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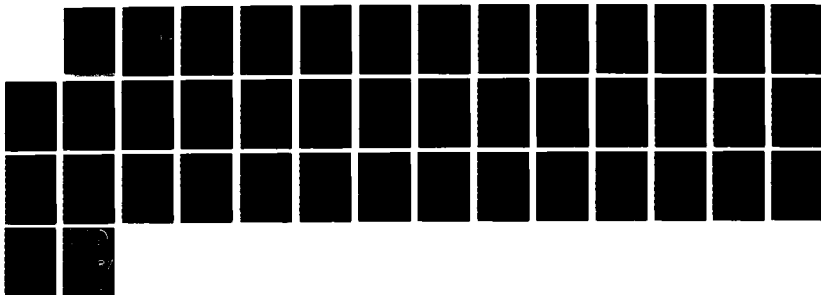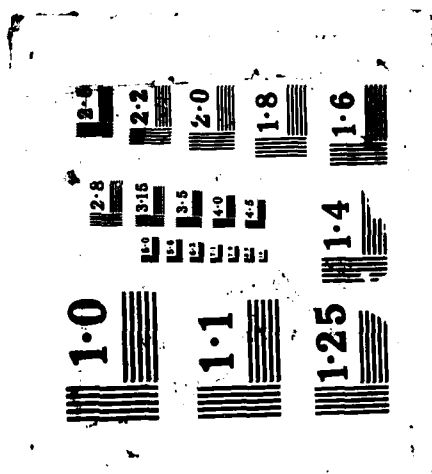   NEUROLOGY J SANDSON ET AL 1987 TR-87-6-ONR
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EFFECTS OF DIVIDED ATTENTION ON IDENTITY AND SEMANTIC PRIMING

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EFFECTS OF DIVIDED ATTENTION ON IDENTITY AND SEMANTIC PRIMING[1]

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According to some models of lexical access visual information can directly activate semantic memory. Priming can be obtained from stimuli that are either physically identical or semantically related to the target. Our studies show that identity priming is not reduced by performance of a simultaneous auditory shadowing task. The strength of identity priming does not vary between conditions in which the relatedness of the prime provides information about the correct response (lexical decision) and conditions in which it does not (semantic classification). On the other hand, semantic priming is reduced during shadowing with lexical decision and in semantic classification. These data suggest that identity primes operate upon a visual code of the input that is not influenced by simultaneous auditory processing while semantic priming involves a system to which both auditory and visual information has access.

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INTRODUCTION

Lexical access has long been a central topic in studies of reading and of cognition in general. One idea common to many models of lexical access is that the visual word is integrated into a word form while still within the visual system (e.g. Carr & Pollatsek, 1985; McClelland & Rumelhart, 1981). The word form then has access to other systems for obtaining a phonetic code of the word name and for obtaining semantic information about word meaning.

According to dual route views, the visual word form can contact phonological and semantic information in parallel. Evidence for this is obtained from reading and lexical decision studies involving regular words as well as nonwords, pseudo-homophones, and exception words (e.g. Carr and Pollatsek, 1985) and from dissociable reading deficits in neurological patients with focal lesions (e.g. Patterson, 1981). There is also evidence of contact between the semantic and phonological routes (e.g. Humphreys & Evett, 1985). The evidence for distinct pathways, however, indicates that visual information about words can exist in a code isolated from auditory word processing.

Powerful visual affects due to the existence of visual word forms have long been a focus of study in cognitive psychology (e.g. McClelland & Rumelhart, 1981). For example, individual letters within a word are perceived better than when presented alone or in a nonword letter string (Reicher, 1969). It has recently been shown that damage to the posterior parietal lobe, known to disrupt covert visual spatial orienting contralesionally (Posner, Walker, Friedrich & Rafal, 1984), impairs reporting of letters on the contralesional side of nonword but not word strings (Sieroff, Pollatsek & Posner, 1987). Cueing healthy subjects to the left or right side of letter strings similarly disrupts the report of letters remote from the cue for nonwords but has no such affect for words (Sieroff & Posner, 1987). These findings suggest that the word form may develop quite early in processing and that spatial attention, necessary for organizing nonword strings, may not be needed.

How might one determine if visual word forms actually exist in a module isolated from higher level codes? A method for studying putative cognitive modules involves the use of multiple tasks. Shallice, McLeod & Lewis (1985), for example, used a secondary task to determine which aspects of two linguistic operations could be time shared. The logic of the paradigm is that tasks tapping independent modules ought to show little decrement when performed together. Dual performance of tasks sharing the same module, on the other hand, should result in considerable slowing. On this basis auditory input logogens used in detecting word names were concluded to be isolated from the articulatory codes needed to pronounce visually presented words.

