The Spanish Journal of Psychology
2012, Vol. 15, No. 3, 891-900
http://dx.doi.org/10.5209/rev_SJOP.2012.v15.n3.39382

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ISSN 1138-7416

Masked and Unmasked Priming Effects as a Function of Semantic Relatedness and Associative Strength

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The study presented in this paper aimed to investigate the pattern of semantic priming effects, under masked and unmasked conditions, in the lexical decision task, manipulating type of semantic relation and associative strength. Three different kinds of word relations were examined in two experiments: only-semantically related words [e.g., *codo* (*elbow*)-*rodilla* (*knee*)] and semantic/associative related words with strong [e.g., *mesa* (*table*)-*silla* (*chair*) and weak association strength [e.g., *sapo* (toad)-*rana* (*frog*)]. In Experiment 1 a masked priming procedure was used with a prime duration of 56 ms, and in Experiment 2, the prime was presented unmasked for 150 ms. The results showed that there were masked priming effects with strong associates, but no evidence of these effects was found with weak associates or only-semantic related word pairs. When the prime was presented unmasked, the three types of relations produced significant priming effects and they were not influenced by association strength.
Keywords: masked and unmasked priming, lexical decision task, semantic and associative relations, association strength.

El presente estudio tenía como objetivo investigar el patrón de efectos de *priming* enmascarado y no enmascarado en la tarea de decisión léxica, manipulando el tipo de relación semántica y la fuerza asociativa entre prime y target. Se llevaron a cabo dos experimentos donde se examinaron tres tipos de relaciones: palabras relacionadas solo semánticamente [e.g., codo (elbow)-rodilla (knee)], palabras semánticamente relacionadas con una asociación fuerte [e.g., mesa (table)-silla (chair)] y palabras con una relación semántica asociativa débil [e.g., sapo (toad)-rana (frog)]. En el Experimento 1 se utilizó un procedimiento de *priming* enmascarado con una duración del prime de 57 ms, y en el Experimento 2, un procedimiento no enmascarado presentándose el prime durante 150 ms. Los resultados mostraron efectos de *priming* enmascarado significativos con pares de palabras que eran asociados fuertes pero no cuando eran asociados débiles o tenían una relación sólo semántica (no asociativa). Cuando el prime se presentaba en condiciones no enmascaradas, los tres tipos de relaciones produjeron efectos de *priming* significativos y no se vieron influidos por la fuerza asociativa.
Palabras clave: priming enmascarado y no enmascarado, tarea de decisión léxica, relaciones semánticas y asociativas, fuerza asociativa.

This research has been supported by a grant from the Spanish Ministerio de Educación y Ciencia (PS12009-12616 and Plan E) and another from the Generalitat de Catalunya (2009SGR-401). We wish to thank the students from the Universitat Rovira i Virgili and the Universidad Pontificia de Comillas (Madrid) who participated in the study.

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https://doi.org/10.5209/rev_SJOP.2012.v15.n3.39382 Published online by Cambridge University Press

The semantic priming paradigm has been widely used in the study of semantic memory both in the monolingual and the bilingual domain (see Altarriba & Basnight-Brown, 2007; Hutchison, 2003; Lucas, 2000; Neely, 1991). In this paradigm, a word is presented (the prime), immediately followed by another word (the target). The prime can be related (e.g., *table-chair*) or unrelated to the target (e.g., *wool-chair*). The so-called semantic priming effect is the reaction time advantage observed in the response to the target after a related prime has been presented, in comparison to when it is preceded by an unrelated prime. To ensure that priming is automatic in nature, studies have used either unmasked versions of the priming paradigm where the influence of strategic factors is reduced to a minimum (e.g., Altarriba & Basnight-Brown, 2007), or a masked version of the paradigm where the prime is not visible and thus is not susceptible of conscious report.

For the last two decades, one of the questions that has been focus of interest regarding semantic priming is whether priming occurs to the same extent for both associative and semantically related words (see Hutchison, 2003; Lucas, 2000 for reviews). Associative relations are assumed to reflect word use rather that word meaning, being the source of this relation temporal contiguity in verbal or written language (Plaut, 1995), or co-occurrence within propositions (McNamara, 1992). Associations are established using normative descriptions of the probability that one word will call into mind a second word. Associated words can be more (e.g., *cat-mouse*) or less (e.g., *frog-toad*) associatively related. In contrast, semantic relations are proposed to reflect overlapping in meaning or in the number of descriptive features (e.g., *duck-chicken* are two words semantically related as they share some descriptive features, such as to have wings, to have feathers, or to be able to fly, among others). There are studies that have examined the pattern of semantic priming distinguishing between the effects produced by these two types of semantic relations separately, but the reported evidence has not always been consistent. (e.g., Bueno & Frenck-Mestre, 2008; Ferrand & New, 2003; Hutchinson, 2003; Hutchinson, Balota, Cortese, & Watson, 2008; Lucas, 2000; Perea & Gotor, 1997; Perea, Gotor, & Nacher, 1997; Perea & Rosa, 2002; Thompson-Schill, Kurtz, & Gabrieli, 1998; Williams, 1996). The general aim of the experiments presented in this paper was to examine the priming effects produced by associative-semantically related words and unassociated or only-semantic related words, in order to determine the conditions under which semantic priming effects can be obtained, and in this way to contribute to an understanding of how associative and semantic relations are represented in memory. If purely semantic priming is shown to differ from priming between words which are also associated, this would indicate that the locus of these effects can be different and therefore, the level at which associative and semantic connections are established or represented.

