Semantic domain and grammatical class effects in the picture-word interference paradigm

Javier Rodríguez-Ferreiro[1], Robert Davies[2] and Fernando Cuetos[3]

[1]University of Barcelona, Spain
[2]University of Oxford Brookes, UK
[3]University of Oviedo, Spain

Corresponding author: Javier Rodríguez-Ferreiro

Dept. Psicologia Bàsica & IR3C,

Universitat de Barcelona,

Mundet, Ponent, Pg.Vall D'Hebron, 171

08035, Barcelona, Spain.

E-mail address: rodriguezferreiro@ub.edu

Tel: (+34) 933125151

Fax: (+34) 934021363

Short title: Semantic and grammatical effects in PWI

Abstract

The role of grammatical class in lexical access and representation is still not well understood. Grammatical effects obtained in picture-word interference experiments have been argued to show the operation of grammatical constraints during lexicalization when syntactic integration is required by the task. Alternative views hold that the ostensibly grammatical effects actually derive from the coincidence of semantic and grammatical differences between lexical candidates. We present three picture-word interference experiments conducted in Spanish. In the first two, the semantic relatedness (related or unrelated) and the grammatical class (nouns or verbs) of the target and the distracter were manipulated in an infinitive form action naming task in order to disentangle their contributions to verb lexical access. In the third experiment, a possible confound between grammatical class and semantic domain (objects or actions) was eliminated by using action-nouns as distracters. A condition in which participants were asked to name the action pictures using an inflected form of the verb was also included to explore whether the need of syntactic integration modulated the appearance of grammatical effects. Whereas action-words (nouns or verbs), but not object-nouns, produced longer reaction times irrespective of their grammatical class in the infinitive condition, only verbs slowed latencies in the inflected form condition. Our results suggest that speech production relies on the exclusion of candidate responses that do not fulfil task-pertinent criteria like membership in the appropriate semantic domain or grammatical class. Taken together, these findings are explained by a response-exclusion account of speech output. This and alternative hypotheses are discussed.

The exact mechanism required for lexical access remains a central concern for theories of speech production. The most influential accounts of lexical access (Dell, 1986; Levelt, 1989) agree that the process involves the spread of information from an activated concept to the corresponding lexical representation. The existence of one-to-many mappings between concepts and lexical representations -the same idea can be expressed with many different words- requires lexical access to cope with the activation of multiple lexical representations, selecting the most appropriate lexical entry among all activated candidates. The dominant view on how this occurs (La Heij, 1988; Levelt, Roelofs, & Meyer, 1999) assumes that lexical selection operates by means of direct competition between the different candidates such that the most highly activated lexical entry is selected. The lexical selection by competition account relies on evidence gathered using the picture-word interference (PWI) paradigm. Our investigation focused on whether conceptually driven competition for selection is modulated by the grammatical properties of candidate words. We tested this possibility in a series of PWI experiments.

The standard version of the PWI procedure requires participants to name pictures whilst ignoring a word, a verbal distracter, that is superimposed on the target picture (e.g. Glaser & Düngelhoff, 1984). In the PWI task, participants are told to ignore the distracter but its presentation generally interferes with their performance, and that interference is most commonly evidenced in effects on reaction times. Manipulations of semantic relatedness between target and distracter stimuli have revealed that semantically related distracters slow down naming latencies (Lupker, 1979), producing the so-called semantic interference effect (SIE). According to the lexical selection by competition hypothesis, the level of activation of lexical competitors, including the

highly activated semantically related distracter word, increases the time needed for the target lexical entry to be selected (for an alternative interpretation of the SIE in the PWI paradigm see Mahon, Costa, Peterson, Vargas, & Caramazza, 2007).

The PWI task is limited because it permits the study of lexical access only in relation to words corresponding to picturable concepts. Thus, the production of noun names for objects has frequently been studied while there is little evidence about lexical access for words of other grammatical classes which correspond to less conveniently depicted concepts. The role of grammatical class in lexical access is, consequently, far from well investigated. Nevertheless, there is plenty of evidence that this relative neglect obscures the possible modulation of the process of lexical access in speech production not just by semantics but also by grammatical class.

Neuropsychological and neuroimaging evidence (Caramazza & Hillis, 1991; Damasio & Tranel, 1993; Shapiro & Caramazza, 2003a, 2003b) indicates, firstly, that words belonging to different grammatical classes, namely nouns and verbs, rely on different representation networks (though see Tyler, Russel, Fadili, & Moss, 2001; Tyler et al., 2003). The analysis of spontaneous error rates during speech production has consistently shown, in addition, that the vast majority of the errors preserve the grammatical class of the target (Fay & Cutler, 1977; Nooteboom, 1969). Together, the evidence about between-class differences in the nature of representations and the character of speech errors can be taken to suggest that some kind of grammatical restriction is imposed on the lexicalization process.

Significantly, the SIE has appeared to be elusive in the action domain. Whereas some studies have found a semantic effect in action naming parallel to that observed in object naming (Roelofs, 1993; Vigliocco, Vinson, Lewis, & Garrett, 2004), others have failed to obtain a consistent SIE in the action domain (Schnur, Costa, & Caramazza, 2002; Schriefers, Teruel, & Meinshausen, 1998). The inconsistency of the SIE in action naming has cast doubt, at minimum, on the usefulness of the PWI paradigm in the study of verb lexicalization (Tabossi & Collina, 2002). Hence, the appearance of the SIE effect in the verb-action domain needs to be clarified. More interestingly, conflicting evidence on the role of grammatical class in lexicalization, and its relation to the impact of semantic information, means we are uncertain about a key property of lexical access in speech.

