

ADDITIVITY FROM MULTIPLE PRIMES IN IDENTIFYING BACKWARD WRITTEN WORDS¹

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Summary.—Activational theories of memory assume that activation from several sources adds up to an intersecting node. We tested this idea in one experiment where we kept constant the number of primes presented and we manipulated the number of different primes related to the target, the number of presentations of the same prime, or the same target, presented as a prime. We used a task in which the target was always a word, which appeared written backward and had to be identified. We found a strong effect of target repetition and diminished priming in the condition in which the target was repeated. We obtained additivity (greater activation) mainly in the condition in which we presented several different primes, replicating and extending past results.

Semantic priming refers to the reduction in reaction time to a target word, when it is preceded by another semantically related word (prime). Semantic priming as a phenomenon and activation as its theoretical referent are important concerns for memory theorists because they provide a tool to explore the organization of semantic memory. In this respect, the phenomenon lends support to network theories which assume that semantic memory is composed of a large conceptual network in which concepts close in meaning are also closely placed and the processing of a concept activates its closest associates. The utility of the activation concept for the study of semantic memory would be greatly strengthened if its empirical characterization could be more clearly specified. This is one of the goals of the present paper, the investigation of the empirical properties of activation.

Several recent research reports have explored a new property of the activation process implied by several current theories (Anderson, 1983; Anderson & Pirolli, 1984; Grossberg & Stone, 1986; McClelland & Rumelhart, 1985). This property can be called additivity of activation and can be defined as the increased facilitation of reaction time to a target word when several associated concepts are activated, in comparison to when only one is activated. We could also talk about additivity of activation from repeated activation of the same prime node, in comparison with conditions in which only one is activated. In spite of this theoretical interest, the assumption of additivity of activation has

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not been investigated empirically but in a few reports and very tangentially. For example, Carroll and Kirsner (1982), using a two-word simultaneous identification task, found that the repetition of the prime stimulus, with relatively long interrepetition intervals, did not affect reaction time to the stimulus pair presented later. On the contrary, using low-frequency words, they found that target repetition diminished semantic priming, a result contrary to the idea of additivity or potentiation as defined in the present paper. The interaction between target repetition and semantic priming has not been replicated by den Heyer (1986) who found complete independence between the variables (statistical additivity as defined by an analysis of variance), although a recent study has shown this consistently (Algarabel, *et al.*, 1988). The reason for the discrepancy among the several studies is probably associated with the interrepetition interval. When short repetition intervals are chosen, chances of obtaining an interaction between repetition and semantic priming are higher.

On the other hand, recent research (Algarabel, *et al.*, 1988), using a lexical decision task, showed no effect of repeating the same related prime or presenting several different related primes on target reaction time. However, when a different task was used, a target preceded by several related primes produced more facilitation than when it was by a unique repeated related prime or simply by a single related prime, demonstrating additivity of activation from different presented primes. The task required variable presentation of a number of primes, with the target written backwards. The subject's task was to press the keyboard when he had identified the target, which led to erasing the stimulus from the computer screen, and to verbalize the word to the experimenter. The idea behind the design of the task was twofold, to avoid on the one hand, the dichotomy word-pseudoword on which lexical decision is based, because this is probably the reason for the contamination of lexical decisions with postlexical factors (de Groot, 1984), and on the other, to have a task sufficiently sensitive to show any effect produced by the independent variables on the latency of identification.

The present experiment was conducted as a stronger test of the additivity assumption than that carried out in past reports (Algarabel, *et al.*, 1988). In particular, we were interested in studying additivity of activation, varying the relatedness variable at a constant number of primes. In past experiments (Algarabel, *et al.*, 1988) we had manipulated simultaneously number of primes together with relatedness. Now we kept constant the number of primes (always three) and varied the number of related primes (1-3) or the number of repeated presentations of the target as a prime (1-2).

