Journal of Experimental Psychology:
Learning, Memory, and Cognition
1990, Vol. 16, No. 5, pp. 862-869

0278-7393/90/$00.75

Visual Word Recognition: A Dissociation of Lexical and Semantic Processing

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These experiments illustrate two new dissociations in word-recognition tasks. In one, relatedness facilitated lexical decision but impaired searching for a common letter in the same pairs of words (a cross-over interaction between relatedness and task). In the other dissociation, lexicality facilitated performance (words processed faster than nonwords) while relatedness impaired performance (related words processed slower than unrelated words) in the letter search task. Two classes of explanation are discussed. In the first, the perception of relatedness serves to focus attention to the word level, thereby making explicit letter level processing more difficult and/or increasing the number of competing lexical entries via priming. In the second, spreading inhibition makes related words more difficult to process than unrelated words.

It is often supposed that the mere presentation of a word is a sufficient condition for the lexical representation of that word to be activated. A further received idea is that there is an obligatory spreading of this activation to related lexical entries. These assumptions form the kernel of what can be called an "automaticity hypothesis" and are important components of a number of theories that assume the existence of a mental lexicon (e.g., Neely, 1976, 1977, in press; Posner & Snyder, 1975; see also Anderson, 1976; Anderson & Bower, 1973; Collins & Loftus, 1975; Schvaneveldt & Meyer, 1973). These theories typically offer a framework for understanding the well-documented finding that target items such as *doctor* are processed more efficiently when preceded by a related item such as *nurse* than by an unrelated item such as *yacht* (e.g., Meyer & Schvaneveldt, 1971). This facilitation, often called "priming," is seen as a direct outgrowth of automatic spreading activation (e.g., Collins & Loftus, 1975).

The results of a series of experiments by Smith (1979), Smith, Theodor, and Franklin (1983), and Henik, Friedrich, and Kellogg (1983) suggest that this automaticity assumption may be too strong. These authors reported that preceding a target item with a related word did not necessarily produce facilitation relative to an unrelated word. Rather the way in which the subject processed the prime word was an important determinant of whether processing of the target word was facilitated. If subjects performed a letter search of the prime—which required explicit processing of individual letters—the related words failed to produce significant facilitation. In other words, searching for the letter *R* in the target word *doctor* was not differentially affected by a prior search for the letter *U* in either the related prime word *nurse* or the unrelated prime word *purse*. Smith et al. concluded from these studies that the spread of semantic activation to related units is not obligatory, but is dependent upon mode of prime processing.

One difficulty with the three previously mentioned studies relates to the issue of whether prime processing resulted in *lexical* activation. Smith and her colleagues argued that the mental set that subjects adopt is crucial: A set to attend to individual letters rather than to the word as a whole activates the lexical entry for that word but does not elicit the spread of activation to related lexical entries. However, no evidence was provided that the lexical entry for the prime word had in fact been accessed. In all of these experiments, the to-be-searched-for letter was visually specified immediately above every letter in the prime, for example,

RRRR

READ

This arrangement may have encouraged subjects to treat the display as a matching task dependent solely upon visual features; such a match could have been done at a prelexical level. Hence, failure to find semantic priming could have resulted either because prime processing produced no lexical activation or because lexical activation occurred without a spread of activation to related items.

A slightly different type of letter search task was used in the present experiments. Instead of asking subjects to signal whether a specified letter was or was not present in a letter string, subjects were asked whether two simultaneously presented strings shared a common letter. Kreuger (1989) used this variation of the letter-search procedure and found that subjects were able to locate a common letter faster in pairs of words than in pairs of nonwords. Provided that the words and

This work was supported by Natural Sciences and Engineering Research Council of Canada Grant A0998 to Derek Besner, Grant A7930 to Marilyn C. Smith, and Grants A7459 and E6532 to Colin M. MacLeod. We are grateful to Andrew Portal, Julie Fraser, and Ken Seergobin for programming support and testing subjects. We also thank Lester Kreuger and two anonymous reviewers for their helpful suggestions on a previous version of the article.