Some reports suggest that lexical selection is constrained by grammatical class but that this constraint is obtained only when syntactical integration is needed (Pechmann, Garrett, & Zerbst, 2004; Pechmann & Zerbst, 2002; Vigliocco, Vinson, & Siri, 2005). Using the PWI task, Pechmann and colleagues found larger interference effects when target object (nouns) pictures were coupled with distracters of the same grammatical class (nouns) compared to distracters of a different class (closed-class words or adverbs). However, this effect of grammatical class only appeared when participants were required to produce sentences rather than single word utterances. These results suggest the modulation of lexical access by grammatical class only if grammatical information is required by the task, *i.e.*, where the current demands on the speech production system entail grammatical processing. Consistent with this line of thinking, Vigliocco et al. (2005) found that both noun and verb distracters produced an SIE in action naming but that that SIE was obtained in inflected but not in infinitival verb

naming. The argument is that inflected verb naming makes syntactic demands on the lexicalization process similar to verb naming within sentences, in a way that infinitival verb naming does not.

Dell, Oppenheim and Kittredge (2008) have suggested that the observation of grammatical class constrains during lexicalization reflect the operation of a dynamic lexical selection mechanism - the "syntactic traffic cop" - in the lexicalization system. The traffic cop is supposed to restrict lexical selection to grammatically appropriate candidates when we are producing sentences. The argument is that if a traffic cop did not constrain lexical selection in this way then speakers would sometimes produce words that may be semantically relevant but are ungrammatical. As has been noted, such errors are not observed. Nevertheless, evidence in favour of the traffic cop is not clear-cut, and the lack of clarity derives from both methodological and theoretical issues.

There is a question over whether the results obtained by Vigliocco et al. (2005) can validly inform us about grammatical restrictions on lexical selection, due to the fact that these authors presented noun distracters with determiners. Vigliocco et al. (2005) presented noun distracters with determiners so as to exclude possible verb interpretations of the word by participants. However, determiner distracters have been shown to affect reaction times in PWI procedures (Alario, Ayora, Costa, & Melinger, 2008). In consequence, Janssen et al. (2010) argued that the presentation of determiners may have confounded the comparison between the effects of noun and verb distracters.

More significantly, a number of studies have been unable to replicate the observation of the effects previously taken to demonstrate grammatical restrictions on lexicalization (Iwasaki, Vinson, Vigliocco, Watanabe, & Arciuli, 2008; Janssen, et al., 2010; Mahon, et al., 2007). Applying the same procedure used by Vigliocco et al. (2005) with Japanese volunteers, Iwasaki et al. (2008) failed to obtain the same results as Vigliocco et al. (2005) study with Italian participants. Iwasaki et al. (2008) attributed the between-study discrepancy to differences between the structural characteristics of the two languages. However, an alternative explanation is that semantic factors are responsible for the apparent grammatical restrictions found in the PWI paradigm.

In an attempted replication of one of the Pechmann and Zerbst (2002) experiments, Janssen et al. (2010) showed that differences in the imageability of the distracters could account for the alleged grammatical effect in the previous study because words belonging to different grammatical classes tend to present different imageability values (e.g. nouns are more imageable than closed-class words, see Bird, Franklin, & Howard, 2001).

Finally, Mahon et al. (2007) found an interaction between semantic and grammatical effects in an object naming task even though sentence integration was not explicitly required in the task. Their results showed an SIE between object pictures and noun distracters but not for object naming with verb distracters. On the basis of their findings, Mahon et al. (2007) presented the response exclusion hypothesis. In this account, speech production tasks evoke "response-relevant criteria", for example, being a noun in an object naming task. Interference effects therefore reflect the degree to which candidate items match these response-relevant criteria, and the speed with which items

can be excluded from the selection process. In these terms, interactions between effects of grammatical class and semantic relatedness can be interpreted as components of the same general process of filtering or excluding non-target candidate items according to task relevance. A specific mechanism for controlling the participation of lexical candidates for selection based on grammatical class, i.e., a syntactic traffic cop, need not, then, be assumed.

The aim of this work was to clarify the role of grammatical characteristics on lexicalization. The lexical selection by competition account has been extended to explain observations of an interaction between grammatical class and semantic relatedness in speech production PWI studies, by assuming the interposition of a syntactic traffic cop. That syntactic traffic cop is assumed to be engaged only where the speech task demands syntactic integration, predicting that one should observe an interaction between grammatical class and semantic relatedness effects under conditions requiring syntactic integration only. Thus, during single word production, a SIE should be obtained irrespective of the grammatical class of pictures and distracters. On the contrary, when producing sentences, the semantic interference effect should only appear between pictures and distracters that belong to the same grammatical classes. In contrast, the response exclusion account does not incorporate a syntactic traffic cop, assuming that grammatical or semantic effects both stem from a general mechanism for excluding non-target responses for speech production. This predicts that one could observe an interaction between grammatical class and semantic relatedness effects even if task conditions do not require syntactic integration. For example, the SIE would not appear in a citation naming task in which distracter words do not belong to the appropriate semantic field, thus including different grammatical class words.

We manipulated semantic relation and grammatical class to establish the exact influence of these two types of information on lexical processing. Three PWI action naming experiments were completed. To anticipate the later discussion of findings, we consistently observed the SIE between action pictures and verb distracters. When different grammatical class distracters were included, the appearance of the SIE was modulated by both the semantic properties and the class of the stimuli. This interaction was observed both under conditions that did and conditions that did not explicitly require syntactic integration.

