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Negative priming and stimulus repetition: A reply to Neill and Joordens (2002)

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Negative priming is reliably obtained with repeated items, but not with novel items. Here, we review why these stimulus repetition effects raise problems for memory-based theories of negative priming. Furthermore, we provide empirical evidence casting doubt on Neill and Joordens's (2002) claim that perceptual facilitation masks the effects of episodic retrieval with novel items. Finally, we discuss several theoretical and methodological issues raised in the reply by Neill and Joordens. We conclude that a more straightforward interpretation of these stimulus repetition effects is one based on activation-sensitive inhibition.

In a typical negative-priming task, two stimuli are presented on each trial, and the participant is required to respond to one stimulus, the target, and ignore another stimulus, the distractor. In the critical *ignored repetition* condition, the distractor on trial N (the prime trial) becomes the target on trial $N+1$ (the probe trial). Performance is slower and less accurate on ignored repetition probe trials than on control trials, defining the negative-priming effect (Dalrymple-Alford & Budayr, 1966; Lowe, 1979; Neill, 1977; Tipper, 1985). These early negative-priming studies spawned a sizable body of research, and several excellent articles are now available that review the negative-priming literature (e.g., Fox, 1995; May, Kane, & Hasher, 1995; Neill, Valdes, & Terry, 1995).

The mechanisms underlying negative priming are still unclear, with theories falling into one of two general classes. *Inhibition-based* theories describe negative priming as a consequence of processing on the prime trial (e.g., distractor inhibition, response blocking, etc.) that carries over into the processing on the probe trial (Houghton & Tipper, 1994; Strayer & Grison, 1999; Tipper & Cranston, 1985). *Memory-based* theories describe negative priming as a consequence of proactive interference from the retrieval of incompatible memories on the probe trial (Milliken, Joordens, Merikle, & Seiffert, 1998; Neill & Mathis, 1998; Neill & Valdes, 1992). These two approaches need not be mutually exclusive, although theories presently treat them as such.

Strayer and colleagues (Grison & Strayer, 2002; Kramer & Strayer, 2001; Malley & Strayer, 1995; Strayer & Grison, 1999) have reported that negative priming was

contingent upon stimulus repetition, because it was obtained with repeated items, but not with novel items. In addition, we found that positive priming in attended repetition conditions (i.e., a situation in which the target is repeated on the prime and the probe trials) decreased with stimulus repetition. These observations were taken as evidence for an activation-sensitive inhibitory mechanism that functions to reduce response competition on the prime trial (see, also, Houghton & Tipper, 1994; Houghton, Tipper, Weaver, & Shore, 1996; Tipper & Cranston, 1985). Because little response competition is produced by novel prime trial distractors, the mechanisms underlying negative priming are not engaged.

In addition, these stimulus repetition effects were considered by Strayer and colleagues to raise problems for memory-based theories of negative priming, particularly the *episodic retrieval model* developed by Neill and colleagues (Neill & Mathis, 1998; Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992). To understand the rationale for this assertion, it is important to remember that negative priming is measured as the difference in performance between a control probe trial and an ignored repetition probe trial. On novel control trials, there should be no effect of episodic retrieval, because the stimuli have not been seen before (at least not in the context of the experiment). On novel ignored repetition trials, performance should be impeded by the retrieval of an instance generated on the prime trial that is incompatible with responding on the current probe trial. Accordingly, the negative-priming effect for novel items should reflect the full contribution of episodic retrieval.

By contrast, with repeated items there should be multiple instances of the stimuli used in both control and ignored repetition trials. The precise effect of multiple instances depends on the processing assumptions of the model.¹ If performance is governed by a *race between all prior instances* (e.g., Logan, 1988), performance may be facilitated by compatible instances (i.e., a prior instance in which the probe trial target served as a target) and impeded by incompatible instances (i.e., a prior instance in which the probe trial target served as a distractor). Thus, on both control and ignored repetition trials, performance could be facilitated or impeded by episodic retrieval, and on average, the net negative-priming effect should be nil. That is, an episodic retrieval interpretation in which multiple instances are retrieved would have difficulty producing negative priming with a repeated stimulus ensemble.