Rollins & Hendricks (1980), using the same logic, had subjects search lists of words for a target word while simultaneously processing auditory information. The targets for the primary task belonged to one of four conditions: a) a specified word in an auditority list; b) a specified word in a visual word list; c) a category instance in a visual list; or d) a rhyme in a visual list. The secondary tasks consisted of: 1) digit repetition; 2) antonym production; or 3) category generation. Target detection was impaired for specified words presented auditorily and for rhyme targets but not for target words presented visually or for semantically specified targets. A more sensitive RT measure, however, might have detected a semantic decrement.

Another use of the dual task technique has involved combining orienting to visual cues with phoneme monitoring (Posner, Inhoff, Friedrich & Cohen, 1987). Performing the language task delayed the usual advantage of cued over uncued spatial locations. Simultaneous performance of visual spatial orienting and phoneme monitoring thus not only increases overall reaction times on the spatial orienting task but results in a reduced advantage for cued locations (validity effect). It is thus possible to conclude that dual task performance reduced the effectiveness of the spatial cue over single task performance and to further infer that cue orienting must require some of the same processing apparatus as attending to auditory phonemes. This result suggests that the dual task method can be applied to the mechanisms used in processing cues or primes as well as to those involved in processing targets.

It is known that priming a target word with a word that is either identical or semantically related to the word will increase the efficiency of its processing. It is possible that the identity prime can facilitate processing through purely visual pathways while the semantic prime works by activating pathways in semantic memory that are shared by the target. If this idea is correct, identity priming should not be reduced by dual tasks that require processing of auditory words while semantic priming should be reduced. To test this hypothesis we study a variety of prime types within the framework of a lexical decision task. Subjects either perform the lexical decision task by itself or at the same time repeat (shadow) an auditory tape recording of a story.

Experiment 1a

Stimuli: Word list stimuli consisted of semantic, identity, unrelated and nonword pairs. Semantic pairs included: 20 good-instance category pairs (e.g. insect - fly); 20 poor-instance category pairs (e.g. ship - ferry); 20 highly associated pairs (e.g. salt - pepper) and 20 less highly associated pairs (e.g. wish - hope). The good and poor instance category pairs were selected on the basis of Battig and Montague (1969) norms for instance dominance. Good instance targets had a mean category dominance rating of 365.8, as compared to 12.6 for the poor instance targets (p <

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.001). High and lower association pairs were obtained from established association norms (Palermo & Jenkins, 1964). High association pairs had a mean rating of 505.4 while the mean rating for the low association pairs was 98.6 (p < .001). Although frequency of occurrence (Kucera & Francis, 1967) was not significantly different across association pairs, high dominance targets had a significantly higher mean frequency than low dominance pairs. There were 40 identity pairs (e.g. train - train), 80 unrelated pairs (e.g. function - lace) and 200 nonword pairs (e.g. route - vorpre). In order to ensure that the effects of prime type would not be attributable to differences in frequency, unrelated pairs were constructed so as to contain the same target words as the categorical and associate pairs. Primes for the unrelated pairs did not differ in frequency from those for the semantically related pairs. Nonword and identity primes were also selected so as not to differ in frequency from those in the unrelated pairs.

In order to meet requirements for disk space, the 400 pair stimulus list was divided into two parts. One half of the items in each pair type were randomly assigned to each list.

The auditory tape used in the shadowing conditions was a reading by Gore Vidal of his novel <u>Abraham Lincoln</u>.

Procedure: Subjects received both word lists first in a no-shadowing and then in a shadowing condition. Each list was presented in a different random order for every subject. List order was counterbalanced such that one half the subjects received each list first.

Target stimuli were presented either a short or a long interval after the onset of the prime (SOA). SOA was randomly assigned to each item at every presentation. Prime stimuli were always initiated 500 msec after the onset of a fixation cross and remained on the screen for 300 msec. Target stimuli were initiated 400 msec after the onset of the prime in the short SOA condition and 900 msec after the onset of the prime in the long SOA condition. The fixation cross remained present throughout the duration of each trial. Primes appeared above and targets below the cross.

Subjects were instructed to fixate on the central cross and to attend to the second stimulus in each trial. Their task was to determine whether that letter string was or was not a real English word. If the target was a real word, the correct response was to press the left key on the response panel with the index of the right hand (or the middle finger of the left hand). Nonword responses were registered by pressing the right key with the middle (index) finger of the same (dominant) hand. Subsequent trials were automatically triggered through the response key.

