

On the Heterogeneity of Negative Priming Effects

by

John Christie

Submitted in partial fulfillment of the requirements  
for the degree of Doctor of Philosophy

at

Dalhousie University

Halifax, Nova Scotia

August, 2003

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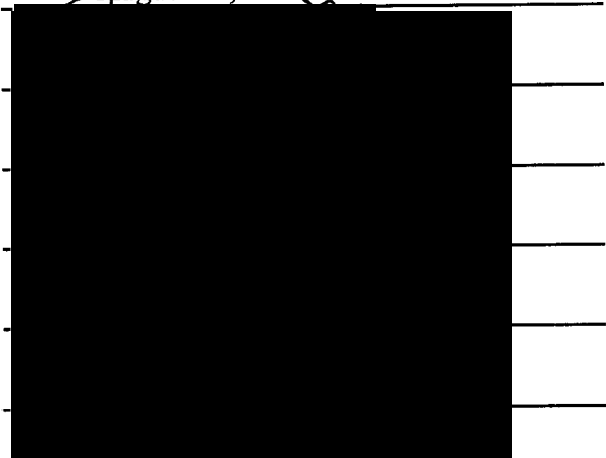
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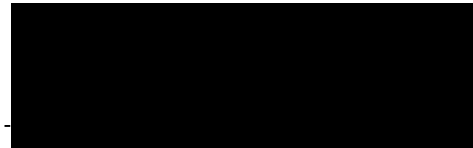
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Degree: Ph.D. Convocation: Fall Year: 2003

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## Abstract

Negative priming from ignored distractors is a phenomenon that typically occurs when one processes the target and distractor on one trial (prime) and then is presented with the prime distractor as a target on the next trial (probe). Performance is reduced compared to an unrelated Control condition in which the target and distractor are new. This finding has been reported using many different paradigms and various stimuli for the target and the distractor. A variety of theoretical frameworks have been developed that seek to explain this finding across the wide range of paradigms in which it has been explored. The theories treat the phenomenon as homogeneous but consideration of the methods and findings in this field suggest otherwise. The initial emphasis on attention as a causal mechanism, which, for many, made negative priming most interesting, has waned with the development of different explanations.

The current line of research was initially launched to investigate two hypotheses. One of these is that the various paradigms that are used to investigate negative priming from ignored distractors may not be tapping the same psychological mechanisms. The second is that it may be possible to isolate a particular paradigm where the negative priming is caused by a selective attention mechanism. In order to avoid confound and contingency problems all six of the possible prime and probe relationships were run, including the one typically used to measure negative priming. While puzzling over the best use for the data in the five extra conditions a pattern of performance was derived that can be interpreted as a signature of negative priming. The pattern uses the six related conditions and does not include the Control condition. There is a general consensus about this signature pattern, called the congruency principle here, among negative priming explanations. The congruency principle states that performance should worsen as the relationship becomes more incongruous (e.g., the distractor and target switch). And, it should improve as the relationship between prime and probe becomes more congruous (e.g., target and distractor both repeat).

The findings revealed that three of the most common paradigms for investigating negative priming, location, letter identity, and Stroop, probably have different causes. Furthermore, a biased version of the letter identity paradigm appears to have an attentional cause when measured using a subtraction from a Control condition. It was further found that, in the unbiased letter identification paradigm, negative priming could be measured using the congruency principle even though it was not present when measured using subtraction from the Control condition.

Negative priming is not homogeneous and sometimes it is caused by selective attention.

## Abbreviations and Symbols

RT.....	Reaction Time
TAP.....	Transfer Appropriate Processing
TIP.....	Transfer Inappropriate Processing
PLSD.....	Fisher's Protected Least Significant Difference
RSI.....	Response-Stimulus Interval
msec.....	Milliseconds
MSE.....	Mean Square Error
ANOVA.....	Analysis of Variance
SOA.....	Stimulus Onset Asynchrony
IOR.....	Inhibition of Return
D-.....	Distractor in the Prime
-D.....	Distractor in the probe
ND-.....	No Distractor in the Prime
-ND.....	No Distractor in the probe
Repeat.....	A probe trial wherein the items are the same as the prime
Target->Target.....	A probe trial wherein the target is the same as the prime
Distractor->Distractor...	A probe trial wherein the target is the same as the prime
Target->Distractor.....	A probe trial wherein the distractor is the same as the target was on the prime

## Abbreviations and Symbols (continued)

Distractor→Target..... A probe trial wherein the distractor is the same as  
the target was on the prime prime

Switch.....A probe trial wherein the prime target and distractor  
have switched location

## Acknowledgments

When finishing a long journey, with its various pitfalls, trials, and successes, one inevitably encounters a number of individuals to thank along the route. I couldn't possibly address them all in this brief statement. But, I hope I haven't missed any of the important ones.

Day to day I have needed support, especially as a single parent. I must thank my immediately family, particularly my parents and my sister-in-law Athena, for everything they did to support me and help with my loving son Jacob. And, I thank him for being there. He was an inspiration to me. Seeing his sweet face every day made me want to be more and accomplish more. I love him with all my heart.

Various research assistants have helped with the day to day tasks involved in the preparation of the document but none more than William Matheson. Near the end of this process Patti Devlin was also a very helpful assistant.

I encountered many student colleagues and instructors along the way that patiently discussed ideas with me and allowed me to dump loads of ideas onto them, often in an incomprehensible flood. Tracy Taylor, has been a stand out in this department. And, while our non work related contact is minimal I must take this time to let her know how much I have appreciated her. Billy Schmidt, was also a good friend while he was in the department and a great colleague.

Bruce Moore was probably the first instructor I encountered that drew me into the study of psychology. I fondly remember the work we did

together and his endless stories about his personal knowledge of the history of psychology. I enjoyed them all. I hope I didn't disappoint him too much by going into cognition.

Raymond Klein has been more than a supervisor. He is a man I both respect and look up to as a person and as a colleague. From the first day he never treated me as anything other than a colleague. While this may seem to conflict with his role as a teacher it does not because there are very few individuals that would not benefit from Ray's advice. His analytical mind and memory are simply unparalleled. He loves his job, his family, and is always willing to venture forward and try new things. His integrity rivals that of my own father. For all of these things and more I love him. When I leave his lab I will miss him a great deal. I hope that we continue to collaborate in the future. I know that I cannot ever thoroughly express all that he is and all that he has meant to me. But, I must say thank you.



## On the Heterogeneity of Negative Priming Effects

### What is Negative Priming?

Negative priming is a phenomenon first named by Neill (1977) who performed experiments based on a discovery by Dalrymple - Aylford & Budayr (1966). The term "negative priming" might easily be used to describe any negative performance caused by the previous presentation of an item. However, in this work it is used as a short form of the phrase "negative priming from ignored distractors".

The phenomenon that early researchers called negative priming was initially observed in modified Stroop (1935) experiments. In a Stroop experiment one is presented with a colour word in a specific ink colour. The participant's task is to name the ink colour. It turns out that if, for example, the word "RED" is written in the colour blue then it is very much more difficult to name the colour of the ink than if the word is just a nonsense string of letters. This effect varies along a continuum of word familiarity and colour name similarity (Klein, 1964). Negative priming occurs in the vocal Stroop paradigm when the target hue of the letters on trial N had been the distracting colour word on trial N-1. In this case performance will be slowed on trial N relative to a word and colour on that trial that share no properties with the word on trial N-1. The word is a distractor the participant attempts to ignore that subsequently becomes the target colour; hence, the descriptive title "negative priming from ignored distractors" which is typically shortened to negative priming. This is most commonly the intended meaning of the term negative priming in the psychological

literature (Neill & Mathis, 1998).

