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Faster might not be better: Pictures may not elicit a stronger unconscious priming effect than words when modulated by semantic similarity

Nicolás Marcelo Bruno[a,b,c,*], Iair Embon[a], Mariano Nicolás Díaz Rivera[a], Leandro Giménez[d], Tomás Ariel D'Amelio[a,b,c], Santiago Torres Batán[b,e], Juan Francisco Guarracino[b], Alberto Andrés Iorio[a,b,c], Jorge Mario Andreau[a,b,c]

[a] Universidad de Buenos Aires, Facultad de Psicología, Buenos Aires, Argentina
[b] Universidad del Salvador, Facultad de Psicología y Psicopedagogía, Buenos Aires, Argentina
[c] Instituto de Biología y Medicina Experimental, Laboratorio de Biología del Comportamiento, Buenos Aires, Argentina
[d] Universidad de Buenos Aires, Facultad de Filosofía y Letras, Buenos Aires, Argentina
[e] Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales, Buenos Aires, Argentina

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ABSTRACT

It has been suggested that unconscious semantic processing is stimulus-dependent, and that pictures might have privileged access to semantic content. Those findings led to the hypothesis that unconscious semantic priming effect for pictorial stimuli would be stronger as compared to verbal stimuli. This effect was tested on pictures and words by manipulating the semantic similarity between the prime and target stimuli. Participants performed a masked priming categorization task for either words or pictures with three semantic similarity conditions: strongly similar, weakly similar, and non-similar. Significant differences in reaction times were only found between strongly similar and non-similar and between weakly similar and non-similar, for both pictures and words, with faster overall responses for pictures as compared to words. Nevertheless, pictures showed no superior priming effect over words. This could suggest the hypothesis that even though semantic processing is faster for pictures, this does not imply a stronger unconscious priming effect.

1. Introduction

1.1. Masked priming paradigm

A growing body of studies has proven that high-level cognitive processes, such as orthographic, phonological, and semantic analyses, can be performed without conscious awareness (Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006; Nakamura et al., 2018). However, the degree in which unconscious (i.e., without conscious awareness) information extracted from a stimulus can influence behavior is still a matter of debate (Kouider & Dehaene, 2007; Ortells, Kiefer, Castillo, Megías, & Morillas, 2016; Van den Bussche, Notebaert, & Reynvoet, 2009). Therefore, the influence of unconscious perception on behavior has encouraged a great amount of research to study the limits of unconscious cognition and its consequent role in consciousness (Dehaene & Naccache, 2001;

* Corresponding author at: Vuelta de Obligado 2490, 1428 Ciudad Autónoma de Buenos Aires, Argentina.
E-mail addresses: nbruno@psi.uba.ar (N.M. Bruno), mario.andreau@usal.edu.ar (J.M. Andreau).

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van Gaal, Ridderinkhof, Scholte, & Lamme, 2010). For this reason, this study is interested in clarifying the influence of the stimulus format of unconscious stimulus over unconscious semantic processing.

Cognitive processing underlying unconscious perception of a stimulus can occur at several processing levels, such as early perceptual stages, semantic representations or motor control (Dehaene, 2011; Naccache, 2008). Each of those levels differ in the amount of information required from the stimulus. For example, early perceptual analyses performed unconsciously by the subject compile low-level sensory information from the stimulus into higher-level information such as size, shape or color (Kiefer, Sim, & Wentura, 2015). Meanwhile, semantic analyses involve extracting meaning from the stimulus (McClelland & Rogers, 2003), whereas motor control refers to the regulation and monitoring of in-process actions (Dehaene, 2011; van Gaal et al., 2010). The aim of the present study is to evaluate if semantic analysis can be influenced by the semantic similarity between concepts and the stimulus presentation format in which each concept is represented.

Understanding the processes underlying unconscious perception in a semantic level can be approached through the masked priming paradigm, which has been widely used in the fields of experimental psychology and cognitive neuroscience (Greenwald, Draine, & Abrams, 1996; Kouider & Dehaene, 2007; Naccache & Dehaene, 2001; Van den Bussche, Smets, Sasanguie, & Reynvoet, 2012). Under this paradigm, participants are presented with a series of stimuli called prime and target. The prime is the stimulus that precedes and facilitates the processing of the target. The target is the stimulus that participants have to decide upon and is completely apprehensible by conscious perception.

In order to achieve unconscious status, the prime stimulus must be visually masked (Kouider & Dehaene, 2007) and presented for a brief period of time (usually, less than 50 ms). Furthermore, to assume that a stimulus is indeed unconscious, participants must be subjectively (e.g., self-report of the awareness of the stimulus) and objectively (e.g., identify the stimulus in a discrimination test) unaware of it (Ortells et al., 2016). The objective measure must be taken into account proportionately to the information the visibility test of the masked prime is evaluating (e.g., perceptual or semantic information). Masking usually involves a stimulus displayed before the prime stimulus (forward mask), a stimulus displayed after the prime stimulus (backward mask), or both types of masks. These masks are configured to prevent the prime stimulus from being consciously perceived. Both masks are used in this experiment.

This paradigm belongs to the sequential priming family of tasks due to the procedure it uses. In a semantic categorization task, individuals are instructed to decide the category (animals and objects in this study) each target stimulus belongs to. When both prime and target stimuli share the same category (namely, they are congruent), individuals tend to take less time to respond correctly than when the stimuli belong to different categories (namely, incongruent). This is known as 'masked congruency priming effect' (Klauer, Eder, Greenwald, & Abrams, 2007; Ortells et al., 2016), and it could account for the facilitation in the processing of the target stimulus given a congruent prime stimulus. This effect is found when the difference between the response times (RT) of each condition (congruent and incongruent) is significantly different.

Originally, two studies claimed to have found evidence of the unconscious semantic processing of prime stimulus (Dehaene et al., 1998; Greenwald et al., 1996). Nevertheless, certain concerns have arisen regarding their results. It has been claimed that the results found in those studies could be reinterpreted in a non-semantic manner: through automatic stimulus-response (S-R) mapping (Damian, 2001) or through automatic associations between expected stimuli and their corresponding response (action triggers; Kunde, Kiesel, & Hoffmann, 2003). The first refers to a setting in which a small stimuli set is used and prime stimuli are presented as targets as well. Consequently, it would be possible for the prime to preactivate a previously acquired S-R link in earlier practice stages instead of the semantic representation of the prime stimulus. The second claim stands for deliberately settled associations across stimuli, which can be executed in order to perform faster responses bypassing semantic processing. This strategy could be elaborated upon if the expected category elements were to be predicted. In spite of those critiques, however, several studies have found evidence of genuine unconscious semantic processing that cannot be explained according to S-R mappings or action-triggers (Dell'Acqua & Grainger, 1999; Ortells et al., 2016; Van den Bussche et al., 2012). These studies solved the S-R mapping problem by using novel prime stimuli that never appeared as target stimuli. Regarding action triggers, they implemented wide-range target sets (i.e., animals vs. objects), which would result in individuals' unlikelihood to form action triggers because of the broad variety of potential objects. As such, using novel prime stimuli, which integrate broad target sets in an experimental design, might prevent the results from being interpreted in a non-semantic way.

After overcoming these methodological critiques, the literature has adopted a more semantic-oriented explanation for unconscious priming effects, referring to an automatic preactivation of the semantic representation of the target (Kiefer & Martens, 2010; Naccache et al., 2005; Ortells et al., 2016). This last claim is often linked with the idea that such preactivation might be influenced by deliberately settled task-control representations (task sets) to the prime (Ansorge, Kunde, & Kiefer, 2014). These represent the conditions to fulfill the experimental instructions, and orient specific information processing of the prime (Kiefer et al., 2015). Therefore, this account allows a suitable explanation of unconscious semantic priming effects because it predicts priming effects for novel primes that cannot be explained by S-R mappings or action-triggers accounts.