One of the factors that has been shown to be critical in determining if priming effects are obtained with these two types of relations is the duration of the prime. When the prime exposure is long and the prime is visible (i.e. from 83 ms onwards), there is clear evidence of both significant semantic priming in the absence of association and associative priming between semantically dissimilar word pairs. Moreover, these priming effects have been observed in both lexical decision and semantic categorization tasks (e.g., Bueno & Frenck-Mestre, 2002; 2008), with words from several semantic relations (synonyms, antonyms, and category coordinates) (e.g., Ferrand & New, 2003; Lund, Burgess, & Audet, 1996; McRae & Boisvert, 1998; Perea & Gotor, 1997; Perea & Rosa, 2002), and different degrees of meaning similarity (i.e., in terms of semantic features between category coordinates) (e.g., MacRae & Boisvert, 1998; Sánchez-Casas, Ferré, García-Albea, & Guasch, 2006; Vigliocco, Vinson, Lewis, & Garrett, 2004). However, the picture is less clear when the prime is presented for short durations (i.e. for less than 66 ms) under masked conditions that prevent the prime from being visible. In this case, semantic priming effects have not been always obtained and their presence appears to depend on the type of semantic relation between the prime-target word pairs (i.e., associative-semantic *vs.* only-semantic), and the experimental task (e.g., Bueno & Frenck-Mestre, 2008; Perea & Gotor, 1997; Perea, Gotor, & Nacher, 1997; Perea & Rosa, 2002).

Recent evidence has shown that semantically related words which are not associates (e.g., *dolphin-whale*) produce reliable masked priming effects in a semantic categorization task, with prime exposures as short as 28 and 43 ms (e.g., Bueno & Frenck-Mestre, 2008). However, this type of semantic non-associative relations has not produced consistent priming effects, if a lexical decision task is used. For instance, while Perea and Gotor (1997) reported significant masked priming effects with a prime of 66 ms with non-associative semantically related words, in similar studies, Perea et al. (1997) and Perea and Rosa (2002) did not obtain evidence of these effects, using the same masked priming procedure and prime duration as Perea and Gotor did. More recently, Bueno and Frenck-Mestre (2008) also failed to obtain significant priming effects when short prime exposures were used (i.e., 23 and 43 ms), even though the same set of word pairs produced significant priming effects in a semantic categorization task. In the case of words that are both associative- and semantically related (e.g., *spider-web, cat-mouse*), the pattern of results, although more consistent across tasks, also appears to vary as a function of duration of the prime. For instance, in different lexical decision experiments, Perea and his colleagues showed significant priming effects with associative-semantic relations, with a prime duration of 66 ms (Perea & Gotor, 1997; Perea et al., 1997; Perea & Rosa, 2002). However, using shorter prime durations (i.e., 23 and 43 ms), Bueno

https://doi.org/10.5209/rev_SJOP.2012.v15.n3.39382 Published online by Cambridge University Press

and Frenck-Mestre (2008) were not able to find reliable priming effects with this type of relations, neither in lexical decision nor in a semantic categorization task. A factor that might contribute to explain the divergences between the previous studies is the association strength between primes and targets. That is, it might be that a minimum level of association strength is necessary to obtain semantic priming when primes are not visible.

In sum, on the basis of this general overview of the available evidence, it seems that both the duration of the prime and the type of task can modulate the semantic priming effects obtained with the two types of semantic relations. On the one hand, reliable priming effects can be obtained with long prime durations with the two types of semantic relations, regardless of the experimental task used (lexical decision or semantic categorization). On the other hand, when short prime exposures are used, non-associative semantically related words show significant priming effects with a semantic categorization task, but not with a lexical decision task. Finally, at short prime exposure, words that are both semantic- and associatively related did not produce priming effects with a semantic categorization task and these effects are not always reliable if the task is lexical decision.