Experiment 1

Participants

Sixty-four native Spanish speakers studying at the University of Oviedo, aged 18 to 20 years, took part in the experiment in exchange for course credits.

Materials

Twenty object pictures (e.g. mesa -table-) and twenty action pictures (e.g. ladrar -to bark-) were selected from existing databases (Druks & Masterson, 2000; Snodgrass & Vanderwart, 1980; Szekely et al., 2004) to be used as target stimuli. Two noun (e.g. hueso -bone-) and two verb distracters, one categorically related (e.g. morder -(to)bite-) and one unrelated (e.g. colar –(to) strain-), were assigned to each of them. The selection of the related and unrelated pairs was done intuitively by the experimenters. Same-class (grammatical class) related distracters were selected from amongst the target coordinates. The manipulation of semantic relatedness among different-grammatical

class distracters was done by assigning two concepts as a target-distracter pair to the related condition where those concepts could be said to normally appear together (e.g. botón –button; abrochar -(to)fasten).

Initial phonological relatedness between distracters and target picture names was excluded. Final phonological overlapping within the noun and verb groups of stimuli is difficult to avoid in our experiments due to the gender and conjugation morpho-phonological markers used in the Spanish language. Orthographic similarity between target and distracter pairs was computed using the Levenshtein distance algorithm implemented by Yarkoni, Balota and Yap (2008) in order to get a measure of phonological overlap in our stimuli. Given the known role of imageability in the grammatical effects in the PWI paradigm (Janssen, et al., 2010), imageability data of the distracter words were also obtained. When available, rated imageability values were gathered from the LEXESP database (Sebastián-Gallés, Carreiras, Cuetos, & Martí, 2000). A rating survey following the same procedure used in LEXESP was conducted to obtain missing imageability values. Two groups of 40 students, different from those who participated in the subsequent experiments, took part in these surveys. Each group rated 75 words, 25 of which also appeared in the LEXESP database. A comparison between the LEXESP values and the values we obtained for these items showed no significant differences and a significant degree of correlation appeared between the two lists supporting the reliability of our rating study. Related and unrelated distracters were matched on lexical frequency (Davis & Perea, 2005; Sebastián-Gallés, et al., 2000) and length in letters. Distracter words were presented superimposed on the pictures, printed in Times New Roman Bold 24pt font. A summary of the psycholinguistic characteristics of all the items used in the study is presented in Table 1.

(Table 1 about here)

Procedure and design

Stimuli were presented and reaction times were recorded using the SuperLab Pro

application (Abboud & Sugar, 1997). Objects and actions were presented in two

separate blocks. Half the participants saw objects first and half saw actions first. The

order of item presentation was randomised within each block. Before each experimental

block, a practice block was presented in which participants were asked to name the

pictures with no distracter. Distracter type was manipulated: a picture was paired with a

related distracter of the same class, an unrelated distracter of the same class, a related

distracter of different class, and an unrelated distracter of different class. To prevent

repetition effects, all participants saw each picture once only. To ensure that the

manipulation of distractor type remained within-participants, such that all participants

responded under all distracter conditions, whether a participant saw a particular picture-

distracter pairing depended upon a counterbalanced stimulus presentation regime. The

pictures were split into four sets, A, B, C and D for each class (actions or objects). The

participants were split into four groups of equal size (groups 1 - 4). Each participant

group was presented with each picture set under a different distracter type condition

according to a Latin Square design. To clarify by example, group 1 saw: set A pictures

with related distractors of the same class (nouns or verbs); set B with unrelated

distractors of the same class; set C with related distractors of different class; and set D

with unrelated distractors of the different class. Other groups saw the same sets of

pictures but with complementary distractor pairings. Hence, group 2 saw: set A pictures

with unrelated distractors of different class; set B with related distractors of the same

class; set C with unrelated distractors of same class; and set D with related distractors of different class.

Naming responses were correct if they corresponded to the normative modal name for the picture in Spanish. If any response was incorrect, the experimenter corrected participants with the dominant picture name. During experimental blocks, the experimenter was present in the test room to record naming errors. Each trial consisted of a fixation point (*) that appeared for 500ms in the centre of the screen, after which the stimulus appeared until the participant named it.

Results and discussion

Productions that differed from the correct picture name, 6.21% of responses, were excluded from analyses. Responses exceeding 2.5 standard deviations from the participant's mean were considered outliers (2.6% of responses), and replaced with the 2.5 standard deviation cut-off, calculated for each participant based on performance across all conditions. Average reaction times are reported in Table 2. Separate ANOVAs were conducted with the object and action naming data sets. In order to minimize the impact of specific characteristics of the distracter words on the results, imageability ratings and values of orthographic similarity with target names were entered as covariates in the by-items analyses.

In the object naming condition, there was an effect of the grammatical class of the distracter ($F_1(1,63)=13.250$, p =.001, $\eta^2_p=.17$; $F_2(1,74)=3.911$, p =.052, $\eta^2_p=.05$) revealing that latencies were significantly longer when distracters as well as target

names were nouns. The effect of semantic relatedness was also significant ($F_1(1,63)=15.920$, p <.001, $\eta^2_p=.2$; $F_2(1,74)=4.620$, p =.035, $\eta^2_p=.059$), with longer latencies for related compared to unrelated distracters. The interaction between the grammatical class and semantic relatedness effects was significant too ($F_1(1,63)=15.644$, p <.001, $\eta^2_p=.2$; $F_2(1,74)=4.336$, p =.041, $\eta^2_p=.055$). Consequently, planned t tests (two-tailed) showed significant differences between related and unrelated noun distracters ($t_1(63)=4.863$, p<.001, r=0.52; $t_2(38)=3.241$, p=.002, r=46), while no significant difference was observed comparing the effects of related and unrelated verb distracters.