The masked congruency priming effect can be regulated by different factors in the experimental design (Van den Bussche et al., 2009), such as the novelty of the prime and the categories' size (the bigger the category, the lower the effect; Forster, 2004). Some studies have found that the size of the prime and target stimulus set used is a positive modulator for the masked congruency priming effect (i.e., as the set size grows, so does the effect; Abrams, 2008a, 2008b; Kiesel, Kunde, Pohl, & Hoffmann, 2006). This study will focus on just two of the effect modulators: the stimulus presentation format, and the semantic similarity between prime and target stimulus (for more detail on modulators of the priming effect, see Van den Bussche et al., 2009).

1.2. Stimulus presentation format

Primes and targets can take different formats, such as words, digits, symbols/ideograms (i.e., Japanese kanji) or pictures (Van den Bussche et al., 2009). Previous studies have found differential processing in the semantic code access, especially for words and pictures. For instance, the kind of task (i.e., categorization, lexical decision or naming) is an important aspect in the processing of pictures and words as it indicates how the stimulus should be processed (Bajo, 1988; Glaser & Düngelhoff, 1984). In categorization tasks, pictures are usually categorized more rapidly than words (Potter & Faulconer, 1975), whereas in naming tasks, words are named faster than pictures (Snodgrass & Vanderwart, 1980).

Differences between picture and word categorization were also observed under unconscious conditions. For example, Kiefer et al. (2015), using an evaluative masked priming paradigm, observed that pictures were categorized faster than words. On the other hand, the study also found that, unlike words, the priming effect for pictures could be observed with small target sets and more target repetitions for unfamiliar primes (i.e., primes that did not belong to the target set).

The apparent reason for the difference in reaction times between pictures and words may be due to an asymmetry in the access to the semantic code. It has been stated that word reading does not necessarily imply access to the semantic content, while picture naming does (Bajo, 1988; Dell'Acqua & Grainger, 1999). In addition, pictures would be able to access the semantic content more rapidly than words (Glaser, 1992), whereas words could access the phonemic information more rapidly than pictures (Andreau & Torres Batán, 2018; Durso & Johnson, 1979; Nelson, Reed, & Walling, 1976).

From these results, it has been suggested that pictures are more effective as primes compared to words (Bajo, 1988; Durso & Johnson, 1979; Glaser, 1992). This could be due to pictures having privileged access to the semantic code and, therefore, making them more sensitive to be primed as targets. For these reasons, some studies have suggested that pictures would elicit a stronger unconscious priming effect than words (Kouider & Dehaene, 2007; Ortells et al., 2016). Nevertheless, to the best of the authors' knowledge, this idea has not received enough supporting evidence under unconscious conditions. For example, Kiefer et al. (2015) found in their first experiment that the priming effect for familiar primes (i.e., prime stimuli that were also presented as target stimuli) was smaller for pictures than for words, although these results were not replicated in Experiment 2. Moreover, when taking into consideration Van den Bussche et al. (2009) meta-analysis, stimulus format (e.g., word primes vs. symbol primes) may not be a relevant effect modulator when relevant modulators were taken altogether into account (e.g. category size, prime novelty, SOA). Therefore, it remain unclear whether pictures would elicit a stronger unconscious priming effect than words.

1.3. Semantic similarity

Another modulator to the masked congruency priming effect is the semantic relatedness between prime and target stimuli. This modulator is comprised by the prime-target association strength and the prime-target semantic similarity. The association strength refers to the probability that a stimulus (e.g., the word 'monkey') brings to mind a second stimulus (e.g., the word 'banana'). The semantic similarity is the superposition of semantic features between both stimuli (i.e., the pair of words monkey/gorilla; McRae & Boisvert, 1998). Several studies on unconscious semantic priming manipulate the task trials in order to obtain congruent and incongruent trials, usually disregarding the semantic relatedness between the stimuli (Ortells et al., 2016). Nevertheless, this semantic modulator has proven to be relevant in order to find a reliable priming effect, since congruence alone may not be enough to reach a priming effect (Ortells et al., 2016; Ortells, Frings, & Plaza-Ayllon, 2012). For instance, Van den Bussche et al. (2012) found a priming effect only when the prime and target stimuli were strongly similar, but no effect was observed when prime and target stimuli were weakly similar. Both strong and weak conditions (regarding similarity or relatedness) imply a degree of relation between two stimuli from the same category (congruent) on account of the attributes shared. Also, Ortells et al. (2012) reported priming effect when prime and target stimuli were strongly related (in terms of association strength and semantic similarity) and no effect was found when the pair were weakly related. This latter study was replicated by Ortells et al. (2016). They found differences between strongly related pairs compared to weakly related and unrelated pairs. Weakly related pairs did not differ significantly from unrelated pairs. Altogether, these results indicate that the strength of the semantic similarity and the association between prime/target is a clear modulator of the unconscious priming effect.

1.4. The present study

The present study manipulates the stimulus presentation format (pictorial and verbal) in a semantic categorization task between groups. This is taken into account as previous studies claimed both formats have differential processing steps over meaning-extraction, though little research has been done with prime-target pictorial stimuli under unconscious conditions. It is expected to find lower RTs for the pictorial condition in comparison to the verbal condition, in line with Kiefer et al. (2015).

Additionally, a second aim is to observe if the masked congruency priming effect is affected by the manipulation of the semantic similarity between prime and target stimuli. To this end, the semantic similarity between prime and target stimuli (strongly similar, weakly similar, and non-similar) was manipulated within groups. It is expected to find differences in RTs between strongly similar and weakly similar conditions. If that is the case, it could be argued that the congruency of the pairs by itself might not be sufficient to obtain a reliable masked congruency priming effect, as observed by Ortells et al. (2012), Van den Bussche et al. (2012) and Ortells et al. (2016).

Finally, the assumption that pictures would elicit a stronger unconscious priming effect than words was evaluated (Kouider & Dehaene, 2007; Ortells et al., 2016). Moreover, the influence of stimulus format over unconscious priming effect across semantic similarity conditions was tested. To the authors' knowledge, this idea has not received enough supporting evidence under unconscious conditions. Taking all these goals together, the current experimental design aims to better clarify the influence of pictorial and verbal stimuli over unconscious semantic processing.

2. Experiment 1

2.1. Material and methods

2.1.1. Participants

Ninety-three native Spanish-speaking individuals, with a normal or corrected to normal vision, participated in the experiment (age M = 21,7 years; range of 18–54 years, 73 female). None of the participants knew the purpose of the investigation nor were they informed of the presence of the prime stimuli. Each volunteer signed a written consent. The experiment was performed according to the Declaration of Helsinki (World Medical Association, 2013).

Participants were randomly divided into two groups: one group with pictorial stimulus format, and the other with verbal stimulus format. Fifteen participants were excluded from the data analysis because of their high level of visibility discrimination in the masked prime identification test (more than 65% of hit rate), leaving 41 participants in the pictorial group and 37 participants in the verbal group.