The priming experiments reported in this study aimed to further examine the semantic priming effects in the lexical decision task, since the reported pattern of results has been less consistent with this task. On the one hand, we manipulated the duration of the prime. In the first experiment, a masked prime of 57 ms was used which is within the range of the short prime exposures previously employed (see Bueno & Frenck-Mestre, 2008, and Perea & Rosa, 2002). In the second experiment, the prime was visible (unmasked) and presented for a longer duration of 150 ms, although considered to be short enough to ensure the automatic nature of priming effects (see Altarriba & Basnight-Brown, 2007). On the other hand, similarly to previous studies, semantic relations with and without association were tested in the two experiments, but in addition we manipulated the association strength, in order to determine whether it could affect the pattern of both masked and unmasked priming effects obtained with the lexical decision task. It is important to notice that, to our knowledge, none of the previous studies have examined the role of associative strength using the masked priming paradigm. These studies have not either compared the priming effects produced by the same set of word associates (weak and strong), with the unmasked and masked priming procedures.

Our predictions are different depending on the duration of the prime. According to previous results, in the case of unmasked primes, we expect to obtain semantic priming for both associative and non-associative semantically related words. In the case of masked primes, we do not expect to find semantic priming with words semantically but not associatively related. With respect to the associatively related words, we hypothesize that the semantic priming effect might be modulated by the strength of the associative relationship between primes and targets.

Experiment 1

Method

Participants

Twenty-five students from the Universitat Rovira i Virgili (Tarragona) participated in the experiment as a course requirement. They were native speakers of Spanish. All of them had normal vision or vision that was corrected to normal.

Materials and design

Three sets of 24 related word pairs were selected (see Appendix for a complete list of materials). Of these sets, two included pairs of words that had a semantic/associative relation and that were created using the free association norms in Spanish (Fernández, Diez, Alonso, & Beato, 2004): 24 pairs were strong associates (SA) [e.g., *mesa* (*table*) – *silla* (*chair*)] with a mean of associative strength of .36 (SD = .09) and the other 24 were weak associates (WA) [e.g., *rana* (*frog*) – *sapo* (*toad*)] with a mean of .17 (SD = .03). The difference between the two association means reached significance ($t(46) = 8.74$, $p < .05$). A third set of 24 pairs included words that had an only-semantic relation: they were coordinates from different semantic categories but they were not associatively related [e.g., *codo* (*elbow*) – *rodilla* (*knee*)]. This last set of pairs was taken from Sánchez-Casas et al. (2006). In that study, we used both a feature generation task and a semantic similarity rating task in order to obtain the pairs of words semantically related, and we observed that there was a significant correlation between the two measures of semantic similarity.

In the present study, we collected similarity ratings for the set of semantically related words as well as for the associative word pairs, to analyze the possible influence of degree of semantic relatedness in the pattern of priming effects. Twenty-five people different from the ones who participated in the experiments, were asked to rate the similarity in meaning of each word pair in the list in a scale from 1 (not semantically related) to 9 (highly semantically related). In all cases, the related condition was judged to be more similar than the unrelated ones. Strong and weak associates were rated equally similar in meaning [$t < 1$], but semantic coordinates were rated more similar than both strong associates [$t(46) = 2.13$, $p < .05$], and weak associates [$t(46) = 1.71$, $p = .09$].

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Table 1
Characteristics of Word Pairs in Experiments 1 and 2

	Associative strength	Semantic similarity	Log. Frequency		Length		N of neighbors	
			Prime	Target	Prime	Target	Prime	Target
Only-semantic relation codo – RODILLA (*elbow-knee*)	0	6.2	.7	.9	6.8	6.8	3.4	2.7
Unrelated control paño – RODILLA (*drap-knee*)	0	1.8	.7		6.8		2.7	
Semantic/associative relation (SA) mesa – SILLA (*table-chair*)	.36	5.5	1.2	1.6	6.4	5.4	3.6	6.3
Unrelated control obra – SILLA (*play – chair*)	0	2.0	1.2		6.4		2.2	
Semantic/associative relation (WA) rana - SAPO (*frog-toad*)	.17	5.6	1.1	1.4	6.1	5.2	6.0	6.2
Unrelated control mago – SAPO (magician-toad)	0	1.4	1.1		6 .1		4.7	

Table 1 shows the means of length, frequency, similarity ratings and association strength of the experimental word pairs in each of the six experimental priming conditions.

Within each of the three semantic relations, the related pairs were matched as closely as possible to the unrelated control pairs in length (number of letters), frequency of use (in logarithms), and number of orthographic/phonological neighbors (Davis & Perea, 2005). None of the comparisons regarding these variables was found to reach significance (all *ts* < 1.4)

In addition to the words, seventy-two nonwords were created for the purpose of the lexical decision task. All of them were pronounceable and orthographically legal sequences in Spanish, and had a similar structure to the words from the experimental set. They were always preceded by a word prime. Thus, there were a total of 72 word prime-word target pairs and 72 word prime – nonword target pairs.