We should expect to obtain, according to predictions of the major theoretical positions (Anderson, 1983; McClelland & Rumelhart, 1985) that increased stimulation of conceptual nodes linked to another conceptual node which rep-

resents the target concept, produces facilitation of target node processing above and beyond facilitation by a single prime. Moreover, we should expect that the repetition of the target word, including it as a prime, should decrease reaction time and lead to diminished priming, given the relevance of priming by sources different from semantic priming. That is, the repetition of the target word includes perceptual factors facilitating reaction time, which should override the facilitative factors produced by semantic priming, as has been shown in past reports (Algarabel, *et al.*, 1988; Carroll & Kirsner, 1982; den Heyer, 1986).

METHOD

Subjects

Thirty-six undergraduate students, 15 of them men, from the University of Valencia (Spain) served as subjects as a course requirement.

Stimuli and Procedure

The stimuli were selected from three different sources: category norms (Pascual, Gotor, Miralles, & Algarabel, 1979), association norms (Algarabel, Sanmartín, García, & Espert, 1986), and a Spanish Dictionary of antonyms and synonyms (Sáinz de Robles, 1981). One hundred and eighty sequences of four related words were selected, composing the original file from which the conditions were randomly derived for every subject. The procedure was as follows. First, the computer chose randomly and independently for every subject a different sequence of stimuli. Second, a random stimulus from each sequence was chosen as the target, and then, depending on experimental condition, the other stimuli were re-paired appropriately to generate the rest of the sequences. This process was repeated for each subject.

The task of the subject included 25 practice and 180 experimental trials, composed of the following events. First, a fixation point (plus sign) appeared in the center of a Macintosh computer monitor for 1000 msec. Second, three signals for 117 msec. duration each, with an interstimulus interval of 0 msec. were presented; all appeared in lowercase letters (Geneva, 12-point size). Third, the stimulus target appeared, always a word, which stayed on until the subject pressed a key (corresponding to the letter "B") after its identification. The stimulus test appeared in bold, capital letters (Geneva type, 12-point size). All stimuli were between 3 and 8 letters long.

In the design we had 12 experimental conditions. There could be from one to three different related primes, two or three related, repeated primes, two or three nonrelated and repeated primes, one or two target-related and repeated targets, one or two targets nonrelated and repeated, and finally a general unrelated control condition with all three primes unrelated.

Subjects were told to respond as fast and accurately as possible.

RESULTS

Errors made were 3.38% of all responses. Given their nonsignificance, no attempt was made to analyze errors. All individual latencies below 500 msec. or higher than two standard deviations from each subject's mean were eliminated from the analysis (8.2%). Data for conditions in which the target was repeated were analyzed separately from those of conditions in which the prime was repeated. Table 1 presents the average reaction times for all conditions in the experiment.

TABLE 1
MEAN BACKWARD WORD IDENTIFICATION TIMES (MSEC.) AND
STANDARD DEVIATIONS FOR CONDITIONS IN WHICH TARGET WAS INCLUDED
AS A PRIME (TARGET REPEATED) OR WHEN IT WAS NOT
(TARGET NONREPEATED) AND FOR NUMBER OF
RELATED, UNRELATED, REPEATED OR NONREPEATED PRIMES

No. of primes	Target nonrepeated						Target repeated				
	Related			Nonrelated			Related		Nonrelated		
	Repeated		Nonrepeated	Repeated		Nonrepeated	M	SD	M	SD	
	M	SD	M	SD	M	SD	M	SD	M	SD	
1	1697	469						1252	373	1365	399
2	1637	476	1527	391	1640	462		1211	431	1222	348
3	1525	412	1507	462	1718	504	1659	393			

A one-way within-subjects analysis of variance was carried out on the condition where there was no target repetition. The effect of experimental condition was significant ($F = 8.16, p < .001, MSe = 30067.57$). To respond to the question of interest, we calculated Newman-Keuls tests which showed that the condition in which one related prime was presented (1697) did not differ from the condition in which three nonrelated and nonrepeated primes were presented (1659), that is, we did not observe priming for one related prime. However, priming was noted when two or three related and nonrepeated primes were presented (1527 and 1507) in comparison with condition in which only one related prime was presented (1697). This indicates a priming effect with two and three significantly different related primes. Also significant was the difference between conditions in which two and three related and nonrepeated primes were presented (1527 and 1507), in relation to the unrelated control (1659).

