A ROLE FOR PARTIAL AWARENESS IN THE MODULATION OF SEMANTIC PRIMING EFFECTS

by

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TABLE OF CONTENTS

LIST OF FIGURES 4
LIST OF TABLES...5
ABSTRACT...6
INTRODUCTION 7
Background...7
An Empirical Semantics Approach ……..9
EXPERIMENT 1 14
Method...*15*
Participants...*15*
Materials and Design...*15*
Procedure..*16*
Results..*17*
Results- High Perceptual Awareness Group (HPA) *21*
Results- High Perceptual Awareness Group (HPA) *22*
Discussion..*24*
EXPERIMENT 2 26
Method...*30*
Participants...*30*
Materials and Design...*30*
Procedure..*31*
Results..*31*
Results- High Perceptual Awareness Group (HPA) *33*
Results- High Perceptual Awareness Group (HPA) *34*
Discussion..*35*
GENERAL DISCUSSION 38
REFERENCES 42

LIST OF FIGURES

Figure 1. E-Detection versus Repetition Priming for all participants in Experiment 1 ……………………..………………………………………….…………………21

Figure 2. E-Detection versus Associate Priming for all participants in Experiment 1 ……………………..………………………………………….…………………21

Figure 3. E-Detection versus Antonym Priming for all participants in Experiment 1 ……………………..………………………………………….…………………21

Figure 4. E-Detection versus Synonym Priming for all participants in Experiment 1 ……………………..………………………………………….…………………21

Figure 5. HPA and LPA Reaction times in Experiment 1 …………………………24

Figure 6. E-Detection versus Repetition Priming for all participants in Experiment 1 ……………………..………………………………………….…………………32

Figure 7. E-Detection versus Associate Priming for all participants in Experiment 1 ……………………..………………………………………….…………………32

Figure 8. E-Detection versus Antonym Priming for all participants in Experiment 1 ……………………..………………………………………….…………………33

Figure 9. E-Detection versus Synonym Priming for all participants in Experiment 1 ……………………..………………………………………….…………………33

Figure 10. HPA and LPA Reaction times in Experiment 2 …………….…………35

LIST OF TABLES

Table 1. Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type at 50 ms SOAs .………………….…….. 18

Table 2. Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type for High Perceptual Awareness participants at 50 ms SOAs ………………………………..………………..…… 22

Table 3. Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type for Low Perceptual Awareness participants at 50 ms SOAs ……………………………………….………...….…23

Table 4. Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type at 70 ms SOAs …………………..…...31

Table 5. Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type for High Perceptual Awareness participants at 70 ms SOAs ..……………………………………..…………….……34

Table 6. Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type for Low Perceptual Awareness participants at 70 ms SOAs ………………….…………………….………………...35

ABSTRACT

The present study sought to investigate the extent to which masked semantic priming is an automatic process and whether its effects vary depending upon the type of stimuli used. Recent studies have shown that there is a differential priming effect for prime-target pairs with different types of semantic relationships. Here, using a semantic categorization task with masked priming, we compared the effects of synonym, antonym, and associatively related non-exemplar prime-target pairs when presented at different stimulus onset asynchronies (SOAs). Participants took a prime visibility posttest in conjunction with the categorization task which served as a measure of "partial awareness" of the prime. The results here indicate that differences in perceptual awareness may produce differential semantic priming patterns across the semantic relationships and SOAs considered. Potential mechanisms for this divergence are proposed.

INTRODUCTION

Background

The semantic priming effect, first demonstrated by Meyer and Schvaneveldt (1971), has been studied extensively in the field of language processing. Here, the prior presentation of a semantically related prime word facilitates faster responses to a given target word in a recognition task when compared to the facilitative effects of a prime that is unrelated to that target. For example, reactions times to the word DOCTOR may be faster when it is preceded by the related prime *nurse* than when it is preceded by the unrelated prime *clock*. The extent to which this effect might be influenced by different types of prime-target relationships under varying conditions, however, has not been fully determined.

There is a growing amount of experimental evidence in support of the claim that priming effects might not simply be the result of automatic language processing. Rather, these effects may in part be dependent upon the attention that a particular task or context focuses on the lexical information in question. In a 1984 study, Seidenberg, Waters, Sanders, and Langer sought to investigate this issue. Specifically, they evaluated differences in the types of "contextual effects" occurring in lexical decision versus naming tasks. The contextual effects they considered included symmetrical-associative (e.g. "spider-web"), backward-associative (e.g. "fly-fruit"), nonassociated-semantic (e.g. "bread-cake"), and grammatical primes (e.g. "whose-planet") as well as changes in the proportion of related items (i.e. high versus low). The tasks were chosen on the basis of preexisting evidence that lexical decision tasks, as opposed to naming tasks, allow for post-lexical judgment effects due to their innate status as signal detection tasks. They found that symmetrical-associative and semantic priming occurred across tasks, while the other contextual effects only produced facilitation during lexical decision. Seidenberg et al. argued that this was due to automatic word decoding effects on the part of symmetrical-associations and semantic relationships *within* the mental lexicon (via spreading activation) as opposed to post-recognition processing which was said to account for the remaining context effects. This demonstrates that lexical priming can be affected both by automatic processes and by post-lexical *strategic* processes.

Seidenberg et al. did not observe task specific effects for semantic primes. There is, however, a growing amount of support for the claim that *semantic* priming effects might also be affected by strategic influences. One source of evidence comes from a 1994 study by Smith, Besner, and Miyoshi. Here, the authors used a lexical decision task to investigate the extent to which semantic priming is automatic. They compared the size of the semantic priming effect between “blocked” conditions in which all primes were presented at either uniformly brief (84 ms) or uniformly long (280 ms) prime durations with a “mixed” condition in which participants were exposed to a mixture of both prime durations throughout the experiment. They found larger semantic priming effects in each of the blocked conditions, but only minimal priming for short duration primes in the mixed condition. Smith et al (1994) subsequently argued that it was the context of prime exposure that modulated the semantic priming effect during this word-level analysis.

Further evidence for contextual influence in semantic priming comes from Vriezen, Moscovitch, and Bellos (1995). They published the results of six experiments that examined the differential effects of perceptual, form-based processing versus semantic, concept-based processing in a variety of tasks using repeated stimuli. They found that priming was best when the same word was evaluated using the same type of semantic classification task successively and that priming was absent when the same word was evaluated using different classification tasks (e.g. whether the order of the evaluation made in task 1 and 2 for a word was "man-made"-"man-made" or "size estimation"-"man-made"). Vreizen et al (1995) also found that there was priming if the same word was first processed in a more semantically oriented task (e.g. semantic classification) and then followed by a more "word form" oriented task like lexical decision or naming. They found no priming if the order of tasks was reversed so that the priming situation only involved word form-level decisions. Together, these outcomes prompted the authors to conclude that priming is the result of an overlap in the processes involved in the priming situation and the test situation. Thus, it appears, semantic priming may be dependent on the specific nature of the task being employed rather than merely being the result of simple exposure to a stimulus.