Two versions of the experiment were prepared, so that each target appeared in the two priming conditions (related and unrelated), without being repeated within each version. Participants were assigned randomly to one of the two versions. Finally, a set of 12 practice items was constructed where all the semantic relations and experimental conditions were represented.

Procedure

Participants were tested singly in separate soundproof booths, in one or other of the versions of the experiment. They were asked to make a lexical decision about the item presented in uppercase letters (the target). Participants indicated their decisions by pressing one of two response buttons, "word" responses being made with the preferred hand. The experiment was run using the DMDX display software (see Forster & Forster, 2003). Items were presented in a computer-controlled video display in which timing display was synchronized with the video raster. Participants pressed the foot-switch to present the stimuli. Each stimulus was centered in the viewing screen, superimposed on the one preceding. The first stimulus acted as a forward mask that was displayed for 500 ms. It consisted of a row of hash marks (#) with a length that was equated to the length of the longest string (prime or target) on a trial-by-trial basis. Immediately following the mask, a lowercase prime was displayed for 57 ms, which was in turn followed by an uppercase target displayed for 500 ms. Primes and targets were displayed using a 10 point Courier font; targets were on average 1.5 cm in length and .6 cm high. Feedback about speed and accuracy was provided to each participant after each response.

Results and discussion

Data corresponding to incorrect responses were discarded from the analyses and reaction times more than two standard deviation units above or below the mean for participant in all conditions were trimmed to the appropriate cut-off values to moderate the influence of outliers (this affected 4.8 % of the data). Any participant who made more than 15 % errors was replaced (this resulted in the replacement of 3 participants).

Mean reaction times and percentage of errors in each of the priming conditions are presented in Table 2.

Separate ANOVAs were conducted on the RT data and the % E data. For each set of data, one ANOVA was carried

https://doi.org/10.5209/rev_SJOP.2012.v15.n3.39382 Published online by Cambridge University Press

Table 2
Experiment 1. Mean RTs and percentage of errors (%E) as a function of type of semantic relation and priming condition

	Related	Unrelated	Priming effect
Only-semantic	682 (4.9)	664 (5.2)	–18
Semantic/associative (SA)	609 (1.7)	636 (2.9)	+27*
Semantic/associative (WA)	632 (2.1)	632 (4.1)	0

Note. * $p < .05$

out for participants´ means and another for the items´ means. The analyses included two factors: one factor, type of semantic relation, with three levels (only-semantic, semantic/associative strong, and semantic/associative weak), and the other factor, prime type, with two levels (related and unrelated). In the analyses by participants both factors were manipulated within-subjects and in the analyses by items, the factor type of relation was between-subjects and the type of prime was within-subjects.

The RT ANOVA showed an effect of type of semantic relation that was significant in both the analysis by participants $F_1(2, 48) = 20.98$, $p < .001$ and by items $F_2(2, 69) = 5.71$, $p < .01$. The effect of prime type was not significant (all Fs < 1). Although the interaction between the two factors failed to reach significance in the analyses by items, $F_2(2, 69) = 1.97$, n.s., it was significant in the participants analysis $F_1(2, 48) = 6.15$, $p < .05$, meaning that there was a difference in the size of the priming effects depending on the type of relation.

The analyses of the error data indicated that there was an effect of type of semantic relation, but this effect was only significant by participants $F_1(2, 48) = 3.60$, $p < .05$, but not by items $F_2(2, 69) = 2,21$, n.s. As in the RT analysis, the effect of prime type was not significant $F_1(1, 24) = 1.76$, n.s.; $F_2 < 1$, but in this case the interaction between semantic relation and prime type did not reach significance in either analyses (all Fs < 1).

In the next experiment, we tested the same materials when the prime was presented under unmasked conditions for a longer duration. Based on previous studies, we expected significant priming effects in both semantic associates and only-semantic relations.

Experiment 2

Method

Participants

A group of fifty students from the Universidad de Comillas (Madrid, Spain) participated in the experiment as a course requirement. They were native speakers of Spanish. All of them had normal vision or vision that was corrected to normal.

Materials and design

The materials and the design were the same as those in Experiment 1. The only difference is that in the present experiment, the prime was unmasked. In order to reduce the influence of strategic factors, a 72 additional unrelated word pairs were included as fillers to keep a low proportion of related items (25% of the total number of words), and a prime exposure of 150 ms was used. Seventy-two word-nonword pairs were also added to the ones used in the previous experiment. In total, there were 144 word pairs and 144 word-nonword pairs.

Procedure

The procedure was the same as the one in Experiment 1, except the sequence of stimulus presentation. In this case, first, a fixation point was displayed for 1000 ms. Immediately after, a lowercase prime was displayed for 150 ms, which was in turn followed by an uppercase target displayed for 500 ms. Participants were also asked to perform a lexical decision task on the uppercase item.