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nonwords are matched for orthography, more efficient letter search through a word than through a nonword is typically taken as evidence for lexical activation (see Henderson, 1982; Kreuger, 1989; Kreuger & Weiss, 1976; Seymour & Jack, 1978, for suggestions as to possible underlying mechanisms). We assume, therefore, that the presence of more efficient processing of words than nonwords is a signature of lexical processing.

Having provided for lexical activation, the question of interest here is whether the presentation of semantically related word pairs will yield a processing difference relative to unrelated pairs. In a variety of different tasks that emphasize word processing, such as lexical decision (Neely, 1977), same–different judgments (Rosch, 1975; Schaeffer & Wallace, 1970), word naming (Meyer, Schvaneveldt, & Ruddy, 1975), and perceptual identification (Schvaneveldt & McDonald, 1981), it has been demonstrated that processing of a word is facilitated when it occurs in the context of a semantically related word. One interpretation of this facilitation is that the activation of a given lexical entry results in a spread of activation to related lexical entries, thereby facilitating their processing. Failure to find contextual priming in the letter search task was interpreted by Smith et al. as resulting from the absence of such a spread of activation. More specifically, it was argued that whether or not contextual facilitation occurs may be dependent upon the way in which the prime is processed: If it is not processed as a word, lexical activation may not spread to related lexical units.

The present experiments were conducted to determine whether a relatedness effect would be observed in a task in which subjects were set to look for individual letters rather than to make word-level decisions, yet where there would still be grounds for assuming that lexical activation occurred. To this end, half the presented word pairs were semantically related and the remainder were unrelated. A further issue concerned whether a relatedness effect, if it occurred, would manifest itself as facilitation or inhibition. Although it is often assumed that relatedness effects reflect a spread of activation between related lexical entries, it is possible that, in the context of the letter search task, this activation could serve either to facilitate or to interfere with performance. On the facilitation account, a related context would result in faster encoding of the target string via activation of associated word targets. This would make it easier to name the word targets (Becker & Killion, 1977), to perceptually identify them (Schvaneveldt & McDonald, 1981), or to make lexical decisions about them (Meyer et al., 1975).

Alternatively, a related context could slow the letter search for several reasons. One possibility relates to the attentional demands of the task: The perception of relatedness may serve to focus attention at the word level (cf. Marcel, 1983), thereby making explicit processing at the letter level more difficult. Such a focus could make it more difficult to search through related words compared with unrelated words. A second possibility derives from related words activating a similar pool of associated word targets. For example, *doctor* and *nurse* may both activate such related concepts as *medicine, hospital,* and *sick*, thereby making the component letters of these unpresented words readily available in addition to those of the two target letter strings. Competition from this extraneous lexical information in the related context condition could interfere with the letter search. Although similar interference should result from activation of associated lexical entries in the unrelated condition, the level of this activation ought to be smaller because each entry is activated by a single item rather than by both items, as is the case when the context is related. A third possibility is that subjects are capable of producing spreading inhibition between related lexical nodes. The benefit of such a process would ordinarily be to reduce the activation of potentially competing irrelevant letter information. The cost would be that it could make related targets more difficult to encode and possibly more difficult to compare as well.

On a priori grounds, therefore, it is unclear whether the manipulation of relatedness in the context of a letter search task should be expected to yield facilitation, interference, or a null effect. It is for this reason that we undertook the present experiments. To preface, in Experiments 2 and 3, a pair of letter strings was presented and subjects were asked whether the two letter strings shared a common letter. Because this task sets subjects to look for component letters rather than to make word level decisions, but nonetheless involves lexical activation (cf. Kreuger, 1989), the question of interest was whether performance of this task would be influenced by semantic relatedness.

Because the presence or absence of a relatedness effect in this experiment will be used to assess whether there is automatic spread of activation under a set to look for component letters, it is important to demonstrate first that a relatedness effect does occur with this particular stimulus set under word level decision conditions. Hence, a standard lexical decision task was conducted in Experiment 1 using the same pairs of stimuli that were to be employed in the letter search experiments (Experiments 2 and 3). To anticipate the results, a standard relatedness effect was found in Experiment 1: Faster lexical decisions were made about related word pairs than about unrelated word pairs. Experiments 2 and 3 provide evidence of a qualitatively different semantic relatedness effect in the context of a letter search task.