In the action naming condition, there was an effect of the grammatical class of the distracter ($F_1(1,63)=21.298$, p<.001, $\eta^2_p=.25$; $F_2(1,74)= 5.088$, p=.027, $\eta^2_p=.064$), also, as latencies were longer when distracters were verbs compared to when they were nouns. The semantic relatedness effect was significant by participants ($F_1(1,63)=9.521$, p=.003, $\eta^2_p=.13$) but not by items, with longer latencies for related than for unrelated distracters. The interaction between the class and semantic relatedness effects was also significant by participants ($F_1(1,63)=6.946$, p=.011, $\eta^2_p=.1$) and near significant in the by items analysis ($F_2(1,74)=2.853$, p=.095, $\eta^2_p=.037$). Planned t tests (two-tailed) showed that naming latencies were longer for semantically related verbs than for unrelated verb distracters ($t_1(63)=3.628$, p=.001, r=.42; $t_2(38)=2.385$, p=.022, r=.36). However, no significant difference was found between the effects of related and unrelated noun distracters.

(Table 2 about here)

These results reveal the SIE in both the object and action domains. Furthermore, the significant interaction between grammatical class and semantic relatedness suggests that this effect appears only when target-distracter pairs belong to the same grammatical class. However, it is possible that a confound between grammatical class and semantic relatedness was responsible for the effect, if target-distracter word pairs were semantically closer within grammatical class than between classes. Experiment 2 was designed to replicate the first experiment but with the addition of a specific control for semantic relatedness based on subjective ratings of semantic similarity.

Experiment 2

Participants

Sixty new participants took part in experiment 2, all were drawn from the same population sampled for experiment 1 and none had taken part in the previous experiment.

Materials

In order to maximize the degree of semantic relatedness between inter-grammatical class pairs, instrumental actions (e.g. pelar -(to)peal-), which are closely linked to the instruments needed to perform them, were selected as targets. We designed a questionnaire to collect subjective rating of semantic relatedness, presenting 40 picturable instrumental verbs coupled with related or unrelated instrumental verbs or related or unrelated instrumental nouns (e.g. cuchillo -knife-). Forty-four students different from the experimental participants were asked to rate the degree of semantic similarity between the different pairs of words on a 7-point scale. We encouraged the raters to consider as semantically related those pairs of words designating concepts that

tend to appear together in the same situations, as well as those that belong to the same semantic categories. We thus implicitly encouraged an approach that combined a semantic network point of view with information from lexical-semantic taxonomies. Given that this perspective could promote an associative interpretation of semantic relatedness, twenty different participants were asked to give the first word that came to mind in response to the forty target verbs to get a measure of semantic association between the critical word pairs. Using the ratings data, 20 drawings of actions were selected as target stimuli for this experiment. For each picture (e.g. pintar –(to) paint-), a related (e.g. dibujar –(to) draw-) and an unrelated verb (e.g. esconder –(to) hide-) as well as a related (e.g. lápiz –pencil-) and an unrelated noun (e.g. raqueta –racket-) were selected. Average rated relatedness was equated between verb-noun and verb-verb target-distracter pairs. The four lists of distracters were matched on lexical frequency and letter length. Distracters that were highly associated to the target words were avoided.

Procedure and design

The procedure was similar to that used in the action naming block of the previous experiment. In order to improve the accuracy of our measures, stimulus presentation and data collection was done using the DMDX software. Responses were recorded to hard disk, and reaction times were established offline by analysis of the waveform and sound spectrogram of participants' recorded responses using the CheckVocal application (Protopapas, 2007).

Results and discussion

Incorrect responses (7.75% of responses) were eliminated from the analysis and outliers (2.15%) were replaced with the 2.5 standard deviation cut-off. Analyses of variance, including distracter characteristics, imageability and orthographic similarity, as covariates in the by-items analyses, showed an effect of semantic relatedness that was only significant by participants ($F_1(1,59)=15.659$, p <.001, $\eta^2_p=.21$; $F_2(1,74)=4.464$, p =.038, $\eta^2_p=.057$). The effect of grammatical class did not reach the significance threshold. The interaction between the two main effects was significant ($F_1(1,59)=13.204$, p =.001, $\eta^2_p=.18$; $F_2(1,74)=4.072$, p =.047, $\eta^2_p=.052$). An effect of orthographic similarity was also evident in the by items analysis ($F_2(1,74)=7.844$, p =.007, $\eta^2_p=.096$). When the effects of verb and noun distracters were analyzed separately, related verb distracters were found to evoke significantly longer reaction times than unrelated verb distracters both in the by items and by subjects analyses ($t_1(59)=4.888$, p<.001, r=.54; $t_2(38)=2.074$, p=.045, r=.32), but no significant difference appeared in a comparison of the effects of related and unrelated noun distracters.

Our results replicated our observation in experiment 1 of the SIE in the action domain and showed that even when closely matched distracter sets are used, the effect is obtained only if stimuli pairs belong to the same grammatical class. These data conflict with previous results (Vigliocco, et al., 2005) showing effects of grammatical class only when participants are asked to name the pictures using an inflected form of the verb. A possible source of the difference between the two studies might be found in the different kinds of noun distracters used. Whilst Vigliocco et al. selected only nouns referring to actions, we used object-nouns as distracters. Experiment 3 was designed with the intention of disentangling the possible confound between grammatical class and semantic domain using both object- and action-nouns. Furthermore, a condition in

which participants were asked to name the action pictures using an inflected form of the verb was included in the design in order to study the effect of requiring syntactic integration in verb lexical selection.