Neill (1977) reported the first explanation for this phenomenon. He theorized that it was caused by a selective inhibition mechanism. He suggested that in order to select the target colour one had to actively inhibit the distracting colour word. This inhibition of the word persisted for some time after the word was removed. If the target ink colour on the next trial was the same as that colour symbolized by the previous distracting word then negative priming would occur and performance would be impoverished.

After these initial studies the phenomenon was largely ignored until another decade passed and Tipper (1985) revisited the issue. Tipper endorsed negative priming as a way to study inhibitory effects in attention even though the only published study twixt his and Neill's (1977) that focused on the issue seriously challenged such an explanation (Lowe, 1979). Subsequent to Tipper's strong endorsement of negative priming as an attentional phenomenon the field exploded. The initial findings of negative priming in the Stroop paradigm were extended to many different experimental paradigms, and complete models of the phenomenon were proposed (a recent thorough review lies in Neill & Mathis, 1998 with a smaller, more current summary in Tipper, 2001). No longer is selective inhibition the single favorite explanation of negative priming. And, perhaps consequently, no longer is there as much excitement around the study of the phenomenon. In addition, two very important trends have persisted in that literature. One is that, in general, all negative priming experiments are thought to be tapping the same psychological mechanism. And the other is

that each of the explanations for negative priming claims to explain this single mechanism and how it relates to all findings of negative priming. In other words theories of negative priming explain all of the experiments that claim to be studying negative priming under a single rubric, with little consideration of the validity of the claims of negative priming, the commonality among the definitions of negative priming used, or the deviations in patterns of results among various paradigms.

While it is admirable that researchers in this field have attempted to attribute so much data from so many diverse paradigms to one explanation, it has also had the side effect of making it difficult to recognize when a result is not due to the current target having been an ignored distractor. The literature is not as homogeneous as one may be led to believe from the various reviews. This is primarily because extant reviews have been designed to support a given theory for how negative priming is caused and because reviews need to assimilate a large and unified set of data in order to justify their publication. A fragmented, unrelated group of findings does not support an easily published review, theory, or combination thereof.

There are many explanations for negative priming, 9 to be described here. It is possible that the proliferation of competing explanations for negative priming is because it has a number of causes. If negative priming has several possible causes then this may account for some of the heterogeneity that is found. It may also be possible to isolate and examine one of those causes within one paradigm. As the description of the history of the effect intimates, an attentional cause with inhibition would be the most interesting to find because that is the explanation of negative priming

that has prompted the most research.

Nevertheless, several of the explanations of negative priming, and two of the current leading ones, are passive with respect to attention. They rely on memory as the primary mechanism for the effect. However, because negative priming necessarily taps memory, memory manipulations would be expected to influence the effect. The performance deficit called negative priming is based on a memory trace of some kind that was encoded on a previous encounter. Even if attention or perception at the time of encoding were necessarily causal in generating negative priming within a given paradigm there could be a manipulation of memory that demonstrated that the causal perceptual or attentional mechanism is not the sole one operating. Demonstrating that the negative priming effect can be manipulated by modifications to encoding of the prime (e.g., masking), or recall on the probe (e.g. time, and similarity variables) does little to disprove hypotheses that do not rely on memory as the cause. They only demonstrate the necessary role of memory that is encapsulated in priming paradigms. A more concrete example may make this point clearer. Suppose that an inhibition process is required in the selection process and that the inhibition remains as a trace that affects future performance. The trace is subject to memorial manipulations. But, because the trace can be manipulated experimentally such that negative priming is reduced, perhaps eliminated, or even enhanced, does not mean that the trace is the primary mental cause of the effect. It is necessary for the effect, but it is the mechanism that generated the trace that is the proximal cause.

Tipper (2001) uses a similar argument to claim that a memorial and an

attentional explanation of negative priming are compatible with one another. There is a distinction between what he suggests and what is proposed here. Tipper's view is that the prime episode must be recalled in order for the initial attentional effect to influence the current processing. The present view is that there may, or may not be an episode at all that is recalled. Only a generalization of memory is proposed such that any trace can be called a memory. Admittedly this is a broad construal of what is meant by memory, but if one attempts to disrupt memories it is very likely that one will also disrupt traces on which something that could formally be called a memory would be based. This is not put forth in support of a specific theory but only as a generalization of Tipper's view.

One of the primary questions of this thesis is whether an attentional negative priming effect can be found. This can best be done by adding an attentional manipulation to a situation where negative priming does not usually occur. If negative priming appears because of the attentional manipulation then one can know the cause in that situation. There is good confidence going into this endeavor that at the very least non homogeneity of negative priming effects will be demonstrated. A quick comparison of letter identity negative priming in Neumann & DeSchepper (1991) or Stadler & Hogan (1995) with Stroop negative priming from Lowe (1979) confirms this guess. In those studies a large range of conditions is explored beyond the simple pair usually required for a claim of negative priming to be made. In spite of the fact that both experimental designs produce negative priming in the simple comparison between the condition where the prime distractor becomes the probe target and the unrelated control

condition, there is a significant difference in the entire pattern of results across other prime and probe relationships.

To summarize, negative priming has many explanations, and more than one may be true. Based on the history of study of the effect, the most interesting explanation is attention. Negative priming effects that have been found may not be homogeneous. Therefore, the proliferation of explanations may be directly related to the proliferation of paradigms. By testing a few broadly representative paradigms for an attentional effect, and for the commonality in data patterns, one may be able to test both homogeneity and attention at once.

#### Overview of Current Studies

Three specific paradigms will be explored. They were selected because, in some form or another, they are the most commonly used negative priming paradigms. The first of these is the location negative priming paradigm (Tipper, Brehaut & Driver, 1990). This is important because there is usually a robust negative priming effect, even in groups that don't show negative priming in other paradigms, such as the elderly (Connelly & Hasher, 1993; Kane, May, Hasher, Rahhal & Stoltzfus, 1997). In fact, Fox (1995) went so far as to assert that this type of negative priming may tap a different mechanism than other negative priming paradigms and Kane et al (1997) theorized that there are separate location and identity paths that are responsible for negative priming. An additional reason for selecting this paradigm is that Tipper et al (1990) claimed that "the majority of work in this area has examined situations that differ fundamentally from the ecological example of the predator"; and that location negative priming is

the most externally valid paradigm because it is most closely related to real world selection requirements. The negative priming in this paradigm appears to be very robust (there are no published cases of it failing). Therefore, the location paradigm is included partly because the demonstration of negative priming will be needed in at least one of the present paradigms in order to have a point of reference that links to the rest of the negative priming literature. Another reason it was conducted is that more than two paradigms will be needed to demonstrate a heterogeneity in the negative priming literature.

The second type of paradigm to be examined is letter identification (Tipper & Cranston, 1985). This is a very commonly used paradigm where one must identify the target letter in a pair of letters. The target is indicated by colour or a bar marker. What is interesting about this paradigm is that it is both ubiquitous in use and requires some interesting paradigmatic components to observe negative priming. Of importance in the present thesis will be examination of the fact that the negative priming effect is eliminated if there are only two letters and the target does not change location from trial to trial (Ruthruff & Miller, 1995). A variation of this procedure will be explored to see if the effect can be recovered through the manipulation of attention.