Another possibility is that episodic retrieval is governed by the *most recent instance* (e.g., Neill & Mathis, 1998). In this case, performance on ignored repetition probe trials would be impeded by the retrieval of incompatible instances, in a manner similar to that observed with novel trials (see above). However, control trials could be facilitated if the most recent instance is

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compatible and impeded if the most recent instance is incompatible. If an incompatible instance is retrieved on the control trial, the negative-priming effect for these trials would be expected to be nil, because both control and ignored repetition trials would involve the retrieval of an incompatible episode. On the other hand, if a compatible instance is retrieved on the control trial, the result would enhance the priming difference score, because performance would be facilitated on the control trial and impeded on the ignored repetition trial.² The net “negative-priming” effect in the latter case would depend on the magnitude of the facilitation on control trials. However, given that positive-priming effects were absent in attended repetition conditions in which repeated items were used, the facilitation from a compatible instance is likely to be negligible, and the negative-priming effects should therefore be nil.

In short, without additional assumptions, it is not clear how models of negative priming that incorporate episodic retrieval can account for the stimulus repetition effects. Indeed, both recency-based and multiple-instance-based models appear to make predictions in the opposite direction from that indicated by the empirical data (i.e., they predict greater negative priming with novel stimuli than with repeated stimuli).

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Neill and Joordens (2002) have developed an alternative explanation for why negative priming is not observed with novel items. According to this interpretation, the novel prime trial distractor (1) activates an internal perceptual representation of that stimulus and (2) creates an instance in memory. On the probe trial, episodic retrieval impedes performance; however, this is offset by the facilitation produced by the persistent activation of the internal perceptual representation of the distractor. That is, two separate (and additive) mechanisms are proposed that have opposite effects on performance, resulting in a net effect of zero.³

In general, we believe that researchers are in a precarious position when they suggest that two processes, *neither observable*, each operate to cancel the effects of the other. What evidence is there that episodic retrieval mechanisms are operating with novel items? What evidence is there for the facilitation of novel distractors? Even if both episodic retrieval and representational activation were operating with novel items, what evidence is there that the effects are of similar magnitude, thereby canceling out one another? The burden of proof is on Neill and Joordens (2002) to demonstrate these effects.

In fact, there are several sources of empirical evidence that cast doubt on Neill and Joordens’s (2002) claim that sufficient facilitation is obtained with novel distractors to obliterate any impediments produced by episodic retrieval. Below, we examine some of these sources of evidence.

1. Strayer and Grison (1999, Experiment 1) obtained 2 msec of positive priming in ignored repetition condi-

tions with novel items and 23 msec of negative priming in ignored repetition conditions with repeated items. If the representations are primed to asymptotic levels in repeated conditions, then according to the logic of Neill and Joordens (2002), an “uncontaminated” estimate of episodic retrieval would be 23 msec in this study.⁴ If the effects of episodic retrieval are the same magnitude for novel and repeated items,⁵ the amount of facilitation produced by a novel distractor would be $23 + 2 = 25$ msec. That is, the 23-msec impediment produced by episodic retrieval would need to be offset by 25 msec of perceptual facilitation in order to obtain the 2 msec of positive priming in the novel ignored repetition condition. By contrast, the amount of positive priming obtained in novel attended repetition conditions was 50 msec. We are skeptical of the suggestion that a novel distractor receives 50% of the perceptual facilitation of a novel target. If this were the case, it would imply that selective attention does not operate very efficiently when novel items are selected on the basis of color; a suggestion that is at odds with subjective experience and the literature on color pop-out (Carter, 1982; Humphries & Boucart, 1997; Triesman & Gelade, 1980; Wolfe, 1994). Such an interpretation would also seem to predict higher error rates than the observed 1.6%. Moreover, this would lead to the prediction that a stimulus, seen one or more times as a distractor but never as a target, would produce substantial interference if paired with a novel target on a subsequent trial. As will be discussed below in (3), the data are at odds with this prediction.

