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Conscious and Unconscious Semantic Activation in Episodic Memory Retrieval

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KEY TERMS

- Semantic Memory
- Retrieval Processes
- Unconscious Priming
- Conscious Priming
- Spreading Activation

ABSTRACT

This research examines the role of conscious and unconscious semantic activation in the episodic retrieval of paired associates. It finds that semantically activating the target of a given cue-target paired associate increases the likelihood that the associate will be successfully retrieved. This increased retrieval accuracy was found in both suprathreshold and subthreshold priming conditions. The study found that subjects responded faster to a given target when said target was semantically activated in both suprathreshold and subthreshold conditions. These findings together support the idea that semantic activation plays a role in the retrieval of episodic memories.

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Professor Balota works on issues related to visual word recognition, semantic memory, priming on implicit memory tests, and attention systems that modulate performance within each of these domains. He investigates these phenomena within young adults, older adults, and individuals who have dementing illnesses such as senile dementia of the Alzheimer's type.

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INTRODUCTION

Humans are constantly retrieving information from their vast storehouse of knowledge. They appear to do this quickly and efficiently. Current models of memory (Tulving, 1972) suggest that there is an important distinction between semantic memory (our storehouse of knowledge) and episodic memory (our autobiographical memory for previous events, e.g., what I had for breakfast). One way to conceptualize semantic knowledge is as a storage of nodes and that these nodes are connected to other nodes via associative pathways. For the specific piece of knowledge stored in a given node to be retrieved (pulled into conscious awareness), that node must be activated above a certain threshold. The theory of spreading activation (Collins & Loftus, 1975) suggests that when a given node is activated, activation spreads to other nodes related to the original node through both conscious and unconscious paths. If a node is strongly related, it will be pushed into conscious awareness and thus recalled. This semantic spreading activation has been a thoroughly-explored concept of psychological research for decades. While this idea has been tested in areas ranging from illusions of memory to recognition paradigms, little research has focused on the role semantic activation might play in episodic memory retrieval.

In semantic priming paradigms, semantically related or identical primes have been shown to increase processing fluency of their targets through semantic activation (Maddox and Balota, 2014). This increased processing fluency, or ease in facility and speed of processing, is reflected by a decrease in response latency and an increase in accuracy. Researchers such as Collins and Loftus (1975) have suggested that upon the presentation of a prime, the semantic representation of that prime is activated, and that activation in turn spreads to representations of semantically related words or concepts. Researchers such as Balota (1983) and Jacoby and Whitehouse (1989) have shown that this activation persists even if the primes are presented below the threshold of conscious processing. Jacoby and Whitehouse studied masked priming in the context of recognition, whereas Balota studied masked priming in a lexical decision paradigm.

The present study addressed the role of spreading activation in a more effortful episodic memory paradigm, i.e., memory retrieval of paired associates. In the present study, participants studied paired-associates, or word-pairs (e.g., DOG-CHAIR) during an initial learning phase. After studying the word-pairs, they were tested during retrieval in which they were given the cue (DOG) and were required to retrieve the word that was paired with this stimulus. It is important to note that, during this testing phase, participants were presented with both masked (in a backwards lexical masked priming paradigm) and unmasked primes. These primes could either increase activation of the target via the identity prime (e.g., CHAIR) or related prime (e.g., TABLE), compared to a baseline unrelated condition (e.g., FROG). It was predicted that increasing the activation of the target in semantic memory would in turn make it easier for participants to successfully recall the target. It was also predicted that subjects would show greater effects in the conscious prime duration, as both conscious and unconscious processes would be engaged by the prime.

METHODS

Subjects

The subjects were 26 undergraduate students living in St. Louis for the summer who participated in the experiment for payment. All subjects were between the ages of 18 and 23. Twenty-five subjects were right handed and one was left handed. Nineteen of the subjects were female, and the remaining seven were male. Fourteen subjects underwent a control procedure as well as the experimental procedure. Subjects were randomly assigned to one of eight counterbalances based on the order in which they signed up.