The third paradigm is the Stroop paradigm. This was the first task used to demonstrate negative priming and is still in common use today. The modification in which the response is pressing a button corresponding to the target colour (Neill, 1977; Neill & Westbury, 1987) will be explored here because, again, this paradigm does not produce negative priming without

some very specific paradigm parameters, whereas negative priming appears to be easily generated and measured with the vocal Stroop negative priming task (Dalrymple et al, 1966; Neill, 1977).

The specific versions of these latter two paradigms were selected primarily because on their face negative priming should occur given that they entail the basic manipulations of target and distractor across prime and probe. When negative priming does not appear one may be able to generate negative priming by manipulating attention. In this way an effect revealed primarily through manipulation of selective inhibition could be examined. The attentional manipulation that will be used is a form of cueing. The prime target will be predictive of the probe target. This should cause participants to maintain orienting toward the response assignment of the prime target (in these cases, colour, identity, or location) during the interval between the prime and probe. If the initial selection necessarily involves selective orienting away from the prime distractor, then causing one to maintain the prime selection state and carry it over to the probe should cause negative priming to be observed if the probe target is the same as, or contains an important component of, the prime distractor.

This method was used as a memorial manipulation in negative priming by Lowe (1979). For the moment it is sufficient to mention here that it is not a method that will increase memory for prime distractor items and is nearly identical to other attentional cueing methods (Posner & Snyder, 1975). This will be discussed at a later point (pp. 61-62).



### Measuring Negative Priming

The measurement of negative priming appears to be straight forward. One first designs an experiment in which participants must make a response indicating the perception of a property of a target that is presented accompanied by an interfering distractor. Measurement is usually accomplished by making certain that in the sequence of the trials there is a control condition in which there is no relationship between the prime and the probe trial, and a Distractor→Target condition in which the distractor property on the prime trial becomes the target property on the probe. If participants perform more poorly in the Distractor→Target condition than in the Control condition then you have negative priming from an ignored distractor. But, unfortunately, things are not this simple.

The most important, and oft neglected, point about measuring negative priming is that these two conditions alone cannot be used to directly attribute the deficit in performance in the Distractor→Target condition to the distractor's status as a distractor.

There are alternative causes for the cost in Distractor→Target that are not excluded by only running these two (Distractor→Target and Control) conditions. One alternative explanation is that probe performance may be impoverished if any stimulus from the prime trial is presented as a target on the probe. For example, target repetition (Target→Target) performance might be equally affected in a negative fashion as Distractor→Target performance. Tipper et al (1990, Experiment 2) explored this potential alternative cause in a location negative priming experiment. They added a Target→Target condition in which the prime target could reappear on the

Control trial. Unfortunately, for their purposes, the manipulation was confounded because Target→Target trials were more likely than would be expected by chance (0.33 v. 0.25), and may have biased participants to expect the repetition. Furthermore, there was no Target→Distractor condition, so any item that appeared in a prime target location must have been a target. Even if it were true that any prime item being presented as a target item on the probe hurt performance, the alternative they were testing, the cost in probe performance when targets repeat, may have been masked by attention being allocated to the target in advance because of the probability confound. In addition, there is the contingency that any stimulus in the previous prime target location was necessarily a target without the participant having to perform any further identification. This latter point is the other principal reason more conditions must be run than merely Distractor→Target, and Control. Without the complete set of prime and probe relationships, untoward contingencies can, and do, occur.

There are other important relationships to examine between prime and probe trials. They are especially important if one is attempting to explain priming effects in general. Most who have generated theories of negative priming have also used those theories to explain positive priming. They have attempted to explain the dynamics of sequences of events that contain targets and distractors – a conceptual effort praiseworthy for its attempt to obtain external validity. However, the explanations have typically only been applied to the prime and probe relationships of Target→Target and Distractor→Target. There are actually 6 kinds of related trials (see Table 1) that can be presented when one target and one distractor is presented on

every trial. If one wishes to explain negative priming in this context it behooves the theorist to explain all 6 of these relationships, demonstrating that the context itself is fully understood.

While the specific relationship between a given prime and probe trial will be described, these will also be assigned to two classes of relationships. The congruent class of relationships is one in which the probe trial contains an item from the prime presented in a way that corresponds with the prime presentation. The Target→Target condition is one example of such a trial where the probe target is congruent with the previous prime target presentation. The two others are Distractor→Distractor, wherein the distractor from the prime trial is the same as the distractor on the probe trial, and the Repeat condition where the probe trial is identical to the prime trial.

The other class of relationships is incongruent. The previously mentioned Distractor→Target condition is an example of an incongruent relationship. In all of these relationships there is an item on the probe trial that was previously on the prime, but is currently presented in a different way, or with a different classification. The other incongruent relationships are Target→Distractor, where the probe distractor is the same as the prime target, and the Switch relationship where the prime target and distractor items appear on the probe, but the distractor and target classifications are switched. The relationships are illustrated in Table 1 using examples from each of the negative priming paradigms to be examined here.

Table 1. These are examples of the main conditions that contain both targets and distractors in the experiments to be presented here. For the Stroop experiments the target is the ink colour and the distractor is the word. For the letter identity experiments the target is the letter adjacent to the "-", always on the left here, while the other letter is the distractor. In the location examples the target is the "0" and the distractor is the "+". Note that all trials are described in relationship to the prime on the first line. In addition, the first 3 probe trials represent the congruent relationships while the next 3 represent the incongruent relationships. The trials are also in order of descending congruency.

	Stroop	Letter Identity	Location
<u>Prime</u>	RED	-AC	_ 0 _ +
<hr/>			
<u>Congruent Probe Conditions</u>			
Repeat	RED	-AC	_ 0 _ +
Target→Target	BLUE	-AB	_ 0 + _
Distractor→Distractor	RED	-BC	0 _ _ +
<u>Incongruent Probe Conditions</u>			
Target→Distractor	GREEN	-BA	_ + 0 _
Distractor→Target	BLUE	-CB	_ _ + 0
Switch	GREEN	-CA	_ + _ 0
<u>Unrelated Probe Condition</u>			
Control	YELLOW	-BD	0 _ + _

These congruent and incongruent trial relationships are important later on for the explanation of the congruency principle where they will be expounded upon more fully. It will help to note the pattern in which trials are listed in all tables and graphs, such that the congruent relationships are listed first, followed by the incongruent relationships, and then the unrelated Control trial. The specific order used is that of descending congruency. See

the section on the congruency principle for further expansion of this idea.

Different patterns of results across these relationships suggest classes of explanations for findings of negative priming (i.e. Distractor→Target worse than Control). For example, it could well be true that any incongruent relationship hurts performance. If this is the case then only measuring the Distractor→Target relationship may lead to incorrect conclusions about the nature of mechanisms underlying the negative priming observed in that condition. Looking at the problem from a theoretical rather than empirical direction, one's explanation of the cause of negative priming may necessarily predict that performance will be impoverished in all incongruent conditions. In that case one would be better armed to defend one's theory if all of the conditions are run. Predicting a lawful organization of data is much more powerful than simply hypothesis testing (Meehl, 1990). Alternatively, there may be explanations that only predict that Distractor→Target relationships will show reduced performance. Merely confirming this fact provides a weak basis for favouring such an explanation. This is particularly true when finding reduced performance in other conditions would disconfirm such a theory.