Experiment 3

Participants

Forty-eight participants were tested. They were drawn from the same population as were sampled for the previous experiments but had not participated in the latter.

Materials

Twenty action pictures (e.g. ladrar –(to)bark-) were coupled with semantically related and unrelated object-nouns (e.g. hueso –bone-; tuerca –nut-), action-nouns (e.g. mordisco -(the)bite-; frenazo –(the)braking-) and action-verbs (e.g. morder -(to)bite-; frenar –(to)brake-) matched on lexical frequency and letter length.

Procedure and design

The procedure was similar to that used in experiment 2. The participants were presented with the 20 pictures twice, but named each picture once using the citation (infinitive) form of the verb, and once using the verb's inflected (third person singular, simple present tense) form. Participants were required to use the different forms in two different blocks, the infinitive form in one block and the inflected form in the other. The order of presentation of the infinitive and inflected blocks was counterbalanced across participants. As in the previous experiments, to ensure that the manipulation of distractor type remained within-participants, the presentation of different distracter types was counterbalanced across participants. In this experiment, there were six

different distracter types and therefore the presentation of a picture with different distracter types was distributed over six groups of participants such that each participant named a picture once only in a block and all pictures were presented with all distracter types over the participant groups. We ensured that if a participant saw a picture with one distracter type (e.g. a related object noun) in one naming condition she would see the same picture with a different distracter type in the other naming condition (e.g. a related action noun).

Results and discussion

A total of 6.25% responses were excluded as incorrect; 1.93% were excluded as outliers and replaced with the 2.5 standard deviation cut-off. Separate analyses of variance were carried out on the results of the infinitive and inflected naming conditions with distracter type (verb vs. action-noun vs. object-noun) and semantic relatedness (related vs. unrelated) as independent variables. Imageability and orthographic similarity values of the distracter words were included as covariates in the by-items analysis.

In the infinitive naming condition there was a significant effect of semantic relatedness ($F_1(1,47)$=21.772, p<.001, η^2_p=.32; $F_2(1,112)$=6.119, p =.015, η^2_p=.052) with longer reaction times for related distracters, while the effect of distracter type was not significant. ANCOVA analysis showed no effect of distracter characteristics on reaction times. The effect of the interaction between the two variables was significant only in the by participants analysis ($F_1(2,94)$=4.534, p =.01, η^2_p=.09). Nevertheless, by participants and by items planned t tests (two-tailed) revealed that related verb distracters yielded significantly longer latencies than unrelated ones ($t_1(47)$=3.410, p=.001, r=.45; $t_2(38)$=5.300, p=.027, r=.65). Regarding noun distracters, related action-

nouns slowed reaction times compared to unrelated action-nouns ($t_1(47)$=5.478, p<.001, r=.62; $t_2(38)$=4.099, p=.05, r=.55) but there was no significant difference between the mean reaction times under related compared to unrelated object-noun distracter conditions.

The analyses of the results of the inflected naming condition revealed an effect of distracter type ($F_1(2,94)$=4.449, p =.01, η^2_p=.09; $F_2(2,112)$=4.151, p =.018, η^2_p=.069). The effect of semantic relatedness was not significant, whereas the interaction between the two main effects was significant in the by-subjects analysis ($F_1(2,94)$=3.274, p=.042, η^2_p=.07). An effect of the covariate imageability was also obtained in this experiment ($F2(1,112)$=4.155; p=.44, η^2_p=.036). Finally, by subjects and by items planned t tests (two-tailed) indicated that related verb distracters evoked significantly longer reaction times than unrelated ones ($t_1(47)$=4.220, p=.002, r=.52; $t_2(38)$=0.009, p=.047, r=.001), but no differences appeared between latencies recorded under related compared to unrelated action-noun distracter conditions or related compared to unrelated object-noun distracter conditions.

<div align="center">Analysis of data collected in all experiments</div>

Finally, in order to assess the robustness of the interaction between the semantic relatedness and grammatical class effects, we conducted an analysis of data drawn from all experiments in the investigation. Our analysis focused on the data corresponding to the infinitive form action naming conditions with noun-object and action-verb distracters in the three experiments. Data collected in these conditions were combined to form a single data-set and experiment number was also introduced as a factor. The variables distracter type ($F_1(1,169)$=20.439, p<.001, η^2_p=.108; $F_2(1,226)$=12.599,

p<.001, η^2_p=.053) and semantic relatedness (F_1(1,169)=27.484, p<.001, η^2_p=.14; F_2(1,226)=6.926, p<.009, η^2_p=.03) were both significant. Crucially, the interaction between these two variables was also significant (F_1(1,169)=22.441, p<.001, η^2_p=.117; F_2(1,226)=8.124, p =.005, η^2_p=.035). Planned t tests (two-tailed) showed that whereas related verb distracters slowed latencies compared to unrelated verb distracters (t_1(171)=6.885, p<.001, r=.24; t_2(118)=3.036, p=.003, r=.3), the difference between related and unrelated noun distracters was not significant (t_1(171)=0.406, p=.685, r=.01; t_2(118)=0.056, p=.955, r=.005). The variable experiment number had a significant effect in the by items analysis (F_2(2,226)=80.996, p<.001, η^2_p=.418) but it did not interact significantly with the effect of any other variable. Orthographic similarity also appeared to have a significant effect on the results (F_2(1,226)=6.989, p =.009, η^2_p=.030).

