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Depth of Automatic Spreading Activation: Mediated Priming Effects in Pronunciation but Not in Lexical Decision

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Lexical decision and pronunciation experiments were conducted to investigate whether activation automatically spreads beyond directly associated concepts within the memory network. Prime-target pairs were constructed such that there was a relation between the prime (e.g., *lion*) and the target (e.g., *stripes*) only through a mediating concept (e.g., *tiger*). The lexical decision results yielded facilitation of directly related priming conditions (e.g., *lion–tiger* and *tiger–stripes*); however, the mediated condition (e.g., *lion–stripes*) did not facilitate performance compared to either a neutral prime or an unrelated prime condition. In contrast, the pronunciation results yielded facilitation of both directly related and mediated priming conditions. The results were viewed as supporting the notion that activation spreads beyond directly related concepts in semantic memory. It is suggested that characteristics of the lexical decision task masked the appearance of a mediated priming effect. Implications of an automatic spread of activation beyond directly related concepts are discussed.

Spreading activation is an important explanatory construct that was developed within network theory as a fundamental memory retrieval mechanism (Anderson & Bower, 1973; Collins & Loftus, 1975; Collins & Quillian, 1969). According to this framework, concepts are represented in memory as nodes and relations are represented as associative pathways between the nodes. When part of the memory network is activated, activation spreads along the associative pathways to related areas in memory. This spread of activation serves to make these related areas of the memory network more available for further cognitive processing.

The concept of spreading activation has been a widely used explanatory construct. Theorists have argued that spreading activation is the underlying search mechanism involved in such tasks as category exemplar production (Loftus, 1973), semantic priming in lexical decisions (Neely, 1977), sentence verification (Loftus, 1973), episodic sentence and word recognition (Anderson, 1983a, 1983b), and perceptual word recognition (McClelland & Rumelhart, 1981). Moreover, spreading activation is now viewed as playing a role in reading comprehension (Foss, 1982; Kieras, 1981; Stanovich & West, 1983) and language processing (Anderson, 1976; McDonald & Hayes-Roth, 1978).

Several important properties of the activation process have been experimentally uncovered. First, the spread of activation is automatic as opposed to being under strategic control (Balota, 1983; Neely, 1977). Second, the amount of activation of a concept node is a function of the "length" of the associative pathway (a reflection of the strength of association) between that node and the source of activation (Lorch, 1982). Third, the amount of activation spreading from a given node along a pathway is a function of the strength of that pathway relative to the sum of the strengths of all paths emanating from that node (Reder & Anderson, 1980). Fourth, because concepts are assumed to be associated within a network of associations, activation may spread not only to directly related concepts but also from those concepts to concepts further in the memory network, that is, multiple steps within the network.

The "multiple-step" assumption of spreading activation theory has been particularly important in accounting for a variety of memory retrieval phenomena. For example, in accounting for category verification response latency, Collins and Quillian (1969) emphasized the number of concept nodes that activation would need to traverse within the memory network. Anderson (1976) has viewed episodic sentence recognition as a parallel spread of activation from terminal concept nodes across intervening concepts until a crucial intersecting concept is sufficiently activated. Within a similar framework, Ratcliff and McKoon (1981) have suggested that differences in asymptotic levels of activation produced by episodic primes are due to the number of intervening concepts between the prime and the target within the memory representation.

Although the multiple-step assumption is widely used, there are both conceptual and empirical reasons to challenge its validity. First, with respect to the conceptual concern, an extensive spread of activation could become unwieldy very quickly. For example, imagine a network in which each node is directly connected to only five other concept nodes. The initial step in the activation process would result in the activation of only five associates. Activation spreading from those associates would activate 25 more nodes, and a third step in the process would result in the activation of an additional 125 nodes! Realizing the potential difficulty with such a mechanism, Anderson (1976, p. 123) postulated a default dampening process where all activated concepts that are not the focus of attention revert back to their

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resting level of activation after some interval (see Anderson, 1983a, p. 265, for a more recent discussion of this issue).

The second concern with the multiple-step assumption is that, despite its prominence, it has not received any direct empirical support. In order to test multiple-step activation directly, it is necessary to demonstrate that the concepts that are presumably only related via multiple links do not also have a direct association. In fact, it was because of a failure to consider the possibility of direct associations that Collins and Quillian's (1969) initial test of multiple-step activation was not definitive (see Conrad, 1972; Smith, Shoben, & Rips, 1974). The only study that has attempted to eliminate direct associations (de Groot, 1983) appears to indicate that activation only spreads a single step within the memory network (i.e., "one-step" activation). Because of the importance of the de Groot study to spreading activation theory and to the present experiments, we shall describe her major results briefly.

de Groot conducted a series of semantic priming lexical decision experiments to test the depth of spreading activation. She constructed a set of triads in which there was a direct relation between the first and second word (e.g., *bull–cow*) and the second and third word (e.g., *cow–milk*) but no direct relation between the first and third word (*bull–milk*). de Groot argued that if subjects were able to make a lexical decision to *milk* more quickly in the mediated prime condition (*bull–milk*) than in the neutral prime condition (*blank–milk*), then this would suggest that activation had spread across two associative pathways from *bull* to *cow* to *milk*. Hence, this would provide evidence for multiple-step spreading activation. Based on a series of seven lexical decision experiments, de Groot concluded that activation spreads to directly related concepts but does not spread any further within the memory network.

There are several reasons to be reluctant to accept de Groot's conclusion. First, all current theories predict less priming facilitation in a mediated priming condition (*bull–milk*) than in a related priming condition (*cow–milk*). This prediction is based on the assumption that the amount of activation available at a node depends on its distance from the source of activation. Given the relatively small priming effects de Groot reports for directly related concepts (26 ms in Experiment 1), the amount of facilitation expected for the mediated condition would be quite small. Thus, with de Groot's materials, considerable power would be required to detect the small predicted effect in the mediated condition.

The second reason for questioning de Groot's conclusion is that the results of her first four experiments provided some weak support for a multiple-step activation process. Two of the experiments demonstrated reliable facilitation of response latencies in the mediated condition and all four experiments showed a tendency towards facilitation in error rates in the mediated condition. Unfortunately, there were no analyses of error rates reported.

