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INVESTIGATING A MEMORY-BASED ACCOUNT OFNEGATIVE PRIMING:
SUPPORT FOR SELECTION-FEATURE MISMATCH

By

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A thesis submitted in conformity with the requirements
for the degree of Doctor of Philosophy
Graduate Department of Psychology
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INVESTIGATING A MEMORY-BASED ACCOUNT OF NEGATIVE PRIMING:
SUPPORT FOR SELECTION-FEATURE MISMATCH

Doctor of Philosophy, 1999

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Abstract

Negative priming is defined as a delay in responding to a stimulus that was recently ignored. To study negative priming, the typical paradigm involves presenting two sequential displays: a prime display followed by a probe display. For each, participants are normally asked to select a target and to ignore a distractor. When the target item on the probe was previously the distractor on the prime, responding is slowed relative to when neither the target nor the distractor was repeated. This delay is used as an index of the processing of unattended information.

Experiments 1A – 3B tested whether ignoring distractors on the prime display is a necessary condition for negative priming. The effect of requiring participants to attend to distractors was investigated. When participants were asked to select the name of the larger animal in a word pair—requiring deep processing of the distractor—the standard negative priming effect was quadrupled. Negative priming not only persisted for attended distractors, it actually was enhanced. Further, this inflated effect was not due solely to increased latencies in the novel referent size-selection task because neither
decreasing base response times in other referent size-selection tasks nor increasing base response times in typical colour-selection tasks substantially affected the respective negative priming scores. These findings challenge the basic assumption that negative priming arises because the repeated item was first ignored on the prime.

The second aim was to differentiate competing explanations of negative priming, using both the typical colour-selection procedure and the referent size-selection task. In Experiments 4 – 6, negative priming only occurred when the repeated item mismatched from the prime to the probe in terms of the feature used as the basis for selection. When the repeated item was congruent on the selection dimension across successive displays, positive priming resulted. This pattern of results occurred whether the repeated item was the distractor or the target on the prime, further dismissing the notion that negative priming results from previously ignoring an item. These findings strongly support the selection-feature mismatch account of negative priming and refute both the distractor inhibition and the episodic retrieval explanations.
Acknowledgements

Foremost, I would like to thank my supervisor, Colin MacLeod. I cannot express how much your guidance and support have meant to me. For all that you have done, my gratitude is immeasurable.

I would also like to thank Steve Joordens, Eyal Reingold, Bruce Milliken, and Doug Lowe, for their helpful comments and suggestions on the thesis. I am especially grateful to Steve Joordens for collaborating on this research.

Thanks to my friends Ken Seergobin, Tom Spalek, and Daryl Wilson. I have enjoyed my time with you immensely.

Finally, I am grateful to my family for their love and encouragement. In particular, I thank Roy Toste, my grandparents, Winnabelle and Lyall McRae, and Brunelle MacDonald, as well as my brother Chris MacDonald. I also thank my daughter Alex for being a patient and loving girl, not to mention a top-notch assistant. I am most indebted, however, to my parents Lila and Neil MacDonald for making every effort to insure my happiness and success.
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Introduction

Early Selection Models of Attention

Efficiently selecting and responding to targets while disregarding distractors is an incredibly adaptive ability. Consequently, it is not surprising that selective attention has been of enduring interest to cognitive psychologists (James, 1890; Pillsbury, 1908). Broadbent (1958) proposed one of the earliest theories of selective attention. He maintained that attention acts as a filter, allowing relevant information to receive further perceptual and semantic processing but denying access to irrelevant information. This selective filtering was assumed to be all-or-none in that a stimulus either received attention, was processed to the level of meaning, and reached awareness, or did not. Irrelevant information was thought to undergo nothing more than crude initial sensory registration.

Support for Broadbent’s (1958) theory came primarily from dichotic listening experiments (Cherry, 1953; Norman, 1969; Treisman, 1964). In these studies, participants were instructed to repeat aloud a message entering one ear while ignoring a message presented to the other ear; a procedure known as shadowing. Broadbent (1958) demonstrated that when shadowing the to-be-attended message, participants only noticed gross physical changes in the unattended message, such as changes in pitch (Cherry, 1953), tone (Ingham, 1957; Lawson, 1966), or voice (Treisman & Riley, 1969). Participants were oblivious to other fairly dramatic alterations in the unattended message as long as these alterations did not involve a major change in the physical qualities of the message. For example, participants usually did not notice when the language of the unattended message was altered or even when the direction of speech changed from
forward to backward (Cherry, 1953; Wood & Cowan, 1995a).

However, subsequent results with the dichotic listening procedure suggested that some unattended information was processed to a deeper level than Broadbents (1958) original results implied (Gray & Wedderburn, 1960; Moray, 1959; Treisman, 1960). The now classic cocktail party phenomenon is an example of such a result. This refers to the finding that people will detect their own name in an irrelevant message, even when they are instructed to attend to and shadow another message, presumably because their own name has personal relevance (Moray, 1959; but see Wood & Cowan, 1995b, for a contradictory interpretation). Gray and Wedderburn (1960) and Treisman (1960) further demonstrated that the demands of the experiment can cause the unattended message to be processed beyond sensory registration. In these studies, when the unattended message was semantically related to the message that participants were shadowing, they inadvertently switched to shadowing the unattended message in the other ear. These results suggest that participants are able to process the information from the unattended ear deeply enough to switch back and forth on the basis of meaning. Participants' tendency to follow the meaningful context into the unattended ear suggests that they can process the unattended message deeply even when their attention is supposed to be directed exclusively to the target message.

To account for these findings, Treisman (1964) proposed an attenuation model of selective attention, supplanting Broadbent's (1958) all-or-none filter theory. This model contended that unattended information was processed, but that the processing was attenuated relative to the processing of attended information. Whereas attended information receives very rich processing, unattended information receives relatively
cursory processing. Unattended information will be processed more deeply and reach awareness, however, if it is especially relevant or meaningful to the participant (e.g., their name, Moray, 1959) or to the current task (e.g., Treisman, 1960).

**Late Selection Model of Attention**

Still other findings suggested that most, if not all, of the unattended message was processed to the level of meaning. In a study conducted by Corteen and Wood (1972), participants demonstrated elevated skin conductance responses only when words that had previously been paired with mild shock were presented to the to-be-ignored left ear while shadowing a passage presented to the right ear (but see Dawson & Schell, 1982; Wardlow & Kroll, 1976). Participants, however, claimed complete unawareness of the contents of the unattended message. In another study, Lewis (1970) showed that response times for shadowing words in the attended ear were slowed when synonyms, and speeded when associates, of these words were presented simultaneously in the other ear (but see Treisman, Squire, & Green, 1974). These findings suggest that the contents of the unattended message are processed for meaning although this message does not reach conscious awareness.

The latter findings are consistent with the late selection model of Deutsch and Deutsch (1963; see also Duncan, 1980; Norman, 1968). According to this account of selective attention, both attended and unattended stimuli are subject to perceptual and semantic analysis. However, only to-be-attended items reach the level of conscious awareness and are responded to. The proposal of the late selection account of attention called for subtler, more indirect means of assessing the extent to which the unattended message was analysed.
Late selection models of attention are also supported by investigations of selective attention in the visual domain. The Stroop effect (Stroop, 1935) provides an early example of an ingenious means for measuring the indirect effect of unattended information on the processing of to-be-attended information (for a review, see MacLeod, 1991). In two of his three experiments, Stroop investigated the effect of irrelevant ink colours on colour-word reading and conversely of irrelevant colour words on ink-colour naming. His paradigm consisted of presenting colour words written in incompatible ink colours (e.g., \textsc{blue} written in green ink) and requiring participants to attend only to one dimension. When participants were instructed to attend to the word dimension and to ignore the colour dimension (i.e., to say "blue" in the example), there was no interference relative to the baseline reading of non-coloured words. However, when they were instructed to attend to the colour dimension and to ignore the word (i.e., to say "green" in the example), significant interference was observed compared to a colour-only baseline. This finding suggested that to-be-ignored information is nonetheless processed to the level of meaning and can even interfere with processing of relevant, target information, especially if the former is more salient than the latter.

The flanker effect (Eriksen & Eriksen, 1974; Eriksen & Hoffman, 1973) is also consistent with the late-selection account of attention (Deutsch & Deutsch, 1963). In these experiments, participants were asked to identify, by means of a key press, a central letter that was flanked by a pair of to-be-ignored, distractor letters. If the flankers and the central letter were associated with opposite response keys, interference was observed relative to when the flankers and the central letter were associated with the same response key. Similarly, Shaffer and LaBerge (1979) found that response times to read central
words were increased if the flanker words were categorically unrelated to the target word compared to when the central targets and flanks were categorically related. These findings again suggest that to-be-ignored distractor information indeed is processed to the level of meaning.

Caveat

Before proceeding, however, there is an alternative interpretation of the findings that have been presented as support for late filtering of attention. Although these results might suggest that unattended information is routinely processed beyond sensory registration, in some cases to the level of semantic analysis, this pattern of data could also result from fast shifts of attention to supposedly unattended items (Allport, Antonis, & Reynolds, 1972). That is, occasional fast switching of attention, either consciously or inadvertently, to the to-be-ignored message could lead to indirect and sometimes direct access to that information.

In support of this alternative interpretation, Wood and Cowan (1995b) found a peak in shadowing errors in a dichotic listening experiment occurring subsequent to the introduction of backward speech in the to-be-ignored message for only those participants who indeed noted the peculiarity in the distractor message. This suggests a lapse in attention from the attended message to the nominally unattended message rather than routine and automatic processing of to-be-ignored information. In a study in the visual domain, Inhoff and Brill (1991) instructed participants to attend to every other line of text and to ignore the text presented on the lines in between. They found that participants gained some semantic details of the unattended message only when eye-tracking devices recorded fixations to the unattended passage, against instructions. Even the absence of
these indicators, however, cannot confirm that attention was directed only to target information and did not shift to distracting information for brief moments. In shadowing experiments, attention quite plausibly could shift from the attended to the unattended message without any measurable deficit in shadowing. Also, simply recording eye movements will not solve the problem in the visual domain because shifts of attention are not necessarily accompanied by eye movements (Hoffman. 1975: Posner. 1980). Holender (1986) argues that it is very difficult, perhaps even impossible, to ensure that nominally unattended information is truly unattended. Clearly, this remains an unresolved issue that will continue to hamper the interpretation of selective attention data. Consequently, experimenters must be mindful of this alternative explanation of the results.

**Spotlight model vs. Dual-Process model of selective attention**

Orthogonal to the early versus late selection controversy, debate also rages as to whether selective attention merely reflects the activation of to-be-attended information (Allport. 1989; Johnston & Dark, 1986; Eriksen & St. James, 1986; Johnston & Dark, 1986; Posner, 1980; Yantis, 1993), or whether another process also operates in concert to prevent or inhibit to-be-ignored information from gaining access to attentional and/or response mechanisms (Desimone & Duncan, 1995; Duncan, 1996; Walley & Weiden, 1973). The first approach compares attention to a spotlight which illuminates target information and facilitates processing. According to this spotlight model (also see the zoom lens model for a highly similar account, Eriksen & St. James, 1986), selective attention is a purely excitatory process. The second approach, the dual-process model, suggests that in addition to a process that activates relevant, target information, another
mechanism functions to actively block out or inhibit irrelevant, distracting information. The data reviewed to this point are consistent with both models.

The advent of the negative priming phenomenon, however, played an important role in bolstering the dual-process model of selective attention. Negative priming was first described in the context of a Stroop experiment (Stroop, 1935). Dalrymple-Alford and Budayr (1966) were examining the effect of Stroop stimuli sequencing on interference when they discovered an enhanced delay and an increased error rate for items appearing in the colour that had been the ignored word for the previous Stroop stimulus (e.g., GREEN in red, say “red”, followed by YELLOW in green, say “green”). This increase in interference for responses that corresponded to the suppressed word on the preceding trial was significantly greater than the effect of all other combinations of serial relations and non-relations. Dalrymple-Alford and Budayr concluded that the suppression of the word resulted in a “temporary unavailability of that response” (p. 1214). Neill (1977) further demonstrated this effect in the Stroop task using discrete trial presentations of single items rather than the list procedure.

The bulk of the negative priming research is no longer embedded in the context of a Stroop task. In fact, negative priming has been demonstrated across a large number of stimulus and task contexts (see Fox, 1995; May, Kane, & Hasher, 1995, for reviews). The typical negative priming procedure consists of presenting two sequential displays: an initial prime display followed by a second probe display. For each display, participants are normally asked to select a target item from among one or more distractor items. For example, a participant might be asked to read a red word and to ignore a white one. The critical experimental manipulation is the relation between the targets and the
distractors on the consecutive prime and probe displays. In the ignored repetition condition, the prime distractor reappears as the probe target. We might expect participants to respond faster to this repeated item, but in fact responses to the probe target in the ignored repetition condition are slower and more error prone than responses to the probe target in the control condition where no relation exists between prime and probe targets and distractors (Tipper, 1985). This difference, referred to as negative priming, has become the target of intense study.

Negative priming seemed convincingly to support the view that attended and unattended information underwent differential processing, with the former being activated and the latter being inhibited. Negative priming was attributed to the inhibitory processing of distracting information, which hampered subsequent processing of previously-ignored items when they reappeared soon after as targets (Neill, 1977; Tipper, 1985). Even though this inhibition account is quite plausible, alternative theories of negative priming have since been proposed and supported empirically. Consequently, the precise mechanism of the effect is still a matter of debate, although the view that negative priming is the product of dual-process selective attention has predominated (Allport, Tipper, & Chmiel, 1985; Fox, 1994; Fox, 1995; Houghton & Tipper, 1994; Moore, 1994; Neill, 1977; 1979; Neill & Westberry, 1987; Neumann & DeSchepper, 1992; Tipper, 1985; Tipper & Cranston, 1985; Tipper, Weaver, Cameron, Brehaut, & Bastedo, 1991; Tipper, Lortie, & Baylis, 1992; Yee, 1991). Perhaps because of its intuitive appeal, in clinical studies for example (e.g., Enright & Beech, 1990; 1993a; 1993b; Enright, Beech, & Claridge, 1995), this account is often the only one considered outside of the negative priming literature proper (see MacDonald, Antony, MacLeod, & Swinson, in press, for a
more detailed discussion). The competing, memory-based models of negative priming (Lowe, 1979; Neill & Valdes. 1992; Neill, Valdes, Terry, & Gorfein, 1992; Park & Kanwisher, 1994), however, will also be examined in this thesis.

Overview

The negative priming phenomenon has profoundly affected the current understanding of attention. Particularly notable is that it has been instrumental in furthering the dual-process model of selective attention (Neill, 1977; Fox, 1995; Milliken & Tipper, 1998; Tipper, 1985). Given this fact, the aim of the present research was to further investigate the precise mechanism of the negative priming phenomenon. In Experiments 1A – 3B, the specific intent was to explore the relation between dual-process selective attention and negative priming. Essentially, the question posed was whether ignoring the distractor—or processing it without attention on the prime trial—is a critical feature of negative priming as is both implicitly and explicitly assumed (DeSchepper & Treisman, 1996; Fox, 1995; May, Kane, & Hasher, 1995; Neill, 1977; 1979; Neumann & DeSchepper, 1992; Tipper, 1985; Yee, 1991). The goal of Experiments 4 - 7 was to discriminate among the prevalent theories of negative priming. Specifically, the predictions of the selection-feature mismatch account of negative priming were tested.

Rationale for Experiments 1A – 3B

Attesting to the dominance of the view that negative priming results from a selection mechanism that activates targets and inhibits distractors, May, Kane, and Hasher (1995) and Fox (1995) begin their reviews by claiming that because we are constantly bombarded by a myriad of relevant and irrelevant information, we cannot
attend to it all. The claim is that because of limitations in processing capacity, we must selectively attend to the important aspects of our environment and selectively ignore that which does not serve an immediate purpose. Fox (1995, p. 145) states that “... a central aspect of coherent perceptual-motor processes is the ability to select and respond to relevant objects and the ability to successfully ignore irrelevant objects.” The implication is that this process of selective attention produces negative priming because an item that was actively selected against becomes a target item on the subsequent trial.

Relating negative priming to these selective attention processes, however, is not straightforward because both early and late selection accounts exist. According to early selection accounts (Broadbent, 1958; Treisman, 1964), only relevant information consistently receives deep processing whereas most irrelevant information receives only cursory processing, focusing on perceptual characteristics. In contrast, according to late selection accounts (Deutsch & Deutsch, 1963), both relevant and irrelevant information undergo deep processing but only selected information is admitted to conscious awareness and is selected for responding. When negative priming is related to processes of selective attention, few authors have clarified the version of selective attention, either early or late, to which they subscribe.