2.1.2. Stimuli and apparatus

The concepts implemented in the experiment were presented in two different formats: verbal and pictorial. The verbal stimuli were obtained from the naming of the pictorial stimuli. The size of each format set consisted of 32 stimuli: 32 Spanish words for the verbal set and 32 pictures for the pictorial set. Both sets contained two different categories: 16 animals and 16 inanimate objects. Each category was also divided into two groups: the prime stimuli set and the target stimuli set. Prime stimuli were never used as a target or vice versa. Words were regulated to strictly consist of 4–6 letters. None of the primes shared the first letter, nor the first or last syllable with its corresponding target pair, in order to minimize the orthographic overlap between stimuli from the same trial. These imposed conditions heavily restricted the number of possible prime-target trials.

Pictorial stimuli were selected from the 'Snodgrass and Vanderwart's "like" objects' picture set (Rossion & Pourtois, 2004). Stimuli were shown on a desk computer (Intel (R) Pentium (R) CPU N3540@2.16 GHz processor) with a keyboard and a 17″ monitor (60 Hz refresh rate). All tasks were programmed in Python language using the Psychopy library (Peirce, 2008). During the verbal stimulus presentation, stimuli were shown at a visual angle of 2.61° wide and 0.85° high. The pictorial stimuli were shown at a visual angle of 2.61° wide and 2.66° high and were put in a 7.15° wide and 7.15° high black and white pixeled frame (Pohl, Kiesel, Kunde, & Hoffmann, 2010). All picture prime stimuli had a leftward orientation, while all picture target stimuli had a rightward orientation to avoid perceptual overlap.

The masking used for the verbal stimuli consisted of two pattern masks: a forward mask of seven ampersand symbols ('&') and a backward mask of seven hash symbols ('#'). Pattern masks were subtended at a visual angle of 4.76° wide and 0.85° high. The mask used in the pictorial stimulus presentation was composed of black and white 4x4 pixel noise (Delord, 1998), with one of five different random patterns presented, and it was 7.15° wide and 7.15° high.

To assemble the prime-target pairs, two pre-tests were carried out. The first had the objective of selecting the possible pairs to be used, and the second was done to evaluate the semantic similarity of the chosen pairs.

For the first pre-test, 48 possible stimuli (12 primes and 12 targets for each category, animals and inanimate objects) were selected as a result of the above-mentioned restrictions. This first pre-test was performed to generate the strongly similar, weakly similar, and non-similar pairs. Subjects were asked to match a stimulus (prime) with the most similar concept in a list of targets according to their semantic similarity. They were shown a series of examples in order to clarify the task (e.g., fox-wolf for strongly similar animals, cow-frog for weakly similar animals, nut-bolt for strongly similar objects, and shoe-violin for weakly similar objects). They were then asked the question 'which of the following concepts do you consider to be the most similar to the current concept?', followed by 'which of the following concepts do you consider to be the least similar to the current concept?' This questionnaire was administered online and was answered by 157 participants.

To arrange the strongly similar pairs, a prime stimulus was matched with the most selected target for that prime (e.g.., cat-dog), resulting in 8 animal pairs and 8 object pairs. The targets that were rarely or never chosen as the most similar to a prime were selected to constitute the weakly similar pairs (e.g.., cat-zebra), also resulting in 8 animal pairs and 8 object pairs. The other stimuli were ruled out of the experiment and were used as practice trials. The non-similar stimuli trials were arranged by matching a prime and a target from different semantic categories (e.g., cat-glass). This condition consisted of 16 pairs with animal primes and 16 pairs with object primes, to match the congruent condition formed by the strong and weak similarity conditions. The sets of prime and target stimuli of the three conditions were the same, but were arranged corresponding to each semantic similarity condition. Finally, in this way, there were 16 strongly similar pairs (8 animal pairs and 8 object pairs), 16 weakly similar pairs (8 animal pairs and 8 object pairs) and 32 non-similar pairs (16 animal pairs and 16 object pairs; see Appendix A Table 1 for the list of stimuli).

A second pre-test was then performed in order to verify the degree of semantic similarity for each pair. Participants were asked to score the semantic similarity between the stimuli of every pair following a Likert scale ranging from 1 ('not at all similar') to 7 ('strongly similar'). This questionnaire was also administered online to a total of 547 participants. Results were considered to measure and identify the strongly similar trials (M = 5.65, SD = 0.45), the weakly similar trials (M = 2.92, SD = 1.16), and the non-similar trials (M = 1.17, SD = 0.17). These three groups of trials were tested using a Kruskal-Wallis test to further verify if the semantic similarity was significantly different between the groups. This analysis yielded a statistically significant difference ($H(2) = 52.3$, $p < .001$).

2.1.3. Procedure

2.1.3.1. Masked priming task. Participants were presented either pictures or words as stimuli, but never both formats together. They were instructed to categorize a target stimulus as either an animal or an object as quickly and accurately as possible. There were 10 practice trials in which a feedback message appeared in order to train participants to perform a faster response if their answer was slower than 1 s. The instructions were given both orally and written on the computer screen.

The sequence of the events in a trial was the same for both format presentation groups (pictorial and verbal; see Fig. 1). At the beginning of each trial, a fixation cross appeared in the center of the screen (0.46° visual angle) for 500 ms. Next, the forward mask appeared for 100 ms, followed by the prime stimulus for 33.5 ms (two screen refresh cycles), and then the backward mask for 33.5 ms. Finally, the target stimulus appeared and remained on the screen until the participant's response or for 2000 ms. The interval was randomly set between 1600 ms and 2000 ms. The prime-target stimulus onset asynchrony (SOA) was 67 ms long (the target stimulus appeared immediately after the backward mask; Ortells et al., 2016). To avoid visual overlap between prime and target stimuli for the pictorial condition, prime stimuli were presented randomly 1° to either side (left or right) with respect to the center of the screen (Dell'Acqua & Grainger, 1999). Target stimuli always appeared at the center of the screen.

The task was divided into 4 blocks of 64 trials each (256 trials in total), thus resulting in every prime and target appearing 4 times for every block. Half the trials per block were congruent trials and the other half were incongruent trials that belonged to the non-similar stimuli condition (32 trials). Congruent trials were split into two groups of the same size (16 trials each): strongly similar and weakly similar trials.

2.1.3.2. Masked prime identification test. The masked priming task was followed by a masked prime identification test, which started by subjects being notified about the existence of the prime stimulus. This test consisted of the same structure as the masked priming task, but with the difference that participants were asked to categorize the prime stimuli, rather than the target ones, as either an animal or an object (Fig. 1). This task was composed of two blocks with 64 trials each, distributed in the same fashion as the masked priming task (every one of the 16 prime stimuli appeared 4 times). Before the presentation of these blocks, two sessions of 10 practice trials were taken. In the first practice test, the prime stimuli were displayed for 101 ms to allow participants to consciously perceive them. In the second practice session, the prime stimulus was shown for the same amount of time as in the masked priming task (33.5 ms). Prime stimuli used for the practice trials were different from the ones used in the masked prime identification test.

2.1.3.3. Semantic similarity assessment. Finally, when the prime visualization task finished, participants completed a questionnaire about the semantic similarity between the prime and target stimuli of each pair (similar to the second questionnaire that was used for the stimuli selection). This was done in order to verify that the results from the previous questionnaires coincided with the study sample.

2.2. Results

2.2.1. Masked priming task

Incorrect trials (1.43% in the pictorial group and 2.31% in the verbal group) or responses that deviated more than 2.5 standard deviations (SDs) from their individual mean (3.89% of the trials of the pictorial condition and 4.7% of the verbal condition) were discarded from the RT analysis.