Materials, Procedures, and Design

A pool of 76 cue-target pairs was selected from Maddox and Balota (2014). In order to reach an even 80, four new word pairs were created using data from the Nelson Free Association Norms (NFAN). Each new word pair was assigned a prime related to the target (second word) of that word pair, taken from the NFAN. The word pairs and their respective primes were then divided into four groups of 20 word pairs each, which would be used to make the word lists for each counterbalance. Across the lists, the word pairs were controlled for word frequency, word length, and strength of both forward and backward relationships.

Subjects were tested for their ability to recall word pairs in various prime conditions. There were three prime conditions: identity (identical to the target), related (related to the target), or unrelated (unrelated to the target). Given the word pair "DOG-chair," an identity prime would be "chair," a related prime would be "table," and an unrelated prime would be "salt." There were also two presentation duration conditions. Primes were either presented for 33 milliseconds (in the masked, unaware condition) or 150 milliseconds (in the aware condition). Each of these manipulations were within subjects; each subject saw all prime types and both prime durations.

Three 20-word pair groups were shown to each subject, with the fourth withheld. The primes for the word pair group in the unrelated condition were taken from the related primes of the withheld word pair group. Therefore, eight lists of 80 words each were created, with the 20-word groups rotating between being used in the identity condition, the related condition, the unrelated condition, or the withheld condition. The 20-word groups also rotated between timing conditions. This counterbalancing insured that every word pair was seen in each condition the same number of times.

Subjects went through three phases of the experiment. The first phase involved a study/encoding phase in which subjects were presented with all word pairs (except those from the withheld list). This phase took approximately eight minutes. Subjects were instructed to learn and memorize the word pairs. They were also informed that immediately after this learning phase they would be tested for their memory of the presented word pairs. Word pairs were presented one at a time for a duration of 4.5 seconds, and were presented CUE-target (e.g., DOG-chair). All word pairs were presented in the same location, the center of the screen. No priming or masking procedures occurred during this encoding phase. The screen advanced from word pair to word pair automatically, to ensure that subjects had equal exposure to all word pairs. Each participant was presented with 60 word pairs.

The second phase involved the primed testing phase, which took between 12 and 15 minutes. On each trial of the second phase, subjects were instructed to provide the target of one of the word pairs they had just studied when given the cue. They were told that throughout the testing phase other words may be flashed on the screen, but when given the first word of the pair, they were to respond with the second. Subjects were first presented with a row of hashtags as an initial mask for 250 milliseconds. They were then presented with a prime in any of the three conditions (word pairs were presented in random order) for either 33 milliseconds or 150 milliseconds. This prime was immediately followed by the cue, which both served as a backwards lexical mask and cued the participant to begin retrieval. The cue was presented in the format "CUE - ?????", to remind the participant of the word pair structure of the task. Participants had ten seconds to recall the target and press enter. If they did not press enter, the program automatically advanced to the response-entering screen. They then typed in their response and pressed enter again to move on to the next trial. Participants were quizzed on all 60 of the word pairs they studied in the previous phase.

The following graphic shows the time course of each trial.