The preponderance of the negative priming data appears consistent with a late selection model of attention. Many studies show that negative priming occurs despite changes in the physical form of the critical stimulus from the prime to the probe (e.g., Dalrymple-Alford & Budayr, 1966; Driver & Baylis, 1993; MacDonald, MacLeod, & Seergobin, 1999; Tipper & Driver, 1988). This suggests that distractors are processed beyond physical features, to the level of a more abstract, central representation. Negative
priming also persists across differing response modalities (Neill, Lissner, & Beck, 1990; Tipper, MacQueen, & Brehaut, 1988), suggesting that distractors are processed beyond physical features.

Tipper and Driver (1988) provided additional support for a late selection explanation of negative priming. They found that negative priming occurred for semantically related items as well as for repeated items. In their experiment, participants were shown pairs of line drawings and were asked to name the red picture. They were slower to name a picture of a dog if they had ignored a picture of a cat on the preceding prime trial. Once again, this finding bolsters the claim that negative priming results from a late selection mechanism of attention because the items corresponded to one another primarily in terms of categorical features. The distractor must have been processed at least to the level of semantic analysis.

Not all of the empirical evidence supports the link between negative priming and a late selection model of attention, however. In a study in which participants were asked to indicate whether the second and fourth letters of a 5-letter string were the same or different, Neill (1991, as cited in Fox, 1995) found negative priming only for letters that were identical in terms of case from prime to probe. For example, if the lower case letter “a” appeared in the distracting locations on the prime (i.e., in locations 1, 3, and 5) and the upper case letter “A” appeared in the target locations on the probe (i.e., in locations 2 and 4), constituting an ignored repetition condition, negative priming was not revealed. This finding seemed to suggest that distracting information was only processed to the level of perceptual characteristics.

Further, Chiappe and MacLeod (1995) performed an experiment analogous to that
of Tipper and Driver (1988), using words instead of pictures. They only obtained negative priming when the critical word was identical on the prime and on the probe. Negative priming failed to occur for semantically related stimuli. MacLeod, Chiappe, and Fox (1999) replicated this finding and further failed to show associative negative priming, as have others (Tipper & Baylis, 1987, Experiment 2; Yee, 1991, Experiment 1 for one ignored word & Experiment 2). The findings with words are more consistent with an early selection account of attention, if indeed negative priming results from selective attention.

Although much of the literature is consistent with selective attention views of negative priming, either early or late, recent evidence even challenges this relation. Milliken and Joordens (1996) conducted a negative priming experiment in which they presented two items on both the prime and probe trials. In contrast to the typical negative priming procedure, though, the prime stimuli only appeared for 100 ms and participants were asked not to respond overtly to either prime word. Negative priming persisted, despite the fact that participants were not required to selectively attend to one word and to ignore the other on the prime trial. These findings cast doubt on the prevalent view that negative priming is a consequence of selective attention on the prime.

In a second series of experiments, Milliken, Joordens, Merikle, and Seiffert (1998) provided another demonstration of negative priming in the absence of selection on the prime trial. Specifically, the procedure involved briefly presenting (i.e., for 43 ms) then masking a single prime word followed by a typical two-word probe display. Responses on the probe trial were slower to targets that matched the briefly presented prime word relative to targets that were not previously presented. This finding of
negative priming when there was only a single word on the prime trial further challenges the notion that negative priming results from selective attention processes on the prime trial. It is unclear why selective attention would be operating in a single-item prime situation.

Although these manipulations broaden the scope of situations that yield negative priming, the results do not completely deny the link between negative priming and selective attention. The possibility remains that participants ignored the prime trial entirely and consequently prime items were ‘selected against’ or processed without attention. Given that participants were not required to respond on prime trials and that prime items were displayed very briefly, this speculation is plausible. In fact, another experiment in the Milliken et al. (1998) study provided results consistent with this possibility. When single prime words were presented for a slightly longer duration (i.e., 200 ms), the instruction to attend to or to ignore these items determined their effect on subsequent probe processing. Participants who were instructed to attend to prime words showed positive priming whereas participants who were instructed to ignore them revealed negative priming in the repeated item condition relative to when the item didn’t repeat. Thus, these manipulations failed to ensure that the critical prime items were not blocked from attention. Because this is the aspect of selective attention that purportedly produces negative priming (Fox, 1995; May, Kane, & Hasher, 1995), these results are not entirely inconsistent with dual-process selective attention accounts of negative priming.

In summary, the current evidence concerning the relation between negative priming and selective attention is ambiguous. Some findings seem consistent with an early selection view of attention (Chiappe & MacLeod, 1995), whereas others support the
relation between negative priming and late selection theories (Tipper & Driver, 1988). More recent studies challenge the link between negative priming and selective attention altogether (Milliken & Joordens, 1996; Milliken et al., 1998). This issue of whether negative priming is produced by a dual-process mechanism of attention needed to be addressed more directly. This was the focus of the first series of experiments.

Purpose of Experiments 1A – 3B

The goal of Experiments 1A – 3B was to investigate the relation between selective attention and negative priming more directly. Specifically, the intent was to test whether actively ignoring distractors or processing them without attention on the prime trial is a critical determinant of negative priming. The strategy employed here stood in contrast to that of Milliken and Joordens (1996) and Milliken et al. (1998). Rather than creating a situation in which neither the target nor the distractor was selectively attended on the prime trial, a situation was created in which both the target and the distractor were attended on the prime and probe trials. If negative priming is produced by a mechanism of selective attention (either early or late), the effect should be contingent on limiting processing of distractors and blocking them from phenomenal awareness on ignored repetition trials. That is, if negative priming is indeed the consequence of having ignored or processed critical items without attention on the prime trial, it should not result when participants are required to attend to both the target and the distractor.

Experiment 1A

The primary objective of Experiment 1A was to compare the results obtained using a typical negative priming procedure to those achieved using a variant of the procedure that required participants to attend to both the targets and the distractors prior
to selection. Participants were asked to read the name corresponding to the larger animal in a stimulus pair in Experiments 1A and 1B. To make this referent size judgment, participants needed to attend to and process semantic characteristics of both the target and the distractor before selecting and responding to the target. This procedure controlled the depth to which targets and, more important, distractors were processed. The selection performed in this task did not determine which items were attended and processed or admitted to conscious awareness. Rather, the selection only determined which item should be responded to. In the more conventional task of Experiment 1A, participants read the word that appeared in red and ignored the word printed in white. As is typical, in this case, participants needed only to identify and select the red word independent of any feature of the distractor. Selection could be made on the basis of colour, and the processing of distractors could end at this level of crude sensory features.

Method

Participants

Twenty volunteers from the introductory psychology class at the University of Toronto at Scarborough took part in the experiment in exchange for bonus credit. All participants had normal or corrected to normal vision. All participants were sufficiently fluent in English to perform the task without difficulty.

Procedure

On both prime trials and probe trials, the names of two animals appeared in the center of the computer screen. One name was in white, the other was in red. In one block of trials, participants were asked to read the animal name printed in red and to ignore the animal name printed in white. This colour-selection task exemplified the
typical negative priming procedure. In the other block, participants were instructed to
name the larger animal in the pair, with size defined relative to a preset continuum. This
referent size-selection task required a size comparison of the referents of the two animal
names before selection and responding could occur. The assumption was that
participants had to attend to, and process to the level of semantics, both the target and the
distractor to make this judgment on every trial.

As illustrated in Figure 1, each complete trial consisted of both a prime and a
probe display, and proceeded as follows: (a) a focal point consisting of four plus signs
appeared in the center of the screen for 600 ms, (b) a blank screen was presented for 500
ms, (c) the prime words appeared and remained on the screen until the participant
responded, (d) the word “Ready?” appeared until the experimenter input the participant’s
accuracy on the prime trial, (e) a blank screen was presented for 500 ms, (f) the probe
words appeared and remained on the screen until the participant responded, (g) the word
“Ready?” appeared until the experimenter input the participant’s accuracy on the probe
trial. (h) a blank screen was presented for 600 ms before the initialization of the next trial.
Participants received 10 practice trials before participating in each block of the
experiment. There were 96 complete experimental trials in each block.

Apparatus

An IBM-486 compatible microcomputer with a 14-in colour VGA monitor was
used for testing. The program was written in QuickBASIC 4.5 using the routines given
by Graves and Bradley (1987, 1988) to achieve millisecond timing accuracy. Response
times were measured as the interval between the stimulus onset and the participant’s
vocal response into a microphone. The experimenter scored accuracy on line.
Figure 1. An example of a control trial and an ignored repetition trial as presented in Experiments 1A, 1B, 2A, and 2B, and for the standard colour-selection task in Experiments 3A and 3B. The darker font is used to represent the red (i.e., target) stimuli.
Stimuli

The stimulus words in the experiment were FLEA, MOUSE, TURTLE, PIG, GOAT, DONKEY, BEAR and CAMEL, in this particular size ordering. Before participants performed the referent size-selection task, they were informed of this ordering. The stimuli were always presented in pairs, one above the other in the center of the computer screen.

There were two tasks in the experiment: the referent size-selection task and the colour-selection task. In each of these tasks, there were two conditions: control and ignored repetition. However, due to the constraints of the referent size-selection task (i.e., that the target always be larger in terms of its referent than the distractor), the ordering and pairing of stimuli differed between the two tasks. Given the complexity, the ordering and pairing of stimuli will be presented separately for each task.

The stimulus assignment was straightforward for the colour-selection task. All stimuli occurred equally often as targets and distractors, and on the top and the bottom of the display. On a control trial, all four items making up a trial were different. The only change on ignored repetition trials was that the distractor on the prime trial reappeared as the target on the probe trial.

The stimulus assignment was more complex for the referent size-selection task. The complications arose primarily due to the special statuses of FLEA and CAMEL. Specifically, because FLEA was the smallest animal in the set, it could never serve as a target. Conversely, because CAMEL was the largest animal, it could never serve as a distractor. This caused a special challenge on ignored repetition trials where an item must serve as both a distractor on the prime trial and a target on the probe trial. These
constraints were dealt with in the following manner.

In the control condition of the size-selection task, all stimuli other than FLEA and CAMEL appeared equally often as targets and distractors. Because it could never be a target, FLEA served as a distractor twice as often as the other stimuli. For the converse reason, CAMEL served as a target twice as often as the other stimuli. In all other respects, stimulus assignment in the control condition of the size-selection task matched that of the colour-selection task.

In the ignored repetition condition, all stimulus words appeared a total of eight times as prime distractors, except for the words CAMEL and FLEA which never appeared as prime distractors. The word CAMEL appeared a total of twelve times as the prime target, whereas the words BEAR, DONKEY, and GOAT each appeared a total of eight times as prime targets. The words PIG and TURTLE appeared six times as prime targets and MOUSE and FLEA did not appear at all as prime targets. The word FLEA appeared as the probe distractor twelve times, whereas MOUSE, TURTLE, and PIG each appeared eight times as probe distractors. The words GOAT and DONKEY each appeared six times as probe distractors, whereas CAMEL and BEAR did not appear at all as probe distractors. Finally, all stimuli appeared a total of eight times as probe targets except for FLEA and CAMEL, which never appeared as probe targets. Once again, this unequal assignment of stimuli was made necessary by the constraints for the referent size-selection task in general, and for ignored repetition trials especially.

To make the referent size-selection and colour-selection tasks as similar as possible, one word in the pair appeared in red and the other appeared in white on both the prime and the probe displays in both blocks of trials. In the referent size-selection task,
the target appeared equally often in red and white. In the colour-selection task, the target was always the red word and the distractor was always the white word.

**Results**

Table 1 presents the response time data for Experiment 1A. In both the referent size-selection and the colour-selection tasks, negative priming was observed. That is, longer latencies appeared in the ignored repetition conditions relative to their respective control conditions. Extremely large negative priming occurred in the referent size-selection task compared to the colour-selection task. Panel A of Figure 2 presents the negative priming for Experiment 1A.

A 2 X 2 repeated measures analysis of variance was conducted on the data from Experiment 1A. The variables were task (colour-selection vs. referent size-selection) and condition (control vs. ignored repetition). For this and all subsequent analyses, response times were only analysed for correctly named probe targets that followed correctly named prime targets. Trimmed as well as untrimmed versions of the data were examined and no relevant differences were revealed. Thus, the results based on the untrimmed data are reported here. With respect to errors, only erroneous probe trials that followed accurate prime trials were considered.

The latency analysis of Experiment 1A revealed significant main effects of both task, \( F (1, 19) = 223.09, MSe = 39995.93, p < .001 \), and condition, \( F (1, 19) = 50.66, MSe = 1886.44, p < .001 \). Participants were slower in the referent size-selection task than in the colour-selection task and slower on ignored repetition trials than on control trials. The task by condition interaction was also significant, \( F (1, 19) = 13.69, MSe = 1671.59, p < .001 \). Participants responded more slowly on ignored repetition trials than on control
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**Experiment 1A**

**Experiment 1B**

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<td>Err (SE)</td>
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Figure 2. Negative priming scores in the referent size-selection task and the colour-selection task in Experiments 1A and 1B. Error bars reflect the standard error of the mean.
trials, and this negative priming effect was significantly larger for the referent size-selection task than for the colour-selection task.

An analogous ANOVA performed on the errors also revealed significant main effects of task, $F(1, 19) = 70.76$, $MSe = 1.80$, $p < .001$, and condition, $F(1, 19) = 4.96$, $MSe = 1.58$, $p < .05$. The significant main effects reflected the fact that participants made fewer errors overall in the colour-selection task than in the referent size-selection task and that they made more errors on control trials than on ignored repetition trials. This last result is noteworthy as it raises the possibility that some or all of the negative priming observed in Experiment 1A was due to a speed-accuracy tradeoff. The task by condition interaction was not significant, $F(1, 19) = 1.77$, $MSe = 1.19$, $p > .15$, in the error-rate analysis.

Experiment 1B

The suggestion of a speed-accuracy tradeoff, in addition to the unprecedented magnitude of negative priming observed in the referent size-selection task of Experiment 1A, prompted a re-examination of this task. An independent replication of the experiment seemed a prudent next step. Thus, Experiment 1B was a direct replication of Experiment 1A with the only change being that the data were collected in a different laboratory, by a different experimenter.

Method

Participants

Twenty volunteers from the introductory psychology class at McMaster University took part. Participants received bonus credit in exchange for their participation. All participants had normal or corrected to normal vision and all had
English as their first language.

**Procedure**

The procedure was identical to that used in Experiment 1A.

**Apparatus and Stimuli**

An IBM-486/DX2-66 compatible microcomputer with a 14-in SVGA colour monitor was used for all testing. In all other respects, the apparatus and stimuli were identical to those used in Experiment 1A.

**Results**

Table 1 presents the latency data for Experiment 1B. As in Experiment 1A, negative priming occurred in both tasks. Panel B of Figure 2 presents the negative priming for Experiment 1B. These negative priming scores are consistent with those obtained in Experiment 1A. Again, the negative priming was considerably larger in the referent size-selection task than in the colour-selection task. The following statistical analyses support these observations.

The data collected in Experiment 1B were subjected to the same analyses as the data in Experiment 1A. The analysis of mean latencies revealed significant main effects of task, \( F(1, 19) = 215.06, \text{MSE} = 33191.96, p < .001 \), and condition, \( F(1, 19) = 53.68, \text{MSE} = 1648.75, p < .001 \). Again, participants were slower in the size-selection task than in the colour-selection task and slower on ignored repetition trials than on control trials. The interaction of these variables was also significant, indicating that the observed negative priming was larger in the referent size-selection task than in the colour-selection task, \( F(1, 19) = 13.97, \text{MSE} = 1771.32, p < .001 \).

The main effect of task was also significant in the analysis performed on errors,
reflecting more errors in the referent size-selection task than in the colour-selection task. $F(1, 19) = 70.30, \text{MSE} = 5.96, p < .001$. The main effect of condition and the task by condition interaction were not significant, both $F < 1$. Thus, in Experiment 1B, there was no worry of a speed-accuracy tradeoff causing the negative priming effects in response times.

**Discussion**

The most important finding of Experiments 1A and 1B was the occurrence of significant negative priming in the referent size-selection task. This result is critical because participants were required to attend to both targets and distractors before making their responses to targets in this task. If negative priming results from a selective attention process (either early or late) that functions to prevent processing of irrelevant information, it should not persist in the referent size-selection task, where participants attended to and processed all items, distractors included. These results imply that negative priming does not derive from an attentional mechanism that facilitates processing of relevant information by preventing processing and conscious awareness of irrelevant information.

These findings are consistent with those of Tipper, Weaver, and Milliken (1995). In their location negative priming study, participants were likewise required to compare targets and distractors directly. As an example, in Experiment 1, participants were presented with a pair of circles and were asked to indicate the location of the physically larger circle. As in the present study, participants had to process and attend to both stimuli. Despite this fact, negative priming was observed. It should be noted that their negative priming was not significantly larger than the standard effect. Tipper et al.'s
study differs from the present experiments, however, in that the targets and distractors were compared on a perceptual feature in contrast to the semantic feature used to distinguish targets and distractors here.