The shadowing task involved repetition of the auditory tape, allowing for minimal lag between the tape and the subject. Subjects practiced shadowing until they felt comfortable with the task. They were then

instructed to again perform the lexical decision task while maintaining the speed and accuracy of their shadowing. No formal measure of shadowing performance was obtained.

Response accuracy and reaction times for the lexical decision task were stored by computer for later analysis.

Results: Each subject's mean reaction time for correct responses was computed for each SOA (short, long) by Prime Type (semantic, identity, unrelated) by task (no shadow, shadow) condition and these data were included in a fixed effects repeated measures ANOVA. Reaction times faster than 200 msec or slower than 2000 msec were considered errors and excluded from the analysis.

The ANOVA revealed significant main effects of SOA (F = 10.573, df = 1,11, p = .007) and Prime Type (F = 3.805, df = 2,22, p = .037). The main effect of Task closely approached, but did not reach significance (F = 4.461, df = 1.11, p = .056). The interaction of Task X Prime Type, however, was highly significant (F = 6.02, df = 2,22, p = .008).

The means and standard deviations for semantic, identity, and unrelated prime types are presented for both short and long SOAs under no-shadow and shadow task conditions in Table 1. Means and standard deviations from nonword targets, although not included in the analysis, are also listed in Table 1.

INSERT TABLE 1 ABOUT HERE

Further analysis of the above data revealed significantly longer reaction times during shadowing for the semantic pairs considered alone (F = 6.589, df = 1,11, p = .025), but not for identity (F = 2.041), or unrelated (F = 2.926). Nonword targets showed no increase in the shadowing over the no-shadowing condition at either SOA. Individual comparisons of the Prime Types revealed that semantic and identity reaction times were both significantly faster than those for unrelated targets (F = 5.482, p = .037 and F = 6.251, p = .028 respectively) but did not differ from each other (F = 1.49). Task X Prime Type interactions were significant for comparisons involving semantic and unrelated (F = 8.665, df = 1,11, p = .013) and semantic and identity (F = 8.841, df = 1.11, p = .012) pairs as the Prime Types but not for the analysis involving identity and unrelated pairs (F = 1.088). SOA did not interact with either Task or Prime Type.

More detailed analysis of the four types of semantic relations uncovered main effects of Task (F = 6.438, df = 1,11, p = .026) and Prime Type (F = 8.309, df = 3.33, p < .001) but no interaction (F = .059). The means and standard deviations of reaction times for the four semantic prime types are displayed in Table 2.

INSERT TABLE 2 ABOUT HERE

The effects of SOA, Task, and Prime Type were further examined by
computing for every subject the difference between the mean unrelated score
and the mean score for semantic and identity pairs. The mean difference
score for each SOA and task condition are presented in Table 3.

INSERT TABLE 3 ABOUT HERE

A fixed-effects repeated measures ANOVA with these data failed to
uncover an overall difference between the two prime types ($F = 1.49$).
Shadowing, however, reduces priming scores significantly more for the
semantic than for the identity pairs as reflected in a significant Task X
Prime Type interaction ($F = 8.841$, $df = 1,11$, $p = .012$).

There was no effect of either Task or Prime Type on the error scores
(percentages) presented in Table 4.

INSERT TABLE 4 ABOUT HERE

The results of this experiment support the hypothesis that capacities
or processes required for auditory shadowing underlie semantic but not
identity priming.

Both semantic and identity priming yielded facilitation as indicated by
overall decreased reaction times as compared to the unrelated condition.
The shadowing condition resulted in significantly longer reaction times
than the no-shadowing condition for the semantic and unrelated pairs.
Reaction times for the identity pairs also tended to be longer in the
shadowing condition. The interaction between Task and Prime Type for both
reaction times and difference scores supports the prediction that shadowing
would have less effect on identity than on semantic targets. The results
of this study thus suggest that semantic priming at the SOAs we used
involves some of the same processes as auditory shadowing. Identity
priming seems to be largely independent of these processes.

Before pursuing differences between semantic and identity priming, it
was necessary to rule out any possible effect of task order in Experiment
1. It is possible that presenting the two shadowing lists after the two
no-shadowing lists in some way confounded the effects of practice with the
effects of task. Experiment 1B was thus conducted to replicate the results
of Experiment 1 while controlling task order.