Another reason to look at all of these conditions is that in a well designed experiment they will all be there. One of the best ways to make certain that there is no bias in the stimulus presentation whatsoever is to present every possible combination of the prime and probe stimuli. Given this constraint, all of the possible relationships will appear; however, they have been reported in only four papers (Connelly & Hasher, 1993; Lowe, 1979; Neumann & DeSchepper, 1991; Stadler & Hogan, 1996) out of well

over 100 surveyed for this thesis. Unfortunately, even though all of those conditions are reported in those papers it is unclear that they were run in an unbiased fashion in all instances. For example, Lowe (1979) balanced probabilities of the conditions described in column 1 of Table 1. This is problematic because there is a much lower probability of some conditions occurring than others based on random selection of stimuli. Given a specific prime, a Repeat condition can only happen in one specific way while there are two possible stimulus configurations that result in a "Control" condition. Neill (personal communication) ran all possible stimulus combinations through random selection in all of his earlier negative priming experiments (Neill, 1977, 1978). Stimuli were randomly selected and all of the possible prime and probe relationships could occur, with replacement. Unfortunately, the data from all of the relationships were not reported in the published papers.

Another interesting methodological issue that arises after analyzing the various related conditions, and considering alternative explanations, is that perhaps the unrelated condition should not be the exclusive control for measuring negative priming. A control condition should deviate from the experimental condition by as few properties as possible in order to assess the precise cause for the experimental effect. A more basic property of the Distractor→Target condition than the fact that a previous distractor property is now a target property is the mere fact that there is a relationship of some kind. The relationship is the most basic property of related trials. Therefore, other types of trials with relationships between the prime and the probe must be analyzed in order to convincingly demonstrate that any loss in

efficiency processing the Distractor→Target condition is unambiguously caused by the fact that the current target shares a property specific to the item that was previously a distractor. For example, the more general suggestion, as mentioned above, that the deficit in performance is merely because the current target item was previously presented, has a corollary. It may not even be necessary that the item be presented again as a target to hurt performance. Perhaps if the item is presented again as a distractor performance will be impoverished as well. In order to make a claim that negative priming from distractors is caused by the specific relationship transformation of the prime distractor to the probe target other relationships between prime and probe must be examined. Various relationships are needed as multiple controls for one another.

Another factor in the history of the measurement of negative priming is the way that responses are requested. Sometimes the paradigm involves withholding, but memorizing, the prime response and then performing it after the probe response (Driver & Tipper, 1989; Neumann & DeSchepper, 1991; Tipper, 1985; Tipper & Cranston, 1985; Tipper & Driver, 1988). In this instance the participant must explicitly hold the prime response in memory. Some theories of negative priming are heavily dependent on memory and propose that it is the contents of memory alone that cause the negative priming effect. An experimental design that requires the participant to hold the prime response in memory biases one towards such explanations since it necessarily enhances the impact of any manipulation of the memory of the prime items. Therefore, it will not be used in the present experiments.

In addition to relationships between the prime and the immediately following probe, one may be concerned about relationships in the long run. Sometimes trials are presented in one long sequence with no distinction between prime and probe pairs from the participant's point of view (e.g., Malley & Strayer, 1995; Neill, Valdes, Terry & Gorfein, 1992; Neill & Westbury, 1987; Strayer & Grison, 1999). In some of these studies the relationship of a probe trial to some trial more than one back is analyzed. Such an experimental design trials more than one back may contaminate immediate prime and probe relationships. The general mode of presentation in the present experiments will be to use discrete prime and probe pairings with feedback and trial initiation between prime and probe pairs. This method insures that relationships, or lack thereof, between any given prime and probe will be less contaminated by the experience of previous trials.

Given that presenting all possible prime and probe relationships is a natural consequence of good experimental design and because, as outlined above, the pattern of results across the entire set of relationships is necessary to confidently endorse one interpretation over another, all possible conditions (cf Table 1) will be used and reported in the experiments presented here. Furthermore, all prime and probe pairs will be presented discretely, and the participant will respond to the prime before encountering the probe. In addition, sometimes conditions with no distractor will be presented to verify distractor interference. However, this is not always the case when distractor interference is well established. There may be some other deviations from the above restrictions primarily to support comparisons with the established literature.



### Generation of Negative Priming

In order for a phenomenon to be measured it must first be generated. The principal way for one to generate negative priming is to present a sequence of trials where trial N-1 contains a target and distractor, and trial N contains the trial N-1 distractor as a target. However, this does not appear to be sufficient in all cases.

While many have designed experiments where deliberate manipulations were made to attempt to reduce or eliminate negative priming, to satisfy some hypothesis about its cause, factors initially believed to be irrelevant have also failed to produce negative priming. Ruthruff & Miller (1995) demonstrated that negative priming does not occur with a single target and distractor using letter identification if the letters do not change position from prime to probe. Tipper & Cranston (1985) showed that when position of items does randomly change from trial to trial negative priming is not present on those trials where the target does not change location from prime to probe. Strayer & Grison (1999) demonstrated that negative priming does not occur in word identification when the items are not repeated in the experiment. Neill (1977, 1978, Neill & Westbury, 1987) showed that negative priming does not occur in a Stroop paradigm with button press responses.

Given these rather ordinary failures of negative priming to occur it appears to be a somewhat elusive, or weak, phenomenon. These authors happened upon these manipulations in the examination of negative priming. On the surface these experiments should produce negative priming, and with small changes in the experiment design the effect can emerge. But because

the procedural variations that give rise to failures to observe negative priming are not consistent across paradigms general principles are difficult to derive.

Neumann & DeSchepper (1991), using letter identification, demonstrated that negative priming does occur when there is a relatively low frequency of stimulus repetition. This, to a degree, contradicts Malley & Strayer's (1995; Strayer & Grison, 1999) finding with words where negative priming did not occur when words did not repeat in the experiment. Furthermore, many experiments find negative priming using button press responses to indicate the identity of items, leaving the lack of an effect with button presses exclusively to the Stroop paradigm. Stroop items rarely change location from trial to trial, which demonstrates that the Ruthruff & Miller findings of changing location do not extend to the vocal Stroop paradigm. Thus, each of these paradigms has particular quirks. Perhaps, even though there is a cost in the Distractor→Target condition that can be generated in all of these paradigms, there may not be a single general pattern of results that extends to other prime-probe relationships. If the pattern of results that occurs in conditions with other relationships is not similar across paradigms then perhaps the Distractor→Target costs have different causes and explanations. If that is the case, then attempting to understand all of them through a single explanation, or even a unifying class of explanations, may be misguided.

In the present paper negative priming will be generated in the conventional fashion, but will be measured in multiple ways. This is explored more fully in the section on the congruency principle.

Negative priming like effects that are not caused by ignored prime distractors

As stated from the outset, the present thesis is concerned with negative priming from ignored distractors. It is critical that the negative priming is attributable to the fact that the current target was previously a prime distractor and not some other property, such as merely having been presented before. Few researchers, however, have made this distinction explicit.

In no way should the present construal of the use of the term negative priming be considered limiting in terms of what can be explored. There may be other paradigms where an item is presented and then a negative effect occurs that is related to negative priming from ignored distractors. However, the contention here is that merely because a negative effect has been found in a priming paradigm does not mean the effect is related to negative priming from ignored distractors.