Experiment 1

Method

Subjects. Eighteen undergraduates were recruited from the Scarborough Campus of the University of Toronto. They were each paid $5.00 for their participation.

Stimuli. The stimulus set consisted of 180 critical pairs of items (either two words or two nonwords) as well as an additional set of 20 filler pairs made up of a word and a nonword. All of the filler items were seen by every subject. The 180 critical pairs consisted of 60 related word pairs (e.g., *dog–cat*), 60 unrelated word pairs (e.g., *dig–cat*), and 60 nonword pairs (e.g., *dok–cit*). These pairs were constructed by choosing words that were strongly semantically related and then changing one or two letters to form an unrelated pair of words. The nonword pairs were derived from the related word pairs by changing one letter in each of the words. The stimuli were thus tightly matched for orthography.

Each subject saw 60 of the 180 critical pairs (20 related word pairs, 20 unrelated word pairs, and 20 nonword pairs). No items were repeated within the set seen by an individual subject, nor did an individual subject see any items in the set that were derived from another item within that set. Therefore, if a subject saw the pair *dog-cat*, that subject did not see either *dig-cat* or *dok-cit*. Six combinations of subsets were thus used three times each across the 18 subjects. In total, each subject saw 80 pairs—60 critical items plus the constant 20 filler pairs. Across subjects, all critical pairs appeared equally often. Half the trials consisted of letter strings with one letter in common; the remaining trials consisted of letter strings with no letters in common. When a common letter was present in a pair of letter strings, its position and identity were preserved across the three conditions. Twenty-four practice trials preceded the experimental trials; these were made up of a different set of pairs.

Procedure. The stimuli were displayed horizontally on a 12-in. monitor driven by an Apple IIe microcomputer. The letter strings appeared in uppercase and were separated by a double space.

A trial consisted of the following sequence. A clear screen was presented for 500 ms. This was followed by a "plus sign" fixation point, which appeared in the middle of the screen for 500 ms. Offset of the fixation point was immediately followed by the stimulus display, which remained on the screen until the subject made a response by pressing either a "yes" key or a "no" key on a response panel below the monitor. Upon presentation of each pair of letter strings, the subject was to decide whether or not the letter strings spelled real words. If both were words, the subject was to respond "yes;" if either or both of the letter strings did not spell a word, the subject was to respond "no."

Results and Discussion

Median reaction times (RTs) and mean error rates were calculated for each subject in each condition. Trials on which an error was committed were excluded from the latency analysis. The data for the related word, unrelated word, and nonword conditions are shown in Table 1.

Median RT was 119 ms faster in the related condition than in the unrelated condition, a reliable difference, $F(1, 17) = 18.1$, $MS_e = 6{,}707$, $p < .001$. The error data yielded a similar pattern of facilitation, $F(1, 17) = 14.8$, $MS_e = 1.4$, $p < .001$. Hence, we have established that, in a task that involves both lexical access and whole-word processing, there is clear evidence of a semantic relatedness effect. Experiment 1 demonstrates the typical finding of facilitation. We turn now to the letter search task to determine whether semantic relatedness influences performance if subjects are set to process the component letters of the word rather than to make a decision about the letter string as a whole.

Experiment 2

Method

The stimulus set, apparatus, and stimulus presentation were identical to that of Experiment 1. A new group of 54 subjects was recruited from the same undergraduate population. Each of the six subsets of stimuli was presented nine times across subjects. Subjects were instructed to respond "yes" if there was a letter that was common to both letter strings and "no" otherwise. As in Experiment 1, the right hand was used for the "yes" response. Subjects were asked to respond as quickly as possible, but at the same time to try to avoid too many errors.

Table 1
Experiment 1: Median Reaction Times (RTs) and Percentage Error Rates in the Lexical Decision Task as a Function of Relatedness and Lexical Status

	Words		
Variable	Related	Unrelated	Nonwords
RT (ms)	685	804	765
% error	1.1	8.6	7.0

Results

Median response times and mean error rates were calculated for each subject in each condition. Trials on which an error was committed were discarded from the latency analysis. The data for the related word, unrelated word, and nonword conditions are shown in Table 2.