General Discussion

Our study investigated the relevance of grammatical and semantic information in lexical access through the study of the SIE in the PWI paradigm. The results of our experiments revealed a significant interaction between semantic and grammatical information during verb lexicalization. The SIE only appeared when target and distracter belonged to the same grammatical class even though actions were named using verbs in their infinitive form (experiments 1 and 2). This finding is incompatible with the "syntactic traffic cop" account of lexicalization, which predicts this interaction only when syntactic integration is required. However, experiment 3 showed that the

apparent interaction between class and relatedness is properly understood as an interaction between two aspects of a semantically based mechanism for lexicalization.

Previous studies (Pechmann, et al., 2004; Pechmann & Zerbst, 2002) had found grammatical effects in the PWI when object pictures were presented with noun and non-noun distracters, but only when syntactic processing appeared to be relevant to the task. Effects of grammatical class have also been obtained in action naming using the PWI paradigm with noun and verb distracters. Vigliocco et al. (2005) found that, while both related nouns and verbs produced a similar SIE in an action naming task (verb in infinitive form), related verb distracters interfered significantly more than related nouns only when participants were asked to produce sentential responses (verb in inflected form). These findings have been argued to support the hypothesis of the "syntactic traffic cop" (Dell, et al., 2008). According to this account, the linguistic system constrains lexical selection to grammatically appropriate candidates when we are producing sentences. This would explain the grammatical effects found in the sentence integration conditions of these studies.

Nevertheless, the legitimacy of the results by the Pechman et al. group to inform the role of grammatical class on lexical selection has been called into question. In a replication of one of their experiments, Janssen et al. (2010) showed that the results obtained by the Pechman group could be accounted for by differences in imageability between the noun and non-noun distracters. In our investigation, effects of grammatical class have been observed even though distracter stimuli were matched on imageability values, when possible, and the effects of this variable have been controlled by means of covariate analyses.

In addition, the results obtained by Vigliocco et al. (2005) were not replicated by Iwasaki et al. (2008) in an experiment conducted with Japanese participants. The authors ascribed the lack of grammatical class effects to the different structural characteristics of Japanese compared to Italian, the language in which the Vigliocco et al. (2005) study was conducted. However, the validity of the conclusions obtained by Vigliocco et al. (2005) has also been criticised due to the use by those authors of noun distracters presented together with determiners. According to Janssen et al. (2010), research indicating effects of determiner presentation (Alario, et al., 2008) on reaction times in PWI suggests that the use of noun-determiner distracters by Vigliocco et al. (2005) could have biased a grammatical interpretation of the task by the volunteers in that study. Our experiments were conducted in Spanish, a language with a very similar structure to Italian, and our selection of distracter stimuli allowed us to avoid using determiners along with noun distracters. Our findings therefore show grammatical class effects in PWI without the confounding presence of determiners. This is consistent with Vigliocco et al. (2005). Nevertheless, a critical difference between the results of our study and the results of that study has also been observed. That difference cannot be ascribed to between-language differences in structure due to the similarity of Spanish and Italian. The difference is that we found grammatical effects even when syntactic information was not directly relevant for the task, when naming was conducted using the infinitive form of the verb.

A grammatical effect was also observed by Mahon et al. (2007) under simple naming conditions (their experiments 1 and 2) not requiring syntactic integration. The SIE was present only when volunteers named object pictures presented with noun distracters, but

not with verb distracters. However, the authors showed that their effect was semantic in nature. According to their interpretation, the absence of a SIE was due to the fact that verb distracters did not meet given semantic constraints (i.e. being an object, in the same domain) and were, thus, rejected post-lexically at response selection during the production process.

The same pattern of results might also be explained in another account in which lexical selection (effectively) does not occur through competition: the model of lexical access in speech proposed by Oppenheim, Dell, and Schwartz (2010). In that account, lexical selection occurs when the activation of a candidate word is greater than that of the average activation of alternate candidates (by some threshold difference). When, as in PWI, there is activation of multiple lexical candidates a booster mechanism is triggered which amplifies the activation of all candidates for production until a winner emerges. As activation amplification is multiplicatively determined by existing activation, the most activated candidate, usually the target, will tend to win selection. The booster mechanism will tend to bias competition according to the semantic suitability of alternates, consistent with the results of the Mahon et al. (2007) and our own studies. This booster mechanism might well operate in concert with the response exclusion mechanism proposed by Mahon and colleagues.

An additional distracter condition used in experiment 3 revealed that the conflict between our results and those of Vigliocco et al. (2005) may indeed be due to a substantial difference in the semantic domains to which the stimuli of the two studies belonged. Whereas noun distracters used by Vigliocco et al. (2005) always referred to actions, those in our experiments 1 and 2 referred to objects. The confound between

semantic domain and grammatical class was examined in experiment 3, in which action-nouns as well as object-nouns were presented as distracters. Both action-nouns and action-verbs evoked an SIE in the infinitive naming condition. Critically, when participants were asked to respond using the inflected form of the verb, only verb distracters elicited an SIE.

In sum, our results suggest that the linguistic production system, at least the aspects of the system tapped in the PWI paradigm, relies on the exclusion of candidate responses that are not pertinent to the task at hand, broadly consistent with the account proposed by Mahon et al. (2007). Hence, whereas both action-nouns and action-verbs were permissible when the participants needed to produce the name of an action, only verb responses were considered when they were asked to produce an inflected verb. The exact way in which production is restricted, or whether more than one mechanism operating with this purpose coexist, cannot be clarified on the basis of our data, however.