The final point to be made regarding de Groot's results concerns her last three experiments. de Groot hypothesized that the lack of clear mediated priming effects for the initial four experiments may have been due to subjects adopting a strategy that canceled out any small effect of multiple-step activation. Specifically, she suggested that subjects in a lexical decision task conduct a postlexical access search for a relation between the prime and target words because of an implicit assumption that words appear in meaningful context and because the detection of a relation indicates that the target must be a word. If a relation is readily available (i.e., related prime condition), subjects can respond quickly that the target is a word. However, de Groot suggested that if a relation is not easily retrieved, then subjects may lose track and reprocess the material until they either make some sense out of the target in the context or reach a response deadline. If the subjects in de Groot's experiments were unable to find a relation in the mediated condition, such a rechecking strategy may have overridden a multiple-step activation process. The use of a postlexical search strategy would thus explain both the failure to observe facilitation in the mediated condition and the finding of inhibition in the unrelated prime condition.

In an attempt to prevent the postlexical access search, de Groot presented the primes too briefly for subjects to be aware of their identity. The rationale was that the primes would be unavailable for a search for a relation between the prime and target. Although priming facilitation was demonstrated for related priming conditions using this procedure (Experiments 5 and 6), there was no evidence of mediated priming (Experiment 7). However, two observations suggest that this demonstration is not definitive. First, there was again a tendency for a lower error rate in the mediated condition compared to the neutral condition, suggesting there may have been some priming in accuracy for the former condition. Second, de Groot's procedure may not have adequately provided a threshold presentation of the prime items across subjects. In fact, about half of de Groot's subjects reported that they had seen some of the primes. This is noteworthy because Dagenbach and Carr (1985) have provided evidence that related prime conditions can produce either facilitation or inhibition effects depending on the subject's actual threshold. Because thresholds were not individually determined in de Groot's study, facilitation and inhibition effects could have combined across subjects to produce the null effect in the mediated condition of the threshold priming experiment.[1]

Because of the above concerns with de Groot's study and the importance of her results to spreading activation theory, the present series of experiments was conducted to discriminate further between the one-step and multiple-step activation

[1] de Groot did find in her masking Experiment 7 that the inhibition for the unrelated condition was eliminated, which is consistent with the notion that subjects were unable to conduct the postaccess search for a relation in this experiment. However, a post hoc partitioning of subjects into those subjects who were above threshold and those who were below threshold indicated that the elimination of the inhibition for the unrelated condition was primarily due to the group of subjects that were above threshold. The suprathreshold group was actually 16 ms faster in the unrelated condition, compared to the neutral baseline, whereas the subthreshold subjects were 9 ms slower in the unrelated condition. Thus, for those subjects who should have been the least likely to conduct the postaccess check, there was still some evidence of inhibition. Finally, because the unrelated primes did not come from the same stimulus set as the related primes, and it is unclear how these items were selected, it is possible that the inhibition effects observed at de Groot's short stimulus onset asynchronies could have been due to characteristics of the prime items.

models. The first experiment replicated de Groot's basic design with two major changes. First, we used a different set of mediated items. One concern we had was that some of de Groot's mediated pairs were actually items involving a weak direct relation (e.g., *shepherd–wool*).[2] If so, this would increase the tendency towards mediated priming effects observed in some of de Groot's experiments. Because a test of multiple-step activation rests on the adequacy of the mediated pairs, we have taken a conservative approach and eliminated such items in the present experiments.

Our second change from de Groot's procedure was that we included a between-subjects manipulation of stimulus onset asynchrony (SOA) between the prime and the target. One group of subjects received a 250-ms prime target SOA whereas the second group received a 500-ms SOA. de Groot included only a 240-ms SOA. The 500-ms SOA in the present study was included to test whether one might find evidence of multiple-step activation at a longer SOA. Because activation must traverse an additional link in the mediated conditions, one might need more time for prime processing (Collins & Loftus, 1975; but see Ratcliff & McKoon, 1981).

The observation of interest in Experiment 1 was whether subjects would be faster to recognize a target word (*stripes*) when preceded by an indirectly related word (*lion*) than when preceded by a neutral or unrelated word. Because *lion* and *stripes* appear to be related only by their common associate *tiger*, such an effect would suggest that activation has spread from *lion* to *tiger* to *stripes*.

Finally, control Experiment 1a tested priming effects for the first link in our mediated pairs (i.e., from *lion* to *tiger*). As noted above, it is important to establish strong direct priming across the first links in the triads because the degree of activation of the first link sets a theoretical limit on the observed priming across both links in the triads.

Lexical Decision Experiments

Method

Subjects. Twenty undergraduate students participated in Experiment 1a and 64 students participated in Experiment 1. Of the 32 subjects in each SOA condition of Experiment 1, 20 subjects were recruited from the University of Kentucky and 12 subjects were recruited from Iowa State University. The assignment of lists and conditions to subjects was completely counterbalanced at both universities. Subjects in the control Experiment 1a were recruited from the University of Kentucky. All subjects participated in the experiments in partial fulfillment of a course requirement.

Apparatus. Stimulus presentation and data collection were controlled by an Apple II plus computer that was interfaced with a Zenith data systems video monitor. The computer included a Thunderclock timing board that was used for obtaining millisecond reaction times.[3] Subjects made word/nonword responses by pressing either the "1" or "0" key on the Apple keyboard.

Materials. The critical stimuli were based on a set of 56-word triads. In each triad, the first and second words (*lion–tiger*) were directly related and the second and third words (*tiger–stripes*) were directly related, but the first and third words (*lion–stripes*) were associated only indirectly by their relations to the second word.

Because of the importance of developing an adequate set of items, the above characterization of the triads was validated in two ways. First, an independent sample of 115 psychology undergraduates produced associates to the mediated prime words (e.g., *lion*). Each student produced eight associates to each of 14 mediated prime words, which were randomly selected from the original set of 56. The assumption underlying this task is that if the mediated target (e.g., *stripes*) does not occur across associates given either within a subject or across subjects, then it is highly unlikely that there is a direct association from the mediated prime to the mediated target. One potential problem with this task is the possibility of subjects chaining associates. That is, a subject may produce *tiger* to *lion* and then produce *stripes* to *tiger*. The instructions given to the subjects emphasized the importance of avoiding such chains and that it was crucial that subjects always produce associates only to the first item.