Next, we looked at the results of the Newman-Keuls test for the condition in which primes are repeated. The condition in which three related primes were repeated (1525) was significantly different from those in which 1 and 2 related and nonrepeated primes were presented (1697 and 1637). This difference was of a semantic priming origin and not merely of stimulus repetition, because the difference between the conditions with three related and repeated primes (1525) was significantly different from the condition with nonrelated

(1718) equivalent primes ($p < .01$). On the other hand, the repetition of a prime *per se* has no effect because the conditions in which the primes were unrelated but repeated (1640 and 1718) did not differ from the condition in which the primes were repeated (1659).

We next examined the effect of number of primes when the target is repeated. For this purpose we carried out a one-way within-subjects analysis of variance which produced significant results ($F = 54.17$, $p < 0.01$, $MSe = 23324.17$). Newman-Keuls tests showed that numbers of target repetitions were significant; all target-repetition conditions differed from the no-repetition control ($p < .05$), although the difference disappeared within two repeated targets.

DISCUSSION

The results of this experiment support, in general, the idea of the additivity of activation, particularly, when additivity is tested with different related primes. That is, even when condition in which only one related prime is presented, the reaction time is not different from that in the condition in which all primes are unrelated and different, mean RTs for the other two levels of the variable (two and three related and nonrepeated primes) are clearly significantly different from the mean of the unrelated condition. Something similar happens with the related and repeated prime condition, which is the only condition in which the three primes were repeated; *semantic priming appears*. Given that the stimulus onset asynchrony is of 350 msec., then the subject could not form expectancies, so the stronger effects found when the two and three related and repeated primes were presented must be produced by build up of activation. It is also worth realizing that the way in which the stimuli were selected for the different conditions was very conservative and may have had the effect of generating weakly associated stimulus sequences. This is so because we had to form four related word chains and to randomize from them all conditions, including the target. That is a very rigorous way of selecting the experimental stimuli, although very conservative. As a further check on the automatic nature of the priming obtained in the experiment, the three unrelated conditions did not differ among themselves although they have, given that the probability of forming an expectancy should have been greater with three than with fewer unrelated primes.

With respect to the conditions in which the target is presented as a prime, the effects are very clear as in past experiments (Algarabel, *et al.*, 1988). The presentation of the target as a prime, even without requiring a response from the subject, produces a drastic reduction in reaction time, greater for the unrelated than for the related condition. This result replicates data obtained recently and argues against den Heyer's suggestion that repetition and priming affect different stages of processing.

Two sets of published data bear upon the current experiment. On the one hand, Neely, *et al.* (1983) found inhibition in responding on a recognition task when the target item was preceded by six items in comparison with two. On the other, Reder (1983) found, on a sentence-comprehension task, that the response to the last ambiguous word of the sentence was faster if both the subject and the relative clause primed the correct interpretation of the ambiguous word. Given the parametric circumstances of the two studies, both can be considered as showing strategic activation, whereas the present study, given the asynchrony used, is constrained to automatic activation.

Theoretically, additivity is a property implied by most activation models of memory (Anderson, 1976, 1983; Collins & Loftus, 1975; McClelland & Rumelhart, 1985), and from this point of view, the empirical finding does not discriminate among theories. However, additivity discards the possibility of viewing activation as an all or none process (Higgins, Bargh, & Lombardi, 1985), which once initiated reaches a maximum more or less instantaneously.