An Empirical Semantics Approach

Given that semantic priming may depend on the type of information that the participant is required to focus on by the task, it is not surprising that there is evidence that different types of semantic information show differential priming effects within a given experimental situation. Using auditory and visual lexical decision tasks with (unmasked) semantic priming, Moss, Ostrin, Tyler, and Marslen-Wilson sought to investigate differences between priming conditions that involved separate types of semantic relationships (1995). In particular, they compared category membership (e.g. pig-horse) and functional relationships including instrumental relationships (e.g. broom-floor) and script/schema relationships (e.g. restaurant-wine). The authors found a dissociation between the effects seen in the two versions of stimulus presentation. When presented in the auditory modality, there was significant priming for each type of semantic relationship independent of the associative relationship between the prime-target pairs, though high associative strength augmented the priming effect in each case. When presented visually, there was a disparity between the results across semantic relationships. Instrumental relationships still produced priming independent of associative status. The effects of category coordinates, however, were only seen in the presence of associative strength between the items. Script relationships failed to produce any priming, either with or without associative strength, when using the visual modality. Moss et al. argue that these results indicate that semantic priming occurs automatically in the case of auditory presentation, but semantic *and* associative priming are contingent upon the type of semantic relationships considered when evaluating the visual domain. It appears then, that empirical data supports the notion that different types of semantic information have diverse profiles with respect to their effects on cognitive processing.

In a 2002 study, Bueno and Frenck-Mestre compared the effects of prime-target relationship in a semantic categorization task. Using the broad category ‘concrete versus abstract’, the authors compared the priming effects for prime-target pairs that were synonyms (e.g. boat-ship), first-order associates (e.g. boat-sea), or unrelated (e.g. boat-milk) at different prime durations (43, 57, and 71 ms). They found a fairly consistent priming effect for synonym pairs across all three prime durations. First-order associates, however, showed a linear increase in priming effect with relatively small effects at 43 ms and synonym-like effects at 71 ms. The authors argue that these results stem from the fact that synonyms are "semantically closer" than associate pairs with respect to their frequencies of co-occurrence. One might also account for the observed differences by considering the nature of the underlying representations of these semantic relationships and how they might be differentially accessed. In either case, it seems clear that appealing to task/context alone may be insufficient with respect to accounting for the full range of the semantic categorization effect.

In this study, we sought to further investigate the extent to which various types of semantic information might "automatically" generate semantic priming effects in semantic categorization tasks. The evidence for task-specific semantic effects cited above suggests that semantic priming may be determined, at least in part, by the types of decision making processes that are employed in one task versus another. For instance, under a feature monitoring account, a participant's response in a semantic categorization task may involve responding YES if a word activates a particular feature (e.g. 'animal' or 'tool') and responding NO if no such feature is detected within a certain amount of time. This potential decision bias could then naturally yield task-specific semantic priming effects for exemplars in a semantic categorization task that would depend on the features that are relevant for a particular category. It is not clear that these priming effects would extend to non-exemplar trials. If, however, there is an automatic component to semantic priming, then the presence of related features between primes and targets could be enough to elicit a priming effect irrespective of whether the prime-target pairs contained exemplars or non-exemplars simply by virtue of the fact that the task forces one to focus on semantic level information. Previous experiments have reported results that collapse over YES and No responses thus precluding one from being able to distinguish between exemplar and non-exemplar cases (Meyer and Schvaneveldt, 1971; Vreizen et al, 1995; Bueno & Frenck-Mestre, 2002). Consequently, the first aim of this experiment is to explore the types of semantic priming effects that can be obtained within non-exemplar conditions.

In her 2005 dissertation, J. Hector conducted a semantic categorization experiment using the category “Animals”. Here, she observed semantic priming effects for non-exemplars. Her items, however, did not distinguish between prime-target pairs that had an associative versus antonymic relationship. Smith et al. (1994) collapsed over associative and antonym word pairs in their analysis as well. There may be good reasons to separate associative and antonymic word pairs. In particular, unlike bare associates, antonyms may be marked by the presence of “distinguishing features”. Evidence in support of the existence of such distinguishing features comes from a 1997 study of Alzheimer’s patients by Gonnerman, Andersen, Devlin, Kempler, and Seidenberg. Here, they evaluated the category specific impairments (i.e. natural kinds versus artifacts) of these patients possessing localized versus “patchy”, widespread damage using both cross-sectional and longitudinal research designs. When modeling the results of patient performance on various tasks, the authors argue that the specific progression of deficits seen across the different types of impairment is best accounted for when semantic organization schemes include “intercorrelations” between distinguishing features used to discriminate between category members. These intercorrelations may perform the same or similar function as association strength does in the psycholinguistic literature. Further, most lexical semantic descriptions of antonyms include some notion of distinguishing features (see Cruse, 1986, p. 246-252 and Saeed, 2003, p. 66-67 for further discussion). Note, that if antonyms are lexically marked by the presence of a distinguishing feature (e.g. +/- hot), this might make them particularly eligible for eliciting semantic priming even in non-exemplar cases due to the automatic activation of these distinguishing features.

Following the Hector dissertation and the work by Bueno & Frenck-Mestre, we sought to examine the potential differences in semantic priming for synonym, antonym, and associate non-exemplar prime-target relationships. If the nature of the semantic categorization task focuses attention on semantic information in general, one should “automatically” get semantic priming in non-exemplar cases and the effects may vary depending on the nature of the semantic relationship between the prime and target.

EXPERIMENT 1

This experiment was designed to determine if one can obtain masked semantic priming effects for non-exemplar items in a semantic categorization task and to assess if these effects vary as a function of semantic relationship type. This task was chosen because some have argued that it serves to "'filter' out category-irrelevant senses from the decision making process" (Finkbeiner, Forster, Nicol, and Nakamura, 2004)). If this assumption is correct, then any effects observed with non-exemplar prime-target pairings should be the result of non-strategic, automatic semantic processing. This is particularly advantageous because focusing on non-exemplars enables one to look at semantic relationships that would otherwise be unavailable for exemplar pairs due to constraints imposed by the categories being used in during the task. In contrast to the work done by Bueno and Frenck-Mestre (2002), small, natural (i.e. non-ad hoc categories like "farm animals" as opposed to "abstract entities") were used here due to evidence that when small categories are used non-exemplars do not show frequency effects (Forster, 2004). Following the semantic categorization task, participants took a prime visibility posttest known as an E-detection task (Finkbeiner et al., 2004). Verification tasks such as these are often used in the field as a measure of "partial awareness" in order to assess the efficacy of the masking procedure (Kouider & Dupoux, 2004).