For the RT analysis, a mixed 3 × 2 repeated measure analysis of variance (ANOVA) was conducted with semantic similarity (strongly similar, weakly similar, non-similar) and stimulus format (pictorial vs. verbal), over the mean RT (see Fig. 2A). This analysis yielded a significant main effect of semantic similarity ($F(2, 152) = 17.6$, $p < .001$, $\eta_p 2 = 0.188$). A main effect of stimulus format ($F(1, 76) = 83.62$, $p < .001$, $\eta_p 2 = 0.977$) was also observed, being the pictorial condition ($M = 520$ ms, $SD = 21$ ms) significantly faster than the verbal condition ($M = 628$ ms, $SD = 37$ ms). On the other hand, no interaction effect between these two factors was found ($F(2, 152) = 0.133$, $p = .875$, $\eta_p 2 = 0.002$).

As no interaction effect was found, both groups were analyzed together in order to observe the simple effects of semantic similarity. For this purpose, a Bonferroni post-hoc analysis was performed. It was found that strongly similar trials ($M = 573$ ms, $SD = 31$ ms; $p < .001$; *priming*[1] = 9 ms) and weakly similar trials ($M = 575$ ms, $SD = 35$ ms; $p = .001$; *priming* = 7 ms) presented significantly lower RTs as compared with non-similar trials ($M = 582$ ms, $SD = 31$ ms), but no statistical difference was found between strongly similar and weakly similar trials ($p = .420$).

Furthermore, a block analysis was done to discard the possibility of implicit learning. The factorial ANOVA revealed neither significant block effect ($F(1, 76) = 2.917$, $p = .092$, $\eta_p 2 = 0.023$) nor interaction of block with relatedness ($F(2, 152) = 1.13$, $p = .323$, $\eta_p 2 = 0.002$) and neither with format ($F(1,76) = 0.015$, $p < .901$, $\eta_p 2 < 0.001$; Fig. 2B).

Another 3x2 mixed repeated measure ANOVA was performed on error rates (ER) for the same factors as the one on RT. This analysis yielded only a main effect for stimuli format ($F(1, 76) = 6.55$, $p = .012$, $\eta_p 2 = 0.107$), indicating that the ER in the verbal

[1] Priming effect measure was obtained from calculating the difference between the mean RT of the congruent condition (strongly similar or weakly similar) and the incongruent condition (non-similar).

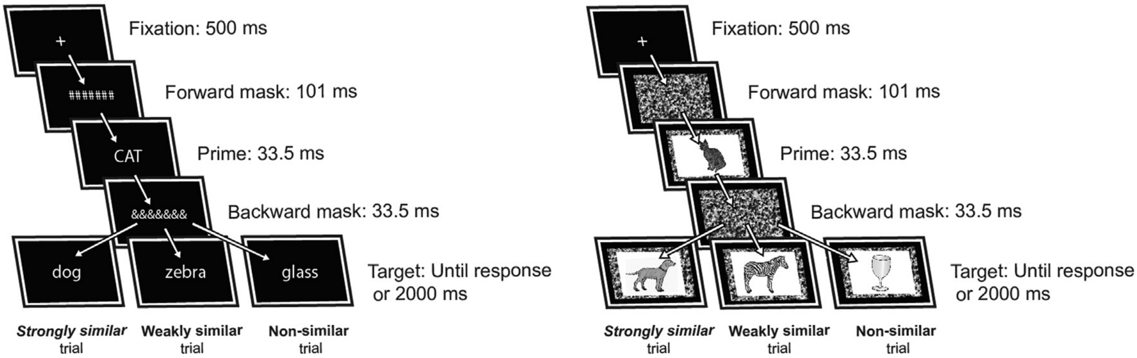

Fig. 1. Temporal sequence of events of the masked priming task procedure. On the left is the sequence for the verbal condition and on the right is the sequence for the pictorial condition. The three conditions for semantic similarity can be observed. The stimuli shown on the verbal condition are the English translation of the words used in Spanish.

condition was higher ($M = 2.31\%$, $SD = 0.23\%$) than in the pictorial condition ($M = 1.43\%$, $SD = 0.15\%$). A main effect for semantic similarity was not found ($F(2, 152) = 1.87$, $p = .158$, $\eta_p 2 = 0.024$). Also, no significant interaction was obtained ($F(2, 152) = 1.66$, $p = .193$, $\eta_p 2 = 0.021$).

2.2.2. Masked prime identification test

The measure of visibility was obtained by computing the *d′* measure from signal detection theory (Macmillan & Creelman, 2005). For this analysis, animal stimuli were considered as the signal, so correct responses to animals were treated as hits, and incorrect responses to objects were analyzed as false alarms. Then the *d′* measure was tested against zero using a *t*-test. If the mean value for the *d′* deviated significantly from zero, this would mean that subjects had seen the prime stimulus above chance. This analysis suggests that participants in the verbal group were not able to discriminate the prime stimuli above chance (d' $M = 0.035$; $t(40) = 0.92$, $p = .359$, Cohen's $d = 0.144$), indicating that the mean value for the *d′* did not deviate significantly from zero. On the opposite side, the *d′* did differentiate from zero in the pictorial group (d' $M = 0.122$; $t(36) = 2.30$, $p = .014$, Cohen's $d = 0.378$), indicating a discrimination of the prime stimuli above chance (Fig. 3A). However, this does not necessarily imply conscious perception of the masked prime stimuli (Brintazzoli, Soetens, Deroost, & Van den Bussche, 2012; Naccache & Dehaene, 2001; Ortells et al., 2012, 2016; Pohl et al., 2010). Naccache and Dehaene (2001) affirm that the *d′* could be contaminated by non-conscious processes. It is usual to resort to other analyses that provide evidence for or against the conscious perception of the stimulus when the *d′* is just above of what was expected by chance, as they do in the following studies: Ortells et al. (2016), Brintazzoli et al. (2012), Pohl et al. (2010), Ortells et al. (2012), Naccache and Dehaene (2001). In order to ensure that the semantic information of the prime was unconsciously perceived, further analyses were carried out.

First of all, a *t*-test between *d′* of both groups was performed to ensure that even though the pictorial condition differentiated from zero, they did not differ from each other. This analysis revealed non-significant differences between both groups ($t(77) = -1.33$, $p = .188$, Cohen's $d = 0.305$). This could suggest that the previous findings cannot be explained in terms of visibility.

Moreover, a linear regression analysis was performed for the pictorial condition, in which the masked priming effects were regressed on the *d′* values (Greenwald et al., 1996; Klauer et al., 2007; Naccache & Dehaene, 2001; Ortells et al., 2016). The intercept of the regression line with the y-axis should be significant when there are priming effects in spite of the absence of prime visibility. As no differential priming effect was obtained between strongly similar and weakly similar trials, they were analyzed together as a congruent condition. Thus, a significant intercept was obtained for masked priming congruency effect on the pictorial condition (intercept: $\beta_0 = 6.36$ ms, $t(36) = 4.458, p < .001$; slope: $\beta_1 = -0.313$ ms, $t(36) = -0.071, p = .943$; Fig. 3 B). These results imply that semantic activation also exists at zero perceptibility for the pictorial group.

Finally, to confirm that the visibility results for the pictorial condition reported above do not explain the effects found in the masked priming task, the pictorial group was divided into two different groups, according to the median of the obtained *d′* values (Ortells et al., 2016). Participants with *d′* values over the median ($Me = 0.12$) were assigned to the high discrimination group and participants with lower values than the median were assigned to the low discrimination group. As expected, no interaction was obtained in the ANOVA ($F(2, 70) = 0.452, p = .638, \eta_p^2 = 0.012$), but a significant effect of semantic similarity was obtained ($F(2, 78) = 0.113, p = .893, \eta_p^2 = 0.003$). These results are crucially important to show that the masked priming effects obtained in the masked priming task were not related to the discrimination above chance of the prime. With all these results taken as a whole, it is argued that the semantic information of the prime was processed unconsciously.