The response exclusion account proposed by Mahon et al. (2007) introduces a restriction on linguistic production that deals with the demands presented by the PWI, According to this account (see also Finkbeiner & Caramazza, 2006; Miozzo & Caramazza, 2003), production relies on the exclusion of candidates that do not fulfil given "response-relevant criteria" (Glaser & Glaser, 1989; La Heij, 1988; Lupker, 1979). Mahon et al. (2007), thus, suggest that the SIE would be located at a post-lexical level, reflecting the ease with which alternative representations can be excluded as possible responses.

Another explanation could be derived from Dell et al.'s (2008) existing account of the function of a "syntactic traffic cop". Dell et al. (2008) introduced a computational mechanism that constrains lexical selection so that only grammatically appropriate lexical entries enter into competition during sentence production. Our results show that some kind of restriction is applied to candidates even when no sentence integration is needed, contradicting that version of the theory. However, we conjecture that a modified version of the account could explain our results, locating the source of effects at the lexical level, provided the "traffic cop" not only excludes grammatically inappropriate candidates but also candidates that are inappropriate based on semantic domain (most of the time, these features will coincide). A still further (similar) alternative explanation of observations, like our findings, of an interaction between grammatical and semantic constraints on lexical selection can also be derived from accounts of lexical selection assuming an indexing system based on activation tags that constrain the response set (Roelofs, 1992, 2001).

Finally, proactive top-down mechanisms have also been proposed to play a comparable role in lexicalization (see Strijkers & Costa, 2011; Strijkers, Holcomb, & Costa, 2011; Strijkers, Na Yum, Grainger, & Holcomb, 2011). Thus, the speaker's intentions, modulated by the characteristics of the task could enhance the activation of pertinent lexical candidates in a given situation, perhaps by triggering the impact of response-relevant criteria for a task on response exclusion or lexical booster mechanisms. In our experiments, the criteria would consist of membership in the relevant semantic domain or, when syntactic integration is needed, grammatical class. Nonetheless, given previous findings, other factors like the appropriate level of categorization (Costa, Mahon, Savova, & Caramazza, 2003) or the correct language in bilingual naming (Costa,

Miozzo, & Caramazza, 1999) could also be included in the task-dependent criteria limiting the scope of the production mechanism.

In conclusion, our results suggest that task-related factors such as membership to the appropriate semantic domain (i.e. referring to an action when we need to name an action) or grammatical class (i.e. being a verb when a verb is required during sentence production) influence lexicalization in the PWI paradigm. These factors can be understood as features of a general exclusion mechanism as proposed by the response-exclusion account. Nevertheless, further research is needed in order to clarify the exact way in which this occurs.

References

Abboud, H., & Sugar, D. (1997). SuperLab Pro: Experimental Laboratory Software. Phoenix: Cedrus Corporation.

Alario, F.-X., Ayora, P., Costa, A., & Melinger, A. (2008). Grammatical and non-grammatical contributions to closed-class word selection. *Journal of experimental psychology: Learning, memory and cognition, 34*, 960–981.

Bird, H., Franklin, S., & Howard, D. (2001). Age of aquisition and imageability ratings for a large set of words, including verbs and function words. *Behavior Research Methods, Instruments, & Computers, 33*(1), 73-79.

Caramazza, A., & Hillis, A. E. (1991). Lexical organisation of nouns and verbs in the brain. *Nature, 349*, 788-790.

Costa, A., Mahon, B., Savova, V., & Caramazza, A. (2003). Level of categorisation effect: A novel effect in the picture-word interference paradigm. *Language and Cognitive Processes, 18*(2), 205-233.

Costa, A., Miozzo, M., & Caramazza, A. (1999). Lexical selection in bilinguals: Do words in the bilingual's two lexicons compete for selection? *Journal of Memory and Language, 41*, 365-397.

Damasio, A. R., & Tranel, D. (1993). Nouns and verbs are retrieved with differently distributed neural systems. *Proceedings of National Academy of Sciences, 90*, 4957-4960.

Davis, C. J., & Perea, M. (2005). BuscaPalabras: A program for deriving orthographic and phonological neighbourhood statistics and other psycholinguistic indices in Spanish. *Behavior Research Methods*.

Dell, G. S. (1986). A spreading activation theory of retrieval in sentence production. *Psychological Review, 93*, 283-321.

Dell, G. S., Oppenheim, G. M., & Kittredge, A. K. (2008). Saying the right word at the right time: Syntagmatic and paradigmatic interference in sentence production. *Language and Cognitive Processes, 23*, 583-608.

Druks, J., & Masterson, J. (2000). *An object and action naming battery*. London: Psychology Press.

Fay, D., & Cutler, A. (1977). Malapropisms and the structure of the mental lexicon. *Linguistic Inquiry, 8*, 505-520.

Finkbeiner, M., & Caramazza, A. (2006). Now you see it, now you don´t: On turning semantic interference effect into facilitation in a Stroop-like task. *Cortex, 42*, 1028-1031.

Glaser, W. R., & Düngelhoff, F. J. (1984). The time course of picture-word interference. *Journal of Experimental Psychology, 10*(5), 640-654.

Glaser, W. R., & Glaser, M. O. (1989). Context effects in Stroop-like word and picture processing. *Journal of Experimental Psychology: General, 118*(1), 13-42.

Iwasaki, N., Vinson, D. P., Vigliocco, G., Watanabe, M., & Arciuli, J. (2008). Naming action in Japanese: Effects of semantic similarity and grammatical class. *Language and Cognitive Processes, 23*, 889-930.