It is also interesting to realize that additivity is a phenomenon closely related to the fan effect (Anderson, 1983) and the target-set size interference (Nelson, *et al.*, 1987), because these last two phenomena seem to imply the subtraction of activation. The three sets of data could be taken as converging evidence in favor of an activation process which grows or decreases stepwise, instead of all or none. Further research will help to delineate more precisely the parametric development of the process.

REFERENCES

- ALGARABEL, S., CORTÉS, F., SOLER, M. J., & PITARQUE, A. (1987) Multistep facilitation and inhibition in the reading of primed rotated words. Poster paper presented at The Second Conference of the European Society for Cognitive Psychology, Madrid.
- ALGARABEL, S., PITARQUE, A., & SOLER, M. J. (1988) Additivity of activation in a word identification task, but not in lexical decision. Manuscript submitted for publication.
- ALGARABEL, S., SANMARTÍN, J., GARCÍA, J., & ESPERT, M. (1986) Normas de Asociación Libre de 400 sustantivos pertenecientes a BASPAL. Informes del Departamento de Psicología Experimental, Universidad de Valencia. (mimeo)
- ANDERSON, J. (1983) Spreading activation theory of memory. *Journal of Verbal Learning and Verbal Behavior*, 22, 261-295.
- ANDERSON, J. R. (1976) *Language, memory, and thought*. Hillsdale, NJ: Erlbaum.
- ANDERSON, J., & PIROLLO, P. L. (1984) Spread of activation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 10, 791-798.
- CARROLL, M., & KIRSNER, K. (1982) Context and repetition effects in lexical decision and recognition memory. *Journal of Verbal Learning and Verbal Behavior*, 21, 55-69.
- COLLINS, A. M., & LOFTUS, E. F. (1975) A spreading activation theory of semantic processing. *Psychological Review*, 82, 407-428.
- DE GROOT, A. M. B. (1984) Primed lexical decision: combined effects of the proportion of related prime-target pairs and the stimulus onset asynchrony of prime and target. *Quarterly Journal of Experimental Psychology*, 36A, 253-280.
- DEN HEYER, K. (1986) Manipulating attention-induced priming in a lexical decision

- task by means of repeated prime-target presentations. *Journal of Memory and Language*, 25, 19-42.
- DEN HEYER, K., & BRIAND, K. (1987) Priming single digit numbers: automatic spreading activation dissipates as a function of semantic distance. *American Journal of Psychology*, 99, 315-340.
- GROSSBERG, S., & STONE, G. (1986) Neutral dynamics of word recognition and recall: attentional priming, learning, and resonance. *Psychological Review*, 93, 46-74.
- HIGGINS, E. T., BARGH, J. A., & LOMBARDI, W. (1985) Nature of priming effects on categorization. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 11, 59-69.
- MCCLELLAND, J. L., & RUMELHART, D. E. (1985) Distributed memory and the representation of general and specific information. *Journal of Experimental Psychology: General*, 114, 159-188.
- NEELY, J. H. (1977) Semantic priming and retrieval from memory: roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, 106, 226-254.
- NEELY, J. H., SCHMIDT, S. R., & ROEDIGER III, H. L. (1983) Inhibition from related primes in recognition memory. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 9, 196-211.
- NELSON, D. L., BAJO, M. T., & CAÑAS, J. (1987) Prior knowledge and memory: the episodic encoding of implicitly activated associates and rhymes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 13, 54-63.
- PASCUAL, J., GOTOR, A., MIRALLES, J. L., & ALGARABEL, S. (1979) Normas categoriales para el estudio de la memoria humana. *Actas del Congreso Nacional de Psicología*. Pamplona, 74. (Resumen)
- REDER, L. M. (1983) What kind of pitcher can a catcher fill? Effects of priming on sentence comprehension. *Journal of Verbal Learning and Verbal Behavior*, 22, 189-202.
- SAINZ DE ROBLES, F. C. (1981) *Diccionario español de sinónimos y antónimos*. Madrid: Aguilar.

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