Results and discussion

Data corresponding to incorrect responses were discarded from the analyses and reaction times more than two standard deviation units above or below the mean for participant in all conditions were trimmed to the appropriate cut-off value to moderate the influence of outliers (this affected 4.2 % of the data). Any participant who made more than 15 % errors was replaced (this resulted in the replacement of 1 participant).

Mean reaction times and percentage of errors in each of the priming conditions are presented in Table 3.

The same analyses were conducted as in Experiment 1. The RT ANOVA also revealed an effect of type of semantic relation that was significant in both the analysis by participants $F_1(2, 98) = 53.99$, $p < .001$ and by items $F_2(2, 69) = 13.75$, $p < .001$. Furthermore, the effect of prime type was also significant $F_1(1, 49) = 24.53$, $p < .001$; $F_2(1, 69) = 29.18$, $p < .001$. However, the interaction between these two factors failed to reach significance in both analyses $F_1(2, 98) = 1.75$, n.s.; $F_2 < 1$. As we can see in Table 3, the reason for the lack of interaction is that the

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Table 3
Experiment 2. Mean RTs and percentage of errors (%E) as a function of type of semantic relation and priming condition

	Related	Unrelated	Priming effect
Only-semantic	611 (3.1)	636 (4.9)	+25*
Semantic/associative (SA)	563 (1.9)	591 (1.9)	+28*
Semantic/associative (WA)	575 (1.7)	590 (4.2)	+15*

Note. * $p < .05$

three types of semantic relations produce the same amount of priming effects.

The analyses of the error data revealed that the effect of type of semantic relation was significant by participants $F_1(2, 98) = 3.51$, $p < .05$, but did not reach significance by items $F_2(2, 69) = 2.33$, n.s. Participants made significantly less errors when targets were preceded by related primes than when primes and targets were unrelated $F_1(1, 49) = 4.40$, $p < .05$; $F_2(1, 69) = 5.81$, $p < .05$. However, the interaction between type of relation and type of prime was not significant either by participants $F_1(2, 98) = 1.55$, n.s., or by items $F_2(2, 69) = 1.57$, n.s.

The results of this experiment contrast with those of Experiment 1 and they clearly demonstrate that unmasked priming effects can be obtained with both types of semantic relations, that is, in the absence and in the presence of association.

In order to compare the data from Experiment 1 and 2, and given that the set of materials were the same in both experiments, we carried out a joined three factor ANOVA (SOA x type of relation x type of prime) for RT and %E separately. In the participant analyses, the SOA was a between-subject factor and the type of relation and type of prime were within-subject factors. In the item analyses, type of semantic relation was a between-subject factor and SOA and type of prime were considered within-subject factors.

The RT ANOVA showed an effect of SOA that approached significance in the analysis by participants $F_1(1, 73) = 4.38$, $p = .057$ and it was significant in the analyses by items $F_2(1, 69) = 129$, $p < .01$. The type of semantic relation was significant in both analyses $F_1(2, 146) = 66.46$, $p < .01$ and $F_2(2, 69) = 9.54$, $p < .01$, and this was also the case of the effect of prime type $F_1(2, 146) = 7.5$, $p < .01$ and $F_2(2, 69) = 13.36$, $p < .01$. The interaction between SOA and type of relation did not reach significance in either analyses (F_1 and F_2 <1) while the interaction between SOA and type of prime was significant in the analysis by participants $F_1(1, 73) = 4.24$, $p < .05$ and it approached significance in the analyses by items $F_2(1, 69) = 3.87$, $p = .053$. The interaction between type of relation and type of prime was significant in the analyses by participants $F_1(2, 146) = 6.86$, $p < .05$, and it failed to reach significance in the item analysis $F_1(2, 69) = 2.62$, n.s. Finally, The three-way interaction (SOA x type of relation x type of prime) was significant in the analysis by participants $F_1(2, 146) = 4.96$, $p < .05$, although it was not so by items ($F_2 < 1$).

