Masked Primes Can Be Genuinely Semantically Processed

A Picture Prime Study

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Abstract. Van den Bussche and Reynvoet (2007) argued that since significant priming was observed for novel primes from a large category, subliminal primes can be processed semantically. However, a possible confound in this study was the presence of nonsemantic effects such as orthographic overlap between primes and targets. Therefore, the first aim of this study was to validate our previous claim when nonsemantic influences are avoided. The second aim was to investigate the impact of nonsemantic stimulus processing on priming effects by manipulating target set size. The results showed that when nonsemantic effects are eliminated by presenting primes as pictures and targets as words, significant priming emerged for large stimulus categories and a large target set. This cannot be explained by nonsemantic accounts of subliminal processing and shows that subliminal primes can be truly semantically processed. However, when using a limited amount of targets, stimulating nonsemantic processing, priming disappeared. This indicates that the task context will determine whether stimuli will be processed semantically or nonsemantically, which in turn can influence priming effects.

Keywords: masked priming, semantic priming, orthographic overlap, picture prime

Dehaene et al. (1998) found that congruent trials, where subliminal prime and target evoke the same response, were responded to faster than incongruent trials, where prime and target evoke opposite responses (i.e., response congruency effect, RCE). They concluded that subliminal primes are semantically processed. Damian (2001) shed a new light on the findings of Dehaene et al. (1998). While in the study of Dehaene et al. the targets were also presented as primes (i.e., repeated primes), Damian found when primes were never shown as targets (i.e., novel primes), the RCE disappeared. According to Damian, this implies that the primes in Dehaene et al. were not semantically processed, but rather that when the stimulus set is limited and prime and target set are identical, subjects create automatized stimulus-response (S-R) mappings that bypass semantic access. When subjects have to overtly respond to a stimulus, which is the case for repeated primes, a direct S-R link can be formed for this stimulus. These direct S-R mappings can lead to the emergence of priming effects. However, for novel primes the formation of S-R mappings cannot be established and no priming effects are expected (see also Abrams & Greenwald, 2000).

However, several studies did obtain RCEs for novel primes, and, therefore, contradicted Damian's S-R account (e.g., Naccache & Dehaene, 2001). Still, Kunde, Kiesel, and Hoffmann (2003) proposed an alternative nonsemantic hypothesis that could explain why novel subliminal primes can elicit priming effects. According to their account, subjects will prepare action triggers for the stimuli they might receive in the experiment during the task instructions. These action triggers create automatic associations between all expected stimuli and their appropriate responses. This can also be managed for novel primes: When novel primes were included in the prepared action trigger set, they can automatically trigger the adequate response, and evoke priming effects without the need to be semantically processed. Kunde et al. (2003) showed that priming effects are indeed observed for the prepared set of stimuli, even when novel primes were used. However, when the primes fell outside the expected stimulus range or when they were presented in an unexpected format, no priming was observed.

The formation of action triggers also seems intuitively limited by the number of stimuli and the size of the stimulus category (Kouider & Dehaene, 2007). It seems unlikely that subjects are able to form action triggers for all possible members of a large category such as animals. Still, recent findings showed that novel primes from large categories and large target sets can elicit priming effects (e.g., Kiesel, Kunde, Pohl, & Hoffmann, 2006; Klauer, Eder, Greenwald, & Abrams, 2007). To further clarify how category size influences priming effects, we conducted a study manipulating this factor (Van den Bussche & Reynvoet, 2007). We found significant priming for novel primes independent of category size, which has important theoretical implications, since it cannot be explained by the nonsemantic accounts and, thus, provides strong evidence for semantic processing of subliminal primes.