2. Strayer, Drews, and Albert (2001) assessed the implicit perceptual memory for words that were presented only once in the priming task, as either a target or a distractor. The implicit perceptual memory of these items was measured by using a dot-clearing task immediately following the priming task. In the dot-clearing task, words were initially masked and then slowly faded into view as the mask was gradually removed. The perceptual memory for each item was estimated by the time taken by participants to report the identity of the word. Previous researchers using this dot-clearing paradigm have found that words previously attended are identified faster than new words and that these effects are long-lasting (e.g., Feustel, Shiffrin, & Salasoo, 1983; Hawley & Johnston, 1991). In our study, we found that words that were presented as a target in the priming task were identified faster than control words that were not presented in the priming task [$t(36) = 3.1, p < .01$]. By contrast, there was no difference in identification times for words that were presented as a distractor in the priming task and control words that were not presented in the priming task ($p > .70$). Thus, the study by Strayer et al. demonstrated strong implicit perceptual memory for novel targets but provided no evidence for enhanced perceptual facilitation of novel distractors.

3. Strayer and Grison (1999; Experiment 3b) repeated an experimentally novel distractor from one to five times before presenting that stimulus as a target. Reliable neg-

ative priming was *never* obtained; indeed, the priming effect averaged +5.4 msec across conditions. These data were considered to raise problems for both multiple-instance and recency-based episodic retrieval models of negative priming, because the only (and most recent) instances of the probe target are as a distractor on the prime trial(s). Neill and Joordens (2002) have suggested that the perceptual representations of the distractor became activated and masked the effects of episodic retrieval. It is important to note, however, that the Strayer and Grison (1999, Experiment 3b) study paired a repeated distractor with a novel target. If a distractor is receiving substantial facilitation, as suggested by Neill and Joordens, the literature on primed pop-out (Dark, Vochatzer, & Van Voorhis, 1996; DeWitt, 1994; Swartling & Johnston, 1998) suggests that greater levels of interference should be observed in the processing of the novel target (see, also, [1], above). Consequently, this predicts that both reaction time (RT) and error rate for the novel target should increase as a function of distractor repetition. From Strayer and Grison (1999, Experiment 3b), we computed the RT means for sequences in which a distractor, repeated from one to five times, was paired with a novel target. The RT means and error rates (in parentheses) for D, DD, DDD, DDDD, and DDDDD sequences⁶ were 635 (4.9), 631 (4.9), 633 (4.3), 636 (4.6), and 636 (4.4), respectively. A one-way analysis of variance revealed no difference as a function of distractor repetition for RT [$F(4,196) = 0.37, p > .80$] or error rate [$F(4,196) = 1.1, p > .35$]. That is, response to the novel target was unaffected by the number of times that the distractor had been repeated. Thus, there is no evidence to support the assertion that the distractor was processed more fluently with repetition.

In sum, several lines of evidence cast doubt on Neill and Joordens's (2002) assertion that the novel prime trial distractor was activated sufficiently to obliterate any negative priming produced by episodic retrieval. These data are, however, consistent with activation-sensitive inhibitory models of negative priming (e.g., Houghton & Tipper, 1994; Strayer & Grison, 1999) that suggest that the mechanisms underlying negative priming are engaged only when the distractor is highly activated and interferes with the processing of the target. Because the representations of novel distractors are not highly activated, the mechanisms underlying negative priming are not engaged.

Theoretical Issues

In this final section, we deal with several theoretical and methodological issues raised in the reply by Neill and Joordens (2002). First, Neill and Joordens argued that the distinction between inhibition-based and memory-based interpretations of negative priming has important consequences. We completely agree. Not only might there be important implications for our understanding of cognitive disorders, but these issues get at the basic architecture of human cognition. For example, how much of

our behavior is governed by episodic retrieval? What is stored in an episode? When is performance governed by the retrieval of multiple instances, and when is performance governed by the retrieval of the most recent instance? To what extent does inhibition function to resolve response competition? Which representations are inhibited? What are the mechanisms underlying this inhibition? These issues are fundamental to our understanding of human cognition.