Twelve subjects were recruited for Experiment 1B in the same manner as
for Experiment 1. The subjects ranged in age from 18 to 49 (Mean = 27.7)

and in education from 12 to 18 (mean = 15.1) years of formal schooling. Stimuli and procedure were identical to those of Experiment 1. In this experiment, however, half the subjects received the tasks in an ABBA design (no shadow first) and half received the tasks in a BAAB design (shadow first). List order was counterbalanced as well.

Reaction times were entered into a mixed between/within analysis of variance with order (ABBA, BAAB), task (first no shadow, second no shadow, first shadow, second shadow), and prime type (high dominance, low dominance, high associate, low associate, semantic, unrelated, identity, and nonword) as factors. The analysis revealed significant main effects of Task ($F = 3.761$, $df = 3,30$, $p = .020$) and Prime Type ($F = 24.462$, $df = 7,70$, $p < .001$) but not Order ($F = 2.343$, $df = 1,10$, $p = .154$. Task interacted significantly with Prime Type ($F = 1.865$, $df = 21.210$, $p = .014$) while Order failed to interact with either task ($F = 2.580$, $df = 3,30$, $p = .071$) or Prime Type ($F = 1.728$, $df = 7,70$, $p = .116$). In a subsequent analysis with high associate, high dominant, identity, and unrelated targets as Prime Types, the Task X Prime Type interaction remained significant ($F = 2.406$, $df = 9,90$, $p = 2.406$) while order again interacted with neither Task ($F = 2.194$, $p = .108$) nor Prime Type ($F = .488$).

A comparison of the difference scores for subjects receiving a no shadow block followed by a shadow block and subjects receiving a shadow block first suggests that shadowing is, if anything, more likely to reduce semantic priming when it occurs in the first rather than the second trial block.

INSERT TABLE 5 ABOUT HERE

The results of Experiment 1B serve to strengthen the conclusions of Experiment 1 by reducing the possibility of a confounding order effect.

Experiment 2

Experiment 1 demonstrates that semantic but not identity priming is reduced by a simultaneous shadowing task. There are two possible explanations for semantic priming in lexical decision. One explanation stresses the influence of the prime in activating pathways shared with the target. The second explanation suggests that some or all of the priming effect occurs after target presentation and results from "backward" facilitation as candidate target words are constrained by the prime.

The typical lexical decision task often confounds relatedness with the task demands (e.g. Chumbley & Balota, 1984; Lorch, Balota & Stamm, 1986) since if a prime is related to the target the response must be "word". Nonwords, by definition, do not have related primes. It is known, however, that priming can be obtained even without this confound as in pronunciation or semantic classification tasks (Schvaneveldt & Durso, 1981, Seidenberg,

Waters, Sanders & Largo, 1984). In our second experiment we use a semantic target classification task in order to prevent the strategic use of relatedness in decision making. This allows us to examine identity and semantic priming in a situation without this possible artifact.

Subjects: 12 subjects were recruited in the same manner as for Experiment 1. One subject was subsequently excluded for failure to follow instructions. The remaining 11 subjects ranged in age from 21 to 33 (mean = 26.4) and had from 15 to 20 (mean = 16.5) years of education. One subject was left-handed.

Stimuli: Word list stimuli consisted of 142 word pairs, 70 with a predator target and 72 with a non-predator target. The predator pairs included 10 targets primed by a category label (e.g. cat - leopard), 12 primed by an associated (e.g. clever - fox), and 12 primed by the identical string (vulture - vulture). The non-predatory stimuli included 12 category pairs (e.g. fowl - chicken), 12 associated pairs (e.g. hump - camel), and 12 identity pairs. 72 unrelated pairs were constructed by pairing each target from the semantically related pairs with a prime dissimilar in meaning (e.g. bay - eel). Category and associate relations as well as predator/non-predator determinations were based on the examiner's judgment without benefit of norms. The difficulty of finding a sufficient number of categorical relations precluded controlling for frequency of occurrence.

The auditory tape used for shadowing was again Gore Vidal's reading of his novel <u>Abraham Lincoln</u>.

Procedure: With the exception of the required decision, the procedure for this experiment was very similar to that for Experiment 1. In this experiment, subjects received two repetitions of the word list without shadowing followed by two repetitions with shadowing. Item order was again randomized for each list presentation.

Subjects were instructed that their task was to determine if the second (target) word was or was not a predatory animal. Predators were described as any animal that is carnivorous or otherwise potentially harmful. If the target was a predator, the correct response was to press the left key on the response panel. Non-predatory responses were registered by pressing the right key. Subjects again used the second and third fingers of their dominant hand to respond.