However, two issues cast doubt on the conclusions of our previous study. First, according to Kiesel et al. (2006), action triggers can be formed not only for individual to be expected stimuli, but also for to be expected semantic categories. Thus, if many targets from broad categories are

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presented (e.g., animals and objects), subjects are thought to form an action trigger for the categories instead of for their individual elements. This would mean that the nonsemantic action-trigger account might offer an alternative explanation for our observed priming effects for large categories and target sets (Van den Bussche & Reynvoet, 2007). A second issue was raised by Abrams (2008). He proposed the possibility that our observed priming effects did not stem from semantic prime processing, but from subword processing of the primes, especially in our Experiment 1c, where a small target set was used, and maybe, although rather unlikely, also in our Experiments 2 and 3, where large target sets were used. Indeed, substantial orthographic overlap between primes and targets was present in our study. For example, the prime "vlieg" (fly) shared two adjacent letters with the target "vlo" (flea). This orthographic overlap may have caused priming effects based on subword processing rather than on semantic processing of the primes (Abrams, 2008). Abrams himself manipulated the amount of orthographic overlap between primes and targets and only found priming when much orthographic overlap was present, indicating that priming was mainly driven by subword processing. If this kind of subword reactivation underlies our priming effects, then our previous study (Van den Bussche & Reynvoet, 2007) cannot be seen as a supporting evidence for semantic processing of subliminal primes.

Therefore, the first aim of this study was to replicate our previous finding (Van den Bussche & Reynvoet, 2007) of significant priming for novel primes from a large category, but additionally to avoid both issues mentioned above. The action-trigger account of Kunde et al. (2003) predicts that subjects will only be able to form action triggers for expected stimuli. If the (expected) format of the targets differs from the (not expected) format of the primes, no action triggers will be formed for these primes and consequently they will be unable to elicit priming. Thus, by presenting primes and targets in different formats, we exclude the formation of action triggers as an explanation for observed priming effects. Furthermore, using different prime and target formats also eliminates orthographic overlap between primes and targets, which excludes subword processing as a possible explanation for observed priming effects. To achieve this, we presented pictures as primes and words as targets. Only one study has used this methodology so far: Dell'Acqua and Grainger (1999) asked subjects to categorize target words that were preceded by subliminal picture primes. They found significant priming, even though the primes were presented in an unexpected format and a large category and target set were used. Kouider and Dehaene (2007) remark that, to date, this is the only study that provides clear-cut evidence for truly semantic subliminal processing. Therefore, our experiment aimed to replicate the findings of Dell'Acqua and Grainger (1999): Is significant priming observed when all nonsemantic effects are excluded? If so, this will strengthen the claim that primes can be truly semantically processed, since all other nonsemantic explanations are eliminated: Observing subliminal priming for novel primes and large target sets cannot be explained by Damian's S-R account; observing subliminal priming for unexpected primes cannot be explained by Kunde et al.'s action trigger-account; observing subliminal priming for primes that do not overlap with the targets cannot be explained by Abrams's subword processing account. If, however, we do not observe priming under these conditions, this would cast doubt on the semantic nature of the priming effects observed in our original study and it would indicate that nonsemantic effects probably were an important confounder there.

Our second aim was to examine whether creating a context that stimulates nonsemantic processing has an impact on priming. By manipulating the number of targets presented to the subjects (i.e., target set size), we created a condition where semantic priming was encouraged (large target set) and a condition where nonsemantic priming was encouraged (small target set). When subjects receive a small target set, it is likely that each target possesses a unique feature (e.g., first letter and adjacent vowels). As a consequence, focusing on certain subword elements might be sufficient for the subjects to correctly categorize the targets, making a semantic analysis redundant. Furthermore, a limited number of targets can be easily stored in working memory and automatically recalled from it during the task, directly linking the targets to their response without the need to semantically process them (Roelofs, 2001). We can assume that when the target processing does not require accessing semantics, the primes will also not be semantically processed. When this is the case, we would expect no priming effects. Contrarily, when a large target set is presented, subjects can no longer rely on unique target features or working memory to categorize them and a semantic analysis becomes indispensable. If targets need to be processed semantically to be classified, then this implies that a similar semantic strategy will be adopted for the primes, which in turn now have the potential to influence target categorization and evoke priming effects. Kiesel et al. (2006) have already provided proof for the differential impact of semantic and nonsemantic effects on priming: They only obtained priming effects for novel primes from a large category when a large target set was used. When the subjects had to judge a small target set, no priming effects emerged. Kiesel et al. (2006) provided two possible explanations for this discrepancy. First, if the target set is large, subjects form nonsemantic action triggers for categories leading to the preactivation of many potential stimuli; whereas when the target set is small, subjects form these action triggers for individual stimuli and preactivate only a few stimuli which decreases the chance that the primes were also preactivated and, thus, the likelihood of obtaining priming. Second, when a small target set is used, the subjects can rely on nonsemantic S-R mappings to fulfil the task, causing the primes to lose their ability to elicit priming. This nonsemantic strategy is impossible for large target sets, where a semantic analysis is needed to perform the task. In our design the former explanation is excluded, since the formation of action triggers is prohibited by the different prime and target modalities. Thus, if we observe differential priming effects for small and large target sets, this would indicate that a context factor, such as target set size, can determine whether the stimuli will be nonsemantically or semantically processed.