The analyses of the error data indicated that there was an effect of type of semantic relation that, as in the RT analyses, reached significance both by participants $F_1(2, 146) = 6.60$, $p < .05$, and by items $F_2(2, 69) = 3.75$, $p < .05$. Similarly, the effect of prime type was significant in both analyses $F_1(1, 73) = 5.10$, $p < .05$; $F_2(1, 69) = 3.75$, $p < .05$. None of the other factors or interactions was significant (all $Fs < 1$)

Since we predicted that the presence of priming effects might depend on the type of SOA and type of semantic relation between primes and targets, and the interaction was significant at least in the participant analyses, we conducted planned comparisons between the three types of word relation (strong associates, weak associates, and only semantic) in each of the SOAs with respect to their controls. In the case of the SOA of 57 ms (masked), these analyses showed that there was a reliable semantic priming effect only when there was a strong semantic/associative relation between prime and target, $t_1(24) = 3.407$, $p < .01$; $t_2(23) = 2.24$, $p < .05$. However, neither only-semantic related prime-target pairs $t_1(24) = 1.41$, n.s.; $t_2 < 1$, nor weak semantic/associatively related pairs [all $ts < 1$] showed a significant priming effect. In contrast, in the case of the SOA of 150 ms, (visible), planned comparisons revealed significant priming effects in the three types of semantic relations: only semantically related words $t_1(49) = 3.98$, $p <. 05$ and $t_2(23) = 2.85$, $p < .05$, strong associates $t_1(49) = 5.32$, $p <. 01$ and $t_2(23) = 3.77$, $p < .05$ and weak associates $t_1(49) = 2.11$, $p < 0.5$ and $t_2(23) = 2.92$, $p < .05$

In sum, what these results seem to suggest is that the pattern of priming effects is not the same in the two SOAs. On the one hand, it seems that for masked priming to occur an associative relation has to exist between the two words, as only word pairs that are associates showed significant facilitation effects. Moreover, the association between the words has to be strong to produce masked priming since weak associates did not show any evidence of these effects (0 ms). Regarding only-semantic relations the analyses did not reveal any facilitation effects. The non-significant 18 ms difference was in the opposite direction. On the other hand, when the prime is unmasked, the effects are observed in all types of relations, regardless of whether the words are associates or not.

https://doi.org/10.5209/rev_SJOP.2012.v15.n3.39382 Published online by Cambridge University Press

General discussion

The study reported here aimed to examine the pattern of priming effects with two types of semantic relations: purely semantic (i.e., coordinates) and associative relations. The relevance of this aim was not only to examine the conditions under which semantic priming effects can be obtained but also to determine what these effects can tell us about how semantically and associatively related words are represented. The available evidence suggests that the type of semantic relation, the duration of the prime as well as the experimental task are some of the factors that seem to determine whether or not these effects emerge. The most important findings from the two experiments that are relevant regarding the role of these factors are the following. On the one hand, when an unmasked priming paradigm was used, in accordance with previous evidence (e.g., Bueno & Frenck-Mestre, 2002; 2008; Ferrand & New, 2003; McRae & Boisvert, 1998; Perea & Rosa, 2002; Sánchez-Casas et al., 2006; Vigliocco et al., 2004), we were able to find reliable priming effects with only-semantic related words, in our case, category coordinates with a high similarity in meaning. Moreover, in line with earlier studies (e.g., Bueno & Frenck-Mestre, 2008; Hino, Lupker, & Sears, 1997; Ostrin & Tyler, 1993; Perea & Gotor, 1997), these effects were not boosted by association, and association strength did not seem to modulate priming effects either.

On the other hand, if we look at the results when the prime was masked and presented for a short duration (57 ms), the pattern of priming effects differs from that obtained when the prime was visible. Under these conditions, the results showed for the first time that some associative strength is required for facilitation effects to emerge. In the case of only-semantically related words, we failed to obtain evidence of these effects. This finding was in the same line as those reported by Perea et al. (1997) and Perea and Rosa (2002) using a prime duration of 66 ms (see however Perea & Gotor, 1997), as well as those observed more recently by Bueno and Frenck-Mestre (2008) with the lexical decision task and shorter prime durations (23 and 43 ms). However, with associative-semantically related words, our results suggest that masked priming effects can be obtained, but only when the association between the words is strong.

As mentioned previously, no other studies have examined the pattern of masked priming effects with strong and weak associates. Of the studies that have tested associatively related words, Perea and his colleagues (Perea & Gotor, 1997; Perea et al, 1997; and Perea & Rosa, 2002) found that these words showed significant masked priming effects, as we did, but Bueno and Frenck-Mestre (2008) failed to do so. One of the differences between these studies that can help to explain the discrepancy of these results is the strength of the word associates they tested. In the study of Bueno and Frenck-Mestre, the associatively related pairs had to be category coordinates and due to this, in most cases they were not able to find strong associates. In fact, the association strength of the word pairs was close to the strength of our weak associative pairs (a mean of .24 *vs.* .17 respectively). Perea and Rosa (2002) used word pairs with a mean of association strength of .26. This mean, although it is close to Bueno and Frenck-Mestre (2008), represents a wide range of word association values (from .09 to .55), and the authors reported a significant correlation between associative strength and size of the semantic priming effects. Thus, Perea and Rosa´s results are also consistent with the role that association strength can play in determining these effects. Finally, the associatively related words used by Perea and Gotor (1997), who reported significant priming effects, had the same average association strength as our strong associative pairs (.36). On the basis of this evidence, it is possible, as Bueno and Frenck-Mestre (2008) suggest, that increasing the associative strength could produce an earlier onset of the semantic priming effects as our results demonstrate (see also Perea, Duñabeitia, & Carreiras, 2008 in the bilingual domain).