The results of this production study indicated that out of the original 56 triads in the target set, there were eight cases in which the mediated target was produced to the mediated prime item (e.g., *rain* was produced as an associate to *dry*). In each of the cases in which the mediated target was produced there was some potential that the subject chained their responses, because the mediating word (e.g., *wet*) was produced before the mediated target in every case. Moreover, there were only two cases that produced the mediated target to the mediated prime more than once. However, because of the importance of obtaining a set of items in which there was no direct relation between the mediated prime and target, we adopted a conservative approach and eliminated these eight items from our target pool. Thus, all reported data analyses are based on the remaining 48 items. It is important to note that the mediated targets were never produced for these 48 items despite a total of 12,880 associates produced across our subjects. The Appendix displays the critical 48 triads.

Our second attempt to validate our characterization of the triads involved an independent sample of 149 psychology students. The students were asked to rate the degree of association for word pairs constructed from the triads. Each subject was presented a list of 65 word pairs to rate on a 5-point scale, ranging from *strongest association* (5) to *no association* (1). The 65 word pairs consisted of: 9 practice items; 14 mediated pairs constructed from the first and third words of the same triads (e.g., *lion–stripes*); 14 related first-link pairs constructed from the first two words of the same triads (*lion–tiger*); 14 related second-link pairs constructed from the last two words of the same triads (*tiger–stripes*); and 14 unrelated pairs constructed by randomly pairing the second and third words of different triads (e.g., *fantasy–stripes*). Four different lists of 65 word pairs were constructed such that a given triad was represented once on a list but occurred in each pairing condition across lists.

The results of the rating experiment confirmed our expectations for the 48 critical triads that were selected based on the production study. Both the related first-link pairs and the related second-link pairs were rated as being highly associated (M = 4.19, SD = .35 for the first-link related pairs; M = 4.01, SD = .43 for the second-link related pairs). The mediated pairs were rated as considerably lower (M = 2.05, SD = .58). The unrelated pairs were rated the lowest (M = 1.41, SD = .41). Although the mediated pairs were rated as somewhat more associated than the unrelated pairs, we attribute this to subjects occasionally finding the mediated association for these items in the untimed rating task. We will later discuss speeded response latency data, which also suggests that there was no direct relation for the mediated pairs.

[2] It should be noted that de Groot's stimuli were not presented in English, and therefore one has to be cautious in making any strong statements regarding weak associations in the English translation of her stimuli.

[3] Because there were no hardware modifications to synchronize the timer with the location of the signal on the CRT, response latency was not actually measured to the nearest millisecond (see Reed, 1979). Any such error, however, should occur randomly across conditions.

Although the data for only the 48 triads that did not produce any evidence of a direct relation for the mediated pairs will be reported, all original 56 triads were used to construct four types of prime-target pairs for the lexical decision experiments.[4] The third words in the triads served as the target words in all priming conditions. The related condition paired the second and third words of the same triads (e.g., *tiger–stripes*). The mediated condition paired the first and third words of the same triads (e.g., *lion–stripes*). The neutral condition used the word *blank* as the prime word (see de Groot, Thomassen, & Hudson, 1982). The unrelated condition paired target words with primes selected from other triads. For a given target, the pool of potential unrelated primes consisted of the related prime words of the other 55 triads and of primes for nonword trials. This meant that there was an 11% probability for a prime to be repeated once for a given subject, so a restriction was placed on the sampling process to prevent a given prime from occurring in the same trial block. The random pairing of prime and target words for the unrelated condition was done independently for each subject.

In addition to the critical word pairs, stimuli were constructed for nonword trials. For each word target, a nonword was generated that matched it in number of letters (the range was three to nine letters). Nonwords were constructed by changing two, three, or four letters in a middle- to high-frequency word. Nonwords were constructed from words that did not serve as stimuli in the experiment. All nonwords were pronounceable. Each nonword was paired with a word prime that did not have any obvious relation to the nonword.

After the stimuli were constructed, they were assigned to four different lists that differed in the assignment of target stimuli to priming conditions. A target word or nonword occurred only once within a given list; each target occurred in each priming condition once across the four lists. Each list consisted of three blocks of word pairs. The initial block of 48 practice items included: 6 neutrally primed nonwords; 18 word-primed nonwords; 6 neutrally primed words; 6 word targets paired with related primes; and 12 word targets paired with unrelated primes. The two test blocks of experimental items each began with 4 buffer items and contained an additional 28 word pairs and 28 nonword pairs. The four priming conditions were equally represented for the word trials in each test block, and there were 21 word-primed nonword trials and 7 neutrally primed nonword trials. The order of presentation of items within each block was randomized independently for each subject. Each subject received only one list.

Procedure. Subjects were instructed that they would be presented with a pair of stimuli on each of many trials. They were told that the initial stimulus in a pair would be a common English word on 75% of the trials and the word *blank* on the remaining trials. They were instructed that the second stimulus would be either a common English word or a pronounceable nonword. Subjects were told to read the first word to themselves but that their major task was to decide whether the second stimulus was a word or nonword. They were to indicate their decision by pressing the "0" key if the second stimulus was a word or the "1" key if it was not a word. Both speed and accuracy were emphasized in the instructions. The experimenter remained in the lab during the first 10–15 practice trials to insure that the subject fully understood the instructions.

The exact sequence of events on each trial was as follows: (a) a row of three asterisks separated by blank spaces was presented in the center of the screen for 360 ms; (b) a blank screen was presented for 360 ms; (c) a warning tone was presented for 140 ms; (d) a blank screen was presented for 360 ms; (e) the prime word was presented (for 200 ms for the 250 ms SOA condition in Experiment 1 and the control Experiment 1a, and 450 ms for the 500 ms SOA condition for Experiment 1); (f) a dark interval was presented for 50 ms; (g) the target word was presented until the subject pressed either one of two keys to indicate word or nonword; (h) if the subject responded incorrectly, the message "ERROR!!!" was presented until the subject pressed one of the two response keys; (i) a 3-s intertrial interval was included before the next trial.

There were three break periods in the experiments. Subjects received a 20-s break after 24 practice trials and 2-min breaks before each of the test blocks. Subjects participated individually and the experiment was conducted in a small, quiet lab room. Throughout an experimental session, the subject was seated comfortably approximately 50 cm from the video monitor.

Design. Experiment 1 was a 2 × 4 (SOA × Prime) mixed-factor design with SOA being a between-subjects factor and prime type being a within-subjects factor. Experiment 1a included only the within-subjects factor of prime type (related vs. neutral vs. unrelated).