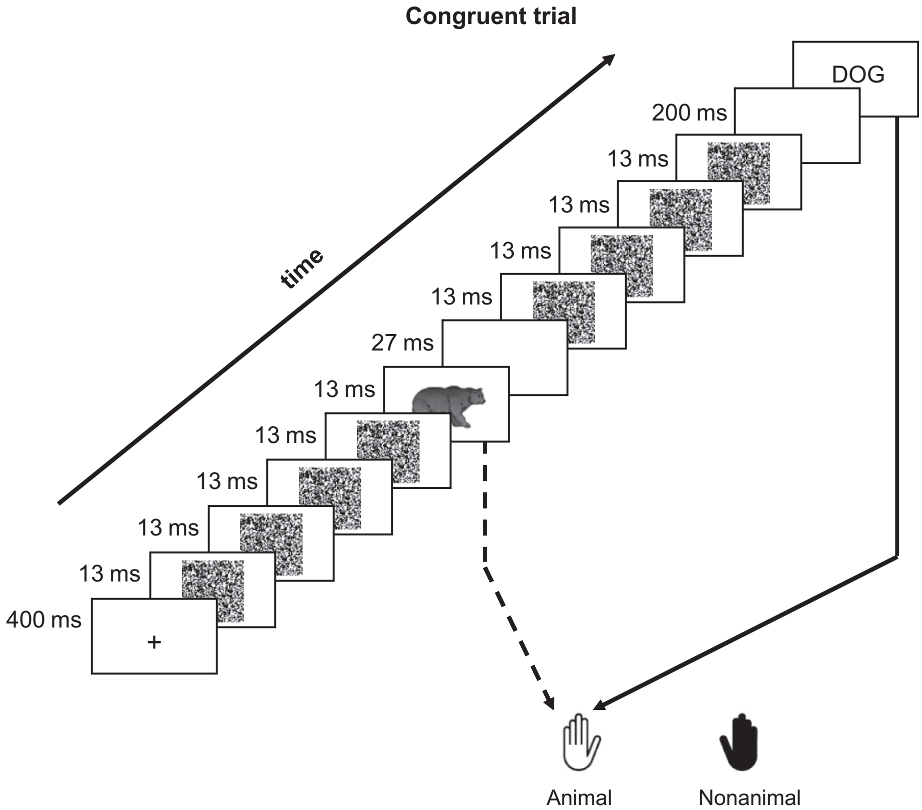

Figure 1. Example of a congruent trial.

Method

Participants

Twenty-three psychology students participated as partial fulfilment of a course requirement. Two subjects were omitted because they were substantially (+3 *SD*) slower. The final sample existed of 21 subjects (20 female, mean age = 18.2).