The second important finding of Experiments 1A and 1B is that negative priming was not only observed when participants were forced to attend to distractors, it was actually enhanced. In fact, the standard negative priming effect, normally ranging from about 15 to 25 ms (Fox, 1995), was quadrupled in the referent size-selection task. Yee, Santoro, Crawford, and Grey (1996) also observed an augmentation of negative priming using a task similar to the referent size-selection task. They presented pairs of animal names, one in upper case, the other in lower case, and one in red, the other in green, with case and colour completely crossed. When participants were asked to indicate the case of the red item, the negative priming effect was approximately 37 ms. When participants were asked to indicate the case of the larger animal, the negative priming effect was approximately 147 ms. Because these parallel results were observed independently, the reliability of the effect appears especially impressive.

This enhanced effect has practical significance. First, it provides a better medium for studying the impact of other factors on the magnitude of negative priming, not possible with the ordinarily small effect. In addition, it provides greater measurement sensitivity when dealing with populations that show reduced negative priming effects, such as obsessive-compulsives (Enright & Beech, 1993) and schizophrenics (Beech, Powell, McWilliam, & Claridge, 1989), or with populations that do not demonstrate the effect altogether, such as the elderly (Hasher, Stoltzfus, Zacks, & Rympa, 1991). The precise degree of impairment can be more clearly assessed, and subtle between-
population differences can emerge.

This enhanced negative priming may also have a role in shaping or differentiating the various theories of negative priming. Do the present findings refine existing theories or constrain their interpretation? Before delving into the theoretical implications of the present results, a less interesting explanation of the large negative priming in the size-selection task needed exploration. Base response times in the referent size-selection task were much longer than those in the colour-selection task. The large negative priming in the size-selection task simply might have been an artifact of longer base response times. Perhaps a performance floor limits the magnitude of the negative priming in standard tasks. That is, the enhanced effect may only have been due to an alleviation of this measurement constraint and not to any theoretically relevant feature of the task. Before relating these findings to the theories of negative priming, it was important to rule out this possibility.

Several experiments were conducted to examine this alleviation-of-measurement-constraint explanation of the enhanced negative priming effect in the referent size-selection task. In Experiments 2A and 2B, this was accomplished by examining versions of the size-selection task that allowed faster responding despite retaining the most relevant characteristic of the task (i.e., selection based on the relative size or value of the items). If the enhanced negative priming was due only to an elevation of the base response time, then negative priming effects in the referent size-selection task should be proportionately reduced as base response time decreases. Experiments 3A and 3B addressed the issue using a converging strategy. In these experiments, the difficulty of the colour-selection task was enhanced with the goal of increasing base response times.
Here the essential characteristic of the colour-selection task (i.e., selection based on the colour of the target item) was also retained. If the alleviation of the performance floor was indeed responsible for the larger negative priming seen in the referent size-selection task, then increasing the base response time in the colour-selection task should also yield larger negative priming in this more standard negative priming task.

Experiments 2A and 2B

The objective of Experiments 2A and 2B was to simplify the referent size-selection task so as to reduce latencies. In Experiments 1A and 1B, the stimuli were not optimal because there was some ambiguity in the size continuum. For example, participants were informed that, for the purposes of the experiment, a goat was larger than a pig. Whereas some goats are larger than some pigs, the reverse is also true. Such counter examples may have interfered with selection, lengthening latencies.

To reduce response latencies, stimuli that varied in value on a more objective continuum were used. In Experiment 2A, the stimuli were SECOND, MINUTE, HOUR, DAY, MONTH, YEAR, DECADE, and CENTURY. In Experiment 2B, the continuum was simplified even further by using the stimuli ONE, TWO, THREE, FOUR, FIVE, SIX, SEVEN, and EIGHT.

Method

Participants

Forty students from McMaster University participated in the experiments, half in Experiment 2A and half in Experiment 2B. Participants received bonus credit for their participation. All had normal or corrected to normal vision and English as their first language.
General

Experiments 2A and 2B only diverged from Experiments 1A and 1B in the use of different stimuli. The procedures, apparatus, stimulus arrangements, and number of trials per block were identical.

Results

Experiment 2A

The mean latencies and the proportion of errors for Experiment 2A are presented in Table 2. With regard to the referent size-selection task, the mean response time in the control condition of Experiment 2A was reduced by 87 ms compared to the mean response time in Experiment 1B, and by 190 ms compared to the mean response time in Experiment 1A. Negative priming again occurred in both the referent size-selection task and the colour-selection task as shown in Panel A of Figure 3. The negative priming effects in both the referent size-selection task and the colour-selection task were reduced slightly relative to the negative priming obtained in the previous experiments. However, the difference in the magnitude of negative priming between the referent size-selection task and the colour-selection task (71 ms), remained equivalent to the differences observed across the two tasks in Experiments 1A (68 ms) and 1B (71 ms).

The analysis of the latency data revealed significant main effects of task, $F(1, 19) = 330.44, MSe = 16977.71, p < .001$, and of condition, $F(1, 19) = 63.52, MSe = 946.35, p < .001$. These results are due to longer latencies in the referent size-selection task than in the colour-selection task and to longer latencies in the ignored repetition condition than in the control condition. The Task x Condition interaction was also significant, indicating greater negative priming in the size-selection task relative to the colour-
Table 2

Mean Response Times (ms), Error Rates (proportion), and (Standard Errors) Across the Conditions and Tasks of Experiments 2A and 2B.

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Experiment 2A

Experiment 2B
Figure 3. Negative priming scores in the referent size-selection task and the colour-selection task in Experiments 2A and 2B. Error bars reflect the standard error of the mean.
selection task, $F(1, 19) = 36.18, MSe = 705.57, p < .001.$

The complementary analysis on errors revealed a significant main effect of task, $F(1, 19) = 94.26, MSe = 3.40, p < .001,$ and a significant main effect of condition, $F(1, 19) = 6.63, MSe = 1.70, p < .02.$ These results indicate that participants made more errors in the referent size-selection task than in the colour-selection task and that they made more errors on ignored repetition trials than on control trials. Finally, the Task x Condition interaction was also significant, reflecting that even in terms of errors, there was more negative priming in the referent size-selection task than in the colour-selection task, $F(1, 19) = 6.63, MSe = 1.70, p < .02.$

**Experiment 2B**

The mean latencies and the proportion of errors for Experiment 2B are also presented in Table 2. The mean latency in the control condition of the size-selection task for Experiment 2B was further reduced by 230 ms relative to the mean latency in the control condition of the referent size-selection task of Experiment 2A. The disparity in the negative priming scores for the referent size-selection task relative to the colour-selection task for Experiment 2B (42 ms) was smaller than the differences obtained in previous experiments.

Statistical analysis of the latency data revealed significant main effects of task, $F(1, 19) = 372.09, MSe = 4498.64, p < .001,$ and condition, $F(1, 19) = 33.21, MSe = 761.00, p < .001.$ These findings reflect longer latencies in the referent size-selection task than in the colour-selection task, and for ignored repetition trials compared to control trials. The Condition x Task interaction was also significant, reflecting greater negative priming in the referent size-selection task than in the colour-selection task, $F(1, 19) =$
11.25. **\( \text{MSe} = 754.67, \ p < .005 \).**

The parallel 2 X 2 ANOVA performed on errors revealed a significant main effect of task, \( F(1, 19) = 50.54, \text{MSe} = 3.68, \ p < .001 \). Once again, this finding was due to more errors in the referent size-selection task than in the colour-selection task. No other effects were significant.

**Discussion**

Of primary importance, negative priming again was obtained when participants were required to attend to and process distractors deeply. These results replicate the pattern found in Experiments 1A and 1B. As in Experiments 1A and 1B, a selective attention account of negative priming (either early or late) seems implausible given these findings.

The modifications in Experiments 2A and 2B were successful in decreasing latencies. Although the negative priming in the size-selection tasks remained considerably greater than the standard effect, the scores were smaller than those observed in Experiments 1A and 1B. Considering only the referent size-selection data, it appears as though decreases in base response time were accompanied by reductions in negative priming. However, examining the disparity in the negative priming scores for the referent size-selection tasks and the colour-selection tasks, the difference decreased slightly in Experiment 2B and not at all in Experiment 2A. Negative priming effects vary with stimuli and with participant groups. Given that the colour-selection and referent size-selection tasks are matched on these variables, considering the referent size-selection task relative to the colour-selection task seemed most appropriate.
Experiments 3A and 3B

The purpose of Experiments 3A and 3B was to provide converging evidence with the results of Experiments 2A and 2B. The intent was to rule out the alleviation-of-measurement-constraint argument as the sole explanation for the enhanced negative priming in the referent size-selection task. In Experiments 3A and 3B, rather than decreasing latencies in the size-selection task, the objective was to increase latencies in the colour-selection task. This was achieved by presenting items interleaved, instead of one above the other, as had been done in previous experiments (Milliken & Joordens, 1996; Milliken et al., 1998). Experiment 3B differed from Experiment 3A in that target and distractor colours were more similar. If the magnitude of the negative priming is a function of base response times, then negative priming in a more difficult version of a colour-selection task should increase as base response latencies increase.

Method

Participants

Thirty-eight undergraduate students at McMaster University participated in the experiments; 20 in Experiment 3A and 18 in Experiment 3B. All received bonus credit in their Introductory psychology class and had normal or corrected to normal vision.

Procedure

All participants performed both the standard and the difficult version of the colour-selection task. The order of tasks was counterbalanced across participants. The procedure for the standard colour-selection task was the same as described in previous experiments. For the difficult version, the only change was that targets and distractors were interleaved in the center of the computer screen (see Figure 4). In Experiment 3A,
targets were red and distractors were white whereas in Experiment 3B targets were red and distractors were brown.

**Apparatus and Stimuli**

The apparatus, stimuli, and stimulus arrangements were the same as in the colour-selection task of Experiment 1B. Because the length of the stimuli varied, all stimuli were made to have an eight-character length by adding asterisks on either side of the word in the difficult version. In the difficult colour-selection task, targets and distractors appeared equally in the position slightly to the right of the display or slightly to the left on both the prime and the probe trials.

**Results**

**Experiment 3A**

Latencies and proportion of errors for Experiment 3A appear in Table 3. In the difficult colour-selection task, the mean latency in the control condition was increased by 242 ms relative to that of the standard colour-selection task. The negative priming scores, however, did not differ despite this change in base response time. Panel A of Figure 5 presents the negative priming. These observations are confirmed by the following statistical analyses.

The analysis of the latencies in Experiment 3A revealed significant main effects of task, $F(1, 19) = 83.76, \ MSe = 14257.32, p < .001$, and condition, $F(1, 19) = 32.40, \ MSe = 540.81, p < .001$. The main effect of task reflects longer latencies in the difficult colour-selection task than in the standard colour-selection task. The main effect of condition was due to longer latencies on ignored repetition trials than on control trials (i.e., negative priming). Critically, the Task x Condition interaction was not significant,
Figure 4. An example of a control trial and an ignored repetition trial in the difficult colour-selection task of Experiments 3A and 3B. The darker font is used to represent the red (i.e., target) stimuli.
### Table 3

Mean Response Times (ms), Error Rates (proportion), and (Standard Errors) Across the Conditions and Tasks of Experiments 3A and 3B.

<table>
<thead>
<tr>
<th></th>
<th>Difficult Colour-selection</th>
<th>Standard Colour-selection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT (SE)</td>
<td>Err (SE)</td>
</tr>
<tr>
<td><strong>Experiment 3A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ignored Repetition</td>
<td>813 (34.12)</td>
<td>.015 (0.00)</td>
</tr>
<tr>
<td>Control</td>
<td>781 (35.16)</td>
<td>.016 (0.01)</td>
</tr>
<tr>
<td><strong>Experiment 3B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ignored Repetition</td>
<td>826 (23.00)</td>
<td>.029 (0.01)</td>
</tr>
<tr>
<td>Control</td>
<td>802 (26.16)</td>
<td>.022 (0.01)</td>
</tr>
</tbody>
</table>
Figure 5. Negative priming scores in the difficult colour-selection task and the standard colour-selection task in Experiments 3A and 3B. Error bars reflect the standard error of the mean.
This result indicates that although responses were much slower in the difficult version of the task, the negative priming was not significantly larger, contrary to what would be predicted by the alleviation-of-measurement-constraint account.

The analysis of errors revealed only a significant main effect of task, $F(1, 19) = 9.50, MSe = 0.53, p < .025$. Participants made more errors in the difficult colour-selection task than in the standard colour-selection task. This effect did not interact with condition, $F(1, 19) < 1$.

**Experiment 3B**

Latencies and errors for Experiment 3B also appear in Table 3. Relative to the mean latency in the control condition of the standard colour-selection task, the mean latency in the control condition of the difficult colour-selection task was increased by 267 ms. Again, the size of the negative priming effect did not differ between tasks. Panel B of Figure 5 presents the negative priming for Experiment 3B.

Analysis of the data collected in Experiment 3B revealed results that parallel those in Experiment 3A. The main effect of condition was significant with longer response times on ignored repetition trials than on control trials, $F(1, 17) = 18.52, MSe = 459.77, p < .001$, indicating reliable negative priming. The main effect of task was also significant with slower responses on the difficult version of the task than on the standard version, $F(1, 17) = 132.74, MSe = 9818.48, p < .001$. These two factors did not interact, $F(1, 17) < 1$. Although latencies increased in the difficult colour-selection version of the task, the negative priming did not.

The complementary analysis of errors revealed only a main effect of task, $F(1, 17) = 9.50, MSe = 1.07, p < .010$. This reflects greater errors in the difficult colour-
selection task than in the standard colour-selection task. This effect did not interact with condition. $F(1, 17) < 1$.

**Discussion**

The manipulations in Experiments 3A and 3B were successful in increasing latencies in the difficult colour-selection tasks relative to the standard colour-selection tasks. Despite dramatic increases in base response times, negative priming was essentially unaffected by the manipulation. Although the intent was to increase latencies further in Experiment 3B, the base response time was not significantly boosted beyond that achieved in Experiment 3A. Most important, however, Experiment 3B replicated the critical pattern of negative priming obtained in Experiment 3A.

In Experiments 2A, 2B, 3A, and 3B, negative priming was only negligibly affected by increases or decreases in base response times observed in the control conditions. Despite its contribution to the enhanced negative priming in the referent size-selection tasks, the alleviation-of-measurement-constraint explanation is by no means the whole story.\(^1\) Figure 6 illustrates the striking difference in negative priming scores between the size-selection tasks and the colour-selection tasks. The large negative priming observed in the referent size-selection tasks occurred mostly due to a unique feature of the task as opposed to an artifact of lengthened latencies.

**General Discussion of Experiments 1A – 3B**

The findings of Experiments 1A – 3B can be summarized quite briefly. Negative priming is obtained even when the typical procedure is modified such that participants

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\(^1\) Correlating the mean response times in the control conditions with the negative priming scores in that particular task for each participant across all experiments in the study also did not support the alleviation-of-measurement-constraint account. Longer latencies were not associated with larger negative priming scores.
Figure 6. Percentage of negative priming relative to the base response time (i.e., negative priming effect divided by the RT for the baseline condition multiplied by 100) across Experiments 1A, 1B, 2A, 2B, 3A, and 3B.
are required to attend to both the targets and the distractors. Not only does it persist under these conditions, the magnitude of the negative priming actually increases dramatically. This enhanced effect is not solely due to an alleviation of a performance floor.

The general discussion of Experiments 1A – 3B is composed of two sections. The first discusses the primary issue brought to light by the study. Specifically, the present results question whether negative priming indeed results from “selective attention” given that it occurs even when both stimuli are attended. In the second section, the three most prevalent theories of negative priming are presented and the implications of the current results for each are discussed.

Selective Attention and Negative Priming

The primary aim of Experiments 1A - 3A was to directly examine the link between negative priming and a dual-process model of selective attention. This was achieved in the size-selection tasks of Experiments 1A, 1B, 2A, and 2B by ensuring that both targets and distractors were attended, were processed deeply, and reached conscious awareness on all trials. Selection only determined which item would be responded to. Negative priming persisted and actually increased nonetheless, suggesting that it is not the result of selective attention, either early or late. These findings, along with those of Tipper, Weaver, and Milliken (1995), Yee, Santoro, Crawford, and Grey (1996), Milliken and Joordens (1996), and Milliken et al. (1998), are inconsistent with the claim that stimuli are responded to more slowly in the ignored repetition condition as a result of being previously ignored or processed without attention. Negative priming does not result from a mechanism that limits deep processing and phenomenal awareness to
relevant items only. Given these findings, the existence of the negative priming phenomenon does not entail an additional process of selective attention that prevents processing of irrelevant information.