2.2.3. Semantic similarity assessment

On the pictorial group, a Kruskal-Wallis test was performed in order to verify if the participants reported a prime-target semantic similarity that differentiated significantly between the three conditions ($H(2) = 51.9$, $p < .001$), being the rating significantly higher for strongly similar trials ($M = 5.60$, $SD = 0.56$) than for weakly similar trials ($M = 2.92$, $SD = 1.12$) and non-similar trials ($M = 1.35$, $SD = 0.37$). Also, weakly similar trials were significantly different from non-similar trials.

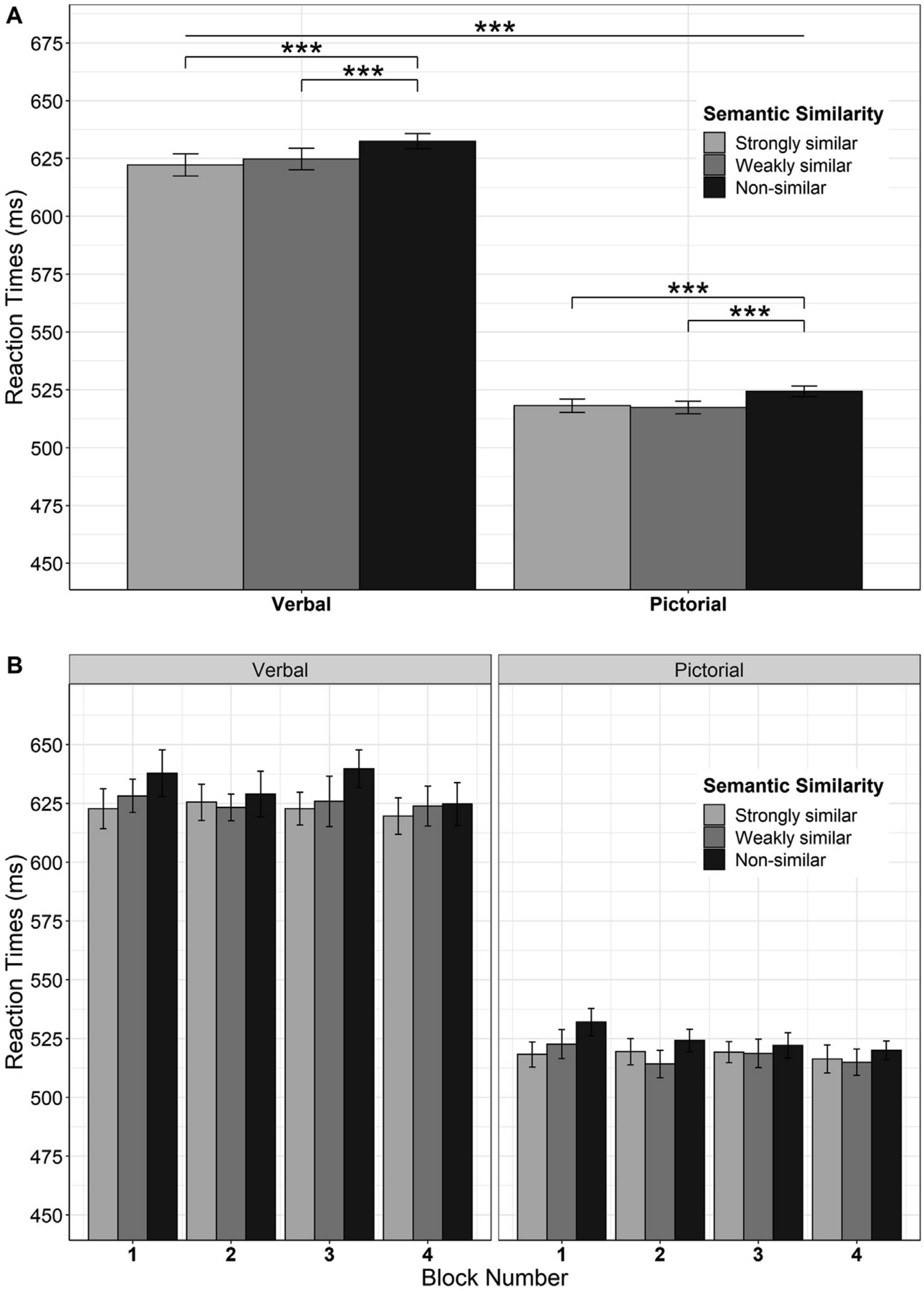

Fig. 2. (A) Mean RTs (in milliseconds) by type of stimuli format (verbal and pictorial) and semantic similarity (non-similar, weakly similar, strongly similar). The error bars represent the confidence intervals corrected for within-subjects designs. The Y-axis represents the mean RTs in the categorization task. The asterisks '***' indicate a significant difference of $p < .001$. (B) Mean RT by block number, semantic similarity, and stimulus format. The error bars represent the confidence intervals corrected for within-subjects designs.

Akin results were obtained for the trials in the verbal condition on the ratings of the semantic similarity ($H(2) = 49.1, p < .001$). Strongly similar trials ($M = 5.26$, $SD = 0.44$) were rated significantly higher than weakly similar trials ($M = 2.89$, $SD = 1.07$) and non-similar trials ($M = 1.46$, $SD = 0.35$). This difference was also revealed between weakly similar trials and non-similar trials.

3. Experiment 2

With the objective of controlling the effect that the masking procedure might have had over the priming effect, it was decided to make a control experiment. For this purpose, a second experiment was carried out, taking the noise masking procedure implemented for the pictorial stimuli and applying it to verbal stimuli. It was decided to use verbal stimuli with pictorial masks, and not the other