Procedure

Figure 1 depicts the sequence of a trial. First, a fixation cross (+) was shown for 400 ms, followed by a forward mask existing of four different random dot patterns with a total duration of 53 ms (4 × 13.3 ms). These random dot patterns, 8.5 cm in width and 8.5 cm in height, were constructed such that 4 × 4 pixels were always chosen randomly to be white or black. Following the mask, a picture prime was presented for 13 ms. The dimensions of the picture stimuli ranged from 2 to 5.5 cm in width and 2 to 5.5 cm in height. After the prime, a blank screen was presented for 27 ms to increase the probability to obtain central instead of energy masking of the prime (see Dell'Acqua & Grainger, 1999). The blank was followed by a backward mask, existing of four different random dot patterns for 53 ms. A blank of 200 ms followed the mask to obtain a prime-target stimulus onset asynchrony of 290 ms. Finally, the target was presented until the participants' response was registered. All targets, ranging from 1.5 to 4.3 cm in width and 0.7 cm in height, were presented as black capital letters on a white background. The inter-trial interval was 1,000 ms. All presentations were synchronized with the vertical refresh cycle of the screen (13.3 ms). Participants were told that they would see words that needed to be classified as animals or nonanimals. Response assignment was varied across participants. Participants were instructed to respond as quickly as possible and to avoid mistakes.

Stimuli

The picture primes consisted of line drawings of 25 objects and 25 animals taken from the greyscale shaded images set of the "Snodgrass and Vanderwart-like" objects[1] (Rossion & Pourtois, 2004). Target words were composed of the names of the picture stimuli and consisted of three to six

[1] See http://titan.cog.brown.edu:8080/TarrLab/stimuli/objects/svlo.zip/view.

Table 1. Median RTs (*SD*) and mean percent error rates (*SD*) as a function of target set size, nature of targets and congruency and the differences (RCEs) between congruent and incongruent trials

		Congruent	Incongruent	Difference
Large target set	Animal targets	505 (32.9)	514 (42.3)	9*
		4.6 (4.6)	4.4 (5.2)	–0.2
	Nonanimal targets	521 (34.1)	529 (40.0)	8*
		4.0 (3.5)	5.1 (3.9)	1.1
Small target set	Animal targets	479 (40.9)	479 (33.4)	0
		4.3 (4.1)	4.4 (3.4)	0.1
	Nonanimal targets	495 (36.7)	496 (32.9)	1
		4.3 (3.5)	5.6 (5.8)	1.3

*$p < .05$.

letters. Three factors were manipulated within subjects: (1) *Target set size*: Subjects received a large target set block and a small target set block. In the large target set condition, the subjects received 50 word targets (25 objects and 25 animals, log frequencies ranging from 0.70 to 2.59) and in the small target set condition they received four word targets (two objects and two animals, log frequencies ranging from 1.36 to 1.86). (2) *Nature of the targets*: On half of the trials the subjects received an animal target and on the other half a nonanimal target. (3) *Priming condition*: In the large target set condition each target was presented in a "congruent" condition, that is, preceded by the picture of a concept belonging to the same semantic category (e.g., the word DOG preceded by the picture of a bear) and in an "incongruent" condition, that is, preceded by the picture of a concept belonging to the opposite semantic category (e.g., the word DOG preceded by the picture of a clock). This led to 100 trials that were presented twice. In the small target set condition each of the four targets was combined with each of the 50 picture primes. This led to 200 trials (100 congruent and 100 incongruent) that were presented once. The order in which the subjects received the large and small target set conditions was varied across participants.

Prime Visibility

Prime visibility was assessed using an objective visibility test. After the experiment, participants were informed about the presence of the primes and were asked to participate in a posttest, where they received the same trials, but the targets were replaced by a string of six "X"s. The 50 picture primes were presented twice and the participants were instructed to apply the same instructions as before, but now to the picture primes. If they were unable to categorize the primes, they were forced to guess.