**Implications for Theories of Negative Priming**

**Distractor Inhibition**

The earliest explanation of negative priming was provided by the distractor inhibition theory (e.g., Tipper, 1985; Neill, 1977). This view attributed negative priming to a dual-process selective attention mechanism that primarily activates targets and inhibits distractors. Although this is the central tenet of all inhibition views of negative priming, with the ever-increasing negative priming literature, the notion of inhibition has been fleshed out with time and has undergone modification. Specifically, distractor inhibition theories have become more precise in terms of the stage in processing at which the inhibition is applied to distractors. Incorporating these modifications, the most recent distractor inhibition explanation has been implemented as a computational model by Houghton and Tipper (1994).

According to Houghton and Tipper (1994), on a typical negative priming trial, both the target's and the distractor's representations receive bottom-up activation. Because of the task instructions (e.g., read the red word), the target additionally receives top-down activation whereas the distractor receives top-down inhibition. As the distractor continues to receive bottom-up activation, the net effect of the inhibition is to slow the distractor's activation gain relative to that of the target, facilitating selection. The differential support from top-down sources results in the target gaining activation at a faster rate than the distractor, and when the target is a criterion amount more activated
than the distractor, the selection is performed. Upon target selection, however, the bottom-up sources of activation are removed (i.e., the physical representations disappear). The top-down inhibition of the distractor is no longer opposed by the bottom-up activation and the cognitive representation of the prime distractor becomes inhibited below baseline. As a result, it takes the repeated item longer to achieve target levels of activation on the probe trial in the ignored repetition condition because it must overcome this artificially low starting level.

Given that distractor inhibition views attribute negative priming to processes of selective attention, the present data would seem quite problematic. Can any version of inhibition account for the present findings? In fact, a recent study by Houghton, Tipper, Weaver, and Shore (1996), examining the related issue of distractor salience, may address the findings of Experiments 1A–3B. Similar to the findings in the present study, Houghton et al. demonstrated that larger negative priming resulted when distractors were made more salient. Their notion was that "... inhibitory systems may be energized by that which they inhibit" (p. 140)." The distractor in their study was perceptually very salient, attracting attention. If their interpretation of the Houghton and Tipper (1994) model purports that the greater inhibition, which gives rise to the large negative priming, serves to keep the highly salient distractors from attentional focus and conscious awareness, then the present findings are at odds with this view of negative priming. If their view, however, is that the greater inhibition serves to suppress responses to distractors, although both targets and distractors are attended and processed, then the inhibition view can account for the data.

Indeed, Tipper and his colleagues appear to favour the latter interpretation with
their espousal of the concept of selection for action (Allport, Tipper, & Chmiel, 1985; Houghton, Tipper, Weaver, & Shore, 1996; Tipper, Lortie, & Baylis, 1992). This is evident in the following: “In short, we ask: How is it that individual responses can be selectively controlled by particular stimuli in the presence of competing inputs?” (p. 140, Houghton, Tipper, Weaver, & Shore, 1996). Despite this endorsement of selective responding or selection for action, this distinction is not consistently and clearly made. In the immediately preceding sentence, the authors stated: “…we consider the problem faced by such an organism to be a problem of selective attention.” Relating negative priming to selective attention and selective responding interchangeably, particularly if it is not explicit whether an early or late attentional mechanism is proposed, confuses the issue and potentially produces erroneous expectations (i.e., that negative priming results from blocking distractors from attentional focus). Given the present data and those of others (Tipper, Weaver, & Milliken, 1995; Yee, Santoro, Crawford, & Grey, 1996), only the view that negative priming results from selective responding or selecting for action remains plausible.

Caveat. It is important to note that this selection for action version of distractor inhibition, however, lacks the intuitive appeal that made early inhibition accounts (Neill, 1977; 1979; Tipper, 1985) so popular. The interpretation of the Houghton and Tipper (1994) model that accommodates the present findings is at a loss to explain how organisms navigate highly complex environments, easily attending to important stimuli and ignoring irrelevant information. Instead, the theory explains only how some objects are selected for responding and others are not.
Episodic Retrieval

The episodic retrieval account provides an alternative explanation of negative priming (Neill, 1997; Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992). This view maintains that distractors and targets undergo different encoding processes and that negative priming results from a routine retrieval process at the time of the probe that attempts to recover information about the current target (cf. Logan, 1988). According to variations of this account, distractors are either encoded with “do not respond” tags or without any response information at all. In contrast, targets are encoded with “respond” tags or with specific response instructions. On ignored repetition trials, a response is required on the probe trial for an item that was previously encoded as the distractor on the prime trial. The memory check at the time of the probe uncovers response information for the repeated item that conflicts with its current target status. A delay ensues (i.e., negative priming) during which this conflict is resolved (see Neill & Mathis, 1998, for a modified episodic retrieval account). The additional assumption that the last episode is most temporally discriminable, and thus most likely retrieved, is required for this explanation to account for the findings adequately.

Does the episodic retrieval account of negative priming explain the results of Experiments 1A – 3B? It seems reasonable to assume that the referent size-selection task requires deeper processing of distractors on both prime and probe trials than does the typical colour-selection task. It follows that the prime-trial memory trace for the distractor should be significantly strengthened. Therefore, from the episodic retrieval view, the probability of recalling the prime episode in the ignored repetition condition of the size-selection task is greater than that probability in the colour-selection task. As a
result, this confusion or response competition will occur on a greater proportion of ignored repetition trials in the referent size-selection task, which should yield larger negative priming. Consequently, the episodic retrieval account provides a straightforward explanation of the findings in the present study.

**Feature Mismatch**

A third explanation of negative priming is provided by the code-coordination theory (Lowe, 1979) or, more recently, the perceptual mismatch theory (Park & Kanwisher, 1994). According to this account, negative priming occurs due to a mismatch in the representation of the repeated item from its prime to its probe presentation. Because targets and distractors are characterized by different perceptual features in typical negative priming tasks, the distractor on the prime that subsequently appears as the target on the probe will differ in terms of its perceptual attributes. For example, if the instructions are to attend to red items and to ignore white ones, on ignored repetition trials, the critical repeated item will appear in white on the prime and in red on the probe. Borrowing from the notions of Kahneman, Treisman, and Gibbs (1992), an object file is retrieved at the time of the probe that contains discrepant features for the repeated item. Whereas the episodic-retrieval account focuses on retrieval of incompatible response information, perceptual mismatch theory centers on retrieval of mismatching perceptual information. This incongruence introduces ambiguity that slows down responding on the probe and hence results in negative priming in the ignored repetition condition.

A 'perceptual' mismatch account of the results in the referent size-selection task seems improbable. Because selection was based on a semantic feature (i.e., relative referent size), there was no systematic mismatch in the perceptual characteristics of the
repeated item from prime to probe in the ignored repetition condition. Nonetheless larger negative priming was observed.

If one assumes, however, that the mismatch of relevance is not at the level of perceptual features per se but rather on the dimension that constitutes the selection criterion, these data are readily explained. If selection is based on a perceptual feature, as in the standard case, then perceptual mismatches are critical and lead to negative priming. If selection is based on a semantic feature instead, as in the referent size-selection case, then semantic mismatches are relevant and result in negative priming. For example, in the ignored repetition condition of the referent size-selection task, when MOUSE first appears with GOAT on the prime display, it is encoded as “smaller”, but when it subsequently appears with FLEA on the probe display, it must be deemed “larger.” The relative size status of the repeated item changes from prime to probe, creating a clear semantic mismatch. In fact, a semantic mismatch might be more difficult to resolve (Joordens & Becker, 1997). Therefore the modified mismatch account—the selection-feature mismatch account—also would predict enhanced negative priming in the size-selection task.

**Summary**

The distractor inhibition account attributes negative priming to processes of selective responding. Negative priming, which is measured by the probe trial in the ignored repetition condition, is ascribed to the inhibition of the general tendency to respond to distractors, which is engaged at the time of the prime. In contrast, selection-feature mismatch and episodic retrieval theories of negative priming are memory-based accounts, assigning greater importance to the retrieval processes at the time of the probe
(see Milliken, Jolicoeur, & Seiffert, 1999, for more extensive discussion). This trend in placing greater emphasis on the retrieval processes engaged at the time of the probe is also apparent in the larger priming literature (Kahneman, Treisman, & Gibbs, 1992; Ratcliff & McKoon, 1988; Whittlesea & Jacoby, 1990).

The present findings are at odds with the predominant view that negative priming results from processes of selective attention, which activate targets and prevent processing and conscious awareness of distractors (Fox, 1994; 1995; Moore, 1994; Neill, 1977; 1979; Neill & Westberry, 1987; Neumann & DeSchepper, 1992; Tipper, 1985; Tipper et al., 1991; Yee, 1991). However, the three main accounts of negative priming are or can be made to be consistent with these findings. The results of Experiments 1A – 3B constrain and refine the interpretations of these theories and their predictions. Further, the augmented effect of the size-selection task may prove useful in differentiating these theories. For example, to confirm the mismatch view of negative priming, it must be shown that negative priming is eliminated when there is no longer a mismatch in the representation of the critical item from the prime display to the probe display. With a small (i.e., 15-25 ms) and somewhat unstable effect (Fox, 1995), eliminating negative priming in the desired condition of the standard task is not especially impressive and could be disputed on the grounds of the inconsistency of negative priming. If a 100 ms effect, which has been demonstrated to occur consistently in the size-selection task, is abolished through the elimination of mismatch, however, the evidence is far less contestable. In fact, this was the goal of Experiments 4 – 6.

Rationale for Experiments 4 – 6

The purpose of Experiments 4 – 6 was to discriminate among the competing
explanations of negative priming and to gain greater insight into the processes underlying this phenomenon. Although the general approach that was undertaken to differentiate these theories was not entirely new, it was coupled with the novel referent size-selection procedure. The negative priming obtained in the referent size-selection task is much larger and more consistent than that obtained in the standard colour-selection negative priming task. Consequently, the pattern of findings using this task should be more compelling and less easily refuted.

**Previous Attempts to Discriminate Among Theories of Negative Priming**

Although many studies have sought to differentiate among competing theories of negative priming, for current purposes the focus will be only on those that have employed a specific approach, with the intent of testing the predictions of mismatch accounts. The predictions of mismatch accounts and subsequently the general approach are considered.

The mismatch account attributes negative priming to a discrepancy in a feature of the repeated item from its prime to its probe presentation in the ignored repetition condition. In its most recent instantiation, the selection-feature mismatch account, it is mismatches in terms of the selection-feature, be it colour or relative referent size, that are critical. Interestingly, of the three prevailing accounts, the mismatch hypothesis stands alone in asserting that negative priming does not occur because the repeated item was previously a distractor on the prime trial. Mismatch views make a testable prediction that is clearly opposed to the predictions of the other accounts. According to this hypothesis, negative priming should be eliminated when there is no longer a discrepancy in the features of the repeated item from prime to probe in the ignored repetition condition. Both the distractor inhibition and the episodic retrieval theories ascribe negative priming
to differential processing of targets and distractors, albeit via different mechanisms.

Therefore, the latter two accounts continue to predict negative priming in the absence of a mismatch on the repeated item as long as the item first serves as a distractor on the prime display and subsequently as a target on the probe display.

The critical test of the prediction would involve presenting the repeated item as the distractor on the prime and as the target on the probe, without altering its selection features across the consecutive displays. In fact, this is quite easily accomplished simply by switching the selection criterion from prime to probe. For example, when selection is based on colour, a match situation could be created by instructing participants to attend to red items and to ignore white items on the prime, and subsequently by asking them to attend to white items and to ignore red items on the probe. In the ignored repetition condition, the repeated item would appear in white on both the prime and the probe. This would satisfy the condition that the repeated item be identical—critically on the selection feature from the selection-feature mismatch perspective—from prime to probe with the exception that on the prime it served as the distractor whereas on the probe it appeared as the target. This match ignored repetition condition could then be contrasted with the typical mismatch ignored repetition condition in which the features of the repeated item are altered from prime to probe. The results of this comparison would differentiate between the mismatch hypothesis and the distractor inhibition and episodic retrieval accounts of negative priming.

In fact, a number of studies have employed this strategy with mixed results. Tipper and Cranston (1985) provided the earliest direct test. In their study, they presented two overlapping green and red letters on both the prime and the probe. In some
experiments, participants were asked to read the red letters and to ignore the green ones. Not surprisingly, those experiments yielded negative priming. In one experiment, however, participants were instructed to name the red letter on the prime and to name the green letter on the probe. By switching the selection criterion from prime to probe, the repeated item in the ignored repetition condition was perceptually identical in each of its presentations. This provided a critical test for the mismatch hypothesis of negative priming. In contrast to the predictions of this account though, negative priming indeed appeared in this experiment.

Tipper, Weaver, and Milliken (1995) also investigated the mismatch theory of negative priming in a series of spatial negative priming experiments. Their aim was to test whether negative priming arose in the ignored repetition condition because the probe target occurred in the position previously occupied by the prime distractor. That is, did negative priming occur because the objects occupying the repeated location were different (i.e. mismatched) from prime to probe? In Experiment 1, participants were asked to indicate the location of the larger circle in a pair by moving a joystick. There were four possible locations (up, down, right, and left) indicated by concentric rings. Seeming to contradict the mismatch account, Tipper et al. found that negative priming persisted even when the probe target appearing in the previously ignored location was identical to the previously-ignored prime distractor. That is, if a circle of the same size appeared in the same location, first as a distractor on the prime, then as a target on the probe, negative priming resulted nonetheless. This finding, apparently at odds with the mismatch hypothesis of negative priming, was also replicated in Experiment 2 using letters of various sizes rather than circles.
Although these findings clearly refute the perceptual mismatch hypothesis of negative priming, are they also inconsistent with the selection-feature mismatch account? According to this view, a mismatch on the selection feature produces negative priming. In both their Experiments 1 and 2, the selection feature was relative size. The repeated item was deemed 'smaller' on the prime and 'larger' on the probe, creating a mismatch on the selection feature, despite matches in terms of both location and perceptual features. Therefore, the finding of negative priming in the purported location/identity-matching condition is not at all inconsistent with selection-feature mismatch.

Tipper et al. (1995) conducted a third experiment, however, that did provide a critical test for selection-feature mismatch. In Experiment 3, colour was the selection cue and the stimuli on all trials were Xs. The target colour changed from trial to trial, indicated by a central colour cue. On some ignored repetition trials, the repeated item appeared in the same location but differed in terms of its print colour from prime to probe; these were the mismatch ignored repetition trials. On other ignored repetition trials, the repeated item appeared in the same location and in the same colour from prime to probe; these were the match ignored repetition trials. Negative priming resulted on both mismatch and match ignored repetition trials, refuting the predictions of the selection-feature mismatch hypothesis. However, these results were not entirely straightforward. The negative priming on the match trials was significantly smaller than that on the mismatch trials, suggesting a role for mismatch in negative priming.

Milliken, Tipper, and Weaver (1994) conducted a series of experiments similar to Tipper et al.'s (1995) Experiment 3. On each trial, in every experiment, there were four possible target locations (up, down, left, and right) indicated by squares, and the task was
to move a joystick in the direction of the target location. In Experiments 1, 2, 3, and 4, participants used colour (blue, green, yellow, or purple) as the basis for selection. In Experiments 4 and 5, participants relied on letter identity (A, B, C, or D) to perform their selections. The target colour or target letter was indicated by a central cue that changed from trial to trial. In Experiments 1, 3, and 5, the cue preceded the onset of the prime trial. In Experiments 2, 4, and 6, the cue onset simultaneously with the prime items. In Experiments 1, 2, and 5, the cue preceded the onset of the probe trial. In Experiments 3, 4, and 6, the cue appeared simultaneously with the probe trial.

The results of Experiments 1, 2, and 5 were quite consistent with selection-feature mismatch. When the selection dimension was colour (Experiments 1 and 2), a mismatch in the association of colour with location across the prime and the probe trials was critical. As predicted by selection-feature mismatch, whenever a location mismatched in terms of the colour associated with it from prime to probe, negative priming arose. Whenever the repeated location matched in terms of the colour associated with it across the two displays, however, positive priming was observed. Interestingly, matches and mismatches in terms of the identity of the letter across the two displays seemed to have no effect on response times.

When the selection dimension was letter identity (Experiment 5), however, a mismatch in the association of letter identity and location in the ignored repetition condition became critical. In most cases, when there was a mismatch in the letter associated with a location from prime to probe, negative priming arose. Whenever the repeated location matched in terms of the letter associated with it across the two displays, however, positive priming was observed. In this experiment, matches and mismatches in
terms of the now irrelevant colour dimension across the two displays had no systematic
effect, mirroring what was obtained for letter identity matches and mismatches when
colour was the selection dimension.