Dagenbach, Carr & Wilhelmsen (1989) generated a priming effect that was negative using subliminal primes. In a lexical decision task participants were presented with a subliminal prime shortly before the target item. Responding to the lexicality of a letter string was slowed when the limen for the prime was determined using semantic matching. In the same experiment with other liminal thresholds, such as perceptual ones, this effect was not found. At all times the participants were encouraged to attend to any stimuli presented. There was no distractor on the prime and there was no request from the experimenters to ignore the prime item. This finding

may reveal an effect that is highly related to negative priming from ignored distractors. However, it does not follow from the method that this is necessarily the case and further tests would need to be performed to make certain that the effects are related. Milliken, Joordens, Merikle & Seiffert (1998) have constructed an entire theory of negative priming around findings similar to those of Dagenbach et al (1989). However, in their experiments they did encourage participants to ignore the prime item, which may make their findings more relevant to negative priming from ignored distractors. Unfortunately, the success in generating an effect of ignoring a masked prime has not been reliably replicated (Neill & Kahan, 1999). This is understandable given that Dagenbach et al clearly demonstrated that it will only occur under very specific masking conditions.

Another paradigm in which a negative effect has occurred and the priming was not from an ignored distractor is the task used by MacDonald, Joordens, & Seergobin (1999; MacDonald & Joordens, 2000). MacDonald et al had participants determine a relative property of two items. The words "elephant" and "mouse" might be displayed and the participant was to judge which of the items was larger. There is certainly a response item and a non response item, but the non response item is not an ignored distractor. It is a fully attended and necessary stimulus used to determine which item is the target item. Up until late in the processing of the stimuli the non response item is a candidate for response and cannot be rejected based on any intrinsic properties, only relative ones. Again, the authors attempted to construct a theory of negative priming from one novel paradigm that does not contain any distractors and that may have no relationship whatsoever to

negative priming from ignored distractors.

Furthermore, due to some design flaws, it has been found that the comparison paradigm used may not even be producing a Distractor→Target cost in the first place. A unique property of the Distractor→Target condition in these experiments is that the probe target can never be an item from the extremes of the comparison set. For example, if one is comparing numbers from 1 through 6, and the task is to select the smallest one, then the smallest distractor is 2 with a target of 1. Moreover, in a Distractor→Target condition the smallest target is 2 because it must be the prime distractor. In these kinds of decision tasks participants perform best when the target is the extreme of the range because a comparison need not be made, nor even identification of the distractor. The problem in these experiments is that while the target at the extreme of the possible range does not occur in the Distractor→Target condition, it does occur in Control. Thus, any differences found between the two conditions could all be due to this one type of trial. Mackintosh, Mathews & Holden (2002) controlled for this confound and verified that negative priming does not occur, or is at least greatly reduced.

Paradigms such as those mentioned above will not be used in the present thesis to explore negative priming from ignored distractors. But they will be referred to if good evidence can be found to show that they are related to negative priming from ignored distractors, or if a good candidate explanation of negative priming from ignored distractors also predicts the results in those paradigms.

### The Congruency Principle

With rare exceptions, all explanations of negative priming are all encompassing. It is treated as a phenomenon with a single cause. The explanations fall into two primary classes. One of these classes gives preeminence to the active process of selection on the prime and the psychological mechanisms related to attention. Selection on the prime is considered the cause of negative priming and is highly related to early explanations of priming effects where the cause is an automatic spreading of activation (Neely, 1976, 1977). The other class treats the selection on the prime as somewhat irrelevant and ascribes the negative priming effect to the nature of the encoded memory trace of the prime and its interaction with the probe trial. This class is more varied and takes on a number of forms but the explanations all essentially have the flavor of refuting the first class.

In the present work a different kind of classification of negative priming theories will also be presented. This is a very simple method and data based classification, as opposed to a theoretical one. No specific psychological mechanisms are necessarily implicated but it can be useful for parsing the space that explanations need to cover. This is the congruency principle.

As was mentioned previously, the relationships between prime and probe can be either congruent or incongruent. In Table 1 the top three probe trials listed are congruent, Repeat, Target→Target, and Distractor→Distractor, while the next three are incongruent, Target→Distractor, Distractor→Target, and Switch. Congruent probe trials are ones in which a probe item appears in the same way that it did on the

prime trial while incongruent probe trials are ones in which an item from the prime appears again on the probe, but is changed from Target to Distractor or from Distractor to Target. The Control condition, which is unrelated, is outside the scope of the congruency principle and is addressed separately.

One may generate a hypothesis about this fundamental pattern in the relationships, and one is proposed here. The congruency principle states that, if the relationship between the prime and the probe is congruent then performance will improve, while if the relationship between the prime and the probe is incongruent then performance will worsen. All of the theories of negative priming can be classified by the degree to which they predict or are compatible with a congruency principle.

Congruency is primarily about the relationship between relevant stimuli and behaviour and not about stimuli per se. In a given experiment on negative priming a novel design may be generated in which there are stimulus inconsistencies across a parameter that is irrelevant to the behaviour required. Some exceptional research designs exist in the literature that may appear troublesome for the congruency principle. For example, some authors have chosen to change the selection rule from prime to probe either dynamically (Milliken, Tipper, & Weaver, 1994), or in a fixed manner (Tipper, Weaver & Milliken, 1995). In these experiments the rule for target selection changes from prime to probe so that identical prime and probe stimuli can be used as different targets and distractors. Therefore, from a purely stimulus based standpoint, the items may appear to contain perfectly congruent relationships that would be expected in a Repeat condition, but are actually the most incongruent, and constitute a Switch

condition in terms of required behaviour. And, of course the opposite can occur, where the stimuli are very different but a response must be repeated.

At first, it appears that these kinds of experiments are outside the scope of congruency principle. But, because they are accepted manipulations in negative priming experiments, they actually teach one something about the most important components of the congruency principle. They imply strong assumptions that the most important part of the negative priming effect is what the participant must do with the stimuli, as opposed to the stimuli themselves. Therefore, if on trial N one must classify a red "A" as a target, and a green "B" as a distractor then a congruent repeat trial may involve classifying a red "A" as a target, and a green "B" as a distractor, or if the colour selection rule reverses from prime to probe the participant may have to classify a green "A" as a target and a red "B" as a distractor. The probe stimuli change but both are related, in action, in the same way to the prime trial. This is a point also made in letter identity tasks where the locations of the items change. If the locations change, then, even if the items are the same, the stimulus similarity will not be as high as if the locations stayed the same. However, because the congruency is primarily about behaviour, with stimulation a secondary influence, if the task was to identify the items, and the items remained the same in identity then it does not matter that they change location for the congruency hypothesis. Also, one must note that the task applies to both overt actions taken and covert actions not taken. In the Distractor→Distractor condition there is a new target action that is taken but there is a relationship between the distractors that is congruent where the