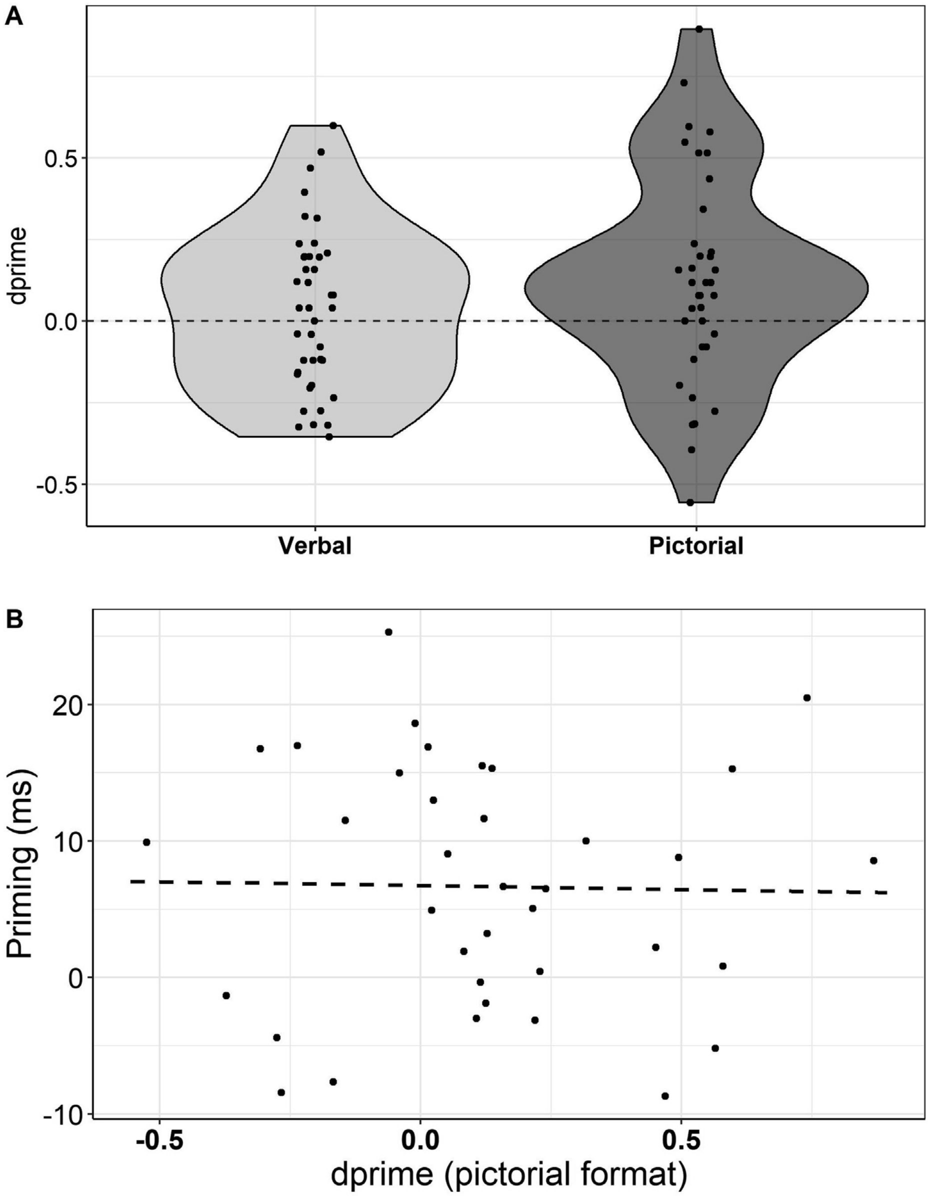

Fig. 3. (A) Violin plot with the scatter point distribution of the *d′* values for each stimuli format condition. (B) Scatter plot of the priming measure (congruent RTs - incongruent RTs) vs. the *d′* measure with the regression line only for the pictorial condition.

way around, because it was considered that it was not possible to mask pictorial stimuli with a verbal mask. The results of this control experiment group were compared with the verbal group obtained in the verbal condition in Experiment 1.

3.1. Materials and methods

3.1.1. Participants

A total of 24 individuals participated in this control experiment (age $M = 21.2$ years; range of 18–31 years, 20 females). From this group, a total of 6 participants were excluded from the final analysis because of a high discrimination in the masked prime identification task (higher hit rate than 65%), leaving a total of 18 participants in the group.

3.1.2. Stimuli and apparatus

For this experiment the exact same stimuli from the verbal condition in Experiment 1 were used. However, the masks from the pictorial condition were used for this new group. Therefore, the presented stimuli were verbal ones masked with a pictorial masking procedure. This group was compared with the verbal group from Experiment 1, which consisted of verbal stimuli and verbal masking.

3.1.3. Procedure

The experiment's procedure was the same as the one used in Experiment 1.

3.2. Results

3.2.1. Masked priming task

A 3x2 repeated measure ANOVA was performed with the variables being semantic similarity (strongly similar, weakly similar, and non-similar) and mask format (pictorial mask and verbal mask). This analysis yielded a significant main effect of semantic similarity ($F(2, 114) = 13.24$, $p < .001$, $\eta p^2 = 0.188$). However, no significant main effect of mask format was obtained ($F(1, 57) = 1.09$, $p = .319$, $\eta p^2 = 0.436$). Also, no significant interaction was found ($F(2, 114) = 0.67$, $p = .514$, $\eta p^2 = 0.011$).

A Bonferroni post-hoc test was performed in order to assess semantic similarity effects. It revealed that strongly similar trials (*M* = 632 ms, *SD* = 39 ms; $p < .001$; *priming* = 11 ms) and weakly similar trials (*M* = 634 ms, *SD* = 44 ms; $p = .001$; *priming* = 9 ms) significantly differed from non similar trials (*M* = 643 ms, *SD* = 38 ms). On the other hand, no statistically significant difference was observed between strongly similar and weakly similar trials ($p = .690$).

3.2.2. Masked prime identification test

To analyze the discriminability of the verbal stimuli with the pictorial masks, a *t*-test against zero with the *d′* values was performed. This analysis showed no significant difference (*d′ M* = 0.08; $t(17) = 1.35$, $p = .192$, Cohen's $d = 0.320$). This suggests that participants in this group were not able to discriminate the prime stimuli above chance, as was the case for the verbal group with verbal masks.

4. General discussion

The current study aimed to shed light on the influence of pictorial and verbal stimuli over unconscious semantic processing. Therefore, Experiment 1 was carried out in order to assess three main issues. Firstly, to corroborate whether pictures are categorized faster than words, as suggested by previous literature (Glaser, 1992; Kouider & Dehaene, 2007; Ortells et al., 2016). Secondly, to analyze if semantic similarity manipulation has an effect over unconscious priming effects. Lastly, to evaluate if stimuli presentation format has an influence over unconscious priming effects across semantic similarity conditions.

First and foremost, it was intended to corroborate that pictures are indeed categorized faster than words. In order to study this, participants were assigned to two separate groups, which differed in the format of the stimulus presented during a masked priming task. The results from this experiment support the idea that pictures have privileged access to semantic content in comparison to words (Dell'Acqua & Grainger, 1999; Durso & Johnson, 1979; Glaser, 1992). Accordingly, in the semantic categorization task, it was found that the RTs for the pictorial condition were significant compared to the verbal condition. These results are in line with previous studies showing a significant global RT difference between verbal and pictorial stimulus presentation format (Glaser & Düngelhoff, 1984; Kiefer et al., 2015; Kiefer, Liegel, Zovko, & Wentura, 2017; Smith & Magee, 1980). Moreover, regarding accessibility to the semantic memory required to perform a categorization decision, it could be interpreted that the pictorial stimuli were susceptible to a faster access to meaning (Dell'Acqua & Grainger, 1999; Durso & Johnson, 1979; Glaser, 1992). Considering this, it is possible that words have a delayed access to the semantic content because of their priority in processing orthographic and phonemic information (Andreau & Torres Batán, 2018; Nelson et al., 1976), which would imply the completion of an additional step prior to accessing conception information. This indirect path for words would make the phonological information more accessible or shallower, in terms of levels of processing, leaving the conceptual attributes at a deeper level, whereas the shallow level for pictures might be the semantic information (Nelson, Reed, & McEvoy, 1977). Thus, this is a possible explanation for the difference observed between the RTs of words and pictures, sustaining the hypothesis that pictures may have advantaged access to semantic information. Furthermore, the verbal condition elicited higher error rates than the pictorial condition, suggesting that both categorization tasks differed in difficulty based on the presentation format of the stimulus (word or picture).