Despite the fact that there was no difference in the results whether the cue
preceded the prime trial or occurred simultaneously with it, in all the experiments where
the selection cue and the probe trial appeared simultaneously (i.e., Experiments 3, 4, and
6), the pattern of negative priming was inconsistent with the selection-feature mismatch
account. In Experiments 3 and 4, in which selection was based on colour, significant
negative priming was observed in all cases where a location repeated from prime to probe
whether the colour associated with the location across the two displays matched or
mismatched. Analogously in Experiment 6, in which selection was based on letter
identity, significant negative priming arose in all cases where a location repeated from
prime to probe regardless of whether the letter identity associated with it matched or
mismatched. As did Tipper et al. (1995), Milliken et al. (1994) concluded that negative
priming was determined by the retrieval of mismatching information on the probe as well
as by inhibition of distractor locations.

In contrast to these results, two recent studies support the mismatch view of
negative priming to the exclusion of all other theories. Park and Kanwisher (1994) also
investigated mismatch in a location negative priming study. In their Experiment 4, they
asked participants to identify the location of ‘X’s on the prime and to attend to the
location of ‘O’s on the probe. In the mismatch case, the probe target ‘O’ appeared in the
location previously occupied by the prime target ‘X’. Although participants attended to
the same location on the prime and the probe, the item bound to that location was
discrepant across displays. In the match case, however, the probe target ‘O’ appeared in the position that was occupied previously by the prime distractor ‘O’. In this case, although the participant attended to different locations from prime to probe, the item bound to the probe target location was the same symbol, the letter ‘O’, across displays. Consistent with the mismatch hypothesis, negative priming only occurred in the mismatch case. On match ignored repetition trials, however, positive rather than negative priming arose.

The findings of Chiappe and MacLeod (1995) also support the mismatch account of negative priming. Using colour as the selection criterion, they found that if the repeated item was presented in white on both the prime and the probe, negative priming was eliminated. Recently, MacLeod, Chiappe, and Fox (1999) replicated these findings. The match trials in both studies were accomplished by alternating the selection criterion from prime trial to probe trial. Despite the fact that the critical repeated item was not selected on the prime, negative priming did not result. These findings suggest that inhibition of the distractor on the prime trial or differential target and distractor encoding are not the crucial events leading to negative priming. Rather, these results imply that a discrepancy on the selection feature of the repeated item across sequential trials is critical.

An additional factor further complicates the interpretation of these somewhat contradictory findings. All previous studies have investigated negative priming using standard tests which typically yield a 15-25 ms negative priming effect (Fox, 1995). When the effect is this small at the outset, it is difficult to ascertain that a specific manipulation, such as the presence or absence of a mismatch, eliminated negative
Moreover, what if the consequence of the experimental manipulation was to reduce negative priming? The statistical power to discriminate a reduction in the initial effect or to differentiate the reduced effect from zero would be extremely small. Thus the implications from these studies remain unclear.

Purpose of Experiments 4 – 6

The goal of Experiments 4 – 6 was to test the selection-feature mismatch hypothesis of negative priming against the distractor inhibition and episodic retrieval accounts using the referent size-selection task. Specifically, the intent was to use the switching selection criterion approach coupled with a larger and more reliable negative priming effect. To this end, negative priming was contrasted for mismatch and match ignored repetition trials. On the mismatch trials, the selection criterion remained constant from prime to probe (e.g., attend to the larger item on both the prime and the probe), causing the repeated item to vary in terms of the selection feature on consecutive displays. On match trials, in contrast, the selection feature changed from prime to probe (e.g., attend to the smaller item on the prime and attend to the larger item on the probe), allowing the repeated item to remain invariant in terms of the selection feature across displays. The selection-feature mismatch account predicts negative priming in the mismatch ignored repetition case only. Negative priming should be eliminated on match ignored repetition trials.

Whereas the selection-feature mismatch account predicts different priming outcomes for match and mismatch trials, neither the distractor inhibition nor the episodic retrieval account of negative priming makes such distinctions. Both accounts predict negative priming for all ignored repetition trials regardless of mismatch in terms of the
selection feature for the repeated item. Recall that the primary tenet of the inhibition account is that the general tendency to respond to distractors on the prime trial is inhibited. Whether or not the selection criterion changes, the distractor is not selected for action or for responding but rather is inhibited. Similarly, according to the episodic retrieval account, negative priming should occur as long as the distractor on the prime display is encoded with no response information or with 'do not respond' instructions. This criterion is also satisfied in all ignored repetition conditions of the present study irrespective of discrepancy in the selection feature for the repeated item from prime to probe. Both of these views pinpoint differential processing of targets and distractors as the central event leading to the negative priming effect. Therefore, the distractor inhibition and episodic retrieval accounts predict negative priming on both match and mismatch ignored repetition trials because targets and distractors are clearly processed differently in the two cases.

In Experiment 6, the plausibility of the selection-feature mismatch account was further tested by investigating the effect of mismatch on attended repetition trials. In the attended repetition condition, the repeated item appears as the target on both the prime and the probe. This usually results in shorter response latencies or positive priming relative to the control condition (Scarborough, Gerard, & Cortese, 1979; Tipper & Driver, 1988). Because selection-feature mismatch does not ascribe negative priming to distinct processing of targets and distractors, but rather to a conflict in the repeated item on the selection feature from prime to probe, it makes predictions for the attended repetition condition that are identical to those for the ignored repetition condition. That is, the selection-feature mismatch account predicts negative priming on mismatch attended
repetition trials. Unlike for the ignored repetition trials, the mismatch trials in the attended repetition condition were accomplished by switching the selection criterion from prime to probe (e.g., attend to the smaller item on the prime and attend to the larger item on the probe) thus introducing a discrepancy in terms of the selection feature for the repeated target item. The theory predicts no negative priming on match attended repetition trials where the selection criterion (e.g., attend to the larger item on both the prime and the probe) and correspondingly the repeated item remain invariant across the consecutive displays. Neither the distractor inhibition account nor the episodic retrieval theory predicts negative priming for repeated targets regardless of feature matches or mismatches.

**Experiment 4**

The objective of Experiment 4 was to investigate negative priming in a block of trials in which the selection criterion remained the same throughout the block compared to a block of trials in which the selection criterion alternated from prime to probe. In both blocks, items were selected based on relative referent size. In the mismatch block, participants were instructed to select the larger animal in the pair on both the prime and the probe. In this condition, the repeated item in the ignored repetition condition was first the smaller animal on the prime and then the larger animal on the probe. In the match block, participants were instructed to select the smaller animal in the pair on the prime trial and to name the larger animal in the pair on the probe trial. Therefore, in this block, the repeated item in the ignored repetition condition corresponded to the larger animal in the pair on both the prime and the probe, although in the first case it served as the distractor and in the second case it was the target.
Method

Participants

Twenty-two students from the introductory psychology class at the University of Toronto at Scarborough participated in the experiment. Participants received bonus credit in their course in exchange for their participation.

Procedure

There were two blocks of trials in the experiment. All participants performed each block, and the order of the blocks was counterbalanced across participants. As in Experiments 1A and 1B, in each block the names of two animals appeared one above the other on both the prime and the probe displays. In both blocks, participants selected targets based on relative referent size. Top or bottom presentation location was randomized, with targets appearing equally often in each location on both the prime and the probe. The print colour and whether the larger or the smaller animal was the target depended on the display (i.e., prime or probe) and the block (i.e., match or mismatch).

The mismatch block of Experiment 4 was a direct replication of the size-selection task of Experiments 1A and 1B with the exception that both targets and distractors were presented in white on the prime and the probe. In this block, the repeated item in the ignored repetition condition mismatched in terms of the selection feature. That is, the repeated item was deemed smaller on the prime and larger on the probe, creating a semantic mismatch across successive displays. Note, however, that the repeated item matched in terms of its non-selection, perceptual attributes.

In the match block, however, participants were instructed to name the smaller animal when both items appeared in red, always corresponding to the prime trial, and to
name the larger animal when both items appeared in white, always corresponding to the probe trial. The selection criterion therefore alternated from prime to probe. In this block, the repeated item in the ignored repetition condition did not mismatch in terms of the selection feature. That is, the repeated item was deemed larger on both the prime and the probe. Note that although there was no semantic mismatch from prime to probe, there was a discrepancy in the non-selection, perceptual features.

In both blocks, the events and their sequence for a complete trial (i.e., both prime and probe) were as described in Experiment 1A and depicted in Figure 1. Participants received 10 practice trials before participating in each block. There were 96 experimental trials in each block.

Apparatus

The apparatus was identical to that described in Experiment 1A.

Stimuli

The stimulus words in both blocks were FLEA, MOUSE, TURTLE, PIG, GOAT, DONKEY, BEAR, and CAMEL as in Experiments 1A and 1B. Participants were informed of this ascending size ordering before beginning the experiment. There were two conditions in each block: ignored repetition and control. As in previous experiments, in the ignored repetition condition, the stimulus word that appeared as the distractor on the prime (i.e., the non-selected word) subsequently reappeared as the target on the probe (i.e., the selected word). In the control condition, the targets and distractors on the prime were different from the targets and distractors on the probe. No other items repeated between prime and probe trials. Again the special statuses of FLEA and CAMEL as the smallest and largest items respectively complicated stimulus assignments and pairings in
both referent size-selection tasks. Further, the stimulus assignments in each condition (i.e., ignored repetition and control) and for each block (i.e., mismatch and match) were different. These will be discussed separately.

In the mismatch block, there were 48 ignored repetition trials and 48 control trials. The target item was always the larger animal in the pair on both the prime and the probe. The stimulus assignments in the ignored repetition and control conditions were the same as in the size-selection block of Experiment 1A.

In the match block, participants also performed 48 ignored repetition trials and 48 control trials. The target item was the smaller animal in the pair on the prime and the larger animal in the pair on the probe. Again there were constraints as to the stimulus assignment in this block. Namely, FLEA could not serve as a distractor on the prime or as a target on the probe whereas CAMEL could not appear as the target on the prime or as the distractor on the probe. This introduced a further complication in the ignored repetition condition. That is, MOUSE could not appear as the distractor on the prime or as the target on the probe in this condition because it would have to appear with FLEA on both the prime and the probe to satisfy the condition that it be the larger item on the prime and the larger item on the probe. This pairing would violate the rule that no items repeat other than the prime distractor, as is required for the ignored repetition manipulation. The following details the stimulus assignment first in the control condition and then in the ignored repetition condition.

In the control condition of the match block, all stimuli other than FLEA and CAMEL appeared equally often—six times—as targets and distractors. Because it could never be a prime distractor or probe target, FLEA served twice as often—twelve times—
as the prime target and the probe distractor. Likewise, CAMEL served as the prime distractor and the probe target twice as often as the other stimuli—twelve times—because it could never appear as the prime target or the probe distractor.

In the ignored repetition condition of the match block, FLEA and MOUSE never appeared as prime distractors or probe targets but appeared twelve times as prime targets and probe distractors. CAMEL appeared twelve times as the prime distractor and the probe target but never as the prime target or the probe distractor for the reasons outlined above. PIG and TURTLE appeared equally often—six times each—as the prime targets and distractors and the probe targets and distractors. GOAT, DONKEY, and BEAR each appeared eight times as prime distractors and probe targets and four times as prime targets and probe distractors.

Results

Table 4 presents the mean latencies and error rates for each block of Experiment 4. In the mismatch block, negative priming was observed in the ignored repetition condition relative to the control condition. In the match block, however, negative priming was eliminated in the ignored repetition condition. Figure 7 presents the difference scores.

A 2 X 2 repeated measures ANOVA was conducted on the data from Experiment 4. The variables were block (mismatch vs. match) and condition (ignored repetition vs. control). For this and all subsequent analyses, response times were again only analysed for correctly named probe targets that followed correctly named prime targets. As well, only errors in naming probe targets that followed correctly performed prime trials were considered.
Table 4
Mean Response Times (ms), Error Rates (proportion), and (Standard Errors) Across Conditions and Blocks of Experiment 4.

<table>
<thead>
<tr>
<th></th>
<th>Size-selection</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>RT (SE)</td>
<td>Err (SE)</td>
<td></td>
</tr>
<tr>
<td><strong>Ignored Repetition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mismatch (non-switch)</td>
<td>1237 (46.95)</td>
<td>.117 (0.02)</td>
<td></td>
</tr>
<tr>
<td>Match (switch)</td>
<td>1354 (70.22)</td>
<td>.122 (0.02)</td>
<td></td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-switch</td>
<td>1161 (49.74)</td>
<td>.105 (0.02)</td>
<td></td>
</tr>
<tr>
<td>Switch</td>
<td>1388 (67.76)</td>
<td>.153 (0.03)</td>
<td></td>
</tr>
</tbody>
</table>
Figure 7. Negative priming scores in the size-selection match and size-selection mismatch blocks of Experiment 4. Error bars reflect the standard error of the mean.
The latency analysis of Experiment 4 revealed a significant main effect of block, $F(1, 21) = 30.29$, $MSe = 21540.06$, $p < .001$. This reflected the fact that longer latencies arose in the match block than in the mismatch block. This is not surprising given the switching of selection criterion from prime to probe. The main effect of condition, $F(1, 21) = 2.86$, $MSe = 3623.44$, $p > .100$, however, was not significant. This is explained by the significant Block X Condition interaction, $F(1, 21) = 14.96$, $MSe = 4402.21$, $p < .001$, indicating that negative priming (i.e., longer latencies in the ignored repetition condition than in the control condition) occurred in the mismatch block, whereas positive priming (i.e., shorter latencies in the ignored repetition condition than in the control condition) arose in the match block. Although the negative priming in the mismatch block was highly significant, $F(1, 21) = 19.76$, $MSe = 3249.41$, $p < .001$, the positive priming in the match block was not, $F(1, 21) = 2.51$, $MSe = 4776.24$, $p > .100$.

An analogous ANOVA was performed on the proportion of errors. The main effect of block was marginally significant, $F(1, 21) = 3.20$, $MSe = 0.005$, $p = .088$, reflecting the fact that more errors occurred in the match block than in the mismatch block. This is consistent with the latency data. The main effect of condition was not significant, $F < 1$. Finally, the Block X Condition interaction was marginally significant, $F(1, 21) = 3.57$, $MSe = 0.003$, $p = .073$, reflecting more errors in the ignored repetition condition than in the non-switch control condition in the mismatch block and more errors in the switch control condition than in the ignored repetition condition in the match block. Thus, the error and latency results correspond, refuting the possibility of a speed accuracy tradeoff. Note, however, that the error negative priming in the mismatch block, $F < 1$, and the error positive priming in the match block, $F(1, 21) = 1.84$, $MSe = 0.006$, $p$
Discussion

The results of Experiment 4 are entirely consistent with the selection-feature mismatch hypothesis of negative priming. Negative priming only occurred when there was a mismatch in the representation of the repeated item from its prime to its probe presentation in the ignored repetition condition. In fact, positive priming arose when the repeated item was congruent in terms of the selection feature across these successive displays. These findings suggest that selection-feature mismatch is a primary determinant of negative priming.

These findings are at odds with both the distractor inhibition (Houghton & Tipper, 1994; Tipper, 1985) and the episodic retrieval (Neill & Valdes, 1992; Neill et al., 1992) accounts of negative priming. Recall that both of these theories ascribe negative priming to differential processing of targets and distractors, albeit with reference to different mechanisms. The distractor inhibition view attributes negative priming to the inhibition of distractors on the prime display of ignored repetition trials. According to the episodic retrieval view, distractors are encoded with ‘do not respond’ instructions or with no response information at all. In the ignored repetition condition, retrieval of the repeated item’s previous processing episode provides information that is discrepant with the item’s current target status. According to both of these explanations, negative priming should not be affected by discrepancies in the relative size value of the repeated item across successive prime and probe trials. Yet in complete opposition to these predictions, and despite the facts that participants attended to and responded to targets and that they ignored and did not respond to distractors in both the match and the mismatch blocks of
Experiment 4, negative priming only resulted when such a mismatch was present.

Given an incidental feature of the procedure in each block of the experiment, these results suggest in particular that a mismatch on the selection feature—in this case relative referent size—is the critical discrepancy leading to negative priming. In the mismatch block, extremely large negative priming resulted despite a match on the non-selection, perceptual feature for the repeated item in the ignored repetition condition. That is, in this block of trials, the repeated items were identical perceptually, appearing in white on both the prime and the probe. Therefore, the only mismatch that could be contributing to the negative priming was in terms of the selection feature. In the match block, by contrast, no negative priming was observed despite a mismatch on the non-selection, perceptual feature for the repeated items in the ignored repetition condition. In this block of trials, the repeated item was incongruent perceptually from prime to probe, appearing in red on the former and in white on the latter. Consequently, a mismatch on a non-selection feature does not appear to contribute to the negative priming effect. This is similar to the results obtained in Milliken et al.'s (1994) Experiments 1, 2, and 5. These findings bolster the selection-feature mismatch account and undermine the original perceptual mismatch explanation of negative priming (Lowe, 1979; Park & Kanwisher, 1994).