Results

In all experiments, an analysis of variance (ANOVA) was initially conducted on the subjects' mean performance per condition to determine if there were any main effects or interactions. Subjects were treated as the only random factor in this analysis. However, because items served in different conditions for different subjects, the error variance due to items was included in the Subject × Condition interactions and therefore the effects should also generalize across items. Planned comparisons were conducted to specify the nature of any significant main effects or interactions. Unless otherwise noted, all tests that are referred to as significant have p values < .05.

Each subject's mean response latency was calculated for each of the conditions in both experiments. Response latencies exceeding 1 s were eliminated from all analyses. The mean outlier rate was 2.2% for Experiment 1a and 2.1% for Experiment 1.

Consider the results for Experiment 1a first. There were reliable differences in response times for the three priming conditions, $F(2, 38) = 16.81$, $MS_e = 912$. Paired comparisons indicated that responses in the related condition (mean response latency = 524 ms, error rate = 2.9%) were significantly faster than responses in both the neutral (mean response latency = 576 ms, error rate = .9%) and unrelated conditions (mean response latency = 565 ms, error rate = 3.3%). The 11-ms difference between the neutral and unrelated conditions was not reliable, $t(19) = 1.24$. There were no significant differences in error rates across the prime conditions.

In sum, the 52-ms facilitation effect observed for the related condition demonstrates a strong relation between the first and second words in the stimulus triads. This finding establishes a necessary condition for predicting mediated priming; namely, that there is considerable activation spreading at least to the second word in our triads. We will now consider the results of Experiment 1 to establish whether activation spreads beyond that point.

The results of Experiment 1 are summarized in Table 1. The results of a 2 × 4 (SOA × Priming Condition) mixed-factor AN-

[4] The results of the present experiments only include those 48 triads for which there were no mediated targets produced to the mediated primes in the production task. The production task was conducted after the experiments were conducted as an extra source of information about such weak associations. Thus, all list construction included the original 56 items. All major trends in the data were not influenced by this restriction to only 48 items. The counterbalancing of items across lists was not affected by this change.

Table 1
Mean Response Latency and Percent Error Rates as a Function of Prime Condition and Stimulus Onset Asynchrony (SOA) in Experiment 1

	Prime condition							
	Related		Mediated		Neutral		Unrelated	
SOA	Latency	% Error	Latency	% Error	Latency	% Error	Latency	% Error
250	519	3.2	559	3.4	562	6.5	564	4.9
500	535	1.9	574	5.2	565	4.0	583	4.6
M	527	2.6	567	4.3	564	5.3	574	4.8

OVA yielded a highly significant effect of prime, $F(3, 186) = 22.51$, $MS_e = 1227$; however, neither the effect of SOA nor the interaction between prime and SOA approached significance, both $Fs(1, 62) < 1$. Paired comparisons confirmed the apparent differences among priming conditions: Responses were significantly faster in the related condition than in each of the remaining three conditions; there were no differences among the remaining three conditions.

Using the neutral condition as a baseline for computing priming effects in the related, mediated, and unrelated conditions, it appears in Table 1 that facilitation and inhibition effects vary across the SOAs. However, separate contrasts of these changes in facilitation and inhibition effects indicated that none of these contrasts approached significance, all $ts(62) < 1.16$. Finally, it should also be noted that the difference between the unrelated and neutral prime conditions did not reach significance at the 500-ms SOA condition, $t(31) = 1.80$.

A comparable ANOVA on the percent error data yielded a significant main effect of prime condition, $F(3, 168) = 2.76$, $MS_e = .009$; however, again neither the effect of SOA nor the interaction between SOA and prime reached significance, both $Fs < 1.70$. The main effect of prime condition was due to fewer errors in the related condition than in the neutral or unrelated conditions. However, it is noteworthy that separate comparisons at the 250-ms SOA condition indicated that both the mediated and related conditions produced significantly fewer errors than the neutral condition. The unrelated condition did not significantly differ from the remaining prime conditions. Similar comparisons at the 500-ms SOA condition indicated that the related condition produced significantly fewer errors than either the mediated or unrelated conditions.

The results from the lexical decision experiments provide very little evidence of a multiple-step activation process. Large facilitation effects were observed for the directly related priming conditions of both Experiments 1 and 1a, demonstrating single-step activation of the associative pathways connecting the first and second words, and the second and third words in the triads. In fact, the 52-ms facilitation produced in the related condition of control Experiment 1a is considerably larger than the 26-ms effect reported by de Groot (1983). Because this effect size limits the size of the mediated effect, the present experiment should have provided a more sensitive test for mediated priming. However, there was no evidence that response latency was facilitated in the mediated condition. Collapsing across the two SOAs, the mediated condition was actually 3 ms slower than the neutral prime condition. Finally, there was some tendency for lower error rates in the mediated condition than in the neutral condition at the 250-ms SOA (but not the 500-ms SOA), just as de Groot reported. Thus, the overall pattern of data is quite consistent with de Groot's lexical decision results and conclusion that activation only spreads one step within the memory network.

Pronunciation Experiments

Although the results of the lexical decision experiments clearly support the single-step activation model, the use of the lexical decision task to test the model may limit the generalizability of this conclusion. Because of the importance of the present results to spreading activation theory, it is necessary to provide converging evidence that activation only spreads one step within the memory network.

As was noted in the introduction, de Groot was concerned that the lexical decision task encourages processing strategies that may override any effects due to activation processes. Consistent with de Groot's concerns, several recent investigations have provided evidence for postaccess processes in the lexical decision task (Balota & Chumbley, 1984; Chumbley & Balota, 1984; Lorch, Balota, & Stamm, in press; Lupker, 1984; Seidenberg, Waters, Sanders, & Langer, 1984; West & Stanovich, 1982). de Groot specifically suggested that subjects may conduct a postaccess check to determine if there is any direct relation between the prime and target. Because such a postaccess checking strategy might obscure multiple-step activation effects, de Groot attempted to prevent this strategy by presenting the prime items at threshold. However, as we noted earlier, the results from her threshold experiments are open to alternative explanations.