Before interpreting the results regarding semantic processing, non-semantic interpretations should be ruled out. Given that in the current study the selected prime stimuli were never shown as conscious targets and belonged to broad categories (animals and objects), these findings might not be interpreted in a non-semantic account. As prime stimuli remained novel during the totality of the task, these results are not likely to reflect previously established S-R mappings (Damian, 2001). This prompts a consideration that participants might have applied previously established task sets, performing a semantic analysis of the prime semantic features that could have driven a pre-activation of the prime's category, making the response to the target more readily and quickly in terms of RTs. By the same token, action triggers (Kunde et al., 2003) could not have been a predominant factor involved in the reported priming congruency effects because it is unlikely that participants could anticipate every element included in both implemented semantic categories. Lastly, the orthographic overlap between prime-target trials was controlled to prevent the results from being interpreted as affected by subword processing of the primes (Abrams, 2008a, 2008b). As such, these results can be regarded as semantic in nature.

Secondly, in order to evaluate if the unconscious priming effect could be modulated by semantic similarity, two congruent conditions were created for both the verbal and pictorial format conditions: strongly similar and weakly similar. The results demonstrated that for both format presentation groups, congruent conditions significantly differed from the incongruent condition (non-similar condition), but the congruent conditions did not differ from each other. Hence, belonging to the same category would seem to be sufficient to produce a masked priming effect. From this it could be inferred that the semantic similarity manipulation by itself does not modulate the priming effect sufficiently to produce statistically differential priming effects. This conclusion is in line with previous studies (Almeida, Mahon, & Caramazza, 2010; Dell'Acqua & Grainger, 1999; Koivisto & Rientamo, 2016), where priming effect could not benefit from semantic similarity, not even when prime-target stimuli belonged to the same basic-level category, nor when they represented identical concepts.

Therefore, this study provides more evidence sustaining the congruency effect and represents evidence against the claim that congruency by itself would be insufficient to lead to an unconscious priming effect (Ortells et al., 2016; Van den Bussche et al., 2012). Moreover, it has been stated that the priming effect could be caused by the subject's unconscious application of the task instructions to the analysis of the prime stimulus, which is supposedly focused on coarse features of the stimulus, such as category alone, to reach response facilitation (Dehaene et al., 1998; Van den Bussche et al., 2012). From here, controlling the semantic similarity might not be compulsory to obtain reliable congruency priming effect, because subjects could directly apprehend the most global features of the prime and target stimuli just to indicate to which category they belong. However, these assumptions are not in line with previous studies' conclusions (Ortells et al., 2016; Van den Bussche et al., 2012), where differential congruency priming effects were found for weakly and strongly semantically related trials – contrary to the present study, where both conditions obtained the same congruency effect.

Nonetheless, it is important to consider some methodological differences that could account for dissimilarities in the results. These studies differ from the present methodology in terms of stimuli selection. Ortells et al. (2016) performed a stimuli selection that not only included semantic similarity measures obtained with Likert scale measures, such as in the present study, but also semantic association strength obtained from associative strength norms (Callejas, Correa, Lupiáñez, & Tudela, 2003). The strongly related trials used by Ortells et al. (2016) were statistically stronger in terms of Likert ratings than the strongly similar trials in the present study. Taking these facts into consideration, it seems that, unlike Ortells et al. (2016), strongly similar trials generated an analogous effect to weakly similar trials in the present study. It is not yet clear whether the current different results could owe to the non-implementation of association strength measures or to differences between semantic similarity selection criteria. For these reasons, we recommend that further studies control the association strength of the pairs. On the other hand, Van den Bussche et al. (2012) performed a stimuli selection by referring to a feature similarity matrix, which consists of featural intercorrelation between concept pairs (McRae, Cree, Seidenberg, & Mcnorgan, 2005). Considering that this matrix could be a more accurate way to assess semantic similarity, it could explain the current different results. In any case, as McRae et al. (2005) norms were constructed in a Canadian English-speaking sample, they were not taken into consideration in the present study, since cultural influences could affect the feature attribution to concepts (Unsworth, Sears, & Pexman, 2005). In addition, Van den Bussche et al. (2012) used an SOA of 40 ms. It is possible that this difference in the method of both studies could have been responsible for the inconsistency in the results. Van den Bussche et al. (2012) found a priming effect only when the prime and target stimuli were strongly similar, but found no effect when prime and target stimuli were weakly similar. In the present study, unlike Van den Bussche et al. (2012), we did find a priming effect of weakly similar pairs. Given these differences, it would be possible to think that the effect of these pairs could be shorter in duration than the strongly similar pairs. This is an interesting hypothesis to be investigated in future studies, which could be explored using an SOA of 40 ms.

The last aim of the present study was to test the influence of stimulus format over unconscious priming effect across semantic similarity conditions. In line with this, a stronger congruency priming effect was expected to be obtained in the pictorial group in comparison to the verbal group. Nevertheless, contradictory assumptions have been wielded around the idea of the semantic access superiority of pictorial stimuli, which has led to different positions on their capability to elicit more robust priming effects than verbal stimuli (Kiefer et al., 2015; Kouider & Dehaene, 2007; Ortells et al., 2016). In the present study no interaction between stimulus format and semantic similarity conditions was found. This could suggest that, despite the differential response times found between stimulus formats, congruency priming effects cannot benefit from presentation format. In accordance with this, no reliable distinct priming amount (i.e., difference in mean RTs between congruent and incongruent trials) was observed between stimulus formats. These findings might challenge the idea that picture stimuli could allow better performance in terms of priming effect since no differential RT modulation was observed. On the other hand, Kiefer et al. (2015) found that the priming effect for familiar primes was stronger for words, as opposed to pictures. They also found priming effect for pictures contrary to words when novel primes were used. Similarly, the implementation of novel primes in the current study allowed observation of similar congruency priming effects both for pictures and words, highlighting the importance of novel primes in studying the unconscious semantic processing of the stimuli. These results could have differed from Kiefer et al. (2015) because of the influence of the different task-control representations used for each procedure. Considering that Kiefer et al. (2015) used an evaluative priming procedure, which consists in the evaluation of the emotional valence of stimuli, these differences could be better explained in terms of the differential emotional responses triggered by the different stimuli format (Kensinger & Schacter, 2006). It could be suggested that pictorial stimuli may not perform better in terms of response facilitation (i.e., priming effect) in a categorization task, but they do in terms of accessibility to the semantic content, which leads to a faster response. Lastly, the present study's results concur with Van den Bussche et al. (2009) meta-analysis conclusions, where they highlighted stimulus format irrelevance over priming effect explained variance. However, Van den Bussche et al. (2009) analyzed words and symbols as a stimulus format, including within the symbol's category digits, letters, pictures or Chinese symbols. But did not focus solely on pictorial stimuli, as the current study did, other than words.

It is important to consider that in Experiment 1 pictorial and verbal conditions differed in stimulus format as well as in the mask used. It is possible that the difference in the masks could have affected the results (Bachmann & Francis, 2014). To test if the masking procedure played a role in the results, Experiment 2 was designed. It was observed that using the pictorial mask with verbal stimuli yielded the same results as when the verbal stimuli were masked with the verbal mask. Considering these results, it could be concluded that masks did not produce any significant effect over the priming effects found in Experiment 1.

Finally, a limitation of this study is the fact that the format varied between subjects. Therefore, it cannot be ruled out that the results may have been influenced by interindividual differences. For future studies, it would be important to test the stimulus format as a within subjects condition in order to test this hypothesis. This could lead to a reduction of the variance, which might help to achieve a statistical significance in case the differential semantic priming effect between prime formats indeed exists.

Another limitation to point out lies in the fact that the stimulus information unconsciously processed is the one measured in the masked prime identification test: that is to say, the semantic information of the stimulus. Therefore, it cannot be affirmed that the entire stimulus has been processed unconsciously. However, arguing that the semantic information of the prime is unconscious, it could be said that if there is a semantic priming effect, it should also be unconscious. For further studies it may be possible to measure not only behavioral effects, but also electrophysiological correlates, such as the ERP N400 priming effect (Ortells et al., 2016) in order to further assess the priming effect between format conditions.