To assess whether letter search efficiency differed among the three critical conditions, overall analyses of variance (ANOVAs) were performed on both the latency data and the error data. These were 3 × 2 repeated-measures ANOVAS with the factors being condition (related words, unrelated words, and nonwords) and match type (positive versus negative letter match). The irrelevant word-nonword filler condition (mixed pairs) was omitted from the analysis.

Condition was a reliable source of variance in the latency data, $F(2, 106) = 6.3$, $MS_e = 152{,}684$, $p < .002$, primarily reflecting the fact that the nonwords were slower than the words. Match type was also a significant main effect, $F(1, 53) = 92.8$, $MS_e = 376{,}547$, $p < .001$, with longer latencies for negative than for positive trials. There was no interaction between these two factors, $F < 1$. An analysis of the error data yielded a main effect only for match type, $F(1, 53) = 269.5$, $MS_e = 1.6$, $p < .001$; the miss rate was much higher than the false-alarm rate. Neither the main effect of condition nor the interaction between condition and match type were reliable in the error ANOVA, $F < 1$. The error data were not

Table 2
Experiment 2: Median Reaction Times (RTs) and Percentage Error Rates in the Letter Search Task as a Function of Relatedness, Lexical Status, and Positive Versus Negative Letter Match

	Words		
Variable	Related	Unrelated	Nonwords
Positive letter match			
RT (ms)	1,633	1,576	1,789
% error	22.5	23.8	26.4
Negative letter match			
RT (ms)	2,323	2,243	2,403
% error	1.4	1.4	.90

analyzed further because the main effect of match type does not bear on any of the issues under discussion.

Further investigation of the differences in the latency data between the three critical conditions was assessed by a pair of contrasts. When words were contrasted with nonwords, median latencies for words were reliably faster than for nonwords, $t(53) = 3.0$, $p < .01$. The second contrast compared related and unrelated words; related words were slower than unrelated words, but this difference was not reliable, $t(53) = 1.4$, $p < .16$. Nonetheless, the 68-ms average difference between related and unrelated words is sufficiently large to make acceptance of the null hypothesis very risky.

Discussion

On the basis of Kreuger's (1989) finding that subjects are able to detect a common letter faster in pairs of words than in pairs of nonwords, our working assumption was that this is a task that involves lexical activation. To ascertain that this result held in our experiment as well, our first interest was in investigating any performance differences between word and nonword pairs. The finding that our data replicated Kreuger's in showing that performance was better in words than in nonwords is taken as confirmation that lexical activation had indeed occurred.

The remaining question of interest was whether a semantic relatedness effect would emerge under conditions in which there was evidence of lexical involvement but where the mental set was to search for letters rather than to process the word as a whole. To answer this question, we examined performance for related and unrelated word pairs. The data were clear in showing no evidence of facilitation. Instead, there was a trend toward an inhibitory effect, although this effect did not reach conventional significance levels. Before further consideration of the nature of any relatedness effect, a third experiment was conducted for two reasons.

First, because any conclusions that we draw depend upon the assumption that lexical activation has occurred, it is essential that the only difference between the words and nonwords be in terms of their lexicality. Although only one letter had been changed in each word to form a nonword, a post hoc analysis revealed that the summed bigram frequency was slightly lower for the nonwords than for the words. It is therefore possible that the longer search times in the nonword condition were the result of variations in orthographic redundancy rather than lexicality. Hence, the absence of a significant semantic relatedness effect is difficult to interpret. This possible confound was eliminated in Experiment 3 by matching the stimuli for orthographic redundancy.

Second, the method of presenting the two letter strings side by side required that subjects continuously scan back and forth. The long search times and high error rates (as well as our own experience in performing the task) suggest that this was a difficult task. If the semantic relatedness effect is small in this task, large error variance may make it more difficult to detect. Consequently, the two letter strings were positioned one above the other in Experiment 3. Experience suggested that this made the detection of a common letter easier.

Experiment 3

This experiment provided a replication of Experiment 2 with two important differences. First, letter strings were positioned one above the other to make detection of a common letter easier. Second, the stimulus set was modified to ensure that the summed bigram frequencies of the words and nonwords were identical. Because bigram frequency counts were available only for letter strings up to seven letters long, four pairs containing a word over seven letters were replaced. The slightly modified stimulus set used in Experiment 3 is presented in the Appendix. The summed bigram frequency counts for the words and nonwords are presented in Table 3.