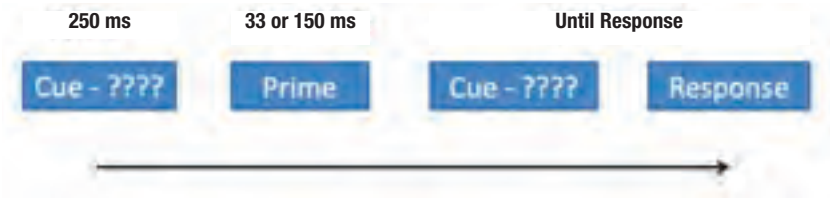

Figure 1

In the third and final phase, subjects were explicitly told that a prime would be flashed between the presentation of the initial stimulus (the hashtags) and the presentation of the cue. This phase was intended to determine if participants could see and produce the unaware, 33 millisecond (ms) primes. The phase followed an identical format to the second (hashtags, followed by prime, followed by cue), but in this case, participants were instructed to identify the briefly presented prime item rather than the target. The primes were presented in both duration conditions, 33 ms and 150 ms. If subjects could not read or see the flashed prime, they were instructed to enter "x" in its place. The word pairs in the withheld list were paired with the related primes from the word pair list in the identity condition, to ensure that participants had never seen either the presented cues or the presented primes previously in the experiment. Participants ran through a total of 20 trials.

The entire procedure was run using E-prime software. Stimuli were presented on a Samsung LCD monitor paired with a Dell PC. The stimuli were presented in the center of the screen and were formatted as white text on a black background. Subjects responded by typing their responses on a keyboard. Subjects were tested individually and sat approximately two feet away from the screen.

RESULTS

Analysis was run on SPSS software using a repeated-measures within-subjects ANOVA. All statistical tests used an alpha level of .05. It is important to note that because we have not yet run our target number of subjects, the experiment is not yet fully counterbalanced. Therefore, it is possible that list effects or stimuli effects are present. It was also found that four words were repeated in the word lists. Trials which contained those repeated words were removed from the analysis.

Accuracy

In the identity condition, participants were correct on 78% of trials in the 150 ms duration, and 52% of trials in the 33 ms duration. In the related condition, participants were correct on 56% of trials in the 150 ms duration, and 54% of trials in the 33 ms duration. Finally, in the unrelated condition, participants were correct on 46% and 44% of trials for the respective durations. These results are displayed in the below graph.

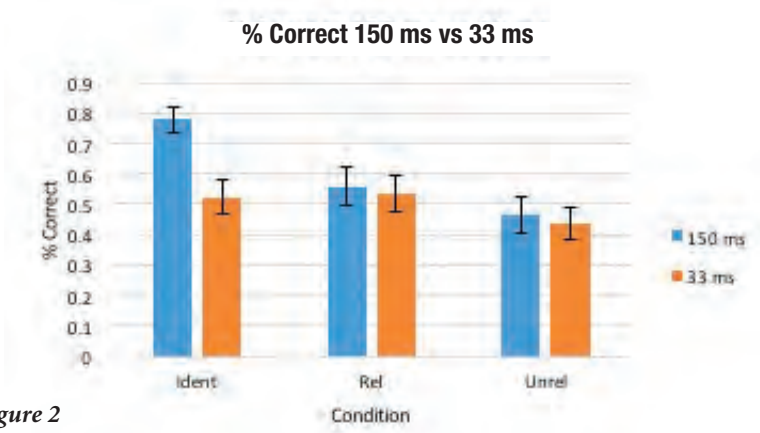

Figure 2

Mean accuracy as a function of condition is displayed in *Figure 2*. Subject means for percentage retrieval accuracy were compiled for each condition and analyzed in a 2x3 repeated-measures ANOVA. The analysis showed a significant effect of the manipulation of prime condition, $F(2,50) = 25.2$, $p < .001$, $n_p^2 = .50$, a significant effect of the manipulation of prime duration, $F(1,25) = 29.6$, $p < .001$, $n_p^2 = .54$, and a significant interaction of time and condition $F(2,50) = 6.9$, $p<.01$, $n_p^2 = .22$.

Pairwise comparisons were then conducted for both duration and prime condition. Participants were significantly more accurate in the 150 ms condition than in the 33 ms condition ($p < .001$). Also, subjects were significantly more accurate in the identity condition than the related condition ($p < .01$), significantly more accurate in the related condition than in the unrelated condition ($p < .001$), and significantly more accurate in the identity condition than in the unrelated condition ($p < .001$).