Second, a problem with most theories of negative priming is that the processing assumptions are not formalized in sufficient detail to derive specific predictions. Many times, the theories have ad hoc assumptions that allow the "theory" to account for everything but to predict nothing (rendering the models unfalsifiable). Indeed, Neill and Joordens (2002) provided a classic example of this sort of problem. They proposed that the effects of episodic retrieval and perceptual activation are of sufficient magnitude to offset each other. Although this may be a plausible assumption (but see above), it is important to have independent evidence for this assertion. Similarly, if Neill and Joordens have suggested that the effects of recency-based episodic retrieval are different for novel and repeated items, there should be some independent evidence for this assertion. As has been noted elsewhere (Grison & Strayer, 2002), theoretical progress in this area will be governed by the extent to which models of negative priming become more computationally explicit and make falsifiable predictions.

Third, we note that the episodic retrieval ideas stem from the seminal work of Logan (1988, 1992). With respect to episodic retrieval, Logan (1988) made three processing assumptions. First, attention to a stimulus is sufficient to commit it to memory. Second, retrieval from memory is an obligatory consequence of attention. Third, each encounter with a stimulus is encoded, stored, and retrieved as a separate episode or instance. Logan (1988) provided compelling evidence for the storage of attended information. However, we question the plausibility of storing episodic traces of all distracting information (especially if that information is novel, can be selected against on the basis of simple perceptual attributes [e.g., color], and generates no response competition). The utility of storing representations of all the irrelevant information from the environment is unclear. Such an architecture would surely overwhelm the capacity of episodic memory. Even so, if one were to retrieve an episode with a "do not respond tag," this would impair responding to that stimulus in the future.

Fourth, most of the studies that Neill and Joordens (2002) pointed to as being problematic for inhibition-based theories of negative priming have a confound in which the task changes from the prime trial to the probe trial. There is a growing literature on task switching (e.g., Rogers & Monsell, 1995) that indicates that some of the task-switching costs are eliminated by predictable sequences, whereas other costs persist even if partici-

pants know full well what the upcoming task will be (e.g., Sohn & Carlson, 2000; Strayer & Kramer, 1994). Although the differences between distractor present and distractor absent on the probe trial are potentially very important, the effects of task switching on the mechanisms underlying negative priming are unclear. Tipper and Cranston (1985) were aware of these task-switching effects and argued that the selection set (i.e., task requirements) must be maintained in order to obtain negative priming. Tipper (1985) argued for a response-blocking model in which perceptual inputs are not suppressed but blocked from access to response mechanisms (hence, the "response-blocking" model).

Fifth, Neill and Joordens (2002) construed a -1% error rate difference in Experiment 1 of Grison and Strayer (2002) as evidence that negative priming is obtained with novel items. However, this "negative-priming" effect was not obtained when the study was replicated/extended in Experiment 2 of Strayer and Grison (2002). Indeed, the analysis that collapsed across experiments revealed no negative priming with novel items in the experiments. In Grison and Strayer, there were 4 conditions in which novel ignored repetition conditions were used. With RT measures, 0 out of 4 produced significant negative priming (in fact, all were slightly positive). With error rate measures, 1 out of 4 produced significant negative priming (the other three produced slight positive priming); however, as was mentioned above, this anomaly was not replicated with very similar experimental conditions. Moreover, Malley and Strayer (1995) had 5 conditions in which novel ignored repetition conditions were used. With RT measures, 0 out of 5 produced significant negative priming (all 5 were slightly positive). With error rate measures, 0 out of 5 produced significant negative priming (all 5 were slightly positive). In the experiments reported by Strayer and Grison (1999), there were 10 conditions in which novel ignored repetition conditions were used. With RT measures, 0 out of 10 produced significant negative priming (7 out of 10 produced slight positive priming). With error rate measures, 0 out of 10 produced significant negative priming (6 out of 10 produced slight positive priming). So the claim that negative priming was obtained with novel ignored repetition conditions and that this is "more easily accounted for by mismatch theories" seems to be a bit of an overstatement. If mismatch theories predict this "negative-priming" effect, then do the 37 out of 38 cases in which it is not reliably obtained constitute evidence against it? It seems pretty clear that a balanced perspective would interpret this as a Type I error, one that does not replicate between very similar experimental conditions.