5. Conclusions

The present study demonstrated that pictures are categorized faster than words, but that semantic priming effects could be independent from the stimulus format. In regards to semantic similarity, no differential results were obtained for weakly and strongly similar trials, and the same congruency effect was obtained for both conditions. Thus, it can be concluded that controlling the semantic similarity between prime and target stimuli might not be necessary to obtain reliable congruency priming effect. Based on these results, it can be hypothesized that unconscious semantic processing would be coarse rather than fine-grained.

CRediT authorship contribution statement

Nicolás Marcelo Bruno: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **Iair Embon:** Conceptualization, Methodology, Validation, Investigation, Writing - original draft, Writing - review & editing, Visualization. **Mariano Nicolás Díaz Rivera:** Conceptualization, Methodology, Validation, Investigation, Writing - original draft, Writing - review & editing, Visualization. **Leandro Giménez:** Conceptualization, Investigation, Writing - original draft, Writing - review & editing. **Tomás Ariel D'Amelio:** Conceptualization, Formal analysis, Writing - original draft. **Santiago Torres Batán:** Software. **Juan Francisco Guarracino:** Formal analysis. **Alberto Andrés Iorio:** Supervision, Project administration, Funding acquisition. **Jorge Mario Andreau:** Conceptualization, Writing - original draft, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

The table is composed of the prime and target stimuli in Spanish and their translations to English in parentheses. The pairs of stimuli are organized in three categories, indicating the semantic similarity level that each pair had been assigned in the masked priming task. The column PreTest corresponds to the semantic similarity results obtained for the online pre-test administered to 547 participants. This test consisted of a 1 to 7 Likert scale in which the participants had to report how semantically similar they consider each pair, with 1 being 'not at all similar' and 7 being 'strongly similar'. The results show the mean semantic similarity for each pair. The 'Pictorial' column shows the results of the semantic similarity test administered to the pictorial group just after the prime visibility task. Lastly, the 'Verbal' column represents the mean results of the semantic similarity scores of the participants in the verbal group (see Table 1).

Table 1
Semantic Similarity of Prime-Target Pairs.

Prime	Target	Pre-test	Pictorial	Verbal
Strongly similar				
ZAPATO (SHOE)	bota (boot)	5,99	6,00	5,41
VASO (GLASS)	copa (glass)	6,29	6,40	5,92
SILLA (CHAIR)	mesa (table)	5,72	5,31	5,18
BIROME (PEN)	lápiz (pencil)	6,09	6,37	5,38
VIOLÍN (VIOLIN)	piano (piano)	5,32	5,11	5,36
SOFÁ (SOFA)	cama (bed)	5,82	5,80	5,67
OLLA (SAUCEPAN)	sartén (frying pan)	5,92	6,14	5,62
ANILLO (RING)	collar (necklace)	5,43	5,63	5,64
GATO (CAT)	perro (dog)	5,49	4,74	4,85
CABRA (GOAT)	oveja (sheep)	5,44	4,94	5,13
PATO (DUCK)	cisne (swan)	5,85	5,89	5,36
LEÓN (LION)	tigre (tiger)	6,05	5,63	5,59
MONO (MONKEY)	gorila (gorilla)	6,15	6,17	5,51
JIRAFA (GIRAFFE)	cebra (zebra)	4,71	4,54	4,44
VACA (COW)	cerdo (pig)	4,97	5,26	4,44
ÁGUILA (EAGLE)	búho (owl)	5,17	5,66	4,74
Weakly similar				
VIOLÍN (VIOLIN)	bota (boot)	1,44	1,74	1,41
BIROME (PEN)	copa (glass)	1,65	1,94	1,64
SOFÁ (SOFA)	mesa (table)	4,53	4,60	4,74
OLLA (SAUCEPAN)	lápiz (pencil)	1,52	1,77	1,54
ANILLO (RING)	piano (piano)	1,75	2,06	1,67
VASO (GLASS)	cama (bed)	2,25	2,31	2,77
ZAPATO (SHOE)	sartén (frying pan)	1,51	1,74	1,72
SILLA (CHAIR)	collar (necklace)	1,72	1,71	2,03
ÁGUILA (EAGLE)	perro (dog)	3,62	3,03	3,23
JIRAFA (GIRAFFE)	oveja (sheep)	4,07	3,34	3,82
LEÓN (LION)	cisne (swan)	3,64	3,06	3,41
VACA (COW)	tigre (tiger)	4,05	4,09	3,51
PATO (DUCK)	gorila (gorilla)	3,66	2,83	2,97
GATO (CAT)	cebra (zebra)	3,85	3,51	3,41
MONO (MONKEY)	cerdo (pig)	3,99	3,34	3,49
CABRA (GOAT)	búho (owl)	3,61	2,97	3,18
Non-similar				
CABRA (GOAT)	bota (boot)	1,35	1,66	1,49
LEÓN (LION)	copa (glass)	1,14	1,06	1,46
JIRAFA (GIRAFFE)	mesa (table)	1,11	1,20	1,46
ÁGUILA (EAGLE)	lápiz (pencil)	1,15	1,14	1,51
VACA (COW)	piano (piano)	1,11	1,29	1,26
MONO (MONKEY)	cama (bed)	1,19	1,17	1,54
GATO (CAT)	sartén (frying pan)	1,11	1,37	1,23
PATO (DUCK)	collar (necklace)	1,14	1,14	1,46
VACA (COW)	bota (boot)	2,03	2,00	1,56
GATO (CAT)	copa (glass)	1,24	1,23	1,85
LEÓN (LION)	mesa (table)	1,11	1,49	1,31
PATO (DUCK)	lápiz (pencil)	1,10	1,14	1,33
JIRAFA (GIRAFFE)	piano (piano)	1,10	1,20	1,23
ÁGUILA (EAGLE)	cama (bed)	1,12	1,14	1,36
MONO (MONKEY)	sartén (frying pan)	1,08	1,14	1,18
CABRA (GOAT)	collar (necklace)	1,29	1,17	1,85
VASO (GLASS)	perro (dog)	1,19	1,34	1,59
ZAPATO (SHOE)	oveja (sheep)	1,30	1,40	1,62
SILLA (CHAIR)	cisne (swan)	1,17	1,14	1,44
BIROME (PEN)	tigre (tiger)	1,07	1,26	1,46
SOFÁ (SOFA)	gorila (gorilla)	1,14	1,43	1,33
OLLA (SAUCEPAN)	cebra (zebra)	1,09	1,09	1,15
ANILLO (RING)	cerdo (pig)	1,09	1,11	1,18
VIOLÍN (VIOLIN)	búho (owl)	1,16	1,54	1,69
BIROME (PEN)	perro (dog)	1,10	1,11	1,33
VASO (GLASS)	oveja (sheep)	1,15	1,66	1,38
SOFÁ (SOFA)	cisne (swan)	1,09	1,11	1,26
OLLA (SAUCEPAN)	tigre (tiger)	1,06	1,11	1,33
VIOLÍN (VIOLIN)	gorila (gorilla)	1,09	1,29	1,26
ANILLO (RING)	cebra (zebra)	1,15	1,11	1,15
ZAPATO (SHOE)	cerdo (pig)	1,18	1,46	1,41
SILLA (CHAIR)	búho (owl)	1,09	1,86	1,36

Note: In parentheses are the names of the stimuli translated into English.

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2020.102932.

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