Based on the results seen in the Bueno and Frenck-Mestre study and the fact that synonyms share a high (and essentially equivalent) degree of feature overlap, it was hypothesized that synonyms would outperform bare associates at 50 ms, a relatively short SOA. Further, given the similarly high degree of feature overlap and presence of distinguishing features present in antonyms, it was hypothesized that they would produce equal or perhaps even superior priming as that observed for synonym prime-target pairings.

Method

Participants

A total of 31 undergraduate students enrolled in an introductory Psychology course at the University of Arizona participated in the experiment. One participant was excluded from the analysis due to excessive errors (> 21%). Participants received course credit for their participation.

Materials and Design

The item set consisted of 192 target words divided equally between eight semantic categories: Wild Animals, Body Parts, Furniture, Fruits, Vegetables, Farm Animals, U.S. Cities, and Tools. For each category, twelve exemplar and twelve non-exemplar target words were selected. For each target word, two primes were selected. For exemplar targets, one prime was a “related” (repetition) prime which consisted of the same letter sequence as the target (e.g. *wolf-WOLF*). The other prime was a completely unrelated word of the same length as the target, e.g. *jazz-WOLF*. For non-exemplar targets, one prime was a semantically related prime and the other was an unrelated prime of the same length as the related prime for that target. There were three types of semantic prime-target relationships in each category (four of each, resulting in twelve total non-exemplars per category): Associative Antonym pairs (e.g. *fast-SLOW*), Associative

Synonym pairs (e.g. *ship-BOAT*), and Associate pairs in which there was at least one 0.5 unidirectional strength of association between the words as determined by the Nelson Free Association Norms (e.g. *circle-SQUARE*). Unrelated primes for both exemplar and non-exemplar targets had low association frequencies relative to the related primes for their target word. Two counterbalanced materials lists were constructed. Each list contained the same targets, but the primes differed. A target that was preceded by a related prime in the first list was preceded by an unrelated prime in the second list and vice-versa.

Procedure

Testing took place in a sound attenuated room. Items were presented as black letters on a white background using a color monitor. Each trial began with a forward mask which consisted of a row of hash marks (########) that was presented for 500 ms. The forward mask was immediately followed by the prime which was presented in lower-case letters for 50 ms. The prime was then immediately followed by the target which was presented in upper-case letters. The target also acted as backward mask and was displayed for 500 ms. The combination of the forward and backward masks effectively blocked the conscious detection of the prime such that no participant reported being aware of it. The experiment was run on a Pentium PC using the Windows-based software, DMDX (Forster and Forster, 2003).

The task was semantic categorization. Each block of items constituted a different category. At the beginning of each block, the name of the category was presented followed by two items that were discarded as practice items. These practice items were then followed by twenty four trials consisting of twelve exemplar and twelve non-exemplar targets. Half of the trials were preceded by a related prime (repetition primes for exemplars and one of three types of semantic primes for non-exemplars) and half were preceded by an unrelated prime. For each participant, the order of both the category blocks and the non-practice items within each block were randomized. Participants were instructed to answer as quickly as possible without making excessive errors by pressing one of two buttons marked “Yes” and “No” according to whether or not the target was a member of the category in question. Feedback was provided after each trial which advised the participant of the speed and accuracy of their response. The participant controlled the pace of the experiment by pushing a foot pedal to initiate each block, but the test items within each block were presented with an inter-trial interval of approximately 500 ms.

An “E-detection” task was conducted at the end of each experiment in order to look at the effects of prime visibility on priming. Participants were informed about the presence of masked primes in the experiment they had just participated in. They were presented with a list of random words and non-words that were presented as prime-target pairs with a mixture of 50 and 150 ms prime durations. Their task was to focus on the prime and report whether or not it contained the letter “e” within the letter string.

Results

In this experiment, incorrect responses and outliers (responses that were above or below two SD from the mean of each participant) were discarded. This resulted in a loss of 4.6% of the data. The mean reaction times and error rates are presented in Table 1.

Two analyses of variance (ANOVA) were performed for each comparison of interest, one treating subjects as a random effect ($F1$), and the other treating items as a random effect ($F2$). Exemplar targets were evaluated separately from nonexemplar targets. For nonexemplar targets, the factors were Groups (subject groups in the subject analysis, and item groups in the item analysis), Semantic Relationship (associates vs. antonyms vs. synonyms for non-exemplars), and Prime Type (related vs. unrelated). The Groups factor was a non-repeated factor in both analyses and was included to remove variance due to the counterbalancing procedure. The Semantic Relationship and Prime Type factors were repeated measures in both analyses. Exemplar targets were evaluated using a similar analysis, with Groups and Prime Type serving as the only factors of interest. A p value of .05 or less was used to indicate a significant effect.

Table 1
Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type at 50 ms SOAs.

	Exemplars		**Non-Exemplars**							
Semantic	*Repetition*		Associates		Antonyms		Synonyms		*Overall*	
	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
Unrelated	527	8.2	575	8.6	545	3.6	569	7.6	563	6.6
Related	493	6.8	565	9.7	538	5.3	561	6.6	555	7.2
Priming	34	1.4	10	1.1	7	-1.7	8	1.0	8	-0.6

As expected, the subject analysis in the exemplar condition revealed a significant repetition priming effect for response times of 34 ms ($F1(1, 28) = 111.31$, $p < 0.001$) which was accompanied by a strong significant effect for exemplar response times in the item analysis as well ($F2(1, 94) = 80.60$, $p < 0.001$). Collapsing over all three types of semantic relatedness for non-exemplars revealed a significant overall semantic priming effect for response times of 8 ms in the subject analysis and a strong trend towards significance in the items analysis ($F1(1, 28) = 7.03$, $p < 0.02$; $F2(1, 90) = 3.81$, $p = 0.054$). None of the individual semantic relationships considered, however, reached significance by themselves with Associative primes yielding a slightly larger priming effect (10 ms) than the other two types ($F1(1, 28) = 2.55$, $p = 0.12$; $F2(1, 30) = 2.27$, $p = 0.14$). Antonym primes ($F1(1, 28) = 1.58$, $p = 0.22$; $F2(1, 30) < 1$, $p = 0.4$) and Synonym primes ($F1(1, 28) = 1.58$, $p = 0.22$; $F2(1, 30) = 1.25$, $p = 0.3$) yielded nearly identical effects with 7 ms and 8 ms response time priming effects, respectively.