In sum, regarding the sensitivity of the lexical decision task to semantic priming effects, our results showed that when the prime is not visible and of a short duration, this task seem to be sensitive to semantic relations but only when the related words are strong associates. Weak associative semantic relations do not seem to produce reliable effects with this task. Importantly, this different pattern of priming effects depending on the type of semantically related words supports the view that they are represented differently in semantic memory.

Different proposals could be suggested to explain how semantic and associative relations can be represented. According to the spreading activation theory originally proposed, semantic memory consists of two networks of interconnected nodes: the lexical and the semantic networks. The lexical network contains only information about the form of the word (orthographic and phonological). Connections between these nodes are established in terms of orthographic and phonological similarity through repeated occurrence of the corresponding word forms. On the other hand, nodes in the purely semantic network represent concepts, generally conceived as holistic units, which are connected to each other on the basis of meaning similarity. In addition, connections exist between the lexical and the semantic network, so that a lexical node corresponding to a given word would be connected to its corresponding concept (e.g., Collins & Loftus, 1975; McKoon & Ratcliff, 1995; McNamara, 1992; McNamara & Altarriba, 1988). Within the framework of this theory, it can be suggested that associative priming would occur as a result of activation spreading across the nodes of the lexical network, since the connections between two associated words would have been established at the form level due to the fact that they are frequently processed together. Therefore, it is important to emphasize that according to this view associative priming

https://doi.org/10.5209/rev_SJOP.2012.v15.n3.39382 Published online by Cambridge University Press

would not have to do anything with meaning. In contrast, priming between only semantically related words would reflect activation in the semantic network, given that, in this case, the connections between the two words would have been built because their similarity in meaning.

An alternative proposal can be suggested from the parallel distributed models (PDP) of semantic memory (McRae, 2004, Plaut, 1995; Plaut & Booth, 2000). In these models, nodes do not represent whole words but highly interconnected features. Thus, concepts are represented by learned patterns of activation over a large number of interconnected processing units (i.e., features) with connections derived from exposed-based learning. The features of a concept that co-occur together will be encoded together, leading to the learning of correlations between the features: the stronger the correlation the stronger the connection weight. In these models, a concept is recognized when the network settles in a "stable state" of the system. Priming between semantically related words is explained in terms of transition between stable states. If the states (concepts) have overlapping features this transition will be faster than if they do not. In the case of associatively related words, priming is not attributed to similarity of representational patterns but to learning on the basis of context-independent co-occurrence of two patterns.

Both of the aforementioned proposals suggest differences between associative and semantic priming effects, the question to be asked then is which proposal could account for the obtained pattern of results. Within the spreading activation account, the locus of the associative priming effect is proposed to be at the lexical level while the semantic priming effect at the conceptual level. Thus, the absence of masked priming effects with the only semantically related words would indicate that these effects are only sensitive to associative relations. These effects emerge earlier than the unmasked priming effects and this might explain why with a longer SOA and visible primes, both semantic and associative priming effects were obtained. Such an interpretation appears to be inconsistent with evidence from other priming studies which show masked priming effects with semantic related words (eg., Perea et al., 2008; Schoonbaert, Duyck, Brysbaert, & Hartsuiker, 2009). However, an examination of the materials used in these studies revealed that the semantically related prime and target word pairs were generally also associatively related (e.g. Bueno & Frenck-Mestre, 2008; Perea et al., 2008; Schoonbaert et al., 2009, Perea & Gotor, 1997; Perea & Rosa, 2002). Moreover, recent ERP data from our lab demonstrate that when word association is strong enough not only masked priming effects are obtained but also a significant N400 component, suggesting the early time course of the associative priming effect.

On the other hand, according to the PDP proposal, the difference between semantically and associative priming effects lies in how representational patterns of the related underlying concepts became activated. Connections between associative related concepts are established on the basis of learning due to co-occurrence of the two corresponding representational patterns, while (non-associative semantic) relations are established based on feature similarity of the related concepts. This account does not suggest different representational locus of the two types of priming effects as such but different accounts of how the underlying nodes became connected. While our results are consistent with this type of proposal in that priming effects become larger as a function of associative strength (only strong associates showed masked priming effects), they are not compatible with simulation studies that Plaut (1995) carried out with associative and semantically related words. This author found early priming effects for the semantic relationship which decreased as prime duration increased, and in the case of associated pairs, more priming with longer prime durations. Our results showed just the opposite, early associative priming and later semantic priming.