Results

RT and Error Analyses

Median RTs from correct responses and mean error rates were submitted to a repeated measures analysis with target set size (small or large), nature of targets (animals or nonanimals)[2] and congruency (congruent or incongruent) as within-subject factors. Median RTs and mean error rates as a function of these factors are reported in Table 1. Inaccurate responses (on average 4.4%) were discarded for the RT analyses. A main effect of the nature of targets was observed ($F(1, 20) = 6.22$, $p = .02$), with animal targets responded to 16 ms faster than nonanimal targets. A significant effect of target set size also emerged ($F(1, 20) = 23.55$, $p < .001$): Subjects responded 30 ms faster to the small target set compared to the large target set trials. The main effect of congruency was marginally significant ($F(1, 20) = 3.92$, $p = .06$): Congruent trials were responded to 5 ms faster than incongruent trials. Target set size and congruency significantly interacted with each other ($F(1, 20) = 5.62$, $p = .03$). The congruency effect was significant for the large target set (9 ms, $t(20) = 3.96$, $p = .001$), but not for the small target set (1 ms, $t(20) = 0.48$, $p = .63$). We also note that when entering the order of presentation of the small and large target sets as a between-subjects factor in the analysis, this factor did not reach significance ($F(1, 19) = 0.73$, $p = .40$), indicating that whether subjects first received the small target set or the large target set had no effect on the obtained results. The same repeated measures analysis performed on error rates revealed no significant effects.

One could argue that the lack of priming for the small target set is due to the generally faster RTs in that condition. To explore this possibility, we conducted a distribution analysis for the RTs. If semantic priming needs time to develop, one would expect to observe priming effects for longer RTs.

2 Nature of targets was included as a within-subjects factor in line with our previous study (Van den Bussche & Reynvoet, 2007; see also Forster, Mohan, & Hector, 2003). As explained by Van den Bussche and Reynvoet (2007), the category search model proposed by Forster (2004) predicts that for stimuli from a large category, exemplar (i.e., animal) primes might interfere with the decision on nonexemplar (i.e., nonanimal) targets, leading to occasional small priming effects for these nonexemplar targets. However, nonexemplar primes will never be able to interfere with exemplar targets leading to no priming effects for exemplar targets. Therefore, including the nature of targets in the analysis allows us to investigate whether a priming effect is obtained not only for nonexemplar targets, but also for exemplar targets, which would eliminate the account proposed by Forster as an alternative explanation of our obtained results.

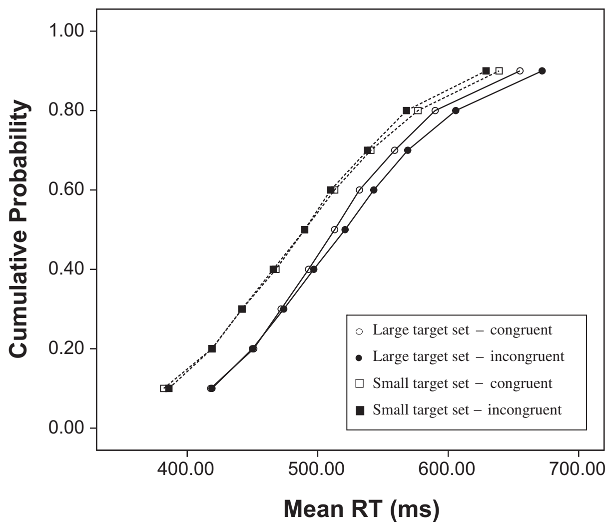

Figure 2. Cumulative density functions for congruent and incongruent trials for the large and small target sets.

Figure 2 shows that this is not confirmed: Even for long RTs, no priming effect emerges for the small target set. Thus, the absence of semantic priming in the small target set was not caused by the fact that participants responded too fast.

Prime Visibility

Analyses of the posttest revealed that participants, on average, could only classify 48% of the primes correctly, which indicates that primes could not be classified above chance. A direct measure of prime visibility (d') was calculated for each subject. The measures are obtained by treating one level of the response category (i.e., animal) as signal and the other level (i.e., nonanimal) as noise. The overall mean d' value was -0.10. A t test against the null mean indicated that this d' value was not significantly different from 0, $t(20) = -2.06$, $p = .053$, indicating that the unconscious nature of the primes was guaranteed. Using linear regression, a nonsignificant correlation was found between the d' measure and the index for the amount of priming for the large target set ($r = -.17$, $F(1, 19) = 0.56$, $p = .46$). Crucially, the regression analysis showed that the priming index at the $d' = 0$ intercept was significant for the large target set (intercept = 8.5 ms, $t(20) = 3.24$, $p = .004$), demonstrating that the significant priming we observed was independent of prime visibility.

