Negative priming in *same-different* matching: Further evidence for a central locus of inhibition

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Responses to recently ignored information may be slower or less accurate than responses to information not recently encountered. Such negative priming effects imply that the mechanism of selective attention operates on unattended, as well as attended, information. In the present experiment, subjects judged the second and fourth letters of five-letter strings (e.g., BABAB) as "same" or "different." Responses were slower when a target letter was identical to the distractors presented in the immediately preceding trial. This effect did not depend on which response was required on the current or preceding trial. The results suggest that ignored information is functionally disconnected from the response system as a whole, rather than from a specific response.

The process of attention is often regarded as a direct allocation of some limited processing resource to certain selected information (see, e.g., Broadbent, 1958; Deutsch & Deutsch, 1963; Kahneman, 1973; Keele, 1973; Norman, 1968; Norman & Bobrow, 1975; Shiffrin & Schneider, 1977). According to this conception, a *de facto* "inhibition" of unattended information may occur because resources are allocated elsewhere (Posner & Snyder, 1975). This inhibition is not regarded as an operation on the unattended information itself (Posner, 1982), and it does not discriminate between ignored stimuli and un-presented stimuli. Consequently, recently ignored stimuli should be processed at least as efficiently as stimuli that have not recently been presented. If ignored stimuli activate mental representations at all, persistence of this activation might actually facilitate subsequent processing.

In contrast, Neill (1977, 1979, 1989; Neill & Westberry, 1987) and Tipper (1985; Tipper & Cranston, 1985) have argued that ignored information is selectively inhibited, with the consequence that such information is temporarily less available for subsequent processing. Using a variation of the Stroop (1935) color-word task, Neill (1977) found that color naming was especially slow if the current color corresponded to the distractor word presented in the immediately preceding trial. (See also Dalrymple-Alford & Budayr, 1966; Lowe, 1979, 1985; Neill & Westberry, 1987.) Similarly, Tipper and Cranston (1985) found that naming a target letter was slowed if that letter had been presented as a distractor on the previous trial. Experiments done to investigate picture naming (Tipper, 1985) and lexical decision (Yee, *in press*) have shown that

inhibition of processing also generalizes to semantic associates of the ignored stimuli.

The locus of such *negative priming* effects does not appear to be perceptual in a strict sense, since negative transfer occurs between physically dissimilar stimuli. In the Stroop task, the negative transfer occurs between a printed word and the corresponding color. Tipper and Driver (1988) found similar negative transfer between pictures and corresponding words. However, this leaves unresolved whether it is a specific response that is inhibited, or a more central, cognitive representation of the stimulus, or perhaps the connection between them. Tipper, MacQueen, and Brehaut (1988) found as much negative transfer between trials requiring separate vocal and manual responses as between trials requiring the same response modality. They concluded that selective inhibition must occur at a central locus that is tied to neither specific properties of the stimulus nor specific motor responses to the stimulus.

The present experiment extends and refines the conclusions of Tipper et al. (1988) by demonstrating negative priming in a *same-different* matching paradigm. In the Tipper et al. study, the remote possibility remains that cross-modal negative priming reflects the inhibition of a specific identification response, albeit in the opposite response modality. However, the matching paradigm allows a complete uncoupling of the overt responses ("same" or "different") from the particular target identities. Tipper (1985; Tipper & Cranston, 1985; Tipper et al., 1988) suggests that the distracting stimulus is effectively denied access to the response system rather than to a specific response; if so, then negative priming should not depend on whether the current response is the same as that made in the previous trial.

The matching task provides a further methodological advantage over identification tasks: If vocal identification is required, premature vocalizations (e.g., "bl . . . uh . . . red!") yield spuriously fast reaction times, and scoring accuracy depends uncomfortably on the subjective judgment of the experimenter. Manual keypress responses (as

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in Neill & Westberry, 1987) ameliorate the scoring problem; however, they obviously limit the number of stimuli that can be employed in an identification task. In a matching task, on the other hand, there is no constraint on the number of stimuli that can be mapped onto the two responses, "same" and "different."

METHOD

Subjects

Twenty-three Adelphi University undergraduates each participated in an individual session of approximately 30 min, to meet an experiment requirement in an introductory psychology course.

Stimuli and Apparatus

Stimuli were selected from the entire set of 26 letters in the English alphabet. They were displayed in uppercase on an AMDEK Color-I Plus video monitor controlled by an Apple IIe microcomputer. Responses were made on the "open apple" and "filled apple" keys on the microcomputer keyboard. Response latencies were measured with a Mountain Hardware Apple Clock.

Procedure

Each trial began with the presentation of a plus sign (+) on the video monitor for approximately 500 msec, which served as a fixation point and warning signal. This was replaced by a string of five adjacent letters, centered on the fixation position. The subjects were instructed to judge the second and fourth letters as "same" or "different," and to respond using the left or right index finger, respectively.