Conclusions

Negative priming is reliably obtained with repeated items but is not obtained with novel items. These data raise problems for episodic retrieval theories, because they predict more negative priming with novel than with repeated items. Neill and Joordens's (2002) suggestion

that perceptual activation masks the effects of episodic retrieval in novel conditions is contradicted by empirical evidence casting doubt on the claim that sufficient perceptual activation is obtained with novel distractors to obliterate any effects of episodic retrieval. Moreover, Neill and Joordens's position fails to account for the robust negative priming obtained with repeated items. We believe that the most straightforward interpretation of these stimulus repetition effects is one based on activation-sensitive inhibition, similar to that originally proposed by Houghton and Tipper (1994).

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NOTES

1. One problem with theories of negative priming is that the processing assumptions are often poorly articulated and change between publications (and sometimes within the same article). For example,

sometimes it is assumed that performance is based on the retrieval of multiple instances (Neill & Valdes, 1992). Other times, performance is assumed to be based on the retrieval of the most recent instance (Neill & Mathis, 1998).

2. This recency-based model predicts greater *within-condition variability* (i.e., variability from trial to trial within condition) on control trials than on ignored repetition trials, because performance on the former could be facilitated or impeded by episodic retrieval, whereas performance on the latter would only be impeded by episodic retrieval. We tested this prediction by using the data from Strayer and Grison (1999, Experiment 1). In this experiment, novel and repeated conditions were factorially combined with control, ignored repetition, and attended repetition conditions. The means and within-condition standard deviations for novel stimuli were 617 (112), 615 (115), and 568 (104) for control, ignored repetition, and attended repetition conditions, respectively. The means and within-condition standard deviations for repeated stimuli were 554 (92), 577 (96), and 556 (96) for control, ignored repetition, and attended repetition conditions, respectively. With respect to recency-based episodic retrieval models of negative priming, the data did not conform as predicted. In particular, in the repeated stimulus ensemble the within-condition variability for control (92) and ignored repetition (96) conditions was in the opposite direction from that predicted by the recency-based episodic retrieval model, although this difference was not reliable [$t(29) = 1.21, p > .20$].

3. We are in agreement with Neill and Joordens (2002) that the locus of negative-priming effects is in the response-based component of processing. Indeed, our ERP studies of negative priming (Strayer & Grison, 2002) offer some of the most direct evidence for a postperceptual locus for the mechanisms underlying negative priming. However, we are in disagreement concerning how these mechanisms operate to impede response-related processes.

4. If one were to argue that the levels of perceptual activation were not yet asymptotic with repeated stimuli, this would result in an underestimation of the magnitude of the episodic retrieval effect and, consequently, an underestimation of the amount of facilitation produced by a novel prime trial distractor.

5. There is no mechanism specified a priori to suggest that episodic retrieval mechanisms differ for repeated and novel items. If there are differences in recency-based episodic retrieval for novel and repeated items, it would be important to develop a principled theoretical account for why this is the case. Just stating that this is warranted by the data is inadequate. Even so, if Neill and Joordens (2002) have suggested that there may be differences in the effects of episodic retrieval for novel and repeated items, it would seem to render their theory untestable.

6. In our terminology, each "D" refers to a trial in which the distractor was paired with a novel target. Thus, DDDDD would refer to a trial in which a novel target was paired with a distractor that had been presented on trials $N, N-1, N-2, N-3$, and $N-4$.

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