Experiment 5

It would be especially convincing to replicate the pattern obtained in Experiment 4 when the mismatch and match trials occurred within the same block. Therefore, the objective of Experiment 5 was to replicate Experiment 4 in a randomized design. In this way, the contextual variables associated with mismatch and match trials would be better
In addition, the aim was to extend the findings from Experiment 4 to a standard negative priming task. Therefore in Experiment 5, in addition to a block using the referent size-selection task with mismatch and match trials, participants completed a block of trials in which selection was based on colour. In this colour-selection task, mismatch and match trials were also intermingled.

**Method**

**Participants**

Twenty participants from the University of Toronto at Scarborough took part in Experiment 5. They received bonus credit in their introductory psychology class in exchange for their participation.

**Procedure**

Participants performed two tasks in the experiment: a referent size-selection task and a colour-selection task. All participants performed both tasks in separate blocks with the order of block counterbalanced across participants. In both tasks, two number words appeared one above the other during both the prime and the probe of every trial.

In the referent size-selection task, participants were instructed to read either the larger or the smaller number depending on a simultaneously occurring cue. For this task, the cue was either a large or a small box surrounding the number pairs. Participants were instructed to read the larger number in the pair if the box was large and to read the smaller number in the pair if the box was small. All words were presented in white in the size-selection task.

In the colour-selection task, participants were instructed to read either the red or
the white number, also depending on a simultaneously occurring cue. For this task, the
cue was either a red or a white box surrounding the word pairs. Participants were asked
to read the red word if the box was red and to read the white word if the box was white.

In both the referent size-selection task and the colour-selection task, there were
two ignored repetition trial types: mismatch and match. The mismatch trials were
standard negative priming trials wherein the selection criterion did not differ from prime
to probe. On these trials participants would either attend to larger, smaller, white, or red
items on both the prime and the probe. In the match trials, however, the selection
criterion changed from prime to probe. Participants would either attend to larger,
smaller, white, or red items on the prime and to smaller, larger, red, or white items,
respectively, on the probe. Control trials in which the selection criterion did not switch
from prime to probe served as the baseline for the mismatch ignored repetition trials
whereas control trials in which the selection criterion switched from prime to probe were
used for comparison with the match ignored repetition trials. Examples of the match and
mismatch ignored repetition trials and their respective control trials are presented in
Figure 8.

As illustrated in Figures 9 and 10, a complete trial—consisting of both a prime
and a probe display—for each task proceeded as follows: (a) the prime words appeared
within a box and remained on the screen until the participant responded, (b) the word
"Ready?" appeared until the experimenter input the participant’s accuracy on the prime
trial, (c) a blank screen was presented for 300 ms, (d) the probe words appeared within a
box and remained on the screen until the participant responded, (g) the word “Ready?”
appeared until the experimenter input the participant’s accuracy on the probe trial, (g) a
Examples of match and mismatch ignored repetition trials and the corresponding switch and non-switch control trials for the referent size-selection task (Panel A) and the colour-selection task (Panel B) of Experiment 5. In the size-selection task, large boxes cued participants to read the larger number in the pair whereas small boxes cued them to read the smaller number. In the colour-selection task, red boxes (represented by bold print) cued participants to read the red number whereas white boxes (represented by fine print) cued participants to read the white number. To assist the reader, in both panels, asterisks appear beside the correct targets.
Figure 9. An example of a control trial and an ignored repetition trial in the size-selection task of Experiment 5. Asterisks appear beside the correct targets.
An example of a control trial and an ignored repetition trial in the colour-selection task of Experiment 5. Bold type represents red in the figure. Asterisks appear beside the correct targets.
blank screen was presented for 500 ms before the initialization of the next trial. The prime and probe stimuli remained in the center of the screen until participants responded by reading the target word into the microphone. Participants received 10 practice trials before participating in each block of the experiment. There were 96 trials in each block of the experiment.

Apparatus

The apparatus was identical to that used in Experiment 1A.

Stimuli

The stimulus words for both tasks were the numbers one through eight (ONE, TWO, THREE, FOUR, FIVE, SIX, SEVEN, and EIGHT). These were the same stimuli used in Experiment 2B. As in previous experiments, on all ignored repetition trials, the prime distractor became the probe target. On control trials, prime targets and distractors and probe targets and distractors did not repeat. The stimulus assignments for each condition (ignored repetition and control) for both trial types within each task were different. These will be outlined separately.

In the size-selection task, there were 24 mismatch ignored repetition trials, 24 match ignored repetition trials, 24 non-switch control trials, and 24 switch control trials. Because on some trials the target was the larger item and on others it was the smaller item, all numbers could appear as targets and as distractors on both the prime and probe trials in the referent size-selection task. For switch and non-switch control trials combined, all items appeared equally often—six times—as prime targets, prime distractors, probe targets, and probe distractors. In both the mismatch and the match ignored repetition trials combined, ONE and EIGHT each appeared four times as prime
distractors and probe targets and six times as prime targets and probe distractors. TWO and SEVEN were each presented equally often—six times—as prime targets, prime distractors, probe targets, and probe distractors. THREE, FOUR, FIVE, and SIX each appeared seven times as prime distractors and probe targets and six times as prime targets and probe distractors.

In the colour-selection task, there were an analogous 24 mismatch ignored repetition trials, 24 match ignored repetition trials, 24 non-switch control trials, and 24 switch control trials. For all trial types (i.e., mismatch and match or switch and non-switch) in each condition (i.e., ignored repetition and control), all items appeared equally often—six times—as prime targets, prime distractors, probe targets, and probe distractors.

**Results**

The mean response times and error rates for Experiment 5 appear in Table 5. In the referent size-selection task, large negative priming occurred for mismatch ignored repetition trials relative to the corresponding non-switch control trials. In the same task, for match ignored repetition trials, however, negative priming was eliminated relative to the corresponding switch control trials. Analogously, in the colour-selection task, negative priming only resulted for mismatch ignored repetition trials whereas it was eliminated for match ignored repetition trials. Figure 11 presents these difference scores.

**Referent Size-Selection Task**

A 2 X 2 repeated measures ANOVA was performed on the latency data from the referent size-selection task of Experiment 5. The variables were trial type (mismatch vs. match or non-switch vs. switch) and condition (ignored repetition vs. control). The main
Table 5

Mean Response Times (ms), Error Rates (proportion), and (Standard Errors) Across Trial Types, Conditions and Tasks in Experiment 5.

<table>
<thead>
<tr>
<th></th>
<th>Size-selection</th>
<th>Colour-selection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT (SE)</td>
<td>Err (SE)</td>
</tr>
<tr>
<td>Ignored Repetition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mismatch (non-switch)</td>
<td>1325 (41.51)</td>
<td>.110 (0.01)</td>
</tr>
<tr>
<td>Match (switch)</td>
<td>1267 (29.32)</td>
<td>.119 (0.02)</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(non-switch)</td>
<td>1228 (45.50)</td>
<td>.142 (0.01)</td>
</tr>
<tr>
<td>(switch)</td>
<td>1289 (34.71)</td>
<td>.137 (0.02)</td>
</tr>
</tbody>
</table>
Figure 11. Negative priming scores for the match and mismatch ignored repetition trials in the size-selection task and the colour-selection task of Experiment 5.
effect of trial type was not significant, \( F < 1 \), revealing no differences in terms of latency for mismatch ignored repetition and non-switch control trials combined relative to match ignored repetition and switch control trials together. This finding indicates that latencies were statistically equivalent for trials in which the selection-feature changed from prime to probe and for trials in which the selection-feature remained the same across the consecutive displays. The main effect of condition was marginally significant, \( F (1, 19) = 4.13, \text{Mse} = 6643.88, p = .056 \), reflecting longer latencies overall in the ignored repetition condition relative to the control condition. This result, however, should be viewed in light of the significant Trial type X Condition interaction, \( F (1, 19) = 14.64, \text{Mse} = 4848.27, p < .001 \), reflecting negative priming for the mismatch ignored repetition trials compared to positive priming for the match ignored repetition trials. Although the negative priming was significant for mismatch trials, \( F (1, 19) = 15.55, \text{Mse} = 6001.44, p < .001 \), the positive priming for match trials was not, \( F < 1 \).

An analogous ANOVA performed on errors revealed that the main effect of trial type was not significant, \( F < 1 \), showing similar error rates for mismatch and non-switch control trials combined compared to match and switch control trials combined. The main effect of condition approached significance, though, \( F (1, 19) = 4.07, \text{Mse} = 0.003, p = .058 \), showing more errors in the control condition than in the ignored repetition condition. The Trial type X Condition interaction was not significant, \( F < 1 \). Further analyses demonstrated that no significant differences arose for mismatch ignored repetition trials and their respective non-switch control trials, \( F < 1 \). However, significantly more errors emerged for switch control trials than for ignored repetition match trials, \( F (1, 19) = 4.75, \text{MSe} = 0.002, p < .050 \). Thus for the match trials, error
rates corresponded to the latency data.

**Colour-Selection Task**

With respect to the latency data in the colour-selection task, both the main effects of trial type, $F(1, 19) = 28.87, \text{Mse} = 3808.58, p < .001$, and condition, $F(1, 19) = 10.50, \text{Mse} = 1504.02, p < .005$, were significant. Longer latencies were observed on match and switch control trials than on mismatch and non-switch control trials. Therefore, when the selection dimension changed from prime to probe, participants responded more slowly. Also, longer latencies were observed in the ignored repetition condition compared to the control condition. The Trial type X Condition interaction was also significant, $F(1, 19) = 27.67, \text{Mse} = 828.21, p < .001$, reflecting negative priming for mismatch ignored repetition trials and positive priming for match ignored repetition trials relative to their corresponding control trials. Again, the negative priming was significant, $F(1, 19) = 31.27, \text{Mse} = 1227.50, p < .001$, whereas the positive priming was not, $F < 1$.

With regard to errors in the colour-selection task, neither the main effects of trial type, $F(1, 19) = 1.78, \text{Mse} = 0.003, p > .150$, nor condition, $F(1, 19) = 2.89, \text{Mse} = 0.002, p > .100$, nor the Trial type X Condition interaction, $F < 1$, were significant. Further analyses confirmed that for both match, $F < 1$, and mismatch trials, $F(1, 19) = 1.34, \text{Mse} = 0.001, p > .250$, no significant differences arose relative to the appropriate control trials.

**Discussion**

The results of Experiment 5 replicated those of Experiment 4. Even in a randomized design, negative priming only occurred for ignored repetition trials in which the repeated item mismatched in terms of the selection feature from its prime to its probe.
presentation. Again, on match trials, nonsignificant positive rather than negative priming was observed. These results are entirely consistent with the selection-feature mismatch hypothesis of negative priming.

This pattern of findings was observed in both the referent size-selection task and the colour-selection task, although larger negative and positive priming resulted in the former than in the latter. It should be noted that even in the colour-selection task, the negative priming was much larger than the standard effect of approximately 15-25 ms (Fox, 1995). This is likely attributable to the fact that distractors received more/deeper processing with the changing selection criterion even when selection was based on a perceptual feature. The more difficult selection process ensured that distractors received more attention than occurs in the typical case where the selection feature is constant and known prior to the onset of every trial.

These findings refute both the distractor inhibition account (Houghton & Tipper, 1994; Tipper, 1985) and the episodic retrieval theory (Neill & Valdes, 1992; Neill et al., 1992) of negative priming. Despite differential processing of targets and distractors on both mismatch and match ignored repetition trials, negative priming only resulted in the presence of a selection-feature mismatch.

Experiment 6

The purpose of Experiment 6 was again to test the predictions of the selection-feature mismatch account of negative priming. Specifically, the intent was to investigate the effect of selection-feature mismatch in the attended repetition condition. Unlike the distractor inhibition and the episodic retrieval theories of negative priming, selection-feature mismatch predicts negative priming even in the attended repetition condition.
when the repeated target item mismatches in terms of the selection feature from prime to probe. The finding of negative priming in the attended repetition condition would be very surprising given that this condition is typically associated with faster responding (Scarborough et al., 1979; Tipper & Driver, 1988).

In Experiment 6, mismatch and match attended repetition trials as well as mismatch and match ignored repetition trials were included. As in Experiment 5, the effect of this manipulation was investigated using both the referent size-selection task and the standard colour-selection task. Mismatch and match trials of both types (i.e., ignored repetition and attended repetition) were presented randomly within the same block in each task.

**Method**

**Participants**

Twenty students in the introductory psychology class from the University of Toronto at Scarborough took part in this experiment. They all received bonus credit toward this course.

**Procedure**

As in Experiment 5, all participants performed both a referent size-selection task and a colour-selection task with order of tasks counterbalanced across participants. The procedures for each task were identical to those described and performed in Experiment 5. In Experiment 6, however, mismatch and match attended repetition trials were included in addition to the match and mismatch ignored repetition trials and the switch and non-switch control trials. Examples of the match and mismatch attended repetition trials and their corresponding control trials are presented in Figure 12.
Examples of match and mismatch attended repetition trials and the corresponding non-switch and switch control trials for the referent size-selection task (Panel A) and the colour-selection task (Panel B) of Experiment 6. In the size-selection task, large boxes cued participants to read the larger number in the pair whereas small boxes cued them to read the smaller number. In the colour-selection task, red boxes (represented by bold print) cued participants to read the red number whereas white boxes (represented by fine print) cued participants to read the white number. To assist the reader, in both panels, asterisks appear beside the correct targets.
match and mismatch ignored repetition trials are presented in Figure 8.

In the attended repetition condition, trials in which the selection criterion switched from prime to probe constituted the mismatch trials whereas trials in which the selection criterion remained the same across the prime and the probe were the match trials. This is opposite to what constitutes match and mismatch trials for the ignored repetition condition. The control trials in which the selection criterion switched from prime to probe served as the baseline for mismatch attended repetition trials. The control trials in which the selection criterion remained the same from prime to probe served as the baseline for the match attended repetition trials. Given this fact, the appropriate baselines for match and mismatch ignored and attended repetition trials were different. As will be explained in the General Discussion for Experiments 4 -- 6, this incidental difference is actually fortuitous as it eliminates selection-feature switching as a potential confounding factor.

Apparatus

The apparatus was identical to that used in Experiment 1A.

Stimuli

The stimuli were identical to those employed in Experiment 2B and Experiment 5. In Experiment 6, however, there were three conditions: ignored repetition, attended repetition, and control. As in previous experiments, in the ignored repetition condition, the prime distractor became the probe target and in the control condition, no stimuli repeated from prime display to probe display. In the attended repetition condition, the prime target subsequently reappeared as the probe target.

The stimulus assignments for the match and mismatch ignored repetition trials in
both the referent size-selection and the colour-selection tasks were the same as in Experiment 5. In Experiment 6, although the distribution of stimuli for both switch and non-switch control trials was proportional to that in Experiment 5, the exact numbers were doubled. That is, there were 48 non-switch control trials and 48 switch control trials in each task as opposed to 24 non-switch control trials and 24 switch control trials in each task of Experiment 5. The stimulus assignments for the attended repetition condition differed for match and mismatch trials in each of the tasks and will therefore be presented separately.

In the referent size-selection task, there were 24 mismatch and 24 match attended repetition trials, corresponding in number to the mismatch and match ignored repetition trials. In the match and mismatch conditions combined, all numbers appeared equally often—six times each—as the prime and the probe distractors. ONE and EIGHT each appeared four times as the prime and probe targets whereas TWO and SEVEN appeared six times each as prime and probe targets. The remaining numbers (i.e., THREE, FOUR, FIVE, and SIX) were presented seven times each as the prime target and the probe target.

In the colour-selection task, there were also 24 mismatch and 24 match attended repetition trials, paralleling the number of ignored repetition trials of each type. For the mismatch and match attended repetition trials combined, all items appeared six times in each of the four possible roles (i.e., prime target or distractor and probe target or distractor).

Results

Table 6 presents the mean latencies and error rates for Experiment 6 in both the referent size-selection and the colour-selection tasks. In the referent size-selection task,
large negative priming occurred for both the mismatch ignored repetition and the mismatch attended repetition trials relative to their respective control trials (i.e., relative to non-switch control trials for the mismatch ignored repetition trials and relative to switch control trials for the mismatch attended repetition trials). For both the match ignored repetition and attended repetition trials, however, positive priming resulted relative to the appropriate control condition for each (i.e., relative to switch trials for the match ignored repetition trials and relative to non-switch control trials for the match attended repetition trials). The results on the colour-selection task were analogous. Reliable negative priming only resulted for mismatch ignored repetition and attended repetition trials whereas it was eliminated for match ignored repetition and attended repetition trials. Figure 13 presents the difference scores.