An alternative approach to studying lexical access processes is to use a speeded pronunciation task. The advantage of the pronunciation task compared to the lexical decision task is that it does not require the subject to make a binary decision. As a consequence, it should be less likely to promote task-specific strategies that might obscure effects due to automatic lexical access processes. Thus, Experiment 2 replicates the design of Experiment 1 using a pronunciation task. Experiment 2a is a control experiment analogous to Experiment 1a to ensure that pronunciation priming occurs across the first link of the stimulus triads.

Method

Subjects. Fifty-six undergraduates participated in Experiment 2. Twenty-eight subjects participated in each SOA condition. Twenty-six subjects participated in the control Experiment 2a. All subjects were recruited from the University of Kentucky and participated as partial fulfillment of a course requirement.

Apparatus. The same Apple computer and timing device that was used in the earlier experiments was used in the pronunciation experiments. A Lafayette model 6602A voice key was interfaced with the computer. Pronunciation latency was measured to the nearest millisecond (see Footnote 3).

Materials. The word triads employed in the lexical decision experiments were used as the basis for constructing prime-target pairs in the pronunciation experiments. The assignment of triads to priming conditions (related, mediated, neutral, unrelated) was counterbalanced across four lists as described for the lexical decision experiments. The nonword stimuli were excluded to discourage subjects from adopting grapheme to phoneme (lexical bypass) pronunciation strategies. Finally, 16 phonologically irregular buffer items (e.g., *live, pint, save*) were included in order to further discourage such pronunciations. If subjects did use grapheme to phoneme conversion rules as the basis for performing the pronunciation task, then they would be expected to mispronounce the irregular words.

A stimulus list consisted of a block of 32 practice items and two test blocks of 40 items each. Each test block began with four buffer items and included eight phonologically irregular pairs and seven word pairs representing each of the four priming conditions. Again, only the data from the 48 triads that did not produce any mediating associations in the norming study will be reported here. The order of presentation of pairs within blocks was randomized independently for each subject.

Procedure. Subjects were instructed that they would see a pair of words on each trial in the experiment. They were informed that the first word would usually be a common English word but that it would be the word *blank* on 25% of the trials. Subjects were instructed to read the first word to themselves and to say the second word aloud as quickly as they could without mispronouncing it. The sequence of events on each trial was the same as in the lexical decision experiments, with the following exceptions. First, the subject pronounced the target item instead of pressing a response key. Second, the following message was presented on each trial immediately after a pronunciation was detected: "If you correctly pronounced the word, press the '0' button, otherwise press the '1' button." This procedure was necessary to exclude occasional mispronunciations and extraneous sounds (e.g., a cough) from being counted as correct responses. As in the earlier experiments, pressing one of the two keys initiated a 4-s intertrial interval.

Results

Consider the results for the control experiment first. The mean outlier rate was 4.1% (again using the 1-s criterion) and subjects indicated an error or premature triggering of the voice key on 1% of the trials. Because there were few errors and we were unable to distinguish inadvertent triggerings of the voice key from actual mispronunciations, our major concern in the present discussion will be response latencies.[5]

The results of the control experiment were that mean response latency was significantly faster in the related condition (525 ms) than in the neutral condition (546 ms) or unrelated condition (550 ms). The difference between the neutral and unrelated conditions was not reliable, $t(25) < 1$. Thus, the results of the control experiment indicated activation of the first link within the triads. We shall next consider the findings of Experiment 2 to determine whether there was any evidence of activation spreading beyond the initial associative link.

Table 2
Mean Pronunciation Latencies as a Function of Prime Condition and Stimulus Onset Asynchrony (SOA) in Experiment 2

	Prime condition			
SOA	Related	Mediated	Neutral	Unrelated
250	545	558	570	574
500	553	558	583	576
M	549	558	577	575

The mean outlier rate in Experiment 2 was 1.9% and the error rate was 1.7% (see Footnote 5). The response latency results are shown in Table 2. Response latencies varied across priming conditions, $F(3, 162) = 14.80$, $MS_e = 671$. Most important, the mediated condition was faster than the neutral condition, $t(55) = 3.77$. Thus, unlike Experiment 1, Experiment 2 produced a mediated facilitation effect. Finally, the SOA manipulation had no main effect and did not interact with priming condition, both $F\text{s} < 1$.

Because of the importance of providing evidence for mediated priming, pairwise comparisons were conducted to directly compare the means at each of the two SOAs. These comparisons indicated that the mediated condition was significantly faster than the neutral condition at both the 250-ms SOA, $t(27) = 2.01$, $p < .05$ (one tailed), and the 500-ms SOA, $t(27) = 3.18$. Furthermore, the mediated condition was significantly faster than the unrelated condition at both the 250-ms SOA, $t(27) = 2.64$, and again at the 500-ms SOA, $t(27) = 2.19$. In addition to these results, responses were slower in the mediated condition than in the related condition at the 250-ms SOA, $t(27) = 2.65$, but this difference did not reach significance at the 500-ms SOA, $t(27) < 1$. Although the mediated condition was not significantly slower than the related condition at the 500-ms SOA, it is important to note that this was due to a few large reversals in the 500-ms SOA condition. In fact, 21 out of 28 subjects demonstrated faster response latencies in the related condition than in the mediated condition, $p < .05$ by sign test. Finally, the neutral and unrelated conditions did not differ at either SOA, both $t\text{s}(27) < 1.17$.

The results of the pronunciation experiment are in sharp contrast to the results of the lexical decision experiment and provide clear evidence for multiple-step spreading activation. Facilitation effects were observed for the mediated pairs at both SOAs, suggesting that activation did spread across the mediat-

[5] We did conduct analyses on the percentage of trials that subjects pressed the "1" button to discard the previous trial. In the control Experiment 2a the percentages were 0.3% for the related condition, 3.8% for the neutral condition and 0.6% for the unrelated condition. The percentages for Experiment 2 were 0.9% for the related condition, 2.1% for the mediated condition, 2.4% for the neutral condition, and 1.3% for the unrelated condition. Analyses of variance did not yield any significant effects of condition.

ing association between the prime and target words of these items.

In order to test whether the apparent differences in the mediated facilitation effects between the lexical decision Experiment 1 and the pronunciation Experiment 2 were significant, an overall 2 × 2 × 2 (Task × SOA × Mediated vs. Neutral) ANOVA was conducted. The results of this analysis yielded a significant interaction between task and prime, $F(1, 116) = 6.70$, $MS_e = 997$. None of the remaining interactions approached significance.