Janssen, N., Melinger, A., Mahon, B. Z., Finkbeiner, M., & Caramazza, A. (2010). The word class effect in the picture-word interference paradigm. *The Quarterly Journal of Experimental Psychology, 63*, 1233–1246.

La Heij, W. (1988). Components of Stroop-like interference in picture naming. *Memory and Cognition, 16*(5), 400-410.

Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. Cambridge: MA:MIT Press.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in

    speech production. *Behavioral and Brain Sciences, 22*, 1-38.

Lupker, S. J. (1979). The semantic nature of response competition in the picture-word

    interference task. *Memory & Cognition, 7*, 485-495.

Mahon, B. Z., Costa, A., Peterson, R., Vargas, K. A., & Caramazza, A. (2007). Lexical

    selection is not by competition: A reinterpretation of semantic interference and

    facilitation effects in the picture-word interference paradigm. *Journal of

    Experimental Psychology: Learning, Memory and Cognition, 33*(3), 503-535.

Miozzo, M., & Caramazza, A. (2003). When more is less: A conterintuitive effec of

    distractor frequency in the picture-word interference paradigm. *Journal of

    Experimental Psychology: General, 132*(2), 228-252.

Nooteboom, S. G. (1969). The tongue slips into patterns. In A. G. Sciarone, A. J. van

    Essen & A. van Raad (Eds.), *Leyden studies in linguistics and phonetics* (pp.

    114-132). The Hague: Mouton.

Oppenheim, G. M., Dell, G. S., & Schwartz, M. F. (2010). The dark side of incremental

    learning: A model of cumulative semantic interference during lexical access in

    speech production. *Cognition, 114*, 227-252.

Pechmann, T., Garrett, M., & Zerbst, D. (2004). The time course of recovery for

    grammatical category information during lexical processing for syntactic

    construction. *Journal of Experimental Psychology: Learning, Memory, and

    Cognition, 30*, 723-728.

Pechmann, T., & Zerbst, D. (2002). The activation of word class information during

    speech production. *Journal of Experimental Psychology: Learning, Memory,

    and Cognition, 28*, 233-243.

Protopapas, A. (2007). CheckVocal: A program to facilitate checking the accuracy and response time of vocal responses from DMDX. *Behavior Research Methods, 39*(4), 859-862.

Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition, 42*, 107-142.

Roelofs, A. (1993). Testing a non-decompositional theory of lemma retrieval in speaking: retrieval of verbs. *Cognition, 47*, 59-587.

Roelofs, A. (2001). Set size and repetition matter: Comment on Caramazza and Costa (2000). *Cognition, 80*, 283-290.

Schnur, T. T., Costa, A., & Caramazza, A. (2002). Verb production and semantic interference effect. *Journal of Cognitive Science, 3*(1), 1-26.

Schriefers, H., Teruel, E., & Meinshausen, M. (1998). Producing simple sentences: Results from picture-word interference experiments. *Journal of Memory and Language, 39*, 609-632.

Sebastián-Gallés, N., Carreiras, M., Cuetos, F., & Martí, M. A. (2000). *LEXESP. Léxico informatizado del español*. Barcelona: Publicacions UB.

Shapiro, K., & Caramazza, A. (2003a). Grammatical processing of nouns and verbs in left frontal cortex? *Neuropsychologia, 41*, 1189–1198.

Shapiro, K., & Caramazza, A. (2003b). The representation of grammatical categories in the brain. *TRENDS in Cognitive Sciences, 7*, 201-206.

Snodgrass, J. G., & Vanderwart, M. (1980). A standarized set of 260 pictures: Norms for name agreement, image agreement, familiarity and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6*, 174-215.

Strijkers, K., & Costa, A. (2011). Riding the lexical speedway: a critical review on the time course of lexical selection in speech production. *Frontiers in Psychology, 2*, 1-16.

Strijkers, K., Holcomb, P. J., & Costa, A. (2011). Conscious intention to speak proactively facilitates lexical access during overt object naming. *Journal of Memory and Language, 65*, 345-362.

Strijkers, K., Na Yum, Y., Grainger, J., & Holcomb, P. J. (2011). Early goal-directed top-down influences in the production of speech. *Frontiers in Psychology, 2*, 371.

Szekely, A., Jacobsen, T., D'Amico, S., Devescovi, A., Andonova, E., Herron, D., . . . Bates, E. (2004). A new on-line resource for psycholinguistic studies. *Journal of Memory and Language, 51*(2), 247-250.

Tabossi, P., & Collina, S. (2002). The picture-word interference paradigm: conceptual effects in the production of verbs. *Rivista di Linguistica,, 14*, 27-41.

Tyler, L. K., Russel, R., Fadili, J., & Moss, H. E. (2001). The neural representation of nouns and verbs: PET studies. *Brain, 124*, 1619-1634.

Tyler, L. K., Stamatakis, E. A., Dick, E., Bright, P., Fletcher, P., & Moss, H. M. (2003). Objects and their actions: Evidence for a neurally distributed semantic system. *Neuroimage, 18*, 542-557.

Vigliocco, G., Vinson, D., Lewis, W., & Garrett, M. F. (2004). Representing the meanings of object and action words: The featural and unitary semantic space hypothesis. *Cognitive Psychology, 48*, 422-488.

Vigliocco, G., Vinson, D., & Siri, S. (2005). Semantic similarity and grammatical class in naming actions. *Cognition, 94*, B91-B100.

Yarkoni, T., Balota, D., & Yap, M. (2008). Moving beyond Coltheart's N: A new

measure of orthographic similarity. *Psychonomic Bulletin and Review, 15*, 971-

979.