As there was a significant interaction between prime duration and condition, post hoc repeated measures ANOVAs were run on both the 33 ms and 150 ms conditions separately (1 factor ANOVA, 3 levels (identity, related, unrelated)). There was a marginally

significant effect of condition for the 33 ms prime duration, $F(2,50) = 3.0$, $p < .06$, $n_p^2 = .10$ and a significant effect of condition for the 150 ms prime duration, $F(2,50) = 22.6$, $p < .001$, $n_p^2 = .48$.

Pairwise comparisons were again run for both durations. In the 33 ms prime duration, there was no significant difference in retrieval accuracy between the identity and related conditions ($p > .05$), but both the identity and related prime conditions showed significantly increased retrieval accuracy relative to the unrelated prime condition ($p < .03$ and $p < .05$, respectively). In the 150 ms condition, participants were significantly more accurate in the identity condition than in the related or unrelated conditions ($p < .01$ and $p < .001$, respectively). Subjects were also significantly more accurate in the related condition than in the unrelated condition ($p < .03$). Therefore, the significant interaction between duration and prime condition is likely due to the increased retrieval accuracy in the identity condition at the 50 ms condition. This pattern is expected because at 150 ms, participants are able to see the correct answer in the prime.

Response Time

It is important to note that the response time result reported below is taken from an incomplete segment of participants (N = 18), because some subjects did not perform well enough to have means in certain conditions. More subjects will be run in the future to account for this fault.

Response times were taken from trials in which participants correctly recalled the target. Response times below 250 ms or above 9000 ms were trimmed out. Next, response times greater than 4 standard deviations from the mean or less than -4 standard deviations from the mean were trimmed as well. Response times were then standardized and run through a 2x3 repeated measures ANOVA (see *Figure 2* for mean standardized response latencies).

The analysis showed a significant main effect of prime condition, $F(2,34) = 5.42$, $p < .01$, $n_p^2 = .242$. There was no interaction present across prime durations. This is likely due to the fact that, across prime durations, participants were slower in responding when

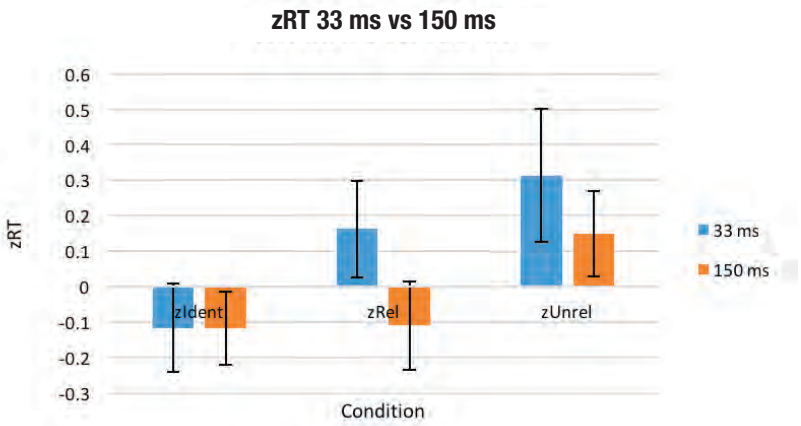

Figure 3

given an unrelated prime than a related or identity prime. *Figure 3* displays the mean z-scored response times.

Control

On average, subjects correctly identified 33 ms primes in the control phase only 5% of the time. In the 150 ms duration, they correctly identified the prime with 91% accuracy. Nine out of the 14 subjects run in the control phase identified 0 primes in the short duration. The analysis showed a significant main effect of prime duration, $F(1,13) = 789.7$, $p < .001$, $n_p^2 = .984$.