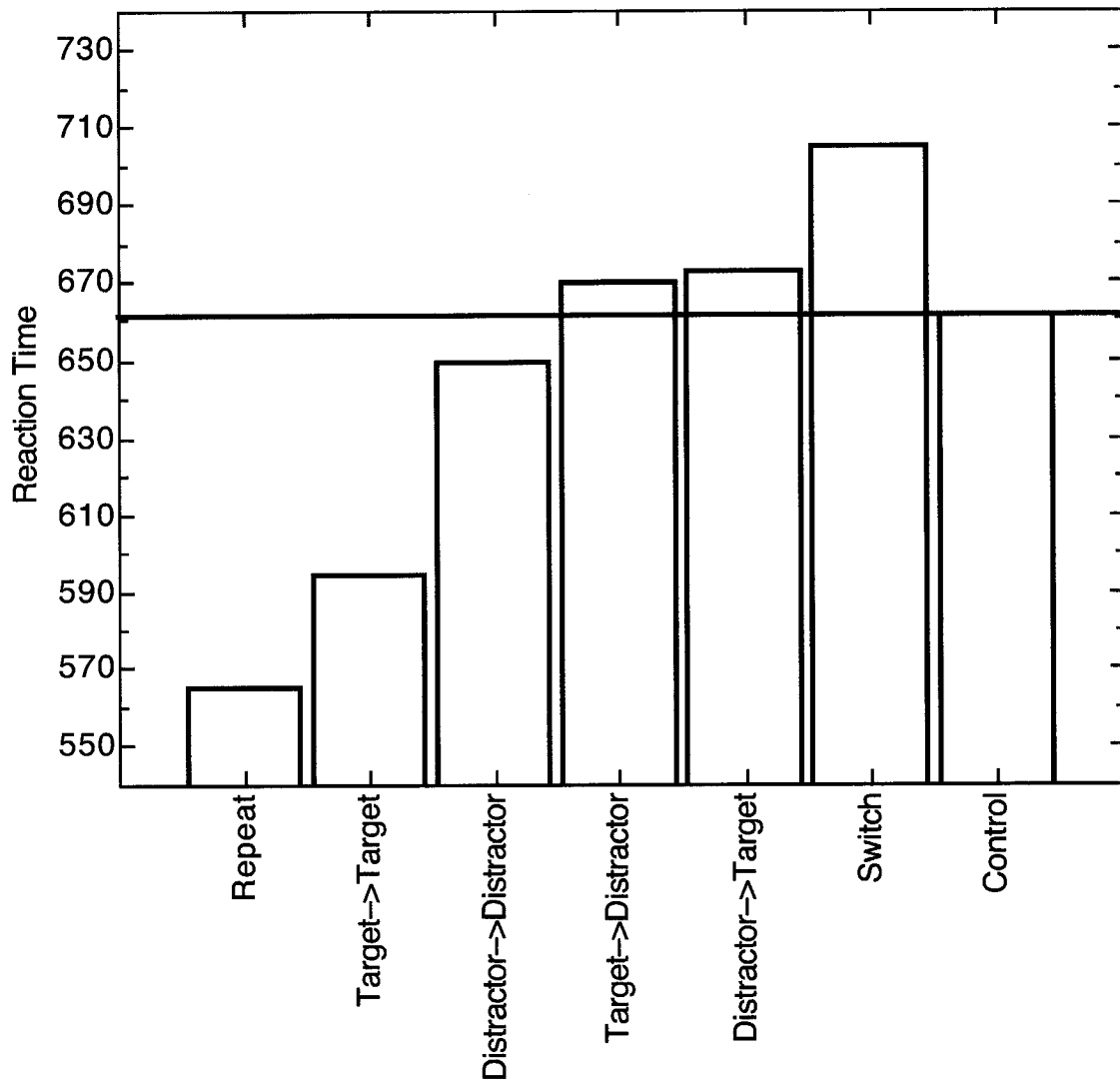
same specific inaction is also taken.

As an aside, a note about experiments with changing rules for prime and probe trials is in order. Negative priming experiments are all about sequence analysis and how one trial can influence a following one. They differ from ordinary priming experiments because the critical factor is supposed to be what a participant did with the current stimuli on a previous trial, whereas priming experiments typically do not require the participant to take any action toward, or even perceive, the prime stimulus. Because of this difference, rule changes about the behaviour required for stimuli between prime and probe make experiments difficult to interpret. That is because what one is doing with stimuli on the probe has changed globally from the prime and the effects of those prime stimuli may change with respect to the new context generated by the rule change. This is true whether a fixed rule is used to change performance from prime to probe or when an indicator for the rule change allows for a varying rules experiment. In Milliken et al (1994) participants could receive the selection rule simultaneous with the stimuli or prior to the stimuli. Milliken et al suggested that the drop in performance with simultaneous presentation was due to increased interference from the distractor. But more properly this should be considered delayed determination of what the target and distractor actually are. In addition, with rule cue onset simultaneous with stimulus onset, the stimuli receive some processing prior to any ability on the participant's part to determine the target and distractor. Moreover, when the cue to the selection requirement is presented in advance, then the participant may modify the contents of memory by noting that a previously ignored

item would now be a target and making the prime distractor more salient. There are so many problems with rule change methods that they are not endorsed here and are only mentioned to illustrate more specifically what is meant by congruent and incongruent in the congruency principle.

Further expansion of the congruency principle will allow rank ordering of all of the related conditions. It is possible to predict that there will be relative magnitudes of the congruency and incongruency effects. Each relationship and its relative magnitude will be considered in turn. These are illustrated in Figure 1 and described below. Note, that Figure 1 is not hypothetical data, but a reprint of the data from Stadler & Hogan (1996). This, and, to a lesser degree, Neumann & DeSchepper (1991) are the only 2 instances of such a pattern of data in the entire negative priming literature. There are only 4 studies of the 140 that I have reviewed that present enough data to verify this congruency effect. Both of the studies that report a congruency effect use a letter identity paradigm similar to the one that will be used here. In one of the instances in which there is no congruency effect the location paradigm is used (Connelly & Hasher, 1993), and in the other Stroop is the method (Lowe, 1979).

Stadler &amp; Hogan, 1996



**Figure 1.** Reaction time data from a negative priming experiment in Stadler & Hogan (1996). It was a letter identity experiment where the letters were free to change location from prime to probe.

The Repeat condition, where all items are the same from prime to probe, should have the strongest positive congruency effect. Performance will be improved the most because it has the most congruency.

Alternatively, the Switch condition is the most incongruent prime-probe

relationship and performance should be worst there. The other conditions have smaller effects than these, but they are still ordered by congruency and the differential potential effects of targets and distractors on current trial performance.

In order to better understand the reason for ordering of items, especially the Target→Distractor and Distractor→Target conditions, it is important to consider the interference effect. In the general paradigm under discussion distractors affect performance in a negative way. Simply put, if there was no distractor on a trial then performance would be better. This is called the interference effect. While the congruency principle itself makes no predictions about the magnitudes of effects that distractor and target congruency can have, the interference effect does. Processing of the target directly affects performance while processing of the distractor only indirectly affects performance to the degree to which it interferes with target processing. If there is a positive congruency then the degree to which it can affect performance differs depending on whether the congruency is that of the distractor or that of the target. If the target is congruent then performance can be directly improved by some amount. If the distractor is congruent then performance can be improved only by an amount that is less than the amount of distractor interference. Therefore, the effects on performance of Target→Target congruence will be stronger than for Distractor→Distractor congruency. Moreover, the performance on the probe trial can be directly affected by a Distractor→Target incongruency, but only indirectly influenced by a Target→Distractor incongruency. Therefore, the Target→Distractor incongruency will degrade performance

to a lesser degree than the Distractor→Target incongruency.

In summary, under the congruency principle, the order of performance for related trials, from best to worst, will be Repeat, Target→Target, Distractor→Distractor, Target→Distractor, Distractor→Target, and Switch. The Control condition would ideally fall between the poorest congruent trial, Distractor→Distractor, and the best incongruent trial Target→Distractor. However, the congruency principle is about related trials and cannot speak to the exact position of the Control condition. Therefore, it is possible for the Control condition to not be in the center between congruent and incongruent trials, while the congruency principle is still fulfilled. Interestingly, as will be shown below, several theories of negative priming do not necessarily predict what Control condition performance will be with respect to related trials, although all theorists have assumed that it will be better than Distractor→Target.