Results: Each subject's mean reaction time for responses was computed for each SOA by Task by Prime Type and these data were again included in a fixed-effects repeated measures ANOVA. Reaction times faster than 200 msec or slower than 2000 msec were considered errors and excluded. The categorical and associated pairs, both predators and non-predators, were combined to create a semantic prime type. The means and standard deviations for semantic, identity, and unrelated pair types for each

condition are presented in Table 6. Error scores for Experiment 2, considerably higher than for Experiment 1, are displayed in Table 7.

INSERT TABLES 6 & 7 ABOUT HERE

The ANOVA revealed significant main effects of Task ($F = 10.958$, $df = 1,10$, $p = .007$) and Prime Type ($F = 22.851$, $df = 2,20$, $p < .001$), but not of SOA ($F = .966$). More detailed analysis demonstrated that the main effect of Task is attributable to longer reaction times in the shadowing conditions for all three prime types ($F = 12.309$, $p = .005$ - identity; $F = 8.335$, $p = .015$ - semantic; $F = 9.442$, $p = .011$ - unrelated). Individual comparisons of the Prime Types revealed that identity pairs were significantly faster than either semantic ($F = 28.256$, $p < .001$) or unrelated ($F = 24.711$, $p < .001$) but that the difference between semantic and unrelated pairs only approached significance ($F = 3.687$, $p = .087$). The major difference between this experiment and Experiment 2 was the absence of an overall Task X Prime Type interaction ($F = .200$, $df = 2,23$).

Difference scores, as presented in Table 8, were entered into a Task X SOA X Prime Type (semantic, identity) ANOVA which revealed significantly greater priming for the identity pairs ($F = 28.256$, $df = 1,10$, $p < .001$). The Task X Prime Type interaction utilizing difference scores was insignificant ($F = .050$).

INSERT TABLE 8 ABOUT HERE

Although the error rates are high, a Task X Prime Type ANOVA using percentage errors uncovered no effects of either variable.

In summary, reducing the strategic post-access component of the decision task reduced priming for semantic but not for physically identical pairs. Semantic priming, in fact, was only of marginal significance in the predator/non-predator task. Shadowing did not reduce physical priming but tended to reduce semantic priming by approximately one-half.

These results suggest that the dissociation between physical and semantic priming was not unique to the structure of the lexical decision task and confirm that physical priming is isolated from the influence of auditory shadowing while semantic priming is not.

Experiment 3

The purpose of Experiment 3 was twofold. The primary purpose was a replication of Experiment 1 with a larger subject population. A secondary purpose was to ensure that the results of Experiment 2 were not item rather than task specific. We thus embedded the stimuli from Experiment 2 into a larger replication of Experiment 1.

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Subjects: 24 subjects were recruited in the same manner for Experiments 1 and 2. Information about age and education was lost for five subjects. The remaining 19 subjects ranged in age from 19 to 49 (mean = 29.5) and had from 12 to 20 (mean = 14.4) years of formal education. None of the 19 subjects was left-handed.

Stimuli: The stimuli for this experiment included 40 categorical, 40 associate, 40 identity, and 120 unrelated prime/word target pairs and 240 prime/non-word target pairs. The categorical stimuli included 20 pairs with animal targets, 10 predators and 10 non-predators, selected from Experiment 2. The remaining 20 category pairs consisted of category label primes and high dominance exemplars. The associated stimuli also included 20 pairs from Experiment 2 (10 predators and 10 non-predators). The remaining associate pairs consisted of 10 antonym sets and 10 common associations. Half of the identity pairs, 10 predators and 10 non-predators, were obtained from Experiment 2. Unrelated pairs were constructed by pairing each semantically related target with an unrelated word. Nonword targets were repeated twice, each time with a different prime.

As in Experiment 2, it was necessary to divide the word list into two parts. Each part contained half the items in each pair type. List order was counter-balanced across subjects.

Procedure: The procedure for Experiment 3 was identical to that for Experiment 1.