Method

Thirty-two undergraduates at the University of Waterloo participated as subjects in this experiment. Subjects were paid for their participation. The procedure was identical to that used in Experiment 2, except that the two letter strings were displayed one above the other.

Results

Median response times and mean error rates were calculated for each subject in each condition. Trials on which an error was committed were discarded from the latency data. The data for the related word, unrelated word, and nonword conditions are shown in Table 4. The irrelevant word–nonword filler condition (mixed pairs) was again omitted from the analysis.

Analysis of the error data revealed that only the effect of match type (the difference between positive and negative responses) was significant, $F(1, 31) = 75.6$, $MS_e = 283$, $p < .001$. Because neither the effect of condition nor the interaction of condition and match type approached significance, $F < 1$, the error data are not considered further.

An ANOVA on the latency data yielded a significant effect of match type ("yes" vs. "no"), $F(1, 31) = 36.2$, $MS_e =$

Table 3
Experiment 3: Summed Bigram Frequencies for Positive and Negative Word and Nonword Pairs (30 pairs per condition)

	Related words		Unrelated words		Nonwords	
Variable	Positive	Negative	Positive	Negative	Positive	Negative
M	383	304	382	307	386	315
SD	209	159	209	149	243	160

Table 4
Experiment 3: Median Reaction Times (RTs) and Percentage Error Rates in the Letter Search Task as a Function of Relatedness, Lexical Status, and Positive Versus Negative Letter Match

	Words		
Variable	Related	Unrelated	Nonwords
Positive letter match			
RT (ms)	1,524	1,339	1,556
% error	25	24	28
Negative letter match			
RT (ms)	2,015	2,017	2,139
% error	5	4	4

452,856, $p < .001$; responses in which a match occurred were 584 ms faster than those in which no match occurred. The effect of condition (related words vs. unrelated words vs. nonwords) was also significant, $F(2, 62) = 5.2$, $MS_e = 87{,}901$, $p < .01$, as was the interaction, $F(2, 62) = 3.2$, $MS_e = 44{,}829$, $p < .05$.

Several *t* tests were performed to investigate the interaction in more detail. Letter search in unrelated words was significantly faster than in nonwords on match trials, $t(31) = 3.3$, $p < .002$, and approached significance on mismatch trials, $t(31) = 1.8$, $.10 > p > .05$. Hence, even with bigram frequency controlled for, search was faster through words than nonwords, providing evidence of lexical involvement.

The second issue was whether there was any evidence of a semantic relatedness effect. There was. On trials in which a match occurred, subjects were significantly slower on related trials than on unrelated trials, $t(31) = 2.7$, $p < .01$. On nonmatch trials, search times through the two types of stimuli[1] did not differ reliably, $t(31) = .04$.

General Discussion

The experiments reported here explored several conditions under which the presence of a related context influenced the processing of a letter string. Previous work suggested that semantic relatedness does not influence performance if subjects adopt a set to process component letters rather than to make word-level decisions. However, because these previous experiments did not ensure that lexical activation had occurred, failure to find an effect of a related context could have resulted because (a) the lexical representations were not accessed, (b) there was no spread of activation between semantically related entries, or (c) semantic activation leads to a processing impairment in this task.

Kreuger (1989) reported that searching for a common letter in two words is faster than it is in two nonwords. This result is consistent with the claim that lexical involvement confers a processing advantage in this task. The question of interest addressed in the present experiments was whether related and unrelated contexts would differentially affect performance in such a task. If it did, the second question of interest was whether this relatedness effect would be manifest as facilitation or inhibition.

Several findings emerged from the present experiments. First, we were able to provide confirmation for Kreuger's observation of faster detection of a common letter in pairs of words than in pairs of nonwords, even under conditions in which orthographic redundancy was comparable for the two types of stimuli. More interestingly, a related context gave rise to the standard finding of facilitation in the context of lexical decision (Experiment 1), but yielded inhibition in the context of the letter search task (Experiments 2 and 3). Hence, even though subjects were set to look for individual letters in the search task, semantic level processing occurred.