Nine explanations of negative priming and compatibility of their predictions with the congruency principle

There is a range in the degree of compatibility a given theory will have with the congruency principle. Strongly compatible theories have a relationship to the congruency principle wherein the data predicted by the principle necessarily follows from the theory. Therefore, if the congruency principle is not upheld in the data when the theory strongly predicts that it is true, then the theory should be rejected. Weakly compatible theories are not necessarily refuted or supported by the congruency principle because they may be neutral with regard to some subset of the congruency effects or may

have already built in an exception that handles deviations from the congruency principle. Neutral theories do not have a necessary relationship to the congruency principle and allow for significant deviation from its predictions.

There are nine explanations of negative priming that will be discussed here. Some are minor; however, each will be considered separately in terms of its relationship to the congruency principle. Table 2 lists the theories and their relationship to the congruency principle. It is apparent that the predictions of the bulk of negative priming theories bear some relationship to the congruency principle and for many the relationship is strong. This is primarily because the results upon which the theories are based, that Target→Target is better than Control and Distractor→Target is worse, follow the congruency principle.

Table 2. Nine negative priming explanations, their relationship to the congruency principle, and the paper in which they are first described. All of the explanations of negative priming to some degree predict that the congruency principle should be true.

Theory	Congruency Relationship	First used to explain negative priming
Selective Inhibition	weak	Neill (1977)
Code-Coordination	weak	Lowe (1985)
Selective Inhibition Model	strong	Houghton & Tipper (1994)
Dual Channel	weak	Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein (1993)
Episodic Retrieval	strong	Neill et al (1992)
TIP/TAP	strong	Neill & Mathis (1998)
Hesitation	strong	Milliken et al (1998)
Perceptual Mismatch	strong	Park & Kanwisher (1994)
Selection Mismatch	strong	MacDonald et al (1999)

As can be seen above, the congruency principle is so commonly predicted by negative priming theories that serious violations of it, even if the traditional Distractor→Target cost is found, may bring into question whether that cost is a negative priming effect based solely on consensus of the theories. In fact, while all of the theories above predict that the complete congruency principle will be true to varying degrees certainty they all explicitly predict a specific subset of the congruency principle's relations strongly. Specifically, they predict that Distractor→Target will be worse than Target→Target. In addition, all of the theorists predict that performance in the Control condition will fall between these two, even though that prediction may not necessarily fall out of the theory. This particular pattern is so well agreed upon that if it is not found to be generally true in a specific paradigm then one can safely say, by consensus of the theorists, that negative priming has not occurred within that paradigm.

A description of the specific properties of items in the paradigms studied in this paper is important, because congruency does not exactly appear the same when viewed from within these paradigms. Most importantly, because congruency is about behaviour, just as is negative priming, the task required within the experimental design defines what kind of congruency or negative priming is being studied.

In the Stroop paradigm congruency is about colours because the *task* is about identifying colours. If the prime and probe target colours match then the items are congruent. This is true whether the actual representation of those colours changes from prime to probe or not. For example, someone

might have implemented an experiment where the probe was a reverse Stroop task where one had to name the word instead of the colour. As long as that target and distractor colours are the same, regardless of their representation, then the items would be congruent. Similarly, for letter identity experiments the letter identity defines congruency and not its selection property (colour or location). Also, in location experiments, target location is the property whose congruency is being examined.

The physical locus of processing of these different item congruencies cuts across very different brain representations. This is especially true given that locations and identities are considered to have fundamentally different paths in the brain, with location information more parietal and identity processing primarily temporal. Also, verbal information uses left frontal areas (Heil, Rösler, & Hennighausen, 1996). If the same congruency principle can be applied broadly over various paths it would demonstrate that each one was tapping the same central mechanisms, or common and redundant mechanisms, in the kind of sequential analysis found in negative priming tasks.

As a final note about the congruency principle, and a warning to the reader, it will later be argued that the necessity of the Distractor→Target performance being worse than Control in order to observe negative priming is an erroneous requirement under some theories of negative priming. In particular, it will be argued that results in accord with the congruency principle are sufficient to demonstrate that negative priming has occurred.

What follows is a description of how each of the explanations in Table 2 fits into the congruency principle framework. It will be noted how



each theory can explain the prime and probe relationships. It will also be explicitly noted whether the Control condition is necessarily predicted to fall between congruent and incongruent relationships in performance. This analysis of the location of the Control condition is given with respect to the principles of the theory that have been elaborated, and not necessarily with respect to the claims of the researchers about the position of the Control condition.

### Selective Inhibition Theory

The first offering of an account of negative priming is the selective inhibition account (Neill 1977; Tipper, 1985). This explanation for negative priming is that target selection is accomplished by attending toward the target item and away from the distractor item, or activating the target and inhibiting the distractor. The residual effect of inhibition of the prime distractor makes it more difficult to process as the probe target and a performance deficit ensues.

While the original authors never proposed an explanation complete enough to compare with the congruency principle, one can be derived from the fundamental explanation. If the target activation or distractor inhibition pattern is matched then performance will be improved. Repeat, Target→Target, and Distractor→Distractor performance will be improved because the pattern of activation, inhibition, or both is matched and does not need to be reestablished. The target will already be activated above a resting level, and the distractor will already be inhibited below a resting level.

However, all of the incongruent trials have conflicting patterns of activation. The Distractor→Target incongruency is the only one

specifically mentioned in the theory. But, the Target→Distractor incongruency should also result in a performance decrement because the distractor on the probe will be more highly activated, and therefore interfere more. The Switch incongruency should result in even worse performance because it is a combination of the other incongruencies. On the switch trial the probe target is inhibited, and the distractor is activated, making the task more difficult.

Because all of these relationships are about stimulus activation levels relative to a neutral level of activation the selective inhibition hypothesis predicts that the Control condition will fall in the center, between congruent and incongruent performance. Under this initial construal of selective inhibition the pattern will follow that predicted by the congruency principle, including an additional strong prediction for the position of the Control condition. The order is Repeat < Target→Target < Distractor→Distractor < Control < Target→Distractor < Distractor→Target < Switch.

From the explanation given above one might conclude that there is a strong congruency principle relationship. However, in Table 2 the selective inhibition is listed as weakly related to the congruency principle. This is because the original hypothesis was modified to account for an apparently conflicting result (Neill, 1978).

It turns out that in a vocal Stroop negative priming experiment performance on the Target→Distractor trial is better than control. Because of this it was hypothesized that the selective inhibition that occurs is late in the selection process and post identification of the items. Late selection was found to be necessary for negative priming by Lavie & Fox (2000) in a

direct test of negative priming using stimuli that are thought to evoke late or early selection mechanisms through a perceptual load manipulation. Neill (1978) proposed that negative priming was caused by inhibition of the distracting item after its identification, and in the process of decision, response selection, or both. Therefore, in contrast to a congruency principle, any item of heightened activation or saliency would be identified faster and speed the selection process. A target from a prime trial that became a distractor on a probe would improve performance because it was identified more quickly, thus making its rejection more efficient. Neill did not test or discuss the logical corollary, that if the distractor is harder to identify (Distractor→Distractor) then performance will be worse.