Referent Size-Selection Task

*Ignored repetition condition.* A 2 X 2 repeated measures ANOVA was performed on the latency data resulting from the match and mismatch ignored repetition trials relative to the control trials in the referent size-selection task of Experiment 6. The variables were trial type (mismatch vs. match or non-switch vs. switch), and condition (ignored repetition vs. control). The main effects of condition and trial type were not significant, $F(1, 19) = 2.29$, $Mse = 6533.66$, $p > .120$, and $F < 1$, respectively. Critically, however, the Trial type X Condition interaction was significant, $F(1, 19) = 8.02$, $Mse = 4572.46$, $p < .05$, reflecting negative priming for the mismatch ignored repetition trials and positive priming for the match ignored repetition trials relative to their appropriate control trials. Although the negative priming was significant, $F(1, 19) = 10.35$, $Mse = 9521.85$, $p < .005$, the positive priming was not, $F(1, 19) < 1$. 
Table 6

Mean Response Times (ms), Error Rates (proportion), and (Standard Errors) Across Trial Types, Conditions and Tasks in Experiment 6.

<table>
<thead>
<tr>
<th></th>
<th>Size-selection</th>
<th>Colour-Selection</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>RT  (SE)</td>
<td>Err  (SE)</td>
</tr>
<tr>
<td><strong>Ignored Repetition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mismatch (non-switch)</td>
<td>1271 (45.43)</td>
<td>.044 (0.01)</td>
</tr>
<tr>
<td>Match (switch)</td>
<td>1241 (60.72)</td>
<td>.133 (0.02)</td>
</tr>
<tr>
<td><strong>Attended Repetition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mismatch (switch)</td>
<td>1320 (41.51)</td>
<td>.167 (0.03)</td>
</tr>
<tr>
<td>Match (non-switch)</td>
<td>1133 (43.17)</td>
<td>.043 (0.01)</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(non-Switch)</td>
<td>1202 (44.37)</td>
<td>.104 (0.01)</td>
</tr>
<tr>
<td>(switch)</td>
<td>1256 (51.88)</td>
<td>.111 (0.02)</td>
</tr>
</tbody>
</table>
Figure 13. Negative priming scores for the match and mismatch, ignored and attended repetition trials in the size-selection task and the colour-selection task of Experiment 6.
The corresponding ANOVA on the proportion of errors revealed that the main effect of condition was not significant, $F(1, 19) = 2.97$, $\text{Mse} = 0.002$, $p > .100$. The main effect of trial type was significant, however, $F(1, 19) = 6.42$, $\text{Mse} = 0.007$, $p < .05$, indicating more errors for match ignored repetition and switch control trials combined than for mismatch ignored repetition and non-switch control trials together. The Trial type X Condition interaction was also significant, $F(1, 19) = 14.45$, $\text{Mse} = 0.002$, $p < .005$, showing more errors for match ignored repetition trials and fewer errors for mismatch ignored repetition trials relative to their corresponding control trials. It would appear that the error findings are discrepant with the latency pattern. However, only the difference between the mismatch ignored repetition and the non-switch control trials was significant, $F(1, 19) = 28.19$, $\text{Mse} = 0.003$, $p < .001$, whereas the difference between the match ignored repetition and the switch control trials was not, $F(1, 19) = 1.47$, $\text{Mse} = 0.007$, $p > .200$.

**Attended repetition conditions.** A 2 X 2 repeated measures ANOVA was performed on the attended repetition latency data relative to the latencies arising in the control trials of Experiment 6. The variables were trial type (mismatch vs. match or switch vs. non-switch) and condition (attended repetition vs. control). The main effect of condition was not significant, $F < 1$, although the main effect of trial type was highly significant, $F(1, 19) = 25.49$, $\text{MSe} = 11345.33$, $p < .001$. The latter finding reflects the fact that participants were slower in responding on trials in which the selection criterion changed from the prime to the probe display (i.e., the mismatch attended repetition trials and the switch control trials). The Trial type X Condition interaction was also highly significant, $F(1, 19) = 31.21$, $\text{MSe} = 4563.18$, $p < .001$, caused by negative priming for
mismatch attended repetition trials and positive priming for the match attended repetition trials relative to their respective control trials. In this case, both the negative priming and the positive priming were significant, \( F(1, 19) = 8.35, \text{Mse} = 9754.48, p < .05 \) and \( F(1, 19) = 18.71, \text{MSe} = 4929.25, p < .001 \), respectively.

The ANOVA on the proportion of errors revealed an identical pattern of findings. There was no main effect of condition, \( F(1, 19) < 1 \). More errors occurred on mismatch attended repetition and switch control trials combined than on match attended repetition and non-switch control trials together, \( F(1, 19) = 18.69, \text{MSe} = 0.005, p < .001 \). Again, the Trial Type X Condition interaction was highly significant, \( F(1, 19) = 27.39, \text{MSe} = 0.002, p < .000 \), reflecting more errors for mismatch attended repetition trials and fewer errors for match attended repetition trials relative to their respective control trials. Thus the error data support the latency findings. As with the latency data, both trends were significant, \( F(1, 19) = 12.71, \text{MSe} = 0.005, p < .005 \), for the negative error priming on mismatch attended repetition trials, and \( F(1, 19) = 16.71, \text{MSe} = 0.004, p < .005 \), for the positive error priming on match attended repetition trials.

**Colour-Selection Task**

**Ignored repetition conditions.** With respect to the latency data in the colour-selection task, both the main effects of trial type, \( F(1, 19) = 54.13, \text{Mse} = 3230.37, p < .001 \), and condition, \( F(1, 19) = 11.45, \text{Mse} = 705.94, p < .005 \), were significant. Longer latencies were observed on trials in which the selection criterion changed (i.e., match ignored repetition and switch control trials) than on those in which it remained the same (i.e., mismatch ignored repetition trials and non-switch control trials). Further, responding was slower in the ignored repetition condition compared to the control
condition. The Trial type X Condition interaction was not significant, however. $F(1, 19) = 2.70, M_{se} = 1632.03, p > .100$. Nonetheless, significant negative priming was only revealed for mismatch negative priming trials relative to the appropriate control trials, $F(1, 19) = 11.59, M_{se} = 2107.21, p < .005$, whereas the small (5 ms) negative priming for match negative priming trials was not significant, $F < 1$.

With regard to errors in the colour-selection task, the main effects of trial type, $F(1, 19) = 10.87, M_{se} = 0.005, p < .005$, and condition, $F(1, 19) = 5.39, M_{se} = 0.001, p < .05$, were significant reflecting more errors on match ignored repetition and switch control trials combined than on mismatch ignored repetition and non-switch control trials combined. More errors also arose on control trials than on ignored repetition trials. This finding should be viewed in light of the significant Trial type X Condition interaction, $F(1, 19) = 7.62, M_{se} = 0.001, p < .05$, resulting from the fact that fewer errors occurred for the match ignored repetition trials relative to their appropriate baseline condition whereas mismatch ignored repetition trials did not differ in terms of errors from their respective control trials. This was supported by follow up tests in which significant positive error priming was found for match trials, $F(1, 19) = 8.09, M_{se} = 0.003, p < .05$, and no differences between mismatch ignored repetition trials and non-switch control trials. $F < 1$. Thus there was no suggestion of a speed-accuracy tradeoff.

**Attended repetition conditions.** The 2 X 2 ANOVA on the latency data of the attended repetition and control conditions in the colour-selection task revealed a significant main effect of trial type, $F(1, 19) = 45.08, M_{se} = 6622.27, p < .001$. This arose due to the longer latencies for mismatch attended repetition and switch control trials combined relative to match attended repetition and non-switch control trials.
combined. The main effect of condition was marginally significant, \( F(1, 19) = 3.36, \text{Mse} = 1360.08, p = .082 \), suggesting longer latencies in the attended repetition condition relative to the control condition. Finally, the Trial type X Condition interaction was significant, \( F(1, 19) = 5.10, \text{Mse} = 749.27, p < .05 \), reflecting negative priming for mismatch attended repetition trials relative to their appropriate control trials and no difference between match attended repetition trials and their respective control trials. The negative priming in the mismatch attended repetition condition was indeed significant, \( F(1, 19) = 8.96, \text{Mse} = 1871.63, p < .05 \), whereas match attended repetition trials and non-switch control trials did not differ significantly, \( F < 1 \).

With respect to errors, the main effect of trial type was significant, \( F(1, 19) = 17.61, \text{Mse} = 0.003, p < .001 \), revealing more errors on mismatch attended repetition and switch control trials relative to match attended repetition and non-switch control trials. The main effect of condition, \( F(1, 19) = 3.60, \text{Mse} = 0.001, p = .073 \), and the Trial type X Condition interaction, \( F(1, 19) = 3.37, \text{Mse} = 0.002, p = .082 \), were marginally significant. The former reflects the fact that more errors occurred in the control than in the attended repetition condition. The latter indicates fewer errors for the mismatch attended repetition trials relative to the switch control trials although there was no difference in terms of errors between match attended repetition trials and non-switch control trials. The error data pattern was not wholly supportive of the latency findings. However, the positive error priming for mismatch attended repetition trials, \( F < 1 \), was not significant and the slight negative priming for match attended repetition trials was only marginally significant, \( F(1, 19) = 4.23, \text{Mse} = 0.004, p = .054 \).
Discussion

The results of Experiment 6 support the selection-feature mismatch account of negative priming to the exclusion of all other accounts. Negative priming arose in all conditions where the repeated item was incongruent in terms of the selection feature from prime to probe. That is, in the ignored repetition condition as well as in the attended repetition condition, negative priming resulted on mismatch trials. This is uniquely predicted by the selection-feature mismatch hypothesis. Also as predicted by the selection-feature mismatch hypothesis, negative priming was eliminated when the repeated item was congruent in terms of the selection feature from prime to probe. That is, negative priming did not result in the match ignored or attended repetition conditions. This pattern of findings was obtained in both the referent size-selection and the standard colour-selection tasks of Experiment 6.

These findings are inconsistent with the distractor inhibition and the episodic retrieval accounts of negative priming. Negative priming arose in the mismatch attended repetition condition even though participants attended and responded to the repeated target item on both the prime and the probe trials. According to distractor inhibition, targets receive activation and distractors are inhibited in the course of processing. Negative priming is attributed to the inhibition of responses to the prime distractor, which subsequently appears as the probe target. Consequently, following from this theory, negative priming should not result for repeated targets regardless of feature mismatches from prime to probe. Addressing the episodic retrieval account, the repeated target item in both the mismatch and the match attended repetition conditions was encoded with compatible response instructions across the prime and the probe. Despite the lack of
conflict in terms of response information from prime to probe, negative priming resulted
in the mismatch attended repetition condition. Both theories fail to provide an adequate
explanation for this surprising result.

General Discussion of Experiments 4 – 6

Experiments 4 – 6 and the Larger Empirical Literature

The results of Experiments 4 – 6 are entirely consistent with the findings of Park
and Kanwisher (1994), Chiappe and MacLeod (1995), MacLeod, Chiappe, and Fox
(1999), and Experiments 1, 2, and 5 of Milliken et al. (1994). Also, in Experiments 1 and
3B of her Master’s thesis, Bates (1998) found results that were compatible with the
selection-feature mismatch account. She demonstrated that negative priming was
eliminated when the repeated item in the ignored repetition condition matched in terms of
the selection dimension from prime to probe. In all of these studies, negative priming
was observed only when there was a mismatch on the selection feature of the repeated
item across consecutive prime and probe displays.

The current findings are also consistent with a now common finding in the
negative priming literature. Namely, negative priming is eliminated for single-item probe
trials (but see Neill, Terry, & Valdes, 1994, for a contradictory finding). Lowe (1979)
first demonstrated this effect in a Stroop experiment. He found that negative priming was
eliminated if an incongruent Stroop stimulus was followed by a collection of same-
coloured dots even if the colour of the dots matched the ignored colour-word from the
previous trial (i.e., the ignored repetition condition). Tipper and Cranston (1985)
replicated this general finding, showing that positive not negative priming arose if a
single letter that had served as the distractor on the prime reappeared on the probe.
Moore (1994) similarly found that negative priming was eliminated for non-conflict probe trials in a letter identification task. Finally, Milliken et al. (1998) extended the finding by showing that negative priming was also eliminated if the single probe item was a word that previously had been the distractor on the prime.

This pattern of results is highly consistent with the selection-feature mismatch account of negative priming and therefore with the data presented in Experiments 4 – 6. The logic is straightforward. In the absence of selection on the probe trial, there is no selection feature and hence no opportunity for selection-feature mismatches. Consequently, negative priming would not be expected.

MacDonald and Joordens (1999) further demonstrated the importance of probe processing relative to prime processing. We investigated negative priming when the selection dimension on the prime (e.g., referent size) and the selection dimension on the probe (e.g., colour) differed. Negative priming was completely determined by the selection feature at the time of the probe. Regardless of the dimension on which prime items were selected, if the prime distractor was incidentally characterized by features that were incongruent with the selection feature on the probe (e.g., it appeared in white on the prime then was selected as the red item on the probe) negative priming arose. Clearly, as predicted by the selection-feature mismatch account, the retrieval processes engaged at the time of the probe are critical.

In line with these findings, selection at the time of the prime is unnecessary for the occurrence of negative priming. Recall that Milliken and Joordens (1996) conducted a study in which two prime stimuli were presented yet participants were instructed to respond selectively to neither. Despite this instruction, negative priming was observed.
Milliken et al. (1998) further demonstrated negative priming for single prime items that required neither an overt nor a covert response (i.e., Experiments 2A, 2B, and 2C). Negative priming emerged despite an obvious lack of selection on the prime trial. In both studies, selection on the probe was based on colour. Crucially for the selection-feature mismatch account, and consistent with the present findings, the repeated items mismatched in terms of colour between their prime and probe presentations. These findings again support selection-feature mismatch.

The selection-feature mismatch account—and consequently the current findings—are not uncontested in the literature, however. The results of Tipper and Cranston (1985), Experiments 3, 4, and 6 of Milliken et al. (1994), and to some extent Experiment 3 of Tipper et al. (1995) directly challenge selection-feature mismatch and are discrepant with the current findings. Potential explanations for the discrepancies are now considered.

Experiment 4 was most similar to the study carried out by Tipper and Cranston (1985). Targets were selected on the basis of identity and were named aloud, with match and mismatch trials occurring in separate blocks in the present Experiment 4, and in separate experiments in Tipper and Cranston’s study. In Experiment 4, the selection feature was relative referent size whereas in their study it was colour. Of course this difference cannot account for the disparity in these findings because, in subsequent experiments, the pattern of data obtained in Experiment 4 was replicated using colour as the basis for selection. Although in the colour-selection blocks of Experiments 5 and 6, match and mismatch trials were randomly presented, Chiappe and MacLeod (1995) and MacLeod, Chiappe, and Fox (1999) also obtained results that were perfectly in line with
selection-feature mismatch when colour was the selection dimension and match and mismatch trials were presented in separate blocks. Although Tipper and Cranston's critical experiment differed from Experiment 4 in a number of procedural details (e.g., using a list procedure rather than a single trial version of negative priming, briefly presenting primes then masking them rather than presenting primes until a response was given, and using letter stimuli as opposed to words), none of these details provide insight into a principled explanation for the divergent findings.

Experiments 5 and 6 resembled those of Milliken et al. (1994) and Tipper et al. (1995) in that the selection feature was cued on each trial, allowing match and mismatch trials to occur randomly within the same block. However, when the selection cue was presented simultaneously with the probe display in Experiments 3, 4, and 6 of Milliken et al., or slightly after the probe display (i.e., 57 ms) in Experiment 3 of Tipper et al., they failed to obtain the pattern of findings predicted by selection-feature mismatch. In the current Experiments 5 and 6, in contrast, presenting the selection cue and the probe display simultaneously produced results that were entirely consistent with selection-feature mismatch; only the presence or absence of mismatch determined the pattern of negative priming.

An obvious difference between their studies and the current set of experiments was the mode of responding. In Experiments 5 and 6, participants responded by reading the target word aloud, whereas participants in the Milliken et al. (1994) and Tipper et al. (1995) studies responded by moving a joystick in the direction of the target letter. However, the contention is not that this procedural difference accounts for the disparity in findings. More important, perhaps, there were only two possible stimulus locations (i.e.,
top and bottom) and on every trial both were occupied in the current experiments. In
Milliken et al. and Tipper et al., by contrast, there were always four possible stimulus
locations (i.e., top, bottom, right, and left) but only two were occupied on a given trial.
Interestingly, in the experiments producing the critical discrepancy, negative priming was
observed in all conditions where the probe stimulus appeared in a location that was
previously occupied on the prime trial. Rather than disputing the effect of selection-
feature mismatches, this pattern of results could simply reflect facilitated orienting
toward objects appearing in novel locations rather than true negative priming in the
match conditions. Contrary to the less parsimonious claim that negative priming results
on some occasions from inhibition of distractor locations and on others from feature
mismatches, the proposal here is that a confound in the critical experiments explains the
contradictory findings.