Analysis of the error rates revealed no significant effects. The average accuracy rates for the E-detection task were 55% for word primes at 50 ms and 59.5% for non-word primes at 50 ms. Evaluation of the correlations between priming and E-detection performance yielded an interesting pattern of results (see Figures 1-4). Repetition priming was positively, though not significantly, correlated with E-detection accuracy, a measure of partial awareness ($r = 0.244$, $p > 0.05$). The pattern of correlations was varied, however, when considering the different types of semantic priming. Like repetition priming, associate priming was positively correlated with E-detection scores ($r = 0.237$, $p > 0.05$). In contrast, antonym priming was negatively correlated with E-detection ($r = -0.209$, $p > 0.05$). Further, synonym priming didn't seem to correlate with E-detection scores at all ($r = -0.037$, $p > 0.05$). These results indicate that partial awareness may be interacting with semantic information processing in ways that modulate priming effects. Note, however, that none of these correlations were significant.

Post hoc analyses were conducted to investigate these dissociations further. Participant data was divided into two groups on the basis of their performance on the E-detection task using the binomial distribution in order to determine better than chance performance. Those obtaining 60% accuracy or better on the task were combined into the High Perceptual Awareness[1] group (N=10) while those scoring below 60% were combined into a separate Low Perceptual Awareness group (N=20).

[1] For these purposes, "perceptual awareness" refers to the participants' ability to detect visual information about the prime. See Ortells, Vellido, Daza, and Nogura (2006) for further discussion about the various terminologies used to refer to this non-conscious cognitive capacity.

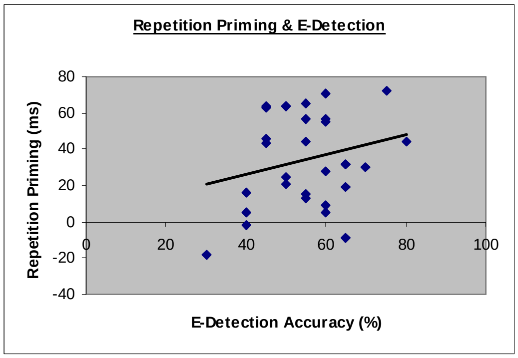

Figure 1: E-detection versus Repetition Priming for all participants in Experiment 1

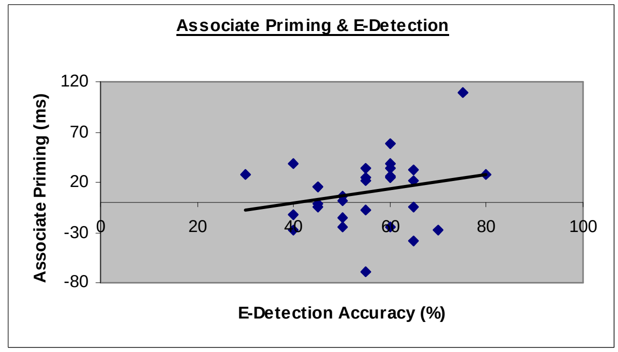

Figure 2: E-detection versus Associate Priming for all participants in Experiment 1

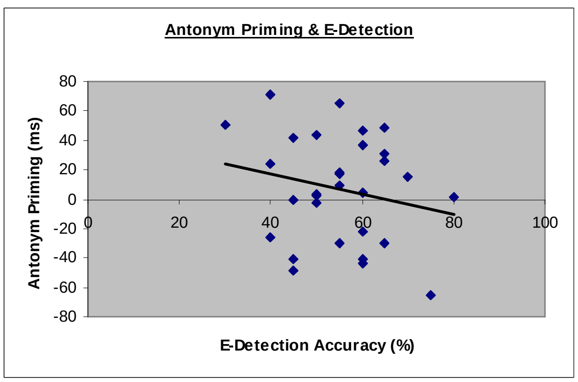

Figure 3: E-detection versus Antonym Priming for all participants in Experiment 1

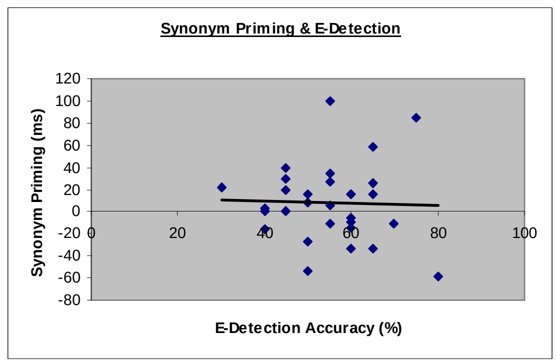

Figure 4: E-detection versus Synonym Priming for all participants in Experiment 1

Results- High Perceptual Awareness Group (HPA)

Ten of the 30 participants met criteria for inclusion in this group. Mean reaction times and error rates for this group are presented in Table 2. Once again there was a strong repetition priming effect (33 ms) that was significant for the subject and item analyses ($F1(1, 8) = 20.37$, $p < 0.002$; $F2(1, 94) < 1$, $p = 0.92$). Collapsing over all three types of semantic relatedness for non-exemplars revealed a non-significant overall semantic priming effect for response times of 10 ms in the subject and items analyses ($F1(1, 8) = 1.91$, $p = 0.2$; $F2(1, 30) = 1.57$, $p = 0.22$). As in the original analyses above, none of the individual semantic relationships of interest reached significance by themselves. Associate primes had a relatively large priming effect (25 ms) that trended towards significance ($F1(1, 8) = 5.19$, $p < 0.052$; $F2(1, 30) = 3.48$, $p < 0.071$). Synonym prime response times had a 10 ms effect ($F1(1, 8) < 1$, $p < 0.51$; $F2(1, 30) < 1$, $p < 0.6$) while antonym primes yielded a surprising -7 ms inhibitory effect ($F1(1, 8) < 1$, $p = 0.4$; $F2(1, 30) < 1$, $p = 0.89$). Analysis of the error rates revealed no significant effects.

Table 2
Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type for High Perceptual Awareness participants at 50 ms SOAs.

	Exemplars		**Non-Exemplars**							
Semantic	*Repetition*		Associates		Antonyms		Synonyms		*Overall*	
	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
Unrelated	523	7.8	600	12.0	553	5.1	574	7.0	576	8.0
Related	490	7.5	575	10.6	560	4.5	564	9.6	566	8.2
Priming	33	0.3	25	1.4	-7	0.6	10	-2.6	10	-0.2

Results- Low Perceptual Awareness Group (LPA)

Twenty of the original 30 participants met criteria for inclusion in this group. Mean reaction times and error rates for this group are presented in Table 3. Repetition primes yielded a 35 ms effect that was significant for the subject and item analyses ($F1(1,$

18) = 110.09, $p < 0.001$; $F2(1, 94) = 69.92$, $p < 0.001$). Overall semantic relatedness for non-exemplars revealed a significant priming effect for response times of 9 ms in the subject analysis and a slight trend towards significance in the items analysis ($F1(1, 18) = 5.24$, $p < 0.04$; $F2(1, 30) = 2.94$, $p = 0.096$). The individual semantic relationships of interest showed a different pattern of results. Neither associate nor synonym primes had significant priming effects ($F1(1, 18) < 1$, $p = 0.6$; $F2(1, 30) < 1$, $p = 0.7$ and $F1(1, 18) = 1.43$, $p = 0.2$; $F2(1, 30) = 1.16$, $p = 0.29$, respectively). Antonym primes, however, yielded an unanticipated significant priming effect of 14 ms ($F1(1, 18) = 4.78$, $p < 0.04$; $F2(1, 30) = 1.61$, $p = 0.2$). See Figure 5 for a comparison between HPA and LPA reaction time performance. Again, analysis of the error rates revealed no significant effects, though there was a trend towards significance in the case of antonym error rates ($F1(1, 18) = 3.67$, $p = 0.07$; $F2(1, 30) = 2.10$, $p = 0.16$).