Trials were randomly selected to be *same* or *different* with equal probability. The following constraints determined the generation of stimulus strings: On one third of the trials, randomly selected, one or both target letters were identical to the distractor letter employed on the preceding trial. No letter appeared as a target on two successive trials, nor did any letter appear as a distractor on two successive trials. The same distractor letter was used for the first, third, and fifth positions of the string (e.g., CACDC). The current distractor letter was always different from the current target letters. As a result of these constraints, each letter sequence was either completely unrelated to that presented in the preceding trial, or related by identity between one or both target letters and the distractor presented in the preceding trial.

Each subject received 10 blocks of 100 trials. Each block was initiated by the subject when ready. On each trial, the stimuli remained in view until terminated by the subject's response. The subjects were instructed to respond as quickly as possible, but to avoid errors. If an incorrect response was made, a tone sounded and the message "ERROR" was displayed for approximately 500 msec. A blank period of approximately 500 msec always preceded the presentation of the fixation signal for the next trial.

RESULTS

Geometric means of the reaction times in each condition were calculated for each subject, excluding error trials and trials following error trials. These means were entered into a $2 \times 2 \times 2$ analysis of variance with within-subject variables of relatedness (related or unrelated to preceding trial), current trial type (*same* or *different*) and preceding trial type (*same* or *different*).

Responses on *same* trials ($M = 792$ msec) were significantly faster than on *different* trials (854 msec) [$F(1,22) = 20.77, p < .001$]. Responses on trials following *same*

Table 1
Mean Reaction Time (RT, in Milliseconds) and Percent Errors with Targets Related or Unrelated to Previous Distractors, as a Function of Current and Previous Trial Type

Trial Type	Related		Unrelated	
	RT	% Error	RT	% Error
Previous Same				
Same	779	4.0	766	4.0
Different	864	3.7	842	3.8
Previous Different				
Same	819	6.2	803	5.4
Different	861	3.7	849	3.5

trials (813 msec) were also faster than responses following *different* trials (833 msec) [$F(1,22) = 4.93, p < .05$]. Current trial type also interacted with preceding trial type [$F(1,22) = 7.19, p < .02$]. Responses on *same* trials following *same* trials (773 msec) were fast, relative to *same* trials following *different* trials (811 msec); however, responses on *different* trials were approximately equal following *same* trials (853 msec) and following *different* trials (855 msec).

Of particular relevance to present hypotheses is that responses on related trials (831 msec) were significantly slower than responses on unrelated trials (815 msec) [$F(1,22) = 15.26, p < .001$]. Relatedness did not interact with either current or preceding trial type (all F s < 1). As is shown in Table 1, negative priming (related-unrelated) was comparable for *same* trials following *same* trials (13 msec), *same* trials following *different* trials (16 msec), *different* trials following *same* trials (22 msec), and *different* trials following *different* trials (12 msec).

A similar analysis of variance was performed on percentages of error responses. More errors were made on *same* trials (4.9%) than on *different* trials (3.7%) [$F(1,22) = 8.00, p < .01$]. In addition, more errors were made following *different* trials (4.7%) than following *same* trials (3.9%) [$F(1,22) = 4.41, p < .05$]. These two variables interacted significantly [$F(1,22) = 9.11, p < .01$]. More errors were made on *same* trials following *different* trials (5.8%) than on *same* trials following *same* trials (4.0%); however, errors on *different* trials were approximately equal following *different* trials (3.6%) and following *same* trials (3.8%). No effects involving the relatedness variable approached significance.

DISCUSSION

The reaction time advantage on *same* trials relative to *different* trials is a common finding, referred to as the "fast-same effect" (Krueger, 1978) or "same-different disparity" (Proctor, 1981). The paradoxically greater error rate on *same* trials is also typical. Krueger's (1978) "noisy operator" model suggests that *same* stimulus pairs are more likely to be misperceived as *different* than vice versa. Thus, when a pair is perceived as *different*, a "rechecking" process is more likely to occur, yielding

longer reaction times. The interactions between current trial type and preceding trial type are not specifically predicted by the model, but they may possibly be accommodated by further assumptions. Such considerations are, however, beyond the scope of the present paper.

The result of immediate importance is that reaction times were reliably slower when the current target stimuli were related to the immediately preceding distractor stimuli. That negative priming occurs at all in the matching paradigm indicates that not just the response per se is inhibited. If, for example, the response "same" were inhibited, that response should be slowed on the next trial regardless of whether or not the target stimuli were related to the preceding distractors. The reliable related-unrelated difference implies that negative priming does depend on stimulus identity.

A more subtle question concerns whether a *particular* response to the distractor is inhibited, or if *all* responses to the distractor are inhibited. Response-specific inhibition could be realized in either of two ways: First, the connection between the distractor stimulus and the response actually made could be inhibited. This would predict more negative priming on *same* trials following *same* trials, and on *different* trials following *different* trials. However, not only does the predicted three-way interaction fail to achieve significance, but the magnitude of negative priming is somewhat larger for *same* trials following *different* trials, and for *different* trials following *same* trials.