One might note that this hypothesis about the way late selection works is in stark contrast to the way the interference effect in Stroop experiments changes when the saliency of the stimulus components is manipulated. Melara & Mounts (1993) found that when the salience of the distractor word was reduced the Stroop effect also diminished. Neill's (1978) hypothesis might predict that because the distractor was harder to process interference might increase. However, one should be careful when drawing analogies between actual stimulus saliency and latent cognitive activation that is measured in priming. The former can attract attention and provides continuous input to the system whereas the latter does not. It is possible that when the stimuli are highly salient because of latent activation they do not attract attention and one can more easily ignore them because there is no external source maintaining activation levels. In addition, if the stimuli are less salient they may be more easily recognized due to activation (Neely,

1976, 1977).

Given that this exception is already built into the theory, however ad hoc, one can only conclude that there is a weak relationship to a congruency principle.

One important point to note is how the traces of attentional activation and inhibition relate to memory. Houghton et al (1994) explicitly stated that the activation and inhibition states were part of an episode that is retrieved on the probe. This thinking is more properly part of the selective inhibition model rather than the selective inhibition theory. It is difficult to infer what the theorists originally intended by this with respect to memory, but one can easily imagine that regardless of explicit reports otherwise, the actual model and the theory do not differ by much on this point.

It would be unreasonable for the selective inhibition theorist to assert that the activation states would not be part of an episode. While activation states may not be considered memories per se they would strongly influence any disruption or modification of the episode and components of the episode. Whether the episode needs to be retrieved on the probe in order for the selective inhibition state to have an effect would be the only point where the selective inhibition theory may deviate significantly from the selective inhibition model.

A specific finding that is considered most damaging to the selective inhibition theory is important to mention here; negative priming is not generally observed when there is no distractor on the probe (see Neill & Mathis, 1999 for full argument). Theories proposing that negative priming is primarily a memory based phenomenon generally suggest that the reason

negative priming does not occur without a distractor on the probe is because the episode is not retrieved because the context becomes very different. The alternative from the selective inhibition camp is that this may be true, but the episode was constructed from activation and inhibition patterns that are the cause of negative priming anyway.

But, this concession to memory theorists may have been a serious error. The sensitivity of the task changes significantly when a distractor is removed. Without the need for selection one may accept whatever stimulus is available and respond immediately. The response can be more directly controlled by the stimulus and the signal to noise ratio is going to be very high. Because of a strong signal to noise ratio the response can be very strongly driven by the target. But, when selection is required one must decide which of two possible stimuli is the target, and the signal to noise ratio will be much lower. Therefore, any latent activation or inhibition of the target will have a stronger relative influence compared to that of the target stimulus.

Hence, while inhibition and activation states are necessarily encoded into any particular episode, episodes do not have to be retrieved in order for those states to affect performance. This weakens the general parsimony argument used to support memory theories (MacLeod, in press). Essentially, it is considered more parsimonious to argue that memory must be the cause of negative priming because memory mechanisms are well trusted to exist while (functional) inhibitory mechanisms are only hypothetical constructs. Furthermore, if it is accepted that a memory has to be retrieved to get the negative priming effect then it is not very efficient to

postulate another cause embedded within the memory that generates negative priming. Some sort of mismatch or incongruency between the retrieved state and the current one should be sufficient. But, if attention theorists avoid conceding that memories containing the attentional states are always retrieved then they stay out of this trap and the general parsimony argument loses some of its elegance.

### Code Coordination

Lowe (1985) used the code-coordination hypothesis (Keele & Neill, 1978; Treisman & Gelade, 1980) to explain negative priming. While little referenced later in the negative priming literature, it is a bridge to some later theories that depend on memory (e.g., Neill et al, 1992).

The presentation of the stimuli automatically activates various codes. This passive activation of codes subsequently requires coordination. Some codes of colour, form, and response are combined into action and retained while others are inhibited so that they can be forgotten. The theory is meant to be viewed as a superset for how selection occurs and entails the assumption that inhibition of distracting items is only one available strategy. This strategy is implemented when the selection difficulty is high, but it is not while selection difficulty is low. Given that Lowe (1979) found that the general difficulty of the task could influence the presence of negative priming, it is unsurprising that he would appeal to such a flexible theory for explaining negative priming. The code-coordination hypothesis does not explicitly predict a congruency effect in itself. But, by rallying the original selective inhibition theory to explain the negative priming effect, when it

occurs, the congruency principle is dragged along.

The code-coordination hypothesis predicts a congruency effect only weakly, slightly less so than the selective inhibition theory, because selective inhibition is only proposed as one way to deal with a stimulus-response problem. In addition, the prediction that the Control condition's performance will lie between congruent and incongruent performance is also included in code coordination through the selective inhibition hypothesis.

### Selective Inhibition Model

The selective inhibition model (Houghton & Tipper, 1994; Houghton et al, 1996) deviates from the original selective inhibition theory on several points while maintaining the primary functional explanation. Furthermore, it was constructed from a richer set of data and has some very specific parameters that were not previously defined. This model is presented separately from the original selective inhibition theory because it makes somewhat different predictions with respect to congruency.

The selective inhibition model is an interactive activation model. When stimuli are sensed, nodes for those stimuli are increased in activation, regardless of whether they are target or distractors (this is at the sensation level). In order to select one stimulus among many, non-target nodes are suppressed while target nodes are activated. However, at this point in time they are not suppressed below resting level, just to a lower level than the stimulus activation would drive them normally. When the difference between target and distractor nodes becomes great enough then selection occurs. If the stimuli are removed activated target nodes will retain some of

their residual extra activation, and suppressed distractor nodes will now be suppressed below normal resting levels. A presentation of a target that activates a node that is currently below normal levels (a previous distractor node) will result in slowed perception of the target item.

The selective inhibition model makes some very strong predictions that have not been upheld in the literature. One of the more fundamental of these is that, because the ongoing stimulation actually still pushes the activation of those nodes above resting levels, there must be a period of time between the offset of the prime stimulus and the onset of the probe stimulus before negative priming will be observed (Houghton et al, 1996). However, both Neill (1977) and Lowe (1979) used methods with tachistoscopes and a Stroop paradigm where there was no offset interval and still successfully generated negative priming. Furthermore, the model is weakly contradicted by negative priming experiments in which all the stimuli are presented at once to be read off of cards as in Dalrymple et al (1966), and Tipper & Cranston (1985). Houghton et al. (1996) did verify several predictions of the model with a location negative priming paradigm, but these confirmations have only been found with that paradigm.

Regardless, the model has garnered significant importance in the negative priming literature, no doubt due to its computational explicitness, and is addressed here with respect to the degree to which it predicts a congruency effect. That is not necessarily simple to determine because of the construction of the model.

In the selective inhibition model negative priming is caused by inhibition, just as in the original theory; but the model also proposes that the



inhibition does not necessarily occur. Selection is accomplished by the combined activation (of targets) and inhibition (of distractors) mechanisms working in tandem. If the difference in activation between the target and distractor stimuli exceeds a threshold for recognition then selection occurs. It need not be true in every case that the inhibition mechanism, or the activation mechanism, is necessary to cause that selection, and the degree to which they are involved will vary on a case by case basis. Therefore, in one instance of selection, activation alone may be sufficient as the primary mechanism by which target and distractor differentiation is accomplished. In that case negative priming will not occur. In another case inhibition alone may be enough to generate the selection