Table 3
Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type for Low Perceptual Awareness participants at 50 ms SOAs.

	Exemplars		**Non-Exemplars**							
Semantic	*Repetition*		Associates		Antonyms		Synonyms		*Overall*	
	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
Unrelated	530	8.4	564	6.9	543	5.1	568	7.8	559	5.9
Related	495	6.5	561	9.2	529	4.5	560	5.1	550	6.6
Priming	35	1.9	3	-2.3	14	0.6	8	2.7	9	-0.7

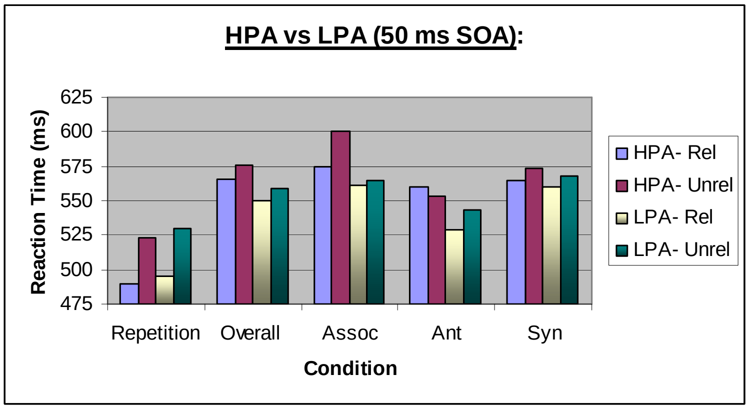

Figure 5: HPA and LPA Reaction times in Experiment 1

Discussion

The results obtained in the present study provide mixed support for the notion of automatic, non-strategic semantic priming in semantic categorization tasks. Though we were able to obtain clear repetition priming effects for exemplar prime-target pairs, we were only able to obtain relatively small semantic effects with the non-exemplars. Further, contrary to the strong effects seen in the Bueno & Frenck-Mestre (2002) study, the results from this experiment yielded only modest significant effects which were only obtained after collapsing over all of the semantic relationships under consideration. Thus, though we can conclude that there is some evidence for automatic semantic priming in this task, we cannot say that it mirrors the effects seen when exemplar stimuli are considered.

Our modest results may simply be characteristic of the nature of responses to non-exemplars in semantic tasks. Note that our overall semantic priming effects (8 ms) are similar to those obtained by Hector (2005) in her non-exemplar condition (14 ms). Further, while Bueno et al and Hector used a single, broad category, we used multiple categories of varying size throughout our experiment. These differences may have provoked participants into using a different decision making strategy or focusing their attention differently than the categorization tasks in the other studies mentioned.

It should be noted that the patterns of priming observed across the various semantic relationships were markedly different when comparing high and low perceptually aware participants. Participants in the HPA group produced a relatively large priming effect for associates that trended towards significance (25 ms as opposed to 10 ms before group separation). This was accompanied by a change from facilitative to inhibitory effects in the case of antonyms. The LPA group, however, generated significant facilitative antonym priming (14 ms) and relatively low associate priming effects (3 ms). Interestingly, synonym performance remained relatively constant across all analyses. These interactions between prime-type and perceptual awareness may be indicative of a difference in the non-conscious cognitive tactics that are being employed dependent upon an individuals ability to detect visual information about the prime. If this is so, the pattern of results seen with LPA participants may be reflective of more non-strategic, automatic processing. HPA participants, then, may be producing result patterns that are more analogous to the types of results that would be observed for the average person with primes at presented at higher SOAs.

EXPERIMENT 2

Experiment 1 produced relatively small priming effects that did not significantly differ across semantic relationship type until participants were evaluated on the basis of their levels of partial awareness. Consequently, the purpose of Experiment 2 was to further investigate the notion that semantic priming may indeed be modulated by perceptual awareness. In a recent review of the visual masking literature, Kouider & Dehaene argued that there are two types of non-conscious processing, subliminal and preconscious (2007). Preconscious processing is said to result from a diversion of attentional resources such that top-down processing of the stimulus is restricted regardless of the amount of stimulus information that is available. In contrast, subliminal processing results from a lack of "strength" in the stimulus signal such that, despite intact attentional focus, there is insufficient "global reverberation" of neuronal activation for each of the cognitive subsystems that would normally be activated during conscious perception to reach threshold. This latter type of processing is said to result from masked presentations of visual stimuli and is most relevant to the current situation. Here, varying levels of perceptual awareness may allow for differential levels of stimulus processing strength. If, for example, semantic feature information is attached to lexical entries, then it may require a relatively small amount of processing strength for these levels of representation to be activated. As a result, feature-based priming of the sort that is presumably involved in antonym and synonym priming may only require little or no perceptual awareness of the prime to allow for facilitative effects. Associative relationships, however, may be represented in a much more distributed fashion, relying more on semantic memory than on lexical representations. Associate primes may therefore require higher levels of perceptual awareness to generate enough stimulus strength to facilitate response times for related target stimuli.

To account for the data from Experiment 1, the description of perceptual awareness above would have to explain why HPA participants, who presumably benefited from higher stimulus strength, seemed to garner benefits only for associative relationships and not antonym and synonym relationships as well. Given that HPA and LPA participants are functioning with different levels of cortical activation under this theory, it may also be the case that they are employing different non-conscious tactics in order complete their task. Recall that a participant's explicit goal when engaging in a semantic categorization task is to determine whether or not a given target is a member of the category in question, not to produce priming. Their conscious *strategy*, therefore, may involve something like remembering the category, identifying the target, and then checking whether or not the target fits the category. This simple strategy may actually involve the execution of a great many non-conscious *tactics*[2] in order to be successful. These may include, holding category features or exemplars in working memory, matching lines in the visual field to letter representations followed by word representations for the purposes of target identification, and finally applying some decision rule to determine correspondences between the target and the category. These

[2] Here I am intentionally using the terms "strategy" and "tactic" in a way that is analogous to their use in military theory, where a strategy is a broad plan designed to achieve a specific goal and tactics are the individual component operations meant to achieve objectives in service of the main goal.

latter decision rules may vary in appropriateness depending on the type of information at hand.

If, for instance, LPA participants only have lower level lexical information to work with, it would be inappropriate, or at the very least inefficient, to deploy a decision rule that involved searching through semantic memory representations when trying to match the target and category. It may be more efficient to attend to feature level representations, especially those containing salient information like that provided by distinguishing features, for decision making. For HPA participants, in contrast, it may be more efficient to give one's self a few more milliseconds before responding and make use of the semantic memory activation provided by associative information (note the larger reaction times for associates versus antonyms and synonyms in Table 1). If cognitive resources are focused on different types of information depending on one's level of perceptual awareness, then this may account for the fact that associates seem to be preferentially benefiting from higher stimulus strength for HPA participants and why antonyms are preferentially facilitated for LPA participants.

There is empirical evidence for a distinction between conscious strategies and non-conscious tactics in the decision-making literature. A 1997 study by Bechara, Damasio, Tranel, and Damasio compared decision-making in patients with prefrontal damage and normal controls performing a gambling task. The task involved choosing cards representing monetary gains and losses from four separate decks of cards so as to maximize rewards and minimize punishments. The different decks of cards each had varying magnitudes of reward and punishment values such that some were overall advantageous while others were disadvantageous. The decks were not marked so that there was initial uncertainty regarding which of the decks were the best decks to choose from. The experimenters simultaneously collected behavioral, psychophysiological, and self-report measures while the task was being performed. They found that "normals" started choosing advantageously before they were able to report which strategy worked best. In contrast, prefrontal patients continued to perform disadvantageously even after they had learned the correct strategy. Further, normals began to produce anticipatory skin conductance responses when pondering risky choices even before they explicitly knew that it was a risky choice. This was not the case for prefrontal patients. The authors argued that these differences were due to the influence of "nonconscious biases" affecting behavior before conscious, declarative knowledge was able to in the case of normals. Thus, if their conclusions are correct, there is good reason to believe that there is a distinction between conscious strategies and non-conscious tactics with each having an effect on our long-term performance in tasks involving trial-by-trial feedback. The individual tactics used may vary depending on the nature of the interaction between the decision rules and the information being used in those decisions that are being reinforced.

To test for the potential modulating influence of perceptual awareness on semantic priming, Experiment 2 was designed to replicate the results of Experiment 1 using a longer SOA. An SOA of 70 ms was chosen in order to increase the proportion of participants who are able to obtain high perceptual awareness of the prime. It was also hoped that the longer SOA would also result in larger magnitudes in the semantic priming effects (see the discussion by Forster, Mohan, and Hector, 2003 on the relationship between SOA and the amount of priming observed). Further, increasing the SOA would allow for a comparison of the pattern of semantic priming across SOAs in a manner that is comparable with Bueno & Frenck-Mestre's approach. Given the arguments above, it was hypothesized that priming at the longer SOA would begin to be significant for some of the individual semantic relationships independent of participants' level of perceptual awareness, most likely starting with antonym priming. It was also hypothesized that there would once again be a disparate pattern of priming between HPA and LPA groups, with LPA participants' showing significant antonym priming, HPA showing significant associate priming, and both groups showing overall semantic priming when collapsing across all types of semantic relationship. No predictions were made for the effects produced by synonym primes, though repetition priming was expected to be robust throughout. Finally, it was also predicted that the HPA group would have longer reaction times for non-exemplar items as a result of the high stimulus strength tactics described above.

Method

Participants

Forty undergraduate students enrolled in an introductory Psychology course at the University of Arizona participated and received course credit for their participation.

Materials and Design

The materials and design of the experiment were identical to those in Experiment 1.

Procedure

Participants performed a semantic categorization task and E-detection task as above except that SOA used here was 70 ms.

Results

As in Experiment 1, incorrect responses and outliers (responses that were above or below two SD from the mean of each participant) were discarded. This resulted in a loss of 4.5% of the data. Mean reaction times and error rates are presented in Table 4. Analyses of variance (ANOVA) were performed as they were before.

Table 4
Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type at 70 ms SOAs.

	Exemplars		**Non-Exemplars**							
Semantic	*Repetition*		Associates		Antonyms		Synonyms		*Overall*	
	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
Unrelated	565	7.7	599	6.0	581	3.8	600	4.7	594	4.8
Related	514	5.4	594	6.9	569	1.7	592	4.2	585	4.3
Priming	51	2.3	5	-0.9	12	2.1	8	0.5	9	0.5

Response times in the exemplar condition yielded robust repetition priming in both the subject analysis (51 ms) and the item analysis ($F1(1, 38) = 175.15$, $p < 0.001$; $F2(1, 94) = 195.20$, $p < 0.001$). There was also a significant overall semantic priming effect for response times in the subject analysis (9 ms) and the items analysis (8 ms)($F1(1, 38) = 7.37$, $p < 0.01$; $F2(1, 90) = 6.21$, $p < 0.02$). Amongst the specified semantic relationships, only antonyms produced significant effects ($F1(1, 38) = 3.67$, $p =$

0.06; *F*2(1, 30) = 6.03, $p < 0.02$). Neither associate nor synonym priming reached significance (*F*1(1, 38) < 1, $p = 0.34$; *F*2(1, 30) < 1, $p = 0.33$ and *F*1(1, 38) = 1.31, $p = 0.26$; *F*2(1, 30) = 1.06, $p = 0.3$, respectively).

Analysis of the error rates revealed no significant effects. The average accuracy rates for the E-detection task were 62.1% for word primes and 60.5% for non-word primes at 70 ms. The correlations between priming and E-detection performance yielded a different pattern than was seen in Experiment 1 (see Figures 6-9 for Experiment 2 results). Here, repetition, associate, and antonym priming were all positively correlated with E-detection accuracy, a measure of partial awareness (r= 0.198, $p > 0.05$, r= 0.075, $p > 0.05$, and r= 0.14, $p > 0.05$, respectively). Again, synonym priming did not seem to correlate with E-detection (r= -0.048, $p > 0.05$).

As before, post hoc analyses were conducted to investigate the differences between correlations. Participant data was divided into either a High or Low Perceptual Awareness group using the same criteria as Experiment 1.

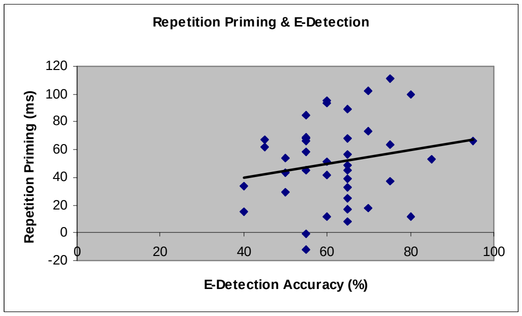

Figure 6: E-detection versus Repetition Priming for all participants in Experiment 2

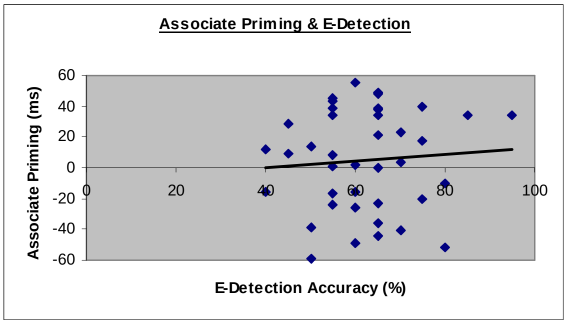

Figure 7: E-detection versus Associate Priming for all participants in Experiment 2

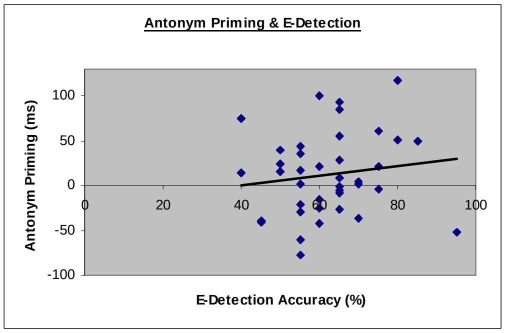

Figure 8: E-detection versus Antonym Priming for all participants in Experiment 2

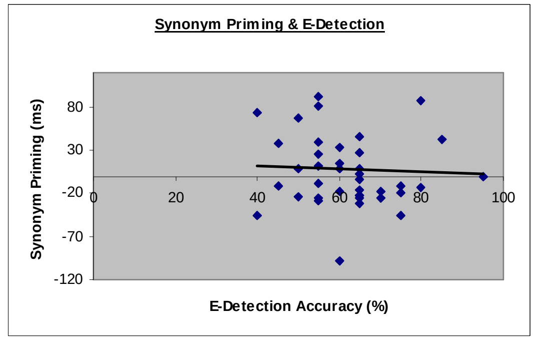

Figure 9: E-detection versus Synonym Priming for all participants in Experiment 2

Results- High Perceptual Awareness Group (HPA)

Twenty-four participants met criteria for inclusion in this group. Mean reaction times and error rates for this group are presented in Table 5. There was a strong repetition priming effect (55 ms) that was significant for the subject and item analyses ($F1(1, 22) = 139.43$, $p < 0.001$; $F2(1, 94) = 165.02$, $p < 0.001$). This was also the case when collapsing over all semantic relatedness conditions for response times in the subject (9 ms) and items analysis ($F1(1, 22) = 4.63$, $p < 0.05$; $F2(1, 90) = 4.35$, $p < 0.04$). Neither associate nor synonym primes produced significant priming effects on their own ($F1(1, 22) = 1.07$, $p = 0.3$; $F2(1, 30) < 1$, $p < 0.3$ and $F1(1, 22) < 1$, $p = 0.9$; $F2(1, 30) < 1$, $p = 0.9$, respectively). Antonym prime response times, however, yielded a 21 ms effect ($F1(1, 22) = 7.41$, $p < 0.02$; $F2(1, 30) = 10.89$, $p < 0.003$). Error rates were only significant for repetition primes ($F1(1, 22) = 4.56$, $p < 0.05$; $F2(1, 94) = 5.85$, $p < 0.02$).

Table 5
Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type for High Perceptual Awareness participants at 70 ms SOAs.

	Exemplars		**Non-Exemplars**							
	Repetition		Associates		Antonyms		Synonyms		*Overall* *Semantic*	
	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
Unrelated	563	7.8	590	5.6	583	2.6	588	5.0	587	4.4
Related	508	5.4	583	1.9	562	1.0	587	3.4	578	4.1
Priming	55	2.4	7	-2.7	21	1.6	1	1.6	9	0.3

Results- Low Perceptual Awareness Group (LPA)

Fourteen participants met criteria for inclusion in this group. Mean reaction times and error rates for this group are presented in Table 6. Repetition primes yielded a 48 ms effect that was significant for the subject and item analyses ($F1(1, 12) = 51.86$, $p < 0.001$; $F2(1, 94) = 59.38$, $p < 0.001$). Overall semantic relatedness for non-exemplars revealed a significant priming effect for response times in the subject analysis (8 ms) and a trend in the items analysis ($F1(1, 12) = 5.41$, $p < 0.04$; $F2(1, 90) = 2.94$, $p < 0.09$). Neither associate nor antonym primes had significant response time priming effects ($F1(1, 12) < 1$, $p = 0.4$; $F2(1, 30) < 1$, $p < 0.4$ and $F1(1, 12) < 1$, $p = 0.9$; $F2(1, 30) < 1$, $p = 0.8$, respectively). Synonym primes, however, yielded an unexpected significant priming effect of 18 ms for item response times ($F1(1, 12) = 1.73$, $p = 0.2$; $F2(1, 30) = 4.25$, $p < 0.05$). See Figure 10 for a comparison between HPA and LPA reaction time performance. Error rates revealed no significant effects with the exception of repetition error rates ($F1(1, 12) = 4.78$, $p < 0.05$; $F2(1, 94) = 4.02$, $p < 0.05$). There was also a slight trend towards significance in the case of antonym item error rates ($F1(1, 12) = 2.84$, $p = 0.1$; $F2(1, 30) = 3.33$, $p = 0.078$).

Table 6
Mean semantic categorization times (ms) and percent error rates for exemplars and non-exemplars as a function of prime type for Low Perceptual Awareness participants at 70 ms SOAs.

	Exemplars		**Non-Exemplars**							
Semantic	*Repetition*		Associates		Antonyms		Synonyms		*Overall*	
	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
Unrelated	564	7.7	609	6.3	576	4.9	612	4.5	599	5.2
Related	516	5.2	602	5.8	574	2.2	596	5.8	591	4.5
Priming	48	2.5	3	0.5	2	2.7	16	-1.3	8	0.7

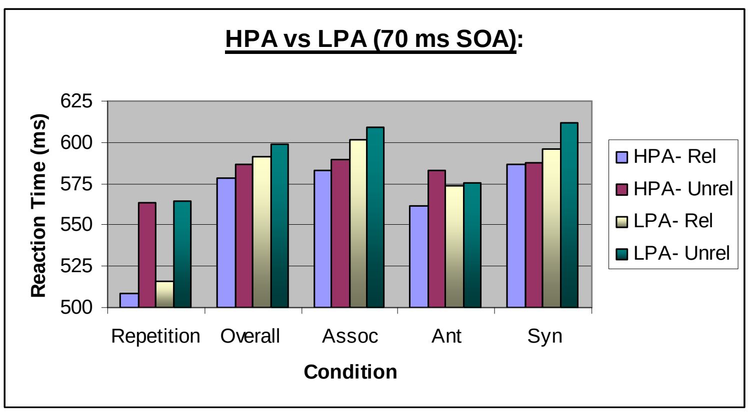

Figure 10: HPA and LPA Reaction times in Experiment 2

Discussion

The results of Experiment 2 provided mixed support for the predictions that were made. There was significant overall and antonym priming when evaluating the non-exemplar data from all participants independent of the level of perceptual awareness[3]. As predicted, HPA and LPA groups produced disparate patterns of semantic priming. The patterns observed, however, were not in the expected direction. Though both groups yielded significant overall priming, here it was the HPA group that achieved significant antonym priming whereas at 50 ms, it was the LPA that produced this effect. At 70 ms, the LPA group no yielded no significant priming for subject reaction times for any of the individual semantic relationships considered. Unexpectedly, however, synonyms produced the largest magnitudes of priming effects. These effects were significant for item reaction times suggesting that there was a genuine effect for some participants. As was the case for the HPA group at 50 ms, the LPA group at 70 ms had a very small sample size and thus inferences from the data in these groups should be taken with caution. It should be noted that these results are not consistent with Bueno & Frenck-Mestre's results in that there does not seem to be either a consistently strong synonym effect or an increasingly strong associate effect when evaluating the data independently of participants' level of perceptual awareness. The extent to which this disparity is due to differences in the task structure, the added presence of antonym primes, or some other factor is uncertain.

In addition to the unforeseen changes in priming patterns, it was not the case that the HPA group had longer reaction times than the LPA group at 70 ms. In fact, the pattern was reversed yet again. Taken together, the available evidence does not support the idea that higher levels of perceptual awareness induces a "wait-and-see" non-

[3] There was a significant item reaction time effect and a strong 0.06 trend for subject reaction times that was interpreted as signifying a genuine effect.

conscious tactic as a result of higher stimulus strength in HPA participants. It should be noted, however, that significant priming for error rates did not emerge until the longer SOA was used. This was consistently the case for repetition primes at 70 ms whether or not one's level of perceptual awareness was considered. This was also the case for antonym primes when ignoring differences in partial awareness and for overall semantic priming for the HPA group at 70 ms. These results suggest that differences in one's awareness of the prime do lead to some changes in the decision processes affecting task output.

GENERAL DISCUSSION

The findings here suggest several factors affecting masked semantic priming. First, there was a fairly consistent significant overall semantic priming effect of around 9 ms for all of the analyses presented, with the exception of the LPA group at 50 ms. Interestingly, this magnitude of the effect did not rise with increasing SOA. This finding indicates that there may be some stable semantic processing effect that manifests itself despite the fact that only non-exemplar semantic priming relations were being considered. Second, each analysis yielded shorter reaction times for antonyms. Further, the priming effects yielded by these items reached significance often and far more than any of the other types of semantic relationships considered. These results provide firm support for influence of distinguishing features on semantic priming effects. Third, it should be noted that though the pattern of priming in HPA versus LPA groups was not consistent across different SOAs, it did seem to be the case that each analysis that was contingent upon participants' level of perceptual awareness was dominated by one type of semantic relationship, most often being antonyms. This suggests that there are some differences in the non-conscious tactics utilized by these groups. The tactics chosen seem to depend on one's level of perceptual awareness as well as the SOA of the stimuli used. The exact mechanism of tactic choice remains unclear at this time.

There is psychophysiological evidence in support of the notion that semantic priming effects are the result of the combination of automatic and strategic (or tactical) processes. In a 2005 study, Mari-Beffa, Valdes, Cullen, Catena, and Houghton investigated the effect of task differences on semantic processing by evaluating eventrelated potentials (ERPs). Here, they used a fairly unconventional priming task in which participants had to perform separate tasks on the prime and the target which immediately followed the prime (2005). Depending on the task block, they first conducted either a semantic categorization (living versus non-living) or a letter detection task (“e” versus “a”) on the prime. Each prime in all conditions was either a living or non-living thing. The following stimulus for each prime was a related target word that participants had to make a lexical decision about. The authors found an early component that was consistent with a “recognition potential” indicating semantic processing for each of the prime related tasks. A later N400 component, however, differed across tasks. This ERP component is a known psychophysiological marker of semantic integration. A semantic priming effect was seen following the semantic categorization but not following the letter search. Mari-Beffa et al. take these results as evidence that early “automatic semantic processing” can be dissociated from “semantic priming”. These results compliment behavioral work done by Brown, Roberts, and Besner (2001) which found that performing a “letter search” on the prime served to block semantic priming effects that would normally appear for the target during a lexical decision task. It should be noted that Mari-Beffa et al.’s results are also consistent with those found by Vriezen et al. in that it was only when the first task involved processing at a “higher” level that priming effects emerged in the subsequent (“lower” processing level) task (1995).

The psychophysiological results above are also consistent with the results presented here. The reliable overall semantic priming effects observed can be interpreted as being reflective of automatic semantic processing of the sort revealed by Mari-Beffa et al.'s recognition potential. These effects may be the result of a mechanism such as spreading activation. "Semantic priming", however, may be heavily influenced by factors that allow for strategic and non-conscious tactical influences such as the task and level of prime awareness achieved in a given situation. Further, the results here demonstrate that the effects obtained may differ depending on the type of semantic relationships used in the experimental setting. Thus, future research investigating masked semantic priming may benefit from restricting, or at least explicating, the types of semantic stimuli being used.

It should be noted that the measure of perceptual awareness used here, the E-detection task, represents only one of many potential ways of assessing this capacity. E-detection is a strategic task that necessarily involves a procedure of pre-cuing in which participants know in advance what aspect of the stimulus they should be attending to. Variations in the awareness task such as switching the letter being searched for between trials or not mentioning the probe letter until after the stimulus has been presented may be sensitive to different aspects of perceptual awareness that may be more or less relevant to the mechanisms by which perceptual awareness modulates semantic priming.

The results here would undoubtedly benefit from further exploration. First, it may be advantageous to test more participants so as to have large enough sample sizes in all HPA and LPA groups after participants have been divided on the basis of their perceptual awareness scores. Given the relatively small size of the semantic effects observed, future experiments may also benefit from limiting the number of semantic relationships that are being simultaneously compared and increasing the number of items in each condition to increase the power of the experimental paradigm. Additionally, following the work of Moss et al. (1995), further investigations should also be conducted by evaluating additional types of semantic relationships using the masked priming paradigm to determine which relationships produce strong effects (and when). Alternately, or perhaps additionally, one might investigate the effects of the same stimuli in a lexical decision task in order to ascertain the extent to which these effects are task-specific. Clearly, further studies are necessary for one to legitimately make strong claims about the role that perceptual awareness plays in influencing semantic priming effects.

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