Three hypotheses were set out in the introduction as to why related words would be processed slower than unrelated words in the letter search task. The first possibility is based on attentional factors. The perception that two words are semantically related may increase the focus of attention at the word level, making it more difficult to attend to processing of the component letters. Given that the purpose of reading is to comprehend, the idea that the perception of relatedness biases attention to text level processes rather than letter level processes follows naturally.

A second explanation for slower search times through related than through unrelated words is based on interference generated via increased letter level activation. As discussed in the introduction, related words may activate a common pool of lexical entries. For example, *doctor* and *nurse* may both activate *hospital*, *medicine*, *illness*, *patient*, and so on. In contrast, unrelated items each activate different sets of entries. Hence, lexical entries activated by unrelated words receive less activation than items related to both target strings. Less activation of competitors should produce less interference.

Although related words were searched more slowly than unrelated words, either of the previous explanations imply that this relatedness effect was the result of activation and not inhibition. If either of these explanations is correct, the important conclusion is that lexical activation results in semantic activation, which spreads to related lexical entries, even if task demands focus attention to the letter level.

However, a third possibility involves spreading inhibition in memory. The benefit of such inhibition is straightforward;

[1] It is a vexing although not novel observation that "yes" and "no" responses do not yield the same pattern of data as regards effects of both lexical and semantic factors. One explanation that has been suggested before is that "no" responses are, at least some of the time, based upon a common deadline for all the conditions (see Besner, 1977, for discussion of this issue). Briefly, the notion is that subjects select a time deadline; if a "yes" response has not been selected by the time the deadline has been reached, the subject responds "no." If all subjects consistently used a deadline, then this would result in no difference between all conditions when a "no" response was called for. To the extent that other strategies for making a "no" response are available to subjects (e.g., actively examining the outcome of each attempted match), different results are to be expected. We do not yet have an understanding of what encourages subjects to use or not use particular strategies for deciding "no."

it reduces the probability of other lexical units offering up competing letter level information. The cost is that it slows the encoding of a related letter string (and possibly the comparison process). It should be noted that appeals to inhibitory mechanisms in word perception are not new; for example, the word identification system proposed by McClelland and Rumelhart (1981) relies heavily upon interactions between activation and inhibition to explain various word perception phenomena. However, inhibitory processes in McClelland and Rumelhart's model are not under the subject's control. What is new in the present context, therefore, is the suggestion that subjects may be able to directly initiate spreading inhibition to related lexical entries.[2] This idea has its roots in the general notion that inhibition is crucial when an overt action is to be taken because coherent actions impose a strong requirement of selectivity. It is thus not surprising that issues surrounding inhibition have been the subject of considerable interest to some recent investigators (e.g., Allport, 1980; Allport, Tipper, & Chmiel, 1985; Keele & Neill, 1978; Lowe, 1979, 1985; Neill, 1977, 1979; Neill & Westberry, 1987; Tipper, 1985; Tipper & Cranston, 1985). The interference observed in these experiments is potentially relevant to the literature on inhibitory processes in that it is consistent with the suggestion that the particular output of a lexical structure can be inhibited, thereby preventing facilitation from a related context and, under some circumstances, producing interference.

It remains for future research to determine whether one or more of these explanations will prove to be a useful heuristic for guiding further investigations of the phenomenon reported here. Whatever that outcome, the present experiments provide the first demonstration of a dissociation between the effects of lexical and semantic factors in the same task. Our suggestion is that this dissociation reflects the operation of basic and qualitatively different processing mechanisms central to cognition in general and to the reading process in particular.

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[2] Note that the concept of inhibition described here is different from that described by Posner and Snyder (1975), Neely (1977), and others. These theorists proposed the active inhibition of unrelated concepts. For example, Neely described a situation in which spreading activation of related concepts was found even under circumstances in which subjects might be expected to inhibit those related lexical entries. When Category 1 items are usually followed by Category 2 items, one might expect to find inhibition of Category 1 items on the rare occasions when they are presented. Nonetheless, Neely found that Category 1 items were facilitated. However, this facilitation was found only at very short stimulus onset asynchronies (SOAs); at longer SOAs, inhibition was found. The long search times involved in the present experiments would provide ample time for the initiation of such inhibition.