General Discussion

The present results are straightforward. The lexical decision results yielded strong priming effects between the first and second links of each triad but very little evidence of a priming effect in the mediated condition. These results provide a replication of de Groot's (1983) lexical decision experiments. Based on these results, one would suggest that activation spreads only one step within the memory network. Because of recent concerns in the literature that strategic decision processes could possibly obscure the contributions of a multiple step activation process in the lexical decision paradigm, a pronunciation experiment was conducted with the same materials. In contrast to the lexical decision results, the pronunciation results indicated clear mediated priming effects. This was the case even though the pronunciation results yielded smaller priming effects in the related conditions. The results of the pronunciation experiment suggest that activation spreads at least two steps deep in the memory network.

Before considering the implications of these results, it is necessary to address the possibility that the mediated facilitation found in the pronunciation experiment was due to some slight direct relation that may have existed for some percentage of our prime-target pairs. Three findings argue against this possibility. First, there should have been facilitation for mediated items in the lexical decision experiments if some of the prime-target pairs involved direct associations. In the present lexical decision experiments, reliable priming effects were observed for related prime-target pairs but not for mediated prime-target pairs. Second, a very conservative criterion was used for the inclusion of the mediated prime-target pairs in these experiments. None of the targets were produced to the mediated primes in 12,880 responses in the free association task. Third, if the mediated priming effects were due to a few items having weak direct associations, one would expect the mediated pairs that were rated as most strongly associated (see Method section) to be the items responsible for the effect. In order to address this possibility, a median split based on the mean ratings per item was conducted. The mean rating for the lower half of the mediated pairs was 1.45 (very similar to the unrelated condition, mean rating = 1.41), whereas the mean rating for the upper half was 2.64 (still considerably lower than the directly related pairs that had ratings of 4.19 and 4.01). A comparison of the priming effects for the items in the lower half (16-ms facilitation) and upper half (18-ms facilitation) indicated that there was very little relation between the item ratings and the priming effects observed in the pronunciation experiments. Furthermore, the correlation between the ratings of the mediated pairs and the size of their corresponding facilitation effects (i.e., the difference between the mediated condition and the mean of the neutral and unrelated conditions) did not approach significance, $r = -.017$. Thus, the observed priming effects were not being produced by items that had higher ratings because of some weak direct associations. For the above three reasons, we believe that the facilitation effects observed in the mediated condition of the pronunciation experiments were due to activation spreading across a mediating node between the prime and target nodes.

The remainder of the present discussion will deal with two broad issues: (a) How are the pronunciation and lexical decision results to be reconciled with each other and with the de Groot research? (b) What are the implications of the present research for spreading activation theory?

Lexical Decision and Pronunciation Tasks

Given the finding that pronunciation was facilitated by the existence of a mediating association between the prime and target, how are we to explain the lack of mediated priming effects in the lexical decision experiments? Following de Groot (1983), we suggest that there are two different influences of a semantic relation in a lexical decision task. The first process reflects spreading activation and influences the speed of lexical access via increased activation of a lexical representation. The second process is a postaccess check for a relation between the prime and target word. Subjects might develop this checking strategy by noticing that: (a) some of the primes and targets are related, and (b) such relations indicate that a "word" response is appropriate. Although the detection of a relation presumably follows lexical access and would therefore seem an inefficient basis for a response, the existence of a prime-target relation is probably very salient information for subjects. Further, it should be emphasized that the lexical decison task is not simply a reflection of lexical access but is a binary choice discrimination task. Thus, subjects can be expected to make their decision based on any information that discriminates word from nonword stimuli (Balota & Chumbley, 1984; Chumbley & Balota, 1984).

Let us consider how the spreading activation and postaccess checking processes operate in the lexical decision task. First, presentation of a non-neutral prime causes an automatic spread of activation to related concept nodes. As a consequence, lexical access is facilitated for both related and mediated target items, although the amount of facilitation is less for mediated items. After lexical access is completed for the target word, the subject then checks to determine whether there is a prime-target association. This postaccess checking process is assumed to be sensitive only to the existence of relatively strong associations (e.g., associations that are activated beyond some criterion). As soon as an association is detected, the subject responds that the target is a word. If no association is detected before a temporal deadline is reached, a decision is made based on any relevant information that has accrued to that point. This was presumably the case for the mediated, unrelated, and neutral conditions where no direct associations were available before the deadline was reached. The major difference between processing in the lexical decision and pronunciation task is that no postaccess check is performed in the pronunciation task. Rather, after lexical access is achieved in the pronunciation task, the subject retrieves the articulatory code for the stimulus and says the word.

Consider how this model of processing in the two tasks accounts for the major results of the current investigation. First, responses were faster in the related condition than in the neutral or unrelated conditions because spreading activation facilitated lexical access in the related conditions of both tasks. Related items in the lexical decision task benefitted additionally from the fact that the postaccess check located a relation before the deadline, whereas responses to targets in all other conditions were delayed until after the deadline was reached. This mechanism explains why facilitation of related items was greater in the lexical decision task (52 ms in Experiment 1a and 37 ms in Experiment 1) than in the pronunciation task (22 ms in Experiment 2a and 28 ms in Experiment 2). Next, mediated targets were responded to faster than neutral or unrelated items in the pronunciation task because spreading activation from the mediated prime facilitated lexical access. Further, the magnitude of the facilitation was less than for related items because the degree of activation of the target would be predicted to be less for mediated than for related targets. Although lexical access should also have been facilitated for mediated targets in the lexical decision task, no facilitation was observed. According to the model, this is because subjects failed to detect a relation between the prime and target during the postaccess check and therefore had to delay responding until the deadline on the checking process was reached. Finally, although response latencies did not differ for the mediated and neutral conditions in the lexical decision task, there was some indication that fewer errors occurred in the mediated condition. In all five of de Groot's (1983) experiments (240-ms SOA) and in the 250-ms SOA condition of the present experiment (but not at the 500-ms SOA), accuracy was higher in the mediated condition than in the neutral or unrelated conditions. The model attributes this apparent facilitation effect in the mediated condition to spreading activation from the prime to the target. The resulting higher activation levels of mediated targets relative to neutral or unrelated targets constituted extra evidence that the target was, indeed, a word. Thus, although response latency was not facilitated in the mediated condition of lexical decision because of the deadline mechanism of the postaccess check, accuracy was affected at the shortest SOA.