DISCUSSION

These results indicate that, as predicted, semantic activation does play a role in controlled episodic memory retrieval. There was a significant effect of prime condition in both prime durations. Importantly, retrieval accuracy increased when the prime was semantically related to the target. Subjects were faster to respond when the prime had some semantic relationship to the target in both durations, indicating that semantic activation facilitates both accuracy of retrieval and ease of retrieval, which together make up retrieval fluency. This result is consistent with the findings of facilitation in both the Balota lexical decision/recognition study and the Jacoby and Whitehouse study of false recognition. This work extends to a controlled episodic retrieval situation.

The analysis of the control items indicates that the 33 ms masked primes were nearly impossible for participants to correctly identify. Therefore, the significant facilitation of the identity and related conditions are associated with unconscious processes rather than conscious direction of attention, as the primes were not available to the conscious mind.

It is noteworthy that both the identity and related conditions showed approximately equivalent facilitation. Hence, the facilitation is likely due to the semantic relationship of the primes and not to the lexical characteristics (letter shape, length, etc.). If subjects were picking up on the lexical characteristics of the primes, the identity condition would produce a larger benefit, because the related primes do not share lexical characteristics with their semantically associated targets. It is the spread of semantic activation that facilitates retrieval in the 33 ms duration.

The fact that participants responded significantly faster to word pairs in the related and identity prime conditions than to word pairs in the unrelated condition lends further support to the idea that semantic activation facilitates retrieval. This finding is in line with the results of Balota's 1983 paper, which saw faster response times to words followed by a related prime than words following an unrelated prime. Interestingly, however, Balota (1983) did not observe an effect of semantic activation from threshold primes in a recognition task: he saw a deleterious effect of prime in the suprathreshold condition, but not in the threshold condition. This apparent conflict, however, appears because Balota et al. used a context recognition test, whereas this study uses a direct retrieval task.

The key difference between the 150 ms prime duration and the 33 ms duration lies in the mean accuracy within the identity condition. Participants reached a mean accuracy of 78% in the 150 ms duration and 52% in the 33 ms condition. This large difference is responsible for the significant time by condition interaction found in the above analyses.

It is likely that at the 150 ms identity condition participants have conscious access to the lexical characteristics provided by the identity prime, which exactly match the lexical characteristics of the target. This would lead to both lexical and semantic priming, greater activation, and easier recall. Additionally, presenting the target to the participant as the prime directly rather than indirectly semantically activates the target in memory, which leads to greater activation of the target in memory. On a threshold-based model of retrieval processes, greater activation should lead to easier recall, as is displayed in the 150 ms results of this paper. While there should be greater semantic activation in the unconscious prime duration as well, there is not significantly greater facilitation, which may detract from this interpretation.

It is also possible that in the 150 ms conscious identity condition, participants are using a different process than in the related and unrelated prime conditions. In the latter two conditions, participants are forced to retrieve the target from memory, while in the identity condition, participants must simply recognize the presented prime as the correct target. This condition requires recognition rather than retrieval. More research is needed to investigate this possibility.

It is important to note that a replication of this study was conducted during the fall of 2016 at Washington University in St. Louis with 19 subjects. The study failed to replicate the effects reported above. Therefore, the results above must be taken with caution. These results are not easily replicable, and are a great example of the importance of the replication in science.

The results of this paper imply that semantic activation affects ease of retrieval both in unconscious and conscious prime durations. This semantic activation can come from either suprathreshold or subthreshold primes. Future research should experiment with Stimulus Onset Asynchrony (SOA) by varying the duration between the presentation of the prime and cue, and with varied retrieval paradigms. It would also be interesting to examine the time course of the activation by testing the participants later in the day or in a second session.

The results of this paper have great relevance in academic contexts, specifically in the memorization-based learning. For instance, it is possible, given these results, that the order of word presentation or choice of words in test questions could have a measurable effect on student performance on said tests. Teachers, when made aware of the importance of enforcing semantic relationships between concepts, could improve their student's ability to retrieve the required information when tested. This study, and others like it exploring the processes that drive retrieval, will help policy-makers and educators alike better design classes and pedagogical techniques for a new generation of students.

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