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Appendix

Word Pairs Used in the Experiments

Related words	Unrelated words	Nonwords
	Positive trials	
table–chair	fable–chair	rable–chait
slow–fast	slob–fast	slom–wast
hot–cold	pot–cold	yot–colp
young–old	yours–old	boung–oid
lion–tiger	limp–tiger	fion–siger
wash–rinse	cash–rinse	jash–ronse
lost–found	cost–found	lort–gound
dusk–dawn	dish–dawn	dosk–dawl
lock–key	luck–key	nock–kry
circle–round	carves–round	bircle–rount
plant–flower	slant–flower	plang–fluwer
army–soldier	arch–soldier	arsy–goldier
tall–short	till–short	talp–chort
king–queen	sing–queen	fing–sueen
spider–web	glider–web	spiler–heb
hammer–nail	farmer–nail	gammer–yail
nurse–doctor	purse–doctor	furse–loctor
life–death	wife–death	lige–ceath
true–false	tune–false	frue–halse
earth–ground	early–ground	barth–groond
joy–happy	boy–happy	hoy–wappy
leaf–stem	lean–stem	geaf–ster
wine–grapes	fine–grapes	wone–brapes
dance–waltz	ranch–waltz	jance–maltz
fat–thin	bat–thin	fot–thip
peace–war	peach–war	pease–har
pen–ink[a]	men–ink[a]	ren–onk[a]
good–bad[a]	gold–bad[a]	goid–nad[a]
hop–skip[a]	mop–skip[a]	fop–skup[a]
rip–tear[a]	rid–tear[a]	rin–mear[a]
hill–mountain[b]	will–mountain[b]	hilp–bountain[b]
scissors–cut[b]	scorpion–cut[b]	scyssors–cet[b]
health–sickness[a]	wealth–sickness[b]	dealth–fickness[b]
add–subtract[b]	age–subtract[b]	ald–rubtract[b]

Related words	Unrelated words	Nonwords
	Negative trials	
blue–sky	glue–sky	alue–sko
dark–night	park–night	darl–nighp
high–low	sigh–low	figh–lew
trout–fish	treat–fish	frout–hish
black–white	slack–white	block–whote
boy–girl	toy–girl	bey–wirl
dog–cat	dig–cat	dou–cit
hard–soft	harp–soft	hird–seft
eagle–bird	weasel–bird	eable–wird
church–steeple	churn–steeple	chorch–steeble
law–justice	paw–justice	liw–justoce
sheep–lamb	steep–lamb	sheex—famb
eat–food	ear–food	eas–jood
insect–bug	invest–bug	onsect–fug
frown–smile	brown–smile	browt–smice
fruit–apple	stout–apple	fruid–asple
square–box	squash–box	squame–bor
village–town	pillage–town	villane–towp
hand–foot	land–foot	yand–foox
ice–snow	ace–snow	oce–snaw
baby–child	busy–child	boby–shild
moon–star	mood–star	hoon–stad
oil–gas	foil–gas	oim–tas
thought–mind	fought–mind	thoughf–mand
play–work	slay–work	galy–hork
shallow–deep	hallow–deep	shandow–meep
egg–yolk	peg–yolk	ege–bolk
pain–hurt	gain–hurt	hort–sain
sharp–dull[a]	shark–dull[a]	shart–dulp[a]
buy–sell[a]	bun–sell[a]	bup–rell[a]
salt–pepper[b]	sand–pepper[b]	suet–hepper[b]
up–down[b]	us–down[b]	ip–bown[b]

Filler pairs

man–wotar	moship–father
rough–smoat	neibon–thread
bread–bottin	brothog–sister
bitter–sweax	capsute–pill
green–gliss	boeh–ale
large–smipo	bosh–water
bed–slorg	nirey–south
afraid–scobet	honip–bee
cabbage–lottir	sconix–marble
door–wingew	porry–cent

[a] Trial pairs appeared in Experiment 3 only.
[b] Trial pairs appeared in Experiments 1 and 2 only.

Received November 10, 1988
Revision received February 13, 1990
Accepted February 20, 1990 ■