Alternatively, response-specific inhibition could affect the response that is elicited by the distractor stimulus. Distractors may have always elicited a "same" response because the three distractors in a given string were identical, or a "different" response because they always differed from the targets. That the magnitude of negative priming was largest for *different* trials following *same* trials (22 msec) is consistent with the latter possibility. However, across several replications of the main results (e.g., Neill & Lissner, 1988), no consistent ordering of response sequences has been found. Therefore, it seems likely that negative priming is truly independent of the particular response sequence.

The present results are most consistent with the position that ignored stimuli are denied access to the response system as a whole. Neill (1979) assumed that selective inhibition works to directly reduce the activation of activated cognitive representations. Tipper (1985; Tipper & Cranston, 1985) has suggested, however, that cognitive representations may be "isolated from the control of action" without actually reducing their activation. (See Lowe, 1979, for some relevant evidence.) Thus, the cognitive representation of a distracting stimulus may somehow be "tagged" as information to be ignored. When that information subsequently becomes task-relevant, its tag may hamper the selection of an appropriate response. In either case, the mechanism of selective attention involves operations on unattended information; indeed, such information might more properly be regarded as "disattended."

REFERENCES

- BROADBENT, D. E. (1958). *Perception and communication*. London: Pergamon.
- DALRYMPLE-ALFORD, E. C., & BUDAYR, B. (1966). Examination of some aspects of the Stroop color-word test. *Perceptual & Motor Skills*, **23**, 1211-1214.
- DEUTSCH, J. A., & DEUTSCH, D. (1963). Attention: Some theoretical considerations. *Psychological Review*, **70**, 80-90.
- KAHNEMAN, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice-Hall.
- KEELE, S. W. (1973). *Attention and human performance*. Pacific Palisades, CA: Goodyear.
- KRUEGER, L. E. (1978). A theory of perceptual matching. *Psychological Review*, **85**, 278-304.
- LOWE, D. G. (1979). Strategies, context, and the mechanism of response inhibition. *Memory & Cognition*, **7**, 382-389.
- LOWE, D. G. (1985). Further investigations of inhibitory mechanisms in attention. *Memory & Cognition*, **13**, 74-80.
- NEILL, W. T. (1977). Inhibitory and facilitatory processes in attention. *Journal of Experimental Psychology: Human Perception & Performance*, **3**, 444-450.
- NEILL, W. T. (1979). Switching attention within and between categories: Evidence for intracategory inhibition. *Memory & Cognition*, **7**, 283-290.
- NEILL, W. T. (1989). Lexical ambiguity and context: An activation-suppression model. In D. S. Gorfein (Ed.), *Resolving semantic ambiguity* (pp. 63-83). New York: Springer-Verlag.
- NEILL, W. T., & LISSNER, L. S. (1988, April). *Attention and selective inhibition in alphanumeric character matching*. Paper presented at the meeting of the Eastern Psychological Association, Buffalo, NY.
- NEILL, W. T., & WESTBERRY, R. L. (1987). Selective attention and the suppression of cognitive noise. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **13**, 327-334.
- NORMAN, D. A. (1968). Toward a theory of memory and attention. *Psychological Review*, **75**, 522-536.
- NORMAN, D. A., & BOBROW, D. G. (1975). On data-limited and resource-limited processes. *Cognitive Psychology*, **7**, 44-64.
- POSNER, M. I. (1982). Cumulative development of attention theory. *American Psychologist*, **37**, 168-179.
- POSNER, M. I., & SNYDER, C. R. R. (1975). Facilitation and inhibition in the processing of signals. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance V* (pp. 669-682). New York: Academic Press.
- PROCTOR, R. W. (1981). A unified theory for matching-task phenomena. *Psychological Review*, **88**, 291-326.
- SHIFFRIN, R. M., & SCHNEIDER, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, **84**, 127-190.
- STROOP, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, **18**, 643-662.
- TIPPER, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology*, **37A**, 571-590.
- TIPPER, S. P., & CRANSTON, M. (1985). Selective attention and priming: Inhibitory and facilitatory effects of ignored primes. *Quarterly Journal of Experimental Psychology*, **37A**, 591-611.
- TIPPER, S. P., & DRIVER, J. (1988). Negative priming between pictures and words in a selective attention task: Evidence for semantic processing of ignored stimuli. *Memory & Cognition*, **16**, 64-70.
- TIPPER, S. P., MACQUEEN, G. M., & BREHAUT, J. C. (1988). Negative priming between response modalities: Evidence for the central locus of inhibition in selective attention. *Perception & Psychophysics*, **43**, 45-52.
- YEE, P. L. (in press). Inhibition processes in selective attention: Negative priming and cognitive masking. *Quarterly Journal of Experimental Psychology*.