Although the hypothesis of a postaccess checking strategy unique to the lexical decision task accounts for many of the major findings of the current study, the resulting processing model is quite complex. We have presented some arguments concerning the plausibility of such a processing strategy. In addition, there is independent evidence of its existence. Koriat (1981) has demonstrated that the presence of a backward association from the target word to the prime influences lexical decision performance. This finding suggests that subjects are searching for a prime-target relation after the target is recognized. Seidenberg et al. (1984) replicated Koriat's findings for the lexical decision task and have further demonstrated that the presence of backwards associations does not affect performance in the pronunciation task. These results support the hypothesis of a postaccess checking strategy in the lexical decision but not in the pronunciation task.

We have argued that a critical difference between the lexical decision and pronunciation tasks is that the former task requires a binary choice discrimination, whereas the latter task does not. It might be argued that the critical difference between our use of the two procedures was that the lexical decision task included nonwords, whereas the pronunciation task did not. Although nonwords could have been included in the pronunciation task, we opted to exclude them for three reasons. First, there is some evidence that the inclusion of nonwords does not influence pronunciation performance, at least when sentence contexts are used as primes (West & Stanovich, 1982). Second, we thought that the presence of nonwords might increase the likelihood that subjects would rely on grapheme to phoneme conversion rules as opposed to lexical access routes. If lexical bypass routes were used then this would decrease the sensitivity of the task for detecting a mediated priming effect. Third, it is possible that the inclusion of nonwords in a pronunciation task might encourage subjects to adopt a word/nonword decision strategy before making their pronunciations. Although this possibility would make the pronunciation task more similar to the lexical decision task, it would also encourage the binary decision aspect of the lexical decision task we were attempting to avoid.

There is one final point to note regarding the recent comparisons of lexical decision and pronunciation performance. Past studies have consistently yielded larger effects of experimental manipulations in lexical decision tasks than pronunciation tasks. Compared to pronunciation performance, lexical decision performance has yielded larger effects of word frequency (Balota & Chumbley, 1984), semantic variables such as meaningfulness and category dominance (Chumbley & Balota, 1984), backward priming (Seidenberg et al., 1984), syntactic priming (Seidenberg et al., 1984), list probability manipulations (Neely & Ross, 1985; Seidenberg et al., 1984), and inhibition in sentential contexts (West & Stanovich, 1982). Based on such a pattern, one might argue that the lexical decision task is simply a more sensitive measure of variables that influence lexical access because of potential grapheme to phoneme lexical bypass routes in the pronunciation task (see Coltheart, Davelaar, Jonasson, & Besner, 1977). The present results are the first demonstration of a lexical manipulation that produces a larger effect in the pronunciation task than in the lexical decision task. Thus, the lexical decision task cannot simply be viewed as a more sensitive task; rather, it is a task that involves qualitatively different processes than the pronunciation task.

In sum, we propose that response latencies in lexical decisions were not facilitated by mediated primes because subjects searched for a direct relation between the prime and target and direct relations were not readily available for mediated prime-target pairs. Such postaccess searches occur because of the decision aspects of the lexical decision task. When a task was used that did not involve postaccess search processes (i.e., pronunciation), response latency was facilitated by mediated primes. This result supports the multiple-step activation model.

Multiple-Step Spreading Activation

Most models of spreading activation assume that activation spreads to directly related concepts and, from those concepts, more deeply into the memory network. This aspect of spreading activation theory has been a crucial component in accounting for a wide variety of cognitive performance. However, the assumption of multiple-step activation has received no direct empirical support until now. The results of the present study and those reported by den Heyer and Briand (in press) using numerical stimuli are the first direct empirical support for the multiple-step activation model.

The assumptions of spreading activation theory are supported not only by the finding of mediated facilitation but also by the finding that the mediated priming effect was smaller than the directly related priming effect (also, see den Heyer & Briand, in press). This result is consistent with two important assumptions of spreading activation theory (Anderson, 1976; Collins & Loftus, 1975). First, mediated priming effects should be smaller than related priming effects because the amount of activation reaching a node in memory is assumed to depend on the "distance" from the source of the activation (Becker, 1980, Experiment 5; de Groot et al., 1982; Lorch, 1982, but see Becker, 1980, Experiments 2 & 4; Neely, 1977). The distance between the prime and target in the mediated condition should have been, on average, twice as long as the distance between the prime and target in the related condition. Second, activation should decrease as it traverses an intermediate concept because the amount of activation emanating from any particular concept is proportional to the strength of all pathways emanating from that concept (Anderson, 1976; Reder & Anderson, 1980). Thus, one should find a reduction as activation traverses the intermediate concept because it travels not only along the associative pathway to the target but also along any other associative pathways emanating from the intermediate concept. Although both factors should reduce the activation reaching the target in the mediated condition, the independent contributions of these factors cannot be discerned from the present results.

The conclusion that activation involves multiple steps raises an important theoretical issue. Specifically, how does the system deal with the potentially enormous amount of information made available by a multiple-step activation process? For example, suppose that multiple-step activation processes occur in language processing. If one considers that an average reading rate is 250 words per minute and that possibly half of the words are content words, then a two-step activation process (with each concept directly connected to five other concepts) would activate as many as 50 concepts during a single second of reading. If the spread of activation is truly automatic, then the activation process itself will incur little cost in resources in the course of making a great deal of potentially relevant information available for further processing. But how does the system then select the most pertinent information from the activated set without incurring heavy costs? One possibility is that only activated intersections receive further processing (Anderson, 1976; Collins & Quillian, 1969). Despite the popularity of this concept, however, there is little direct evidence for a selection process based on intersecting searches. Thus, the present finding of mediated priming effects raises the important issue of how relevant information is selected for further processing from a multitude of activated representations.

Finally, it is of historical importance to note that there has been a long tradition of research and debate concerning mediational effects. In fact, one important issue in verbal learning research was whether one could produce true mediational positive transfer effects in a paired-associate learning situation (see Kjeldergaard, 1968). Concerns regarding direct versus indirect associations producing positive transfer effects were dominant then as they are today. The present research provides continuity with this basic research interest and strongly indicates that there is a measurable impact of indirectly related information.

References

Anderson, J. R. (1976). *Language, memory and thought.* Hillsdale, NJ: Erlbaum.

Anderson, J. R. (1983a). *The architecture of cognition.* Cambridge, MA: Harvard University Press.