Recall that in the experiments where a central cue preceded the presentation of the
probe trial, the resulting negative priming conformed perfectly to the predictions of
selection-feature mismatch. The claim in essence is that presenting the pre-cue between
the prime trial and the probe trial, with all four locations unoccupied, eliminates the bias
in orienting toward the previously unoccupied positions. When there was a pre-cue, all
locations were equally novel and selection feature matches and mismatches determined
response times. In the pre-cue experiments, the pattern of negative priming that emerges
is that predicted by selection-feature mismatch and is consistent with the present findings
as well as with those of Park and Kanwisher (1994), Chiappe and MacLeod (1995),
MacLeod, Chiappe, and Fox (1999), and Bates (Experiments 1 and 3B, 1998).

Unfortunately, longer latencies are expected when the selection cue occurs
simultaneously with the experimental display compared to when the selection cue precedes the onset of the display. Further, the pre-cue versus simultaneous-cue conditions were conducted in separate experiments. Therefore, straightforward comparison of the latencies in the respective control conditions (i.e., pre-cue controls versus simultaneous-cue controls) which could differentiate the alternative interpretations was not possible. The opposing explanations of the findings, however, could be discriminated by conducting an experiment modeled on Milliken et al. (1994) in which all locations were occupied on probe trials.

Considering the larger empirical literature, however, other findings that challenge both selection-feature mismatch and the present data emerge. Milliken et al. (Experiment 4, 1998) revealed that attending versus ignoring on the prime trial can affect the pattern of negative priming. In a modification of their single-prime paradigm, they presented primes for a slightly longer duration (i.e., 200 ms) and instructed one group of participants to ignore the words and another group of participants to read the words covertly. Despite mismatches in terms of the selection feature from prime to probe for both the ‘ignore’ group and the ‘read’ group in the repeated word condition, only the ‘ignore’ group showed the predicted negative priming. Positive priming in fact resulted for the latter group.

These results are at odds with the findings of Experiment 6 of the present study. In Experiment 6, negative priming occurred in the attended repetition condition even though the repeated word was attended and read overtly on both the prime and the probe, as long as a mismatch was present in terms of the selection feature from the prime to the probe. Further, Wood and Milliken (1998) also provide evidence that negative priming
results for attended items and that negative priming is not the result of ignoring the repeated item at the time of the prime. Can these inconsistencies be resolved?

A procedural detail in Milliken et al. (Experiment 4, 1998; see also Bates, Experiments 3A & 3B, 1998), might hint at a possible explanation for the discrepant findings. In these single-prime experiments, the prime display appears very briefly (i.e., 33 ms in Experiments 2A, 2B, 2C, 3, or 200 ms in Experiment 4) and is post-masked for 500 ms before the onset of the probe display. Given the brevity of this presentation and the short interval between the prime and probe displays, the positive priming observed in the ‘read’ group might reflect the fact that the covert reading response remains in mid-production and consequently is highly available. Continuing activation of the repeated item as well as facilitation of the motor response, which are potentially more influential on response times than are feature mismatches in this instance, could account for the 19 ms of positive priming in this condition. Again, the alternative interpretations quite easily can be differentiated empirically by examining the effect of lengthening the prime-probe interval in the single-prime ‘read’ group.

Finally, somewhat at odds with the data presented here, as well as with the selection-feature mismatch account, Bates (Experiments 2 & 3a, 1998) presents evidence of a slowing on probe trials in the match condition, when an item is repeated from prime to probe on only 25% of the trials. The contention is that this proportion manipulation has the effect of discouraging the automatic retrieval process that normally operates on the probe trial, reducing both the facilitating effect of matches and the interfering effect of mismatches on processing. She states that: “...it seems possible that lowering the proportion of repeated trials might reasonably lower reliance on automatic retrieval
processes” (p. 37). Inconsistent with this claim, however, the negative priming observed in the mismatch case, when words repeat on only 25% of the trials is double the negative priming observed for the match case. Obviously, feature mismatches are being retrieved and are affecting response times. Even more convincing, however, the negative priming in the mismatch case when words are repeated only 25% of the time, is also double the negative priming that is observed in the mismatch case when repeated and unrepeated trials are equal (i.e., in Experiment 1). The latter result would suggest that reducing the proportion of repeated trials actually increases the tendency to retrieve prior instances of the repeated item or to rely upon that retrieval, but only in the mismatch case. Clearly, this is counterintuitive and quite unreasonable. Fortunately, another explanation for these findings is available.

The proposal is that the slowing in the 25% repeated-words match condition does not reflect negative priming. Rather, when the prime trial rarely predicts the probe target, it could be that participants are surprised by the repetition. Others have shown similar delays caused by expectancy effects (Neely, 1977; Posner & Snyder, 1975). In the mismatch case, however, in addition to the influence of expectancy, negative priming occurs due to the mismatch on the selection feature for the repeated item from prime to probe. This is consistent with the result that the delay was doubly long in the mismatch case compared to the match case.

**Theoretical Implications**

In Experiments 4 – 6, the selection-feature mismatch hypothesis of negative priming was strongly supported. According to this account, negative priming results from a mismatch in the selection feature of the repeated item from its prime to its probe
presentation. Indeed, negative priming arose only under this condition in all three experiments. Even when the repeated item was the target in both displays (i.e., in the attended repetition condition), negative priming arose if there was a mismatch in terms of the selection feature. When this discrepancy was eliminated, even when the repeated item served first as the distractor on the prime display (i.e., in the ignored repetition condition), positive rather than negative priming resulted. In fact, the only consistent predictor of negative priming in these three experiments was mismatch on the selection feature across the prime and the probe, which appears to be a necessary condition for the negative priming effect. These results clearly distinguish between the competing theories of negative priming, favoring the selection-feature mismatch account.

These results refute the distractor inhibition account of negative priming (Houghton. & Tipper, 1994; Houghton et al., 1996). According to this account, negative priming results from the inhibition of responses to the distractor at the time of the prime. Because of this lingering inhibition, when the repeated item reappears in the role of the target on the probe, a delay occurs during which the inhibition dissipates and until the item is boosted to target levels of activation. In all ignored repetition conditions of the three experiments, the distractor item on the prime trial was not selected for responding relative to the target and should presumably have been inhibited. Negative priming, therefore, should have occurred in all ignored repetition conditions according to the distractor inhibition account. Clearly it did not, appearing only when a mismatch on the selection feature was present. Given this failed prediction, these results call into question the inhibition view of negative priming. This account also can not explain the finding of negative priming in an attended repetition condition. This view does not predict the
inhibition of responses to targets yet negative priming arose in the mismatch attended repetition condition nonetheless. Slight modifications that would render this theory consistent with the present data are not readily apparent.

These findings are also at odds with the episodic retrieval theory of negative priming (Neill & Valdes, 1992; Neill et al., 1992). According to this account, negative priming results from the retrieval of response information that conflicts with the target status of the repeated item at the time of the probe. That is, during the prime, the critical item in the ignored repetition condition is encoded as a distractor with 'do not respond' instructions or with no response information at all. When the item reappears as the target on the probe, and past processing episodes are retrieved, the item’s current target status conflicts with its previous distractor status in terms of this response information. A delay ensues during which the conflict in response instructions is resolved. In Experiments 4 – 6, on both the match and the mismatch ignored repetition trials, the prime distractors should have been encoded with 'do not respond' instructions or with no response information at all. At the time of the probe, this information should have conflicted with the repeated item’s target status in the ignored repetition condition, delaying accurate responding. According to this view, negative priming should have resulted in all ignored repetition conditions. Further, upon retrieval of the prime episode at the time of the probe in the attended repetition conditions, the available congruent response instructions should have accelerated accurate responding regardless of mismatches in terms of the selection feature. Despite this fact, negative priming arose in the mismatch attended repetition condition. These findings contradict the episodic retrieval account of negative priming.
In defense of episodic retrieval, however, Neill (personal communication) contends that by switching the selection criterion from prime to probe on match ignored repetition trials and on mismatch attended repetition trials, the displays have been rendered sufficiently distinct that the initial prime encoding episode is not being retrieved at the time of the probe. On mismatch ignored repetition trials and on match attended repetition trials, however, because the processing context is identical across displays, the retrieval process at the time of the probe is highly successful. Therefore, only on mismatch ignored repetition trials will the conflicting response information consistently be available during probe processing whereas on match ignored repetition trials this information is not regularly retrieved. Conversely, the argument is that only on match attended repetition trials will the congruent response information be regularly retrieved at the time of the probe whereas on mismatch attended repetition trials retrieval failures occur. This would explain the absence of negative priming in the match ignored repetition condition. However, it would not explain the significant negative priming that arose in the mismatch attended repetition condition, in which the selection feature indeed switched from prime to probe. Further, in the referent size-selection task, where both distractors and targets are processed to a semantic level, it is unlikely that participants are unable to retrieve the immediately preceding prime episode despite these changes in the selection criterion.

Moreover, an opposite argument is equally plausible. That is, on match trials, the perceptual or semantic characteristics of the repeated item are identical across prime and probe. This congruency should in fact enhance retrieval of the previous presentation of the critical repeated item according to theories of transfer-appropriate processing (e.g.,
Roediger & McDermott, 1993). Following this logic, the episodic retrieval account would in fact expect larger negative priming on match than on mismatch trials. This of course was not the case.

Mismatch trials in the ignored repetition condition were accomplished by keeping the selection feature constant from prime to probe but mismatch trials in the attended repetition condition were achieved by switching the selection feature across the successive displays. Conversely, match trials in the ignored repetition condition were accomplished by switching the selection feature from prime to probe but match trials in the attended repetition condition were achieved by keeping the selection feature constant from prime to probe. Given this incidental difference between the ignored and attended repetition conditions, it was possible to rule out selection-feature switching as the cause of the pattern of negative priming obtained in this study. That is, negative priming occurred in both mismatch conditions but was eliminated in both match conditions even though the ignored repetition case and the attended repetition case differed in terms of whether the selection feature switched from prime to probe. In this manner, mismatch and selection-feature switching were unconfounded.

Larger Theoretical Frameworks that Emphasize Mismatches

Until now, the focus has been only on distractor inhibition, episodic retrieval, and selection-feature mismatch accounts of negative priming. Consider now, recent theoretical frameworks that attempt to explain negative priming as well as other related empirical phenomena. Milliken et al., (1998) have proposed the temporal discrimination theory and Neill and Mathis (1998) have proposed the transfer inappropriate processing-transfer appropriate processing (TIP-TAP) theory to this end. Interestingly, both
accounts incorporate aspects of mismatch.

**The Temporal Discrimination Account.** The temporal discrimination account (Milliken et al., 1998) attributes negative priming to a lengthened discrimination process at the time of the probe in the ignored repetition condition. Borrowing from the episodic-retrieval account, this theory of negative priming postulates that selective responding can arise from automatic retrieval of previously emitted responses or actions as well as from performing a slower algorithmic process of perceptual analysis with the goal of distinguishing targets from distractors (cf. Logan, 1988). Normally this faster automatic retrieval operates unless an orienting system alerts the observer that this operation is inappropriate for the present processing episode. In this event, perceptual processes are engaged.

According to this account, negative priming arises in the ignored repetition condition because of a lengthened decision process as to what type of processing is appropriate. Given that the probe target in this condition is in fact repeated, there is a tendency for this familiarity to engage the automatic retrieval process. Concurrently, however, the orienting system detects a discrepancy between the current probe episode and the previous prime episode suggesting that analytic processing is appropriate. This ambiguity in deciding whether to retrieve previous responses (or to rely upon that retrieval) versus to process information by more analytical means slows processing in the ignored repetition condition, producing the negative priming effect. In the control condition by contrast, the decision to proceed with processing by virtue of perceptual analysis is unambiguous. Conversely, in the attended repetition condition, it is clear that retrieving the prior response is appropriate, leading to very fast and accurate responses.
The temporal discrimination account gives no priority to discrepancies in terms of the selection feature from prime to probe. According to this account, negative priming should occur in all cases where the orienting system detects incongruent information with respect to the repeated item (i.e., in both ignored repetition conditions and in the mismatch attended repetition condition). According to temporal discrimination, negative priming should arise due to mismatches in terms of either selection and/or non-selection features of the repeated item from its prime to probe presentation. Despite congruency on the selection feature for repeated items on match ignored repetition trials, these items were incongruent in terms of response and other non-selection features (e.g., perceptual features in Experiment 4). Contrary to this prediction, negative priming only arose in the presence of a mismatch on the selection feature for the repeated item in the current experiments.

TIP-TAP. The most recent instantiation of the episodic retrieval account also incorporates premises of mismatch (Neill & Mathis, 1998). This modification of episodic retrieval, called the transfer inappropriate processing-transfer appropriate processing (TIP-TAP) theory, is a more general theory of cognitive processing that attempts to explain and unite various phenomena from the fields of visual attention and memory (e.g., negative priming, repetition blindness, inhibition of return). The theory delineates conditions that should give rise to interference or transfer inappropriate processing (TIP) and those that should yield facilitation or transfer appropriate processing (TAP). Within this theory, negative priming is a TIP phenomenon. Specifically, it is attributed to the retrieval of conflicting or irrelevant information from previous processing episodes. Although retrieval of discrepant features as well as response information from prime to
probe could yield negative priming according to this account, it emphasizes task-relevant processing mismatches. Further, in light of the findings of Wood and Milliken (1998) that negative priming can occur for objects that were attended on both the prime and the probe, TIP-TAP does not ascribe negative priming to differential processing of targets and distractors at the time of the prime. Given these modifications that bring it more in line with the selection-feature mismatch account, in addition to its emphasis on task relevant processing mismatches, this revised episodic retrieval theory of negative priming can accommodate the present findings.

Conclusion

The interest in the negative priming phenomenon originally stemmed from the belief that it provided evidence for a dual-process model of selective attention whereby relevant information was activated and irrelevant information was inhibited (Allport, Tipper, & Chmiel, 1985; Fox, 1994; Fox, 1995; Houghton & Tipper, 1994; Moore, 1994; Neill, 1977; 1979; Neill & Westberry, 1987; Neumann & DeSchepper, 1992; Tipper, 1985; Tipper & Cranston, 1985; Tipper, Weaver, Cameron, Brehaut, & Bastedo, 1991; Tipper, Lortie, & Baylis, 1992; Yee, 1991). The present findings as well as the evidence of others (Milliken & Joordens, 1996; Milliken et al., 1998; Wood & Milliken, 1998; Yee, et. al., 1996) deny this link. Negative priming does not result from the inhibition of distractors. Touted as a paradigm for exploring processes of selective attention, apparently negative priming sheds more light on automatic retrieval processes.

Negative priming does reveal that to-be-ignored information undergoes significant processing at the time of the prime, however. Distractor features—even those that are not relevant to processing (Bates, 1998; MacDonald & Joordens, 1999; Milliken
& Joordens, 1996; Milliken et al., 1998)—are encoded during the prime episode.

Whether this encoding reflects automatic, pre-attentive processing of truly unattended items, as would be predicted by late selection theories (e.g., Deutsch & Deutsch, 1963) and by the attenuation model of selective attention (i.e., Treisman, 1964), or whether it is due to quick shifts of attention (Allport et al., 1972), which would be consistent with early selection attention models (e.g., Broadbent, 1958), remains debatable. Nonetheless, despite participant’s intentions, they encode and store quite detailed information about irrelevant distractors even if the record might be fleeting (Neill & Valdes, 1992; Neill et al., 1992, but see DeSchepper & Treisman, 1996; Tipper et al., 1991).

Despite the claim that negative priming is not the result of a selective attention process, it appears that this small, somewhat unstable effect is easily masked by other attentional influences on response times (e.g., proportion manipulations, stimulus set manipulations, orienting biases). Negative priming arises from mismatches in terms of the selection feature from prime to probe. Whether these mismatches are available at the time of the probe, however, depends on attentional factors that affect both the encoding of the repeated item at the time of the prime (e.g., whether distractors are repeated and belong to a small stimulus set. Malley & Strayer, 1995; Strayer & Grison, 1999) as well as the retrieval of the critical item at the time of the probe. Minor alterations of the procedure can cause other facilitation or interference effects to attenuate the negative priming that is measured.

In conclusion, mismatch in terms of the selection feature is a necessary condition for negative priming. In the mismatch ignored repetition condition, the repeated item becomes associated with the distractor feature (e.g., ‘smaller’ or ‘white’ or ‘word’ or
‘top’) on the prime trial. At the time of the probe, this previous association with the non-target feature interferes with the necessary coupling of the repeated item and the current target concept (e.g., ‘larger’ or ‘red’ or ‘colour’ or ‘bottom’). Consequently, selection of the target at the time of the probe is delayed. The present findings further reveal that this discrepancy in the repeated item slows down processing irrespective of whether the repeated item was previously a target or a distractor on the prime. When this incongruence is eliminated, so is the negative priming. This compelling pattern of results suggests that a discrepancy on the processing dimension relevant to performing the selection task at the time of the probe is the primary determinant of negative priming.
References


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Memorv & Cognition, 16, 64-70.