Results: Each subject's mean reaction time for correct "yes" responses was initially entered into a three way (SOA by Task by Prime Type) analysis of variance. The Prime Types for this analysis were semantic (all categorical and associate pairs), identity (both animate and inanimate) and unrelated. This analysis yielded significant main effects of Task (F = 12.789, df = 1.23, p = .001) and Prime Type (F = 38.383, df = 1,23, p < .001) but not SOA (F = .077, df = 1,23). The means and standard deviations for each cell are presented in Table 9. Further analyses of the main effects reveal significant effects of Task for both semantic (F = 17.083, df = 1,23) and unrelated (F = 16.835, df = 1,23) pairs considered alone. Reaction times for nonwords, also included in Table 9, increased significantly with shadowing in this experiment (F = 6.662, df = 1,23, p = .016). The effect of task on identity pairs considered alone approached, but failed to reach significance (F = 3.301, df = 1,23, p = .079). The main effect of Prime Type was significant at the .001 level for all three possible two-prime type comparisons. The Task X Prime Type interaction was significant overall (F = 6.456, df = 2.46, p = .003) and when identity pairs were considered with either semantic (F = 12.611, p = .002) or unrelated (F = 4.8, p = .036) pairs alone. The Task X Prime Type interaction for semantic and unrelated pairs considered without identity pairs, unlike Experiment 1, was insignificant (F = 1.729).

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INSERT TABLE 9 ABOUT HERE

Difference scores (Table 10) were entered into a three way (SOA by Task by Prime Type) ANOVA, revealing both a significant main effect of Prime Type (F = 19.83, df = 1,23, p < .001) and a significant Task by Prime Type interaction (F = 12.611, df = 1,23, p = .002).

INSERT TABLE 10 ABOUT HERE

The overall error rates for the semantic, identity, unrelated, and nonword categories are listed in Table 11. There were no significant effects of Task or Prime Type on percentage error.

INSERT TABLE 11 ABOUT HERE

The effect of experiment (lexical decision versus semantic classification) was further explored by re-defining the semantic category in Experiment 3 to include only those stimuli that were presented in Experiment 2 (PSEM). The reaction times for this condition (Table 12) differ minimally from those for the semantic category in Table 9. The full set of analyses reported above was repeated replacing the semantic category with the PSEM category. The results are extremely similar. The three way ANOVA with reaction time data and three Prime Types yielded significant main effects of Task (F = 12.202, df = 1,23, p = .002) and Prime Type (F = 30.034, p < .001) but not SOA. The Task X Prime Type interaction remained significant overall (F = 4.136, df = 2,46) but was not significant when PSEM and unrelated pairs were considered without identity pairs (F = .636.

INSERT TABLE 12 ABOUT HERE

The PSEM reaction times from Experiments 2 and 3 were directly compared by entering them in a three way between/within (Experiment by Task by SOA) ANOVA. This ANOVA revealed longer reaction times for Experiment 2 than for Experiment 3 (F = 6.342, df = 1,33, p = .016). Although there was a significant main effect of Task on the reaction times (F = 19.6, df = 1,33, p < .001), the Task X Experiment interaction was not significant (F = .114). The difference scores for the PSEM category for each experiment are presented in Table 13. An Experiment by Task by SOA analysis revealed none of the predicted effects.

INSERT TABLE 13 ABOUT HERE

The results from all three experiments, averaged across SOA, are presented together in Table 14.

In summary, the results of Experiment 3 largely replicate the results of Experiment 1. Shadowing again increased reaction times overall. When the prime types are considered individually, shadowing reaction times are again significantly longer for semantic and unrelated targets while the difference for identity targets does not quite reach significance.

Experiment 3 also yielded a significant main effect of prime type. In addition, all possible two prime type comparisons were significant. There can be no doubt that both semantic and identity priming were obtained.

As in Experiment 1, the Task by Prime Type interaction was significant. However, omitting the identity pairs (considering only semantic and unrelated pairs) eliminated the effect. More importantly, the difference scores in Table 8 reveal a decrease in priming with shadowing for semantic but not for identity targets. Inspection of the table reveals that, unlike Experiment 1, the effect is occurring only at the long SOA. It is possible that the long SOA would allow for greater reliance on attentional processes which would then be minimized during shadowing.

Lastly, in order to ensure that the priming pattern obtained for Experiment 2 was not item specific, the analyses considered above were repeated using only the semantic stimuli that were presented in Experiment 2. Separating these stimuli from the larger set of semantic targets did not alter the pattern of results. It is reasonable to conclude that differences in priming patterns between the experiments are due to processing demands and not specific item demands. Unfortunately, the direct comparison of semantic priming across the two experiments did not yield the predicted Experiment by Task interaction.