Anderson, J. R. (1983b). A spreading activation theory of memory. *Journal of Verbal Learning and Verbal Behavior, 22,* 261–295.

Anderson, J. R., & Bower, G. H. (1973). *Human associative memory.* Washington, DC: Winston.

Balota, D. A. (1983). Automatic semantic activation and episodic memory encoding. *Journal of Verbal Learning and Verbal Behavior, 22,* 88–104.

Balota, D. A., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 340–357.

Becker, C. A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory & Cognition, 8,* 493–512.

Chumbley, J. I., & Balota, D. A. (1984). A word's meaning affects the decision in lexical decision. *Memory & Cognition, 12,* 590–606.

Collins, A., & Loftus, E. (1975). A spreading activation theory of semantic processing. *Psychological Review, 82,* 407–428.

Collins, A., & Quillian, M. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior, 8,* 240–248.

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and performance VI* (pp. 535–555). New York: Academic Press.

Conrad, C. (1972). Cognitive economy in semantic memory. *Journal of Experimental Psychology, 92,* 149–154.

Dagenbach, D., & Carr, T. H. (1985). *Now you see it, now you don't: Relations between semantic activation and awareness.* Manuscript submitted for publication.

de Groot, A. M. B. (1983). The range of automatic spreading activation in word priming. *Journal of Verbal Learning and Verbal Behavior, 22,* 417–436.

de Groot, A. M. B., Thomassen, A. J. W. M., & Hudson, P. T. W. (1982). Associative facilitation of word recognition as measured from a neutral prime. *Memory & Cognition, 10,* 358–370.

den Heyer, K., & Briand, K. (in press). Priming single digit numbers: Automatic spreading activation dissipates as a function of distance between prime and target. *American Journal of Psychology.*

Foss, D. J. (1982). A discourse on semantic priming. *Cognitive Psychology, 14,* 590–607.

Kieras, D. (1981). Component processes in the comprehension of simple prose. *Journal of Verbal Learning and Verbal Behavior, 20,* 1–23.

Kjeldergaard, P. M. (1968). Transfer and mediation in verbal Learning. In T. R. Dixon & D. L. Horton (Eds.), *Verbal behavior and general behavior theory* (pp. 67–96). Englewood Cliffs, NJ: Prentice-Hall.

Koriat, A. (1981). Semantic facilitation in lexical decisions as a function of prime-target association. *Memory & Cognition, 8,* 587–598.

Loftus, E. F. (1973). Activation of semantic memory. *American Journal of Psychology, 86,* 331–337.

Lorch, R. F. (1982). Priming and search processes in semantic memory: A test of three models of spreading activation. *Journal of Verbal Learning and Verbal Behavior, 21,* 468–492.

Lorch, R. F., Balota, D. A., & Stamm, E. G. (in press). *Locus of inhibition effects in the priming of lexical decisions: Pre- or post-lexical access? Memory & Cognition.*

Lupker, S. J. (1984). Semantic priming without association: A second look. *Journal of Verbal Learning and Verbal Behavior, 23,* 709–733.

McClelland, J. I., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88,* 375–407.

McDonald, D., & Hayes-Roth, F. (1978). Inferential searches of knowledge networks as an approach to extensible language-understanding systems. In D. Waterman & F. Hayes-Roth (Eds.), *Pattern-directed inference systems.* New York: Academic Press.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited capacity attention. *Journal of Experimental Psychology: General, 106,* 226–254.

Neely, J. H., & Ross, K. L. (1985, May). *Effects of the probability of related primes on semantic priming and nonword facilitation effects in lexical decision and pronunciation tasks.* Paper presented at the meeting of the Midwestern Psychological Association, Chicago, IL.

Ratcliff, R., & McKoon, G. (1981). Does activation really spread? *Psychological Review, 88,* 454–462.

Reder, L. M., & Anderson, J. R. (1980). A partial resolution of the paradox of interference: The role of integrating knowledge. *Cognitive Psychology, 12,* 447–472.

Reed, A. V. (1979). Microcomputer display timing: Problems and solutions. *Behavior Research Methods and Instrumentation, 11,* 572–576.

Seidenberg, M. S., Waters, G. S., Sanders, M., & Langer, P. (1984). Pre- and postlexical loci of contextual effects on word recognition. *Memory & Cognition, 12,* 315–328.

Smith, E. E., Shoben, E. J., & Rips, L. J. (1974). Structure and process in semantic memory: A feature model for semantic decisions. *Psychological Review, 81,* 214–241.

Stanovich, K. E., & West, R. F. (1983). On priming by a sentence context. *Journal of Experimental Psychology: General, 112,* 1–36.

West, R. F., & Stanovich, K. E. (1982). Source of inhibition in experiments on the effect of sentence context on word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8,* 395–399.

Appendix

Stimulus Triads

Mediated	Related	Target	Mediated	Related	Target
Lion	Tiger	Stripes	Cat	Mouse	Cheese
Beach	Sand	Box	Summer	Winter	Snow
War	Peace	Quiet	Wedding	Ring	Finger
Birthday	Cake	Pie	Tooth	Brush	Hair
Deer	Animal	Vegetable	Sport	Baseball	Glove
Breeze	Blow	Bubbles	Rough	Smooth	Silk
Oyster	Pearl	Necklace	Cry	Baby	Bottle
Eyes	Nose	Smell	Bull	Cow	Milk
Minute	Hour	Glass	Tree	Maple	Syrup
Soap	Water	Drink	Pen	Pencil	Lead
Priest	Church	Bell	Beer	Wine	Grape
Ceiling	Floor	Carpet	Day	Night	Dark
Hand	Foot	Kick	Wrist	Watch	Clock
Bat	Ball	Bounce	White	Black	Coal
Lemon	Sour	Sweet	Navy	Army	Tank
Sky	Blue	Color	Pretty	Ugly	Duckling
Hard	Soft	Cotton	Moon	Sun	Hot
Tea	Coffee	Bean	Window	Door	Knob
Phone	Number	Letter	School	Bus	Stop
Nurse	Doctor	Lawyer	Valley	Mountain	Peak
Reality	Fantasy	Island	Gas	Oil	Slick
Knife	Gun	Trigger	Flower	Rose	Thorn
Circle	Square	Dance	Heavy	Light	Feather
Fast	Slow	Turtle	Pants	Shirt	Collar

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