To conclude, we have reported two priming experiments that have shown a dissociation between associative and semantic priming effects. We have argued that such finding is more consistent with the spreading activation theory that suggests an early lexical locus of the associative priming effects. Additional research needs to be done to provide further evidence of the use of the masked and unmasked paradigms to investigate these and other types of word semantic relations.

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Received July 7, 2010
Revision received September 6, 2011
Accepted September 15, 2011

https://doi.org/10.5209/rev_SJOP.2012.v15.n3.39382 Published online by Cambridge University Press

APPENDIX

Pairs of words used in experiments 1 and 2

Semantic/associative relations

Strong association

Primes	*Targets*
Mesa (*table*)	silla (*chair*)
Lechuga (*lettuce*)	ensalada (*salad*)
Búho (*owl*)	noche (*night*)
Cerradura (*lock*)	llave (*key*)
Cuernos (*horns*)	toro (*bull*)
Hembra (*female*)	macho (*male*)
Jaula (*cage*)	pájaro (*bird*)
Cuchillo (*knive*)	cortar (*to cut*)
Pimiento (*pepper*)	rojo (*red*)
Cosecha (*harvest*)	trigo (*wheat*)
Huésped (*guest*)	invitado (*guest*)
Charla (*talk*)	hablar (*to speak*)
Anillo (*ring*)	dedo (*finger*)
Delirio (*delirium*)	locura (*craziness*)
Cielo (*sky*)	azul (*blue*)
Bueno (*good*)	malo (*bad*)
Hombre (*man*)	mujer (*woman*)
Antigüedad (*antiquity*)	viejo (*old*)
Abrir (*to open*)	cerrar (*to close*)
Batido (*milkshake*)	fresa (*strawberry*)
Sandía (*watermelon*)	verano (*summer*)
Cebolla (*onion*)	llorar (*to cry*)
Grande (*big*)	pequeño (*small*)
Labios (*lips*)	beso (*kiss*)

Weak association

Primes	*Targets*
seta (*mushroom*)	veneno (*poison*)
cerdo (*pig*)	jamón (*ham*)
ojo (*eye*)	gafas (*glasses*)
tambor (*drum*)	ruido (*noise*)
barro (*mud*)	sucio (*dirt*)
bonita (*pretty*)	fea (*ugly*)
delgado (*thin*)	gordo (*fat*)
columpio (*swin*)	niños (*boys*)
cucaracha (*cockroach*)	asco (*disgust*)
rana (*frog*)	sapo (*toad*)
cuchara (*spoon*)	tenedor (*fork*)
garbanzo (*cheekpeas*)	comida (*meal*)
ratón (*mouse*)	queso (*cheese*)
cantidad (*amount*)	mucho (*much*)
naranja (*orange*)	zumo (*juice*)
cobardía (*cowardice*)	miedo (*fear*)
cristal (*glass*)	ventana (*window*)
descanso (*rest*)	cama (*bed*)
fruta (*fruit*)	manzana (*apple*)
fuerte (*strong*)	débil (*weak*)
gato (*cat*)	perro (*dog*)
gracioso (*funny*)	chiste (*joke*)
jabón (*soap*)	limpio (*clean*)
alma (*soul*)	cuerpo (*body*)

Only-semantic relations (pairs non associatively related)

Primes	*Targets*
Mantel (*tablecloth*)	servilleta (*napkin*)
Colcha (*bedspread*)	sábana (*sheet*)
Golondrina (*shallow*)	gorrión (*sparrow*)
Tomillo (*screw*)	perejil (*parsley*)
Colmillo (*canine tooth*)	muela (*tooth*)
Medias (*stokings*)	calcetines (*shocks*)
Corcho (*cork*)	madera (*wood*)
Judía (*green bean*)	guisante (*green pea*)
Lubina (*sea bass*)	atún (*tuna*)
Almeja (*clam*)	mejillón (*mussel*)
Marioneta (*puppet*)	muñeca (*doll*)
Ciruela (*plum*)	melocotón (*peach*)
Gaviota (*seagull*)	paloma (*dove*)
Camino (*path*)	calle (*street*)
Caballo (*horse*)	burro (*donkey*)
Taza (*cup*)	vaso (*glass*)
Lenguado (*sole*)	merluza (*hake*)
Espinacas (*spinach*)	acelgas (*silverwheet*)
Huracán (*hurricane*)	tormenta (*storm*)
Jarra (*jar*)	botella (*bottle*)
Codo (*elbow*)	rodilla (*knee*)
Encendedor (*lighter*)	cerilla (*match*)
Cojín (*coixin*)	colchón (*matress*)
Limonero (*lemon tree*)	naranjo (*orange tree*)

https://doi.org/10.5209/rev_SJOP.2012.v15.n3.39382 Published online by Cambridge University Press