Conclusions

Our results show no evidence of a reduction in identity priming during shadowing but a clear effect on semantic priming. However, in our experiment we used only two intervals between prime and target. In some of the experiments there is some evidence that effect of divided attention increases with interval for the semantic task, but decreases for the identity task. In no experiment was this interaction between SOA and attention significant. Even when we combined the data over all experiments the F test was still insignificant. However, it remains possible that at still shorter SOAs than 400 millisec that there would be some influence of the shadow task even on physical priming. It is quite clear, however, that physical priming is uninfluenced by the dual task at intervals where

semantic priming is greatly attenuated. There are at least two possible
explanations for the relative lack of a shadowing effect on physical
priming. One account is that physical priming is more automatic than
semantic priming. Thus, when attention is reduced by shadowing the effect
is greater on less automatic semantic processes. While plausible, this
account is not a sufficient explanation. It is well known that even
physical priming can be influenced by attentional manipulations (e.g.
Posner & Snyder, 1975). In addition, there is evidence that semantic
priming can be automatic (e.g. Neely, 1977). Further, if greater
automaticity of physical priming is the full explanation, priming by highly
related primes should be less affected by shadowing than priming by less
highly related primes. Although highly related primes yielded greater
priming, shadowing produced approximately equivalent effects on all
semantic prime types. Thus, while probably contributory, the automaticity
argument does not seem adequate to support the clear dissociation between
semantic and identity primes found in Experiments 1 and 3.   ·

Another account suggests that identity priming depends primarily upon
pathways that are visual in character. Activation of these pathways would
lead to facilitation of the visual word in reaching areas that contain
semantic information. Kinsbourne & Hicks (1978) suggest a general
principle of functional cerebral distance in which activity in functionally
distant anatomical areas produces less interference than in functionally
related areas. If identity priming involves activation of purely visual
areas little interference from shadowing would take place. However, the
same theory would expect considerable interference when purely semantic
priming is involved since semantics would be contacted both by the visual
input and by the story that was being shadowed. According to this logic
the dual task method can be extended to produce information on the anatomy
as well as on the functional autonomy of lexical systems.

Recent work on auditory and visual processing of lexical items using
Positron Emission Tomography (Petersen, et al, 1986, 1987) has produced a
picture of the anatomy of these systems. Visual words are processed in
several areas of the occipital lobe. It is thought that these areas
produce an integrated visual word form in the way postulated by the lexical
network views of interactive visual word processing (McClelland &
Rumelhart, 1982). The integrated word form is then sent to several areas
of the frontal lobe. Among these areas are parts of the dorsolateral
prefrontal cortex (area 45) that seem closely related to tasks demanding
semantic analysis. It is notable that this general area is also activated
in auditory word processing (Petersen, et al, 1987). While the visual and
auditory activations are not identical, they are in relatively close
proximity within area 45. This anatomical picture fits rather well with
the shadowing data presented here. Since our shadowing task had a strong
semantic character (subjects did understand the story) it would be expected
to involve the semantic areas that would also be needed for priming
associates and category exemplars. The PET data imply that purely
phonological priming (e.g. individual word naming) would not activate the

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semantic areas. This suggests that shadowing of isolated words and/or nonsense material, although more difficult, would not produce the effect of semantic priming found in the current study even though it would be more difficult. Such studies may provide closer methods of integrating purely cognitive studies and those involving anatomical localization.

TABLE 1

REACTION TIMES FOR LEXICAL DECISION - EXPERIMENT 1

	Semantic	Identity	Unrelated	Nonword
Short No Shadow	663 (108)	652 (111)	716 (109)	819 (141)
Short Shadow	748 (154)	690 (143)	737 (114)	812 (117)
Long No Shadow	627 (90)	629 (136)	670 (124)	769 (147)
Long Shadow	712 (112)	644 (130)	739 (113)	768 (115)

Numbers in Parentheses are Standard Deviations

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TABLE 2

REACTION TIMES TO LEXICAL DECISION FOLLOWING FOUR TYPES
OF SEMANTIC PRIME – Experiment 1

	High Dominance	Low Dominance	High Associate	Low Associate	Unrelated
Short No Shadow	663	700	629	659	716
Short Shadow	757	779	704	753	737
Long No Shadow	643	681	588	596	670
Long Shadow	733	766	676	671	739

TABLE 3

DIFFERENCE SCORES FOR SEMANTIC AND IDENTITY PAIRS

EXPERIMENT 1

	Semantic	Identity
Short No Shadow	53.7 (29.5)	64.8 (98.5)
Short Shadow	-10.6 (99.8)	47.1 (93.6)
Long No Shadow	43.1 (58)	40.4 (129.1)
Long Shadow	27.4 (72)	95.5 (91.5)

Numbers in Parentheses are Standard Deviations

TABLE 4

PERCENTAGE ERRORS - EXPERIMENT 1

	Semantic	Identity	Unrelated
No Shadow	5.7 (4.5)	3.8 (4.4)	6.0 (4.7)
Shadow	9.3 (6.6)	7.9 (7.4)	10.0 (7.4)

Numbers in Parentheses are Standard Deviations.