Discussion

Van den Bussche and Reynvoet (2007) argued that since significant priming was observed for novel primes from a large category, subliminal primes can be processed semantically. However, the presence of nonsemantic effects might have confounded this previous study. Therefore, the first aim of this study was to validate our claim using a more stringent design where nonsemantic effects were eliminated. Our second aim was to examine the influence of target set size on priming effects. We found significant priming using subliminal picture primes, but only when using a large target set. When a small target set was presented, no priming effect emerged.

These findings have important theoretical implications. The observation that significant priming can be observed for novel primes from a large category and a large target set when primes are presented in an unexpected modality is not in line with any of the nonsemantic accounts. The only theory able to explain this finding is a semantic account which claims that subliminal primes are semantically processed (Dehaene et al., 1998). Thus, this experiment strengthens our previous claim (Van den Bussche & Reynvoet, 2007): Subliminal information can be genuinely semantically processed.

However, such a semantic account as proposed by Dehaene et al. (1998) would predict that when subliminal primes are processed semantically, they should always have the ability to influence the target processing. Still, we did not obtain a priming effect using a small target set, which is in line with the observations of Kiesel et al. (2006). As argued above, the absence of priming for a small target set could be due to the fact that a limited amount of targets can be stored in working memory with their adequate responses, which can then be directly recalled from memory or to the fact that each target possesses unique target characteristics and focusing attention on these lower-level features is sufficient to trigger the correct response. Either way, subjects will quickly comprehend that a nonsemantic analysis of the targets is sufficient to categorize them without the need of semantically processing them. This indicates that a context factor, such as target set size, is able to determine whether the stimuli are processed semantically or nonsemantically.

Our pattern of results cannot be explained by the reigning accounts on subliminal processing without assuming additional modifications. Therefore, we proposed a new context-dependent processing account (Van den Bussche & Reynvoet, in press). The crucial assumption of our account is that subliminal priming can be influenced both by nonsemantic and semantic effects and that whether a subliminal priming effect will be based primarily on nonsemantic or semantic processing will be determined by the context. The findings of this study can be explained by this account as well: The task context will direct the subjects' attention to a certain processing level and will determine whether the stimuli will be semantically or nonsemantically processed. A small target set will stimulate a nonsemantic processing strategy: Paying attention to certain lower features (letters, bigrams, etc.) is sufficient to fulfil the task. Once a semantic or nonsemantic strategy has been selected to perform the task on the targets, a similar kind of strategy (semantic or nonsemantic) will also be adopted for the processing of the primes. Thus, for a small target set the primes will only be processed nonsemantically. A large target set will encourage subjects to use a semantic strategy to process the stimuli since paying attention to lower feature levels will no longer suffice to classify the targets. Again, the primes will be submitted to a similar semantic processing strategy, and will therefore be able to elicit priming.

Although our results contradict the asemantic action-trigger account, it could be that action triggers should, under certain circumstances, be considered as less asemantic and less modality-specific as previously assumed. For example, Kiesel et al. (2006) suggested that action triggers can be formed not only for individual to-be-expected stimuli, but also for to-be-expected semantic categories such as animals. If many targets from a broad category are presented, the preparatory activation induced by the action trigger can include an object category. However, if action triggers are developed at a more amodal, category level, they can only be semantic in nature. If the preparatory activation based on the action triggers includes a semantic category, then a subliminal prime should at least activate its category before the action trigger can be formed. This is certainly a form of semantic processing and using this semantic action-trigger account to alternatively explain these results would ultimately lead to the same conclusion: Subliminal information can be genuinely semantically processed.

We note that the observed priming effects were rather small. This is probably due to the very stringent methodology: The picture primes were only presented for 13 ms and were severely masked. The observed priming effects in our previous study (Van den Bussche & Reynvoet, 2007) were more prominent. Less severe masking could explain these larger priming effects. Our very short prime duration and severe masking technique could also explain why our observed priming effects were smaller than those observed by Dell'Acqua and Grainger (1999) who presented primes for 17 ms and used different masks.

In addition, the discrepancy between the priming effects observed in this study and our previous study could indicate that S-R effects influenced our previous study: In line with the suggestion of Abrams (2008), the presence of substantial orthographic overlap between primes and targets in our previous study (e.g., vlieg-vlo) may have caused priming effects based on subword processing rather than on semantic analysis of the primes, which might have boosted the observed effects. Eliminating the influence of such S-R effects (as was the case in this study) might lead to a decrease in observed priming. In any case, it becomes clear that researchers should avoid orthographic overlap between primes and targets when designing subliminal priming studies.

We can conclude that even when all nonsemantic effects are eliminated, significant subliminal priming can be observed. This observation cannot be explained by the nonsemantic accounts of subliminal processing and provides strong evidence in favour of the fact that subliminal primes can be genuinely semantically processed. However, when the context encourages nonsemantic stimulus processing (e.g., by presenting a small target set) this can have a severe impact on the priming effects.

References

Abrams, R. L. (2008). Orthographic overlap and category size in unconscious category priming: Comment on Van den Bussche and Reynvoet's (2007) experiment 1c. *Experimental Psychology, 55*, 350–357.

Abrams, R. L., & Greenwald, A. G. (2000). Parts outweigh the whole (word) in unconscious analysis of meaning. *Psychological Science, 11*, 118–124.

Damian, M. F. (2001). Congruity effects evoked by subliminally presented primes: Automaticity rather than semantic processing. *Journal of Experimental Psychology: Human Perception and Performance, 27*, 154–165.

Dehaene, S., Naccache, L., Le Clec'H, G., Koechlin, E., Mueller, M., Dehaene-Lambertz, G., et al. (1998). Imaging unconscious semantic priming. *Nature, 395*, 597–600.

Dell'Acqua, R., & Grainger, J. (1999). Unconscious semantic priming from pictures. *Cognition, 73*, 1–15.

Forster, K. I. (2004). Category size effects revisited: Frequency and masked priming effects in semantic categorization. *Brain and Language, 90*, 276–286.

Forster, K. I., Mohan, K., & Hector, J. (2003). The mechanics of masked priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 3–37). New York: Psychology Press.

Kiesel, A., Kunde, W., Pohl, C., & Hoffmann, J. (2006). Priming from novel masked stimuli depends on target set size. *Advances in Cognitive Psychology, 2*, 37–45.

Klauer, C. K., Eder, A. B., Greenwald, A. G., & Abrams, R. L. (2007). Priming of semantic classifications by novel subliminal prime words. *Consciousness and Cognition, 16*, 63–83.

Kouider, S., & Dehaene, S. (2007). Levels of processing during nonconscious perception: A critical review of visual masking. *Philosophical Transactions of the Royal Society B, 362*, 857–875.

Kunde, W., Kiesel, A., & Hoffmann, J. (2003). Conscious control over the content of unconscious cognition. *Cognition, 88*, 223–242.

Naccache, L., & Dehaene, S. (2001). Unconscious semantic priming extends to novel unseen stimuli. *Cognition, 80*, 223–237.

Roelofs, A. (2001). Set size and repetition matter: Comment on Caramazza and Costa (2000). *Cognition, 80*, 291–298.

Rossion, B., & Pourtois, G. (2004). Revisiting Snodgrass and Vanderwart's object set: The role of surface detail in basic-level object recognition. *Perception, 33*, 217–236.

Van den Bussche, E., & Reynvoet, B. (2007). Masked priming effects in semantic categorization are independent of category size. *Experimental Psychology, 54*, 225–235.

Van den Bussche, E., & Reynvoet, B. (in press). The mechanisms of masked priming: A state of the art. In E. B. Hartonek (Ed.), *Experimental psychology research trends*. New York: Nova Science.

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