evidence for this view, studies have attempted to manipulate the context in which word selection takes place, thereby testing whether target selection is affected by the activation levels of non-target words. In a study by Kroll and Stewart (1994), participants were asked to name pictures in the *semantic blocking task*. In this task, there are blocks of trials on which all pictures are from the same semantic category (homogeneous condition), and there are blocks of trials on which all pictures are from different semantic categories (heterogeneous condition). Kroll and Stewart observed that picture naming latencies were longer in the homogeneous versus the heterogeneous condition (see also Abdel Rahman and Melinger, 2009; Damian et al., 2001). The authors interpreted this result in terms of a

* Corresponding author at: Grupo Neurociencia Cognitiva & Psicolingüística, Dpto. de Psicología Cognitiva, Social y Organizacional, Facultad de Psicología - Universidad de La Laguna, Campus de Guajara s/n, La Laguna, 38205, Tenerife, Spain. Fax: +34 922 31 91 38.
E-mail address: njanssen@ull.es (N. Janssen).

1053-8119/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.neuroimage.2011.05.015

competitive word selection process, where it was assumed that alternative non-target representations were more activated through shared semantic representations in the homogeneous than in the heterogeneous condition. Consequently, selecting a target takes longer in the homogeneous than in the heterogeneous condition.

The semantic blocking task is frequently used in different fields to examine language production processes. For example, the task has been used to investigate the neuro-anatomical regions involved in word selection using neuro-psychological (e.g., McCarthy and Kartsounis, 2000; Schnur et al., 2006; Wilshire and McCarthy, 2002), and fMRI techniques (e.g., Heim et al., 2009; Schnur et al., 2009). Two recent studies have used the semantic blocking task to investigate the time course of word selection processes using electrophysiological techniques.[1] First, Maess et al. (2002) recorded MEG while participants named pictures in the homogeneous and heterogeneous conditions. The results revealed a larger negative wave for the homogeneous compared to the heterogeneous condition that peaked around 150 ms, primarily over temporal regions. Second, Aristei et al. (2011) used a more complex experimental design in which participants named pictures in two different homogeneous (categorical, associative) and one heterogeneous conditions that were also accompanied by auditory distractor words that could be categorically, associatively or unrelated to the pictures. The authors found results that were similar to those reported by Maess et al. There was a larger negative wave for the homogeneous compared to the heterogeneous condition that peaked around 200 ms over temporal regions. The behavioral data in Maess et al. and Aristei et al. revealed inhibitory effects of semantic context, suggesting competitive word selection processes. Accordingly, the electrophysiological effect in both studies was interpreted in terms of word selection processes that start around 200 ms post-stimulus onset.

However, there are three problems in the two studies cited above that undermine this conclusion. First, the critical results in both studies were obtained using post-hoc analyses of the data. Thus, in Maess et al. the results were found in a post-hoc principal component analysis that included only a subset of the participants (only those who showed the effect in the behavioral analysis). The analysis on the untransformed data that included all the participants did not reveal an effect of semantic context. Likewise, in Aristei et al., the electrophysiological effect that formed the basis for the interpretation in terms of word selection was found in a post-hoc analysis that included only a subset of the trials (only the first repetition of each item), and only a subset of the participants (only those who started the experiment with the homogeneous condition). General problems with post-hoc analyses are that there are no clear a-priori reasons for them, and that they involve a subset of the data that might have biased the results.

A second problem is that the polarity of the electrophysiological effect of semantic context reported by Maess et al. (2002) and Aristei et al. (2011) is opposite from that reported in other language production studies. For example, in Dell'Acqua et al. (2010), participants named pictures (e.g., car) in the context of semantically related (e.g., truck), phonologically related (e.g., cat) or unrelated (e.g., pen), visually presented, distractor words. As in the semantic blocking task, behavioral results in the picture–word interference task typically reveal longer naming latencies for semantically related versus the unrelated condition, which have been interpreted in terms of word selection processes (e.g., Roelofs, 1992). Regarding the electrophysiological data, Dell'Acqua et al. reported a larger negative wave for the unrelated (heterogeneous) compared to the semantically related (homogeneous) context that peaked around 100 ms, and around 400 ms. This effect was broadly distributed over the scalp. Similar results were found by Jescheniak et al. (2002) and by Jescheniak et al. (2003), in which unrelated distractor words generated a more negative wave than semantically related distractors in a delayed picture naming task. Thus, the polarity of the semantic effect reported in these studies is opposite in polarity from that found in the studies using the semantic blocking task. Although this contrast might reflect task differences, this inconsistency between studies shows that the empirical pattern that results from a manipulation of semantic context in language production studies has not been clearly established.

A final problem with the production studies using the semantic blocking task is that they have ignored a large body of research on effects of semantic context in the language comprehension literature. These studies have revealed effects of semantic context in picture recognition, and are therefore relevant to language production studies using the picture naming task. Consider, for example, a comprehension study by Ganis et al. (1996); see also Nigam et al., 1992). In this study, participants silently read sentences that provided a semantic context that was either related or unrelated with the final stimulus of the sentence (e.g., "the old man lay on the grass and lit his wooden [pipe]"). The final stimulus was either a picture or a word. Both picture and word stimuli generated a greater negativity for the unrelated context between 325 and 475 ms, and the distribution of the effect was anterior for pictures, and posterior for words. The onset of the effect occurred earlier for pictures than for words. These effects are generally interpreted in terms of input processing, where they are thought to reflect the processing of the meaning of stimuli. The processing of the meaning of a stimulus is thought to be easier in a related context, resulting in a reduced negativity (i.e., the classic N400 effect, see Kutas and Federmeier, 2011 for a review).

The finding of an effect of semantic context in tasks in which no overt response is required illustrates that the effect of the semantic context in the semantic blocking task could arise during the input stages of picture naming, or during its output stages. In other words, the effect of semantic context could arise during the visual or semantic processing of the pictures, or it could arise during the retrieval of the name of the picture (i.e., word selection). The available data do not allow us to distinguish between these two possible loci of the semantic context effect in the semantic blocking task.

To summarize, the semantic blocking task has recently been used to study word selection processes from an electrophysiological perspective (Aristei et al., 2011; Maess et al., 2002). The effect of semantic blocking observed in these studies has been interpreted in terms of output processes related to word selection. However, as we discussed above, there are two problems with this conclusion: 1) the empirical pattern that results from a manipulation of semantic context has not been clearly established, and 2) there are data from comprehension studies that undermine an interpretation of the effect of semantic context in terms of the presumed output processes. The Experiment reported below was directly aimed at resolving these issues. Participants named picture and word stimuli in the semantic blocking task. We used both pictures and words since these stimuli have been used in previous studies investigating the effect of semantic context in language comprehension (e.g., Ganis et al., 1996). We generated three criteria in order to determine the locus of the effect.

First, on the assumption that both the reaction time and electrophysiological effects are caused by the same output processes in the brain, one would expect a correlation between them. Specifically, we computed correlations between the electrophysiological and behavioral effects (size and latencies) on a by-participant basis. Second, given that naming latencies in the semantic blocking task are generally slower for pictures than for word stimuli (e.g., Kroll and Stewart, 1994), one would expect a later onset of the semantic context effect for pictures than for words, if the effect was occurring at output stages of the production process. Finally, on the assumption of an input locus of the effect, one would expect that the polarity and scalp distribution of the effect will be similar to those typically found in studies of language comprehension with no correlation with the behavioral measures. Specifically, one

[1] The task was also used in an EEG study of Ganushchak and Schiller (2008). However, this study focused on the influence of semantic context on word monitoring, and is therefore not directly relevant to the current study.

would expect a larger negativity for the unrelated condition peaking around 400 ms after stimuli onset, anteriorly distributed for pictures and posteriorly for words.

Experiment

Methods

Participants

Twenty native speakers of Spanish (15 females) took part in the study (mean age = 24 years, range = 17 to 35 years). All had normal or corrected to normal vision, and were right-handed based on the Edinburgh Handedness Inventory. The results from two participants were discarded due to excessive eye-blink related artifacts. Participants were either paid €10, or received course credit. All participants gave informed consent prior to participation in the study.

Materials

Twenty-five line drawings were selected from the Snodgrass and Vanderwart's (1980) picture set. These pictures were identical to those used in the study of Damian et al. (2001). Each picture belonged to one of five semantic categories (i.e., vehicles, tools, animals, furniture, clothing). These five sets of five semantically related pictures formed the homogeneous condition. The pictures were also rearranged into five sets of five unrelated pictures to form the heterogeneous condition. Thus, the same pictures appeared under the two levels of the factor semantic context. Pictures were presented as white-line drawings on a black background. The size of a picture was around 10 by 10 cm, and they were viewed from a distance of around 80 cm (visual angle around 3.4°).

For the picture naming task, these homogeneous and heterogeneous picture sets were combined into 10 blocks of homogeneous, and 10 blocks of heterogeneous trials. Within a block, the five pictures from a homogeneous or heterogeneous set were repeated 4 times, leading to a total of 20 trials per block. Homogeneous and heterogeneous blocks did not alternate, but instead, these blocks were organized into two groups of five consecutive homogeneous (A), or five heterogeneous blocks (B). The order of these two groups was counterbalanced within and across participants (ABBA, BAAB). These constraints led to the creation of four different lists containing 400 pseudo-randomized trials.

We made sure that there was no repetition of phonological onset between picture names on consecutive trials. In addition, we controlled for the overlap of the final vowel of the word, and for the repetition of grammatical gender on consecutive trials. Controlling these latter two factors was more difficult, given that Spanish often marks grammatical gender on the final vowel of the word, and that there are only two grammatical genders. This meant that overlap of the final vowel or grammatical gender on some consecutive trials was unavoidable. However, we ensured that such trials were evenly distributed between the homogeneous and heterogeneous conditions of the semantic context variable. Specifically, overlap of the final sound occurred on average on 25% of the trials, of which 13% were in the homogeneous and 12% in the heterogeneous condition ($X^2(1) = 0.183$, $p = 0.669$). Likewise, grammatical gender overlap took place on average on 45% of the trials, of which 24% were in the homogeneous and 21% in the heterogeneous condition ($X^2(1) = 1.032$, $p = 0.31$).

The word naming task was created by simply presenting the picture name instead of the picture itself. Words were presented in a white Arial font on a black background, and subtended around the same visual angle as the pictures (3.4°). The same stimulus lists were used as in the picture naming task, although we made sure that a given participant received different stimulus lists in the picture and word naming tasks of the experiment. Finally, the order of the picture naming and word naming tasks was counterbalanced, where half of the participants started with the picture naming task, and the other half started with the word naming task.

Procedure

The experiment consisted of two sessions corresponding to the picture naming and word naming tasks. Each session started with a practice part. Participants in the picture naming session were first familiarized with all the pictures and their names. They were given a booklet in which on each page a picture was printed with its name below. Participants were instructed to look carefully at each picture and say its name aloud. Then they practiced the naming task by producing the name of each of the 25 pictures in the experiment once. On each trial a fixation cross appeared for 700 ms, followed by the presentation of the target picture or word for 500 ms, or until the voice-key triggered, finally followed by a pause of 1200 ms. Participants in the word naming task received only the practice session where they named the 25 words in the experiment. The trial structure for the picture and word naming tasks was identical, and was the same as in the respective practice session. Halfway through the picture and word naming sessions there was a pause.

EEG recording and analyses

The continuous EEG signal was recorded with 27 Ag/AgCl electrodes embedded in an elastic cap (Easycap; www.easycap.de) referenced to the left mastoid. The signal was amplified (BrainAmp amplifiers) and digitized at a sampling rate of 250 Hz, with a 0.01–100 Hz band pass filter. The horizontal EOG was measured by placing two electrodes at the outer canthi, and the vertical EOG was measured with two electrodes placed above and below the left eye. Electrode impedance was kept below 5 kΩ for all electrodes. The data were offline re-referenced using the average of the left and right mastoids, and passed through low cutoff (0.1 Hz, slope: 24 dB/oct) and high cutoff (30 Hz, slope: 24 dB/oct) filters. Eye movement artifacts were removed using the automatic ICA eye-blink detection procedure of BrainAnalyser 2.0 (www.brainproducts.com). In addition, other artifacts were defined as those events in which there was a difference of 100 μV in amplitude within less than 50 ms, or when the absolute amplitude exceeded −100 or 100 μV. In these instances, 200 ms before and after the artifact event was removed from the EEG signal. Finally, we excluded from the EEG signal all trials on which the participant did not produce the correct target stimulus, and those on which the target naming latency was less than 300 ms.

The final EEG data were then segmented into epochs of 900 ms, starting 100 ms before the onset of the target stimulus and ending 800 ms after stimulus onset. Given that we were interested in the processes prior to the onset of speech, and that unimodally distributed picture naming latencies typically center around 650 ms, this choice of time window covers the processes of interest. These epochs were baseline corrected using the average amplitude between −100 and 0 ms, and finally averaged for the homogeneous and heterogeneous conditions in the picture and word naming tasks. For the picture naming task, there were 3064 out of 3600 (85.1%) segments in the homogeneous condition, and 3147 out of 3600 (87.4%) segments in the heterogeneous condition. For the word naming task, there were 3024 out of 3600 (84.0%) segments in the homogeneous condition, and 2930 out of 3600 (81.4%) in the heterogeneous condition.

Three types of statistical analysis were considered. First, running t-tests of the effect of semantic context were computed at every time point (i.e., every 4 ms) from −100 to 800 ms, for the picture and word naming tasks. Second, ANOVAs (type III, assuming sphericity) were performed on the time windows identified in the first analysis separately for picture and word naming tasks. These tests considered the main effect and interaction of the factor Context (homogeneous versus heterogeneous) with two other factors that relied on clusters of electrodes: Hemisphere with the two levels: left (F7, F3, FC5, FC1, T7, C3, CP5, CP1, P7, P3) versus right (F8, F4, FC2, FC6, T8, C4, CP2, CP6, P8, P4), and Anteriority with the two levels: anterior (F7, F3, F4, F8, FC5, FC1, FC2, FC6) versus posterior (P7, P3, P4, P8, CP5, CP1, CP2, CP6). Finally, two Pearson correlations between the reaction time and electrophysiological measures of the effect of semantic context were computed on a by-participant basis. The first correlation considered the relationship between the reaction time effect and the mean amplitude of the difference between the heterogeneous and homogeneous conditions in the time window identified in the first analyses, averaging across those electrodes at which the effect was most pronounced. The second correlation considered the relationship between the reaction time effect and the peak amplitude of the context effect for the single electrode at which the effect appeared most pronounced. Peak amplitudes were determined by investigating the maximum amplitude of the effect in the time window identified in the first step of the statistical analysis. The same electrode was examined for each participant. The correlation analyses were conducted separately for picture and word naming tasks, and were expressed in terms of t-tests.

Results

Behavioral results

Fig. 1, panel A shows the distribution of the log-transformed naming latencies in the two tasks, and panel B shows the mean latencies for the two levels of the Context effect in each task. Naming latencies in the picture naming task ranged from 314 to 1858 ms (median 604 ms), and from 302 to 1225 (median 455) in the word naming task.

Previous studies using the semantic blocking task have relied on ANOVA analyses to examine the data, and here we also reported the results from these analyses. However, it has been argued that traditional by-subjects and by-items analyses are less sensitive than more recent mixed effect approaches in which both subject and item variability jointly contribute to statistical parameter estimation (Baayen, 2008; Bates, 2005). Accordingly we also analyzed the reaction time data using a mixed effect analysis. In both ANOVA and mixed effect analyses participants and pictures were used as random factors (in separate F1 and F2 ANOVAS), and Task (picture naming and word naming) and Context (homogeneous and heterogeneous) as fixed within-subject and within-item factors. Trials on which participants produced the incorrect target, hesitated, or produced any other non-vocal sounds were excluded from the analyses, as well as trials on which the RT was less than 300 ms (2.4%).

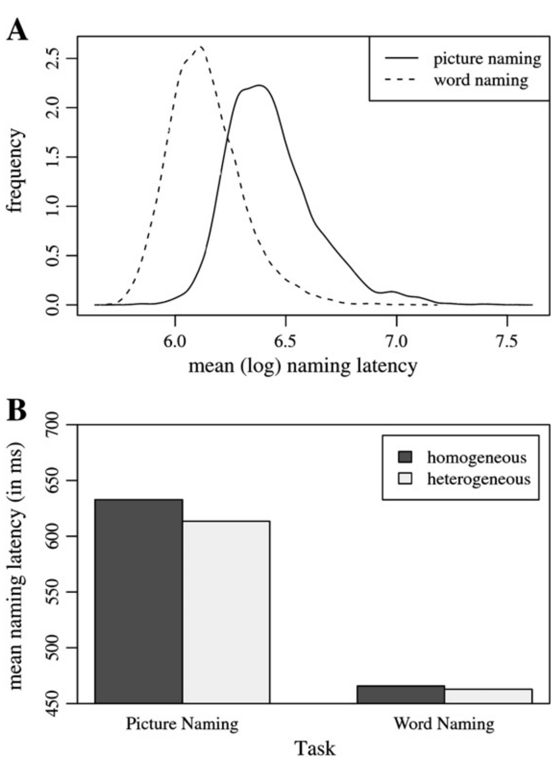

Fig. 1. Panel A, distributions of the log-transformed naming latencies in the picture and word naming tasks. Panel B, mean naming latencies for the homogeneous and heterogeneous conditions in the picture naming and word naming tasks.

For the ANOVA analyses, outliers were defined as those reaction times that exceeded 2.5 standard deviations above or below a given subject's mean. This resulted in the discarding of 197 data points (2.8%) from picture naming task, and 136 (1.9%) from the word reading task. There was an effect of Task ($F1(1,17)=293.58$, $p<0.001$; $F2(1,24)=244.48$, $p<0.001$), an effect of Context ($F1(1,17)=21.91$, $p<0.001$; $F2(1,24)=36.2$, $p<0.001$), and an interaction between Task and Context ($F1(1,17)=8.69$, $p<0.009$; $F2(1,24)=26.60$, $p<0.001$). This interaction was further explored by examining the effect of Context separately for the picture naming and word naming tasks. In the picture naming task, there was an effect of Context ($F1(1,17)=18.01$, $p<0.001$; $F2(1,24)=34.43$, $p<0.001$). In the word reading task, the effect of Context was marginal ($F1(1,17)=1.77$, $p=0.20$; $F2(1,24)=5.81$, $p<0.03$).

The mixed effect analyses involved 14,059 data points and excluded only the aforementioned trials on which participants produced incorrect responses. In an effort to control the influence of extreme reaction times, we performed the analyses on the log-transformed latencies (using the outlier criteria used for the ANOVA did not change the results), using Participants and Pictures as random factors, and Task and Context as fixed factors. There was an effect of the factor Task ($t(14055)=-76.88$, $p<0.001$), where latencies were faster in the word naming than picture naming task, and an effect of Context ($t(14055)=8.46$, $p<0.001$), where the homogeneous condition elicited slower latencies compared to the heterogeneous condition. Finally, Task and Context interacted ($t(14055)=-4.80$, $p<0.001$), indicating a smaller effect of Context in the word naming task compared to the picture naming task.

This interaction was further explored by evaluating the effect of Context separately for each level of the factor Task. In both tasks, naming latencies were significantly slower in the homogeneous compared to the heterogeneous condition, but the Context effect was quantitatively less evident in the word naming ($t(7087)=2.18$, $p<0.03$) compared to the picture naming task ($t(6968)=7.59$, $p<0.001$).

ERP results

Time course analyses

Visual inspection of the ERPs revealed a P1–N1–P2 complex that is typically associated with the presentation of visual stimuli (Fig. 2). The effect of semantic context appeared most pronounced between 200 and 500 ms, with a larger negativity for the heterogeneous condition compared to the homogeneous condition for both pictures (Fig. 2, panel A), and words (Fig. 2, panel B). The distribution of the effect was anterior for pictures, and posterior for words. Visual inspection also suggested differences in the onset of the effect between the two stimulus types, where the effect started around 200 ms post stimulus onset for pictures and around 300 ms for words.

Further exploration of the data confirmed these observations. For the picture naming task, running t-tests revealed that the effect appeared most reliable between 220 and 450 ms, with an anterior distribution (Fig. 3, panel A). For the word naming task, the effect appeared later, between 350 and 500 ms, with a posterior distribution (Fig. 3, panel B). The time course and topographical distribution of the context effect at representative electrodes FC1 for picture stimuli, and Pz for word stimuli are illustrated in Fig. 4.

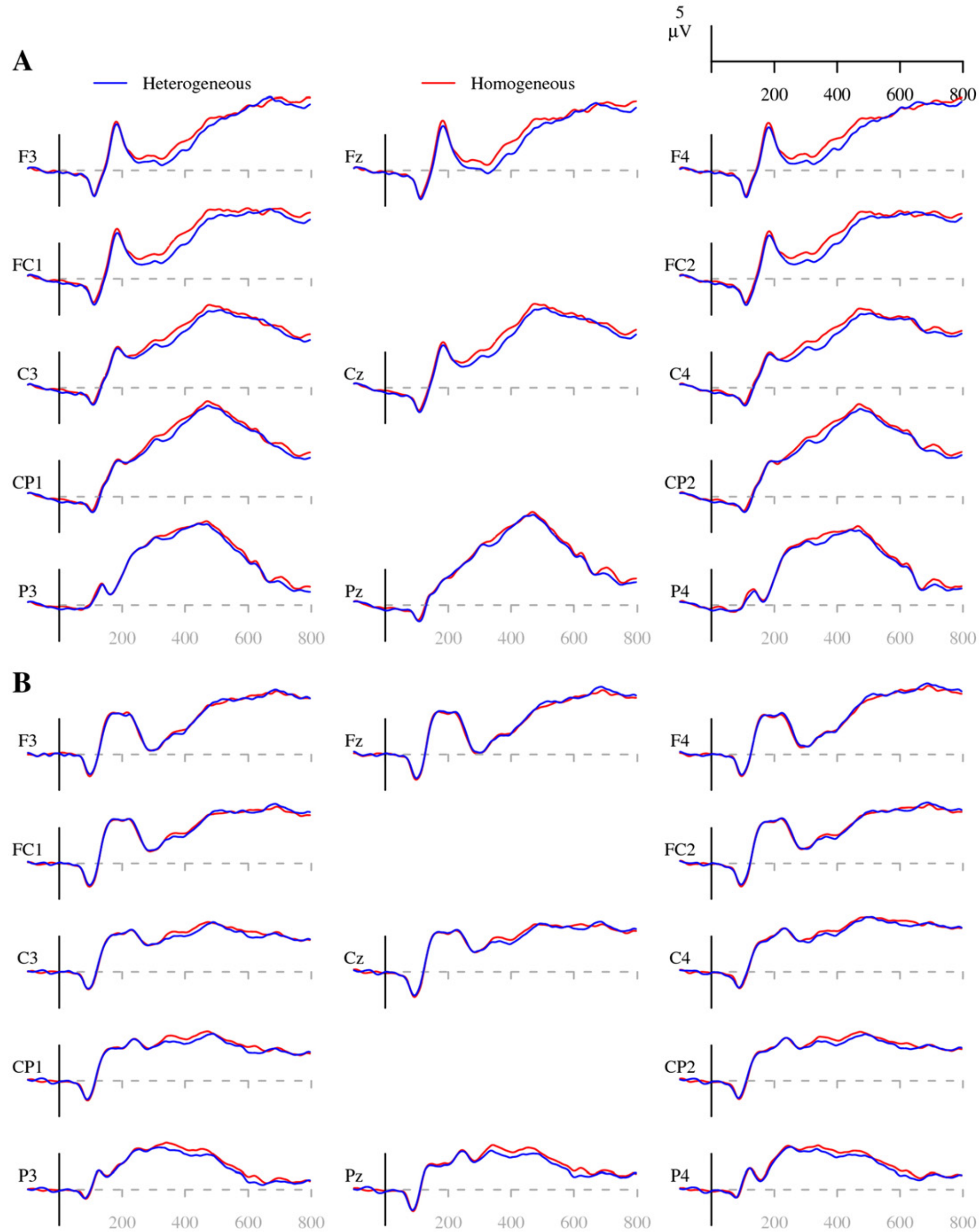

Fig. 2. Homogeneous and heterogeneous ERPs for the picture (A) and word naming (B) tasks at anterior, central, and posterior scalp locations. Homogeneous condition in red, heterogeneous condition in blue.

Window analyses

For the picture naming task, in the time window between 220 and 450 ms, there was a main effect of Context ($F(1, 17)=12.98$, $p<0.003$), and an interaction between Context and Anteriority ($F(1, 17)=11.36$, $p<0.004$). Further exploration of this interaction revealed that the Context effect was more pronounced at anterior ($t(17)=4.14$, $p<0.002$) than at posterior electrodes ($t(17)=2.30$, $p<0.04$).

For the word naming task, in the time window between 350 and 500 ms, there was a two-way interaction between Context and Anteriority ($F(1, 17)=4.94$, $p<0.05$). Further exploration of this interaction revealed that the context effect was more pronounced at posterior ($t(17)=2.34$, $p=0.06$) than at anterior electrodes ($t(17)=0.14$, $p=0.87$).

Correlation analyses

In the picture naming task, there was no correlation between the mean amplitude difference of the homogeneous and heterogeneous conditions across the frontal electrodes FC1, FC2 and Fz in the time window between 220 and 450 ms and the context effect found in the naming latencies on a by-participant basis ($t(16)=0.20$, $p=0.84$). In addition, there was no correlation between the peak amplitude of the context effect on electrode FC1 in the time window between 220 and 450 ms and the naming latencies effect ($t(16)=0.47$, $p=0.64$). Likewise, for the word naming task, there was no correlation between the mean amplitude difference of the two context conditions across the parietal electrodes Pz, P3 and P4 in the time window 350 to 500 ms and the context effect found in the naming latencies ($t(16)=0.60$,

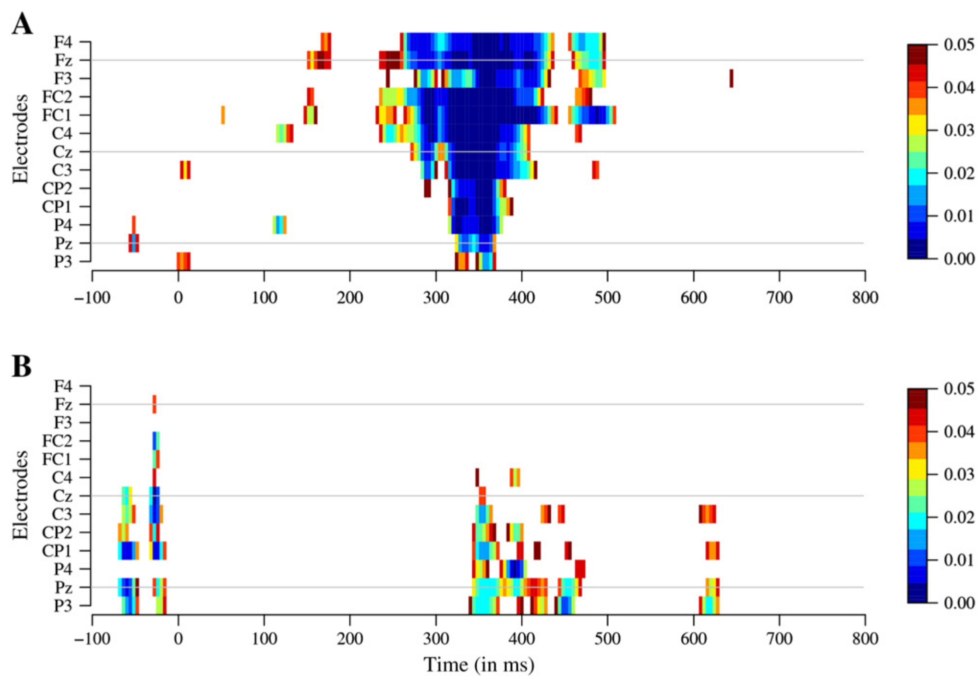

Fig. 3. P-values associated with the context effect in the picture (A) and word naming (B) tasks at each time point (as defined by the sampling rate) between −100 and 800 ms at anterior, central and posterior scalp locations. Only p-values less than 0.05 are plotted.

$p = 0.56$), nor was there a correlation between the peak amplitude of the context effect on electrode Pz in the time window between 350 and 500 ms and the naming latency effect ($t(16) = 0.90$, $p = 0.39$).

Discussion

Recent work in the language production literature has started to uncover the time course of the various stages of speech production. Of particular importance are the results from two studies that have used the effect of semantic context in the semantic blocking task to conclude that word selection processes start around 200 ms post-stimulus onset (Aristei et al., 2011; Maess et al., 2002). The current experiment had two goals. The first was to establish the empirical pattern that results from the manipulation of semantic context in the semantic blocking task. The second goal was to establish the output locus of the effect. In the experiment, participants named pictures and words in the homogeneous and heterogeneous conditions of the semantic blocking task. The behavioral analyses revealed longer naming latencies for the homogeneous compared to the heterogeneous condition for both picture and word stimuli, and the EEG analyses revealed a larger negativity for the heterogeneous compared to the homogeneous condition for picture stimuli between 220 and 450 ms, and for word stimuli between 350 and 500 ms. The distribution of these effects was anterior for pictures, and posterior for words. Finally, there was no correlation between the electrophysiological and reaction time effects of semantic context.

The ANOVA and mixed effect analyses of naming latencies revealed longer naming latencies in the homogeneous compared to the heterogeneous condition for picture stimuli. These results are consistent with those previously reported (Abdel Rahman and Melinger, 2009; Belke et al., 2005; Damian et al., 2001). For word stimuli, previous studies have observed either no effects (e.g., Kroll and Stewart, 1994), or facilitatory effects (Damian et al., 2001). One possible explanation for this inconsistency is that these previous studies used standard by-participant and by-item ANOVAs, which are arguably less sensitive than the mixed effect analyses employed here (e.g., Baayen et al., 2008). In line with this argument, for word stimuli, we did not find reliable differences between the homogeneous and heterogeneous conditions using the ANOVA analyses, but reliable differences were found using the mixed effect technique. These inhibitory semantic effects in word naming, if further confirmed, could suggest the involvement of a lexical route in word naming (e.g., Coltheart et al., 2001).

The polarity and scalp distribution of the effect reported here differ from that reported by Maess et al. (2002) and Aristei et al. (2011). However, as we argued in the Introduction, the results of Maess et al. and Aristei et al. were obtained using post-hoc analyses involving only a subset of trials and a subset of participants. These restrictions might have biased their results. Furthermore, the polarity of the effect of semantic context reported in the current study is comparable to that observed in studies of semantic context effects using the picture–word interference task (Dell'Acqua et al., 2010; Jescheniak et al., 2002, 2003). Consistent with the results reported here, Dell'Acqua et al. and Jescheniak et al. reported a larger negative wave for the unrelated (heterogeneous) compared to the related (homogeneous) context that was broadly distributed over the scalp. Thus, it seems that the empirical generalization that follows from the results reported here is that the manipulation of semantic context leads to a larger negative wave for the unrelated compared to the related condition in the semantic blocking and the picture–word interference tasks.

In the Introduction we discussed three criteria for determining the locus of the effect. We argued that on the assumption of an output effect, there should be a correlation between the electrophysiological and behavioral effects. If the reaction time effect and the electrophysiological effect were generated by processes in the brain related to word selection, one would have expected a correlation between the two effects, as has been found in previous studies using different tasks (e.g., Strijkers et al., 2010; Dell'Acqua et al., 2010). However, neither the amplitude nor the peak amplitude correlated with the reaction time effect. This does not readily agree with an output interpretation of the effects reported here.

Second, we argued that an output locus of the effect of semantic context in the picture naming task predicts a later onset of the effect for picture than for word stimuli. This is because naming latencies are

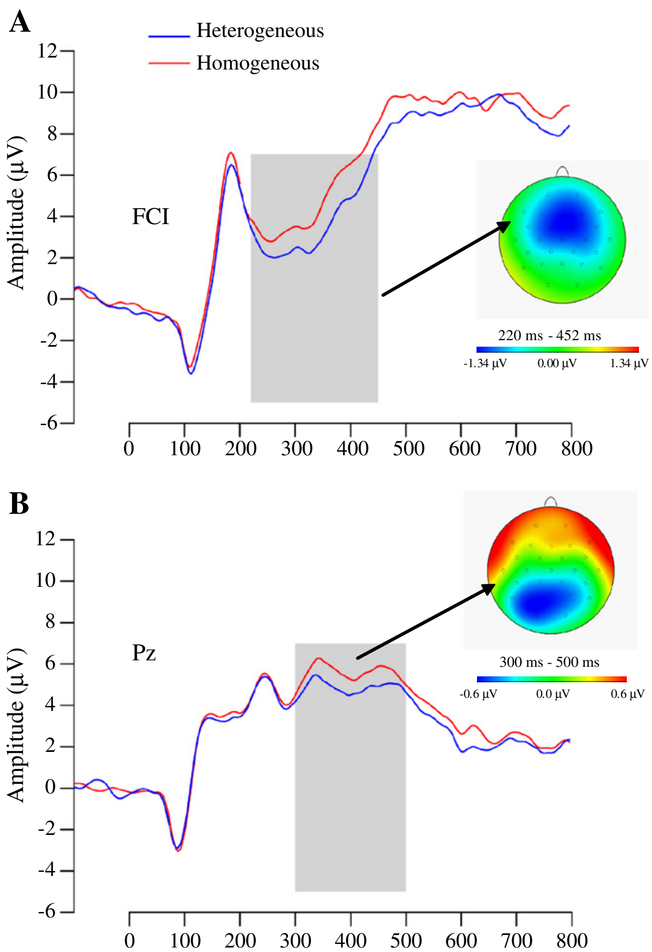

Fig. 4. Homogeneous ERPs compared with heterogeneous ERPs in the picture naming task (A) at electrode FC1 and the topographic distribution of this effect in the time window of 220 to 450 ms (gray area), and in the word naming task (B) at electrode Pz and the topographic distribution of this effect in the time window 300 to 500 ms.

typically longer for pictures than for words in this task, and therefore one would expect an output effect to appear later for stimuli with longer onset latencies than for stimuli with shorter onset latencies. At odds with this prediction, we found that the semantic effect had an *earlier* onset for pictures than for words. That is, the electrophysiological effect started around 220 ms post-stimulus onset for pictures, and around 350 ms post-stimulus onset for words (see Fig. 3, panels A and B; see also Ganis et al., 1996 for similar findings). This state of affairs is difficult to reconcile with an output locus of the semantic effect. A more likely explanation of these differences in the onset of the electrophysiological effects between pictures and words is in terms of input processes. Specifically, it could be that this onset effect reflects the differences in the access to semantic information, where pictures have more direct access to semantic information than words (e.g., Potter et al., 1984).

Finally, the overall polarity, scalp distribution, and latency of the effect reported here cannot be distinguished from the effect of semantic context that is typically found in language comprehension studies. For example, as discussed in the Introduction, Ganis et al. (1996) reported a larger negativity for the unrelated compared to the related context between 325 and 475 ms, with an anterior distribution for pictures and a posterior distribution for words.[2] The results of Ganis et al. are identical to those reported here in terms of polarity, scalp distribution and latency. Thus, the three criteria are not consistent with an output locus of the effect of semantic context, and suggest instead that the effect of semantic context in the semantic blocking task arises during the input stages of processing in the picture naming task.

An interesting aspect of these data concerns the differences in the topography of the effect of semantic context between pictures and words. Thus, the effect had an anterior distribution for pictures and a posterior distribution for words. This distribution of the semantic effect mirrors the effects found in various language comprehension studies that have compared pictures and words (e.g., Barrett and Rugg, 1990; Ganis et al., 1996; McPherson and Holcomb, 1999). There is a current debate on the exact interpretation of these different topographies. One is that the neural generators underlying the semantic effect are different for pictures than for words, suggesting that there are different semantic systems underlying pictures and words (e.g., Paivio, 1990). An alternative interpretation is that the same semantic processes underlie pictures and words, and that the contrasting topographies are the result of a picture-specific component that overlaps with and distorts the observed N400 in picture processing. Specifically, McPherson and Holcomb (1999) suggest that the N400 effect is comparable between pictures and words, and that there are two components (N300 and N400) that contribute to the scalp distribution of the semantic effect in picture processing. Although our data do not allow us to distinguish between these possibilities, it is clear that the results reported here are compatible with these studies suggesting an input locus of the effect.

One possible interpretation of the results reported here is that the inhibitory effects observed in the naming latencies reflect output processes related to word selection, and that the corresponding electrophysiological effect reflects input processes. One might object to this interpretation and argue that it is inconsistent — the interpretation of the behavioral effect differs from that of the electrophysiological effect. However, this inconsistency clearly depends on the assumption that the inhibitory effect of semantic context observed in the naming latencies reflects output processes related to word selection (Roelofs, 1992). There is at present a fierce debate in the language production literature concerning the question of whether inhibitory effects of semantic context reflect word selection processes, or whether they reflect pre- or post-word selection processes (e.g., Abdel Rahman and Melinger, 2009; Dhooge and Hartsuiker, 2010; Mahon, Costa, Peterson, Vargas, and Caramazza, 2007). In the context of this research, one might question the reliability of the interpretation of the inhibitory effect of semantic context in the semantic blocking task in terms of output processes related to word selection. If research in this area were to show that the effects of semantic context in the semantic blocking task arise before word selection (e.g., Navarrete et al., 2010), there would be a consistent interpretation between the behavioral and electrophysiological effects observed here.

To conclude, language production research has only recently begun to examine the time course of the various stages of processing from an electrophysiological perspective. A valuable contribution with respect to this issue concerns the studies that have argued that word selection processes start around 200 ms post-stimulus onset on the basis of the electrophysiological effect of semantic context in the semantic blocking task (Aristei et al., 2011; Maess et al., 2002). However, the results reported here suggest that the effects of semantic context in the semantic blocking task do not necessarily arise during output stages of picture naming, and therefore undermine an interpretation of the effects of semantic context in the semantic blocking task in terms of output processes related to word selection. An alternative interpretation of these data is that they arise during input stages of picture naming, such as those associated with semantic processes. These results do not mean that there is no electrophysiological correlate of word selection, nor that the inhibitory effect in the reaction times reflects input rather than word selection processes. The results reported here only imply that the electrophysiological effect of semantic context in the semantic blocking task cannot be used to make claims about word selection.

[2] Note that the relatively small effect-size in our experiment could be due to the fact that stimulus repetition was high (each stimulus was repeated 32 times), and that N400 amplitude is known to decrease with repetition (e.g., Van Petten et al., 1991).

Acknowledgments

NJ was supported by a Juan de la Cierva post-doctoral fellowship from the Spanish Ministry of Science and Technology. MC was supported by Grants PSI2009-08889 and CONSOLIDER INGENIO 2010 CSD2008-00048 from the Spanish Ministry of Science and Technology. HAB was supported by grants PSI2010-19767 and HA2008-0011 from the Spanish Ministry of Science and Technology.

References

Abdel Rahman, R., Melinger, A., 2009. Semantic context effects in language production: a swinging lexical network proposal and a review. Lang. Cogn. Processes 24, 713–734.
Aristei, S., Melinger, A., Abdel Rahman, R., 2011. Electrophysiological chronometry of semantic context effects in language production. J. Cogn. Neurosci. 23, 1567–1586.
Baayen, R.H., 2008. A practical introduction to statistics using R. Analyzing Linguistic Data. Cambridge University Press.
Baayen, R.H., Davidson, D.J., Bates, D.M., 2008. Mixed-effects modeling with crossed random effects for subjects and items. J. Mem. Lang. 59, 390–412.
Barrett, S.E., Rugg, M.D., 1990. Event-related potentials and the semantic matching of pictures. Brain Cogn. 14, 105–115.
Bates, D.M., 2005. Fitting linear mixed models in R. R News 5, 27–30.
Belke, E., Meyer, A.S., Damian, M.F., 2005. Refractory effects in picture naming as assessed in a semantic blocking paradigm. Q. J. Exp. Psychol. 58A, 667–692.
Caramazza, A., 1997. How many levels of processing are there in lexical access? Cogn. Neuropsychol. 14, 177–208.
Collins, A.M., Loftus, E.F., 1975. A spreading activation theory of semantic processing. Psychol. Rev. 82, 407–428.
Coltheart, M., Rastle, K., Perry, C., Langdon, R., Ziegler, J., 2001. DRC: a dual route cascaded model of visual word recognition and reading aloud. Psychol. Rev. 108, 204–256.
Damian, M.F., Vigliocco, G., Levelt, W.J.M., 2001. Effects of semantic context in the naming of pictures and words. Cognition 81, B77–B86.
Dell'Acqua, R., Sessa, P., Peressotti, F., Mulatti, C., Navarrete, E., Grainger, J., 2010. ERP evidence for ultra-fast semantic processing in the picture-word interference paradigm. Front. Psychol. 1, 177. doi:10.3389/fpsyg.2010.00177.
Dell, G.S., 1986. A spreading-activation theory of retrieval in sentence production. Psychol. Rev. 93, 283–321.
Dell, G.S., Reich, P.A., 1981. Stages in sentence production: an analysis of speech error data. J. Verbal Learn. Verbal Behav. 20, 611–629.
Dhooge, E., Hartsuiker, R.J., 2010. The distractor frequency effect in picture-word interference: Evidence for response exclusion. J. Exp. Psychol. Learn. Mem. Cogn. 36, 878–891.
Ganis, G., Kutas, M., Sereno, M.I., 1996. The search for “common sense”: an electrophysiological study of the comprehension of words and pictures in reading. J. Cogn. Neurosci. 8, 89–106.
Ganushchak, L.Y., Schiller, N.O., 2008. Motivation and semantic context affect brain error-monitoring activity: an event-related brain potentials study. Neuroimage 39, 395–405.
Heim, S., Eickhoff, S.B., Friederici, A.D., Amunts, K., 2009. Left cytoarchitectonic area 44 supports selection in the mental lexicon during language production. Brain Struct. Funct. 213, 441–456.
Janssen, N., Caramazza, A., 2009. Grammatical and phonological influences on word order. Psychol. Sci. 20, 1262–1268.
Jescheniak, J.D., Schriefers, H., Garrett, M.F., Friederici, A.D., 2002. Exploring the activation of semantic and phonological codes during speech planning with event-related brain potentials. J. Cogn. Neurosci. 14, 951–964.
Jescheniak, J.D., Hahne, A., Schriefers, H., 2003. Information flow in the mental lexicon during speech planning: evidence from event-related brain potentials. Cogn. Brain Res. 15, 261–276.
Kutas, M., Federmeier, K.D., 2011. Thirty years and counting: finding meaning in the N400 component of the event related brain potential (ERP). Annu. Rev. Psychol. 621–647.
Kroll, J.F., Stewart, E., 1994. Category interference in translation and picture naming: evidence for asymmetric connections between bilingual memory representations. J. Mem. Lang. 33, 149–174.
Levelt, W.J.M., 1989. Speaking: from Intention to Articulation. MIT Press, Cambridge, MA.
McCarthy, R.A., Kartsounis, L.D., 2000. Wobbly words: refractory anomia with preserved semantics. Neurocase 6, 487–497.
McPherson, W.B., Holcomb, P.J., 1999. An electrophysiological investigation of semantic priming with pictures of real objects. Psychophysiology 36, 53–56.
Maess, B., Friederici, A.D., Damian, M.F., Meyer, A.S., Levelt, W.J.M., 2002. Semantic interference in overt picture naming: sharpening current density localisation by PCA. J. Cogn. Neurosci. 14, 455–462.
Navarrete, E., Mahon, B.Z., Caramazza, A., 2010. The cumulative semantic cost does not reflect lexical selection by competition. Acta Psychol. 134, 279–289.
Nigam, A., Hoffman, J.E., Simons, R.F., 1992. N400 to semantically anomalous pictures and words. J. Cogn. Neurosci. 4, 15–22.
Paivio, A., 1990. Mental Representations: a Dual Coding Approach. Oxford University Press, New York.
Potter, M.C., So, K.-F., Von Eckardt, B., Feldman, L.B., 1984. Lexical and conceptual representation in beginning and proficient bilinguals. J. Verbal Learn. Verbal Behav. 23, 23–38.
Roelofs, A., 1992. A spreading-activation theory of lemma retrieval in speaking. Cognition 42, 107–142.
Schnur, T.T., Schwartz, M.F., Brecher, A., Hodgson, C., 2006. Semantic interference during blocked-cyclic naming: evidence from aphasia. J. Mem. Lang. 54, 199–227.
Schnur, T.T., Schwartz, M.F., Kimberg, D.Y., Hirshorn, E., Branch Coslett, H., Thompson-Schill, S.L., 2009. Localizing interference during naming: convergent neuroimaging and neuropsychological evidence for the function of Broca's area. Proc. Natl. Acad. Sci. U.S.A. 106, 322–327.
Schriefers, H., Meyer, A.S., Levelt, W.J.M., 1990. Exploring the time course of lexical access in language production: picture–word interference studies. J. Mem. Lang. 29, 86–102.
Snodgrass, J.G., Vanderwart, M., 1980. A standardized set of 260 pictures: norms for name agreement, image agreement, familiarity, and visual complexity. J. Exp. Psychol. Hum. Learn. Mem. 6, 174–215.
Snyder, H.R., Hutchison, N., Nyhus, E., Curran, T., Banich, M.T., O'Reilly, R.C., 2010. Neural inhibition enables selection during language processing. Proc. Natl. Acad. Sci. 107, 16483–16488.
Strijkers, K., Costa, A., Thierry, G., 2010. Tracking lexical access in speech production: electrophysiological correlates of word frequency and cognate effects. Cortex 20, 912–928.
Van Petten, C., Kutas, M., Kluender, R., Mitchiner, M., McIsaac, H., 1991. Fractionating the word repetition effect with event-related potentials. J. Cogn. Neurosci. 3, 131–150.
Wilshire, C.E., McCarthy, R.A., 2002. Evidence for a context-sensitive word retrieval disorder in a case of nonfluent aphasia. Cogn. Neuropsychol. 19, 165–186.