TABLE 5

DIFFERENCE SCORES FOR TWO ORDERS - EXPERIMENT 1B

	High Associate	Low Associate	High Dominant	Low Dominant	Semantic	Identity
No Shadow						
first	49	26	42	-56	15	25
Shadow						
second	37	34	26	13	28	74
No shadow						
second	38	29	33	-42	14	44
Shadow						
first	- 5	30	13	- 5	8	66

TABLE 6

REACTION TIMES FOR SEMANTIC CLASSIFICATION FOLLOWING
THREE TYPES OF PRIME - EXPERIMENT 2

	Semantic	Identity	Unrelated
Short No Shadow	656 (74)	597 (103)	700 (80)
Short Shadow	770 (150)	712 (116)	771 (141)
Long No Shadow	674 (64)	597 (72)	669 (56)
Long Shadow	749 (138)	679 (96)	775 (134)

Numbers in Parentheses are Standard Deviations.

TABLE 7

PERCENTAGE ERRORS - EXPERIMENT 2

	Semantic	Identity	Unrelated
No Shadow	17.5 (4.8)	16.9 (5.9)	17.0 (5.1)
Shadow	21.6 (5.4)	17.2 (6.1)	19.2 (5.2)

Number in Parentheses are Standard Deviations.

TABLE 8

DIFFERENCE SCORES - EXPERIMENT 2

	Semantic	Identity
Short No Shadow	43.4 (53)	102.7 (61)
Short Shadow	0.4 (49)	58.4 (62)
Long No Shadow	-5.8 (42)	71.5 (57.6)
Long Shadow	26.0 (54)	94.8 (86)

Numbers in parentheses are Standard Deviations

TABLE 9

REACTION TIMES TO LEXICAL DECISION - EXPERIMENT 3

	Semantic	Identity	Unrelated	Nonword
Short No Shadow	584 (79)	561 (103)	619 (86)	698 (121)
Short Shadow	649 (111)	600 (128)	688 (120)	743 (138)
Long No Shadow	574 (85)	566 (99)	616 (84)	669 (122)
Long Shadow	676 (85)	601 (136)	681 (111)	720 (126)

Numbers in Parentheses are Standard Deviations

TABLE 10

SEMANTIC AND IDENTITY PAIRS - EXPERIMENT 3

	Semantic	Identity
Short No Shadow	36 (38)	58 (49)
Short Shadow	40 (59)	88 (72)
Long No Shadow	42 (43)	50 (49)
Long Shadow	5 (77)	80 (87)

Numbers in Parentheses are Standard Deviation

TABLE 11

PERCENTAGE ERRORS - EXPERIMENT 3

	Semantic	Identity	Unrelated	Nonword
No Shadow	4.5 (3.5)	5.8 (3.4)	5.4 (4.0)	5.4 (4.0)
Shadow	3.8 (4.0)	4.4 (4.6)	4.8 (3.5)	5.5 (4.4)

Numbers in Parentheses are Standard Deviations

TABLE 12

REACTION TIMES TO LEXICAL DECISION FOR THE SEMANTIC PAIRS

IN EXPERIMENTS 2 AND 3 (PSEM)

PSEM

	PSEM
Short No Shadow	587 (79)
Short Shadow	657 (94)
Long No Shadow	585 (94)
Long Shadow	677 (164)

Numbers in Parentheses are Standard Deviations

TABLE 13

DIFFERENCE SCORES FOR SEMANTIC PAIRS SHARED BY

EXPERIMENTS 2 AND 3.

	No Shadow	Shadow
Exp. 2 - Short SOA	43.4 (53)	0.4 (49)
Exp. 3 - Long SOA	-5.8 (42)	26 (54)
Exp. 3 - Short SOA	32.1 (35)	31 (82)
Exp. 3 - Long SOA	30.6 (50)	4.5 (108)

Numbers in Parentheses are Standard Deviations

TABLE 14

REACTION TIMES AND DIFFERENCE SCORES ACROSS SOA

FOR EXPERIMENTS 1, 2 AND 3

	Semantic		Identity		Unrelated
	RT	Difference	RT	Difference	RT
Exp. 1a					
No Shadow	645	48.4	640	52.6	693
Shadow	730	8.4	667	71.3	738
Exp. 3					
No Shadow	579	39	564	54	618
Shadow	662	22.5	600	84	684
Exp. 2					
No Shadow	665	18.8	597	87.1	684
Shadow	760	13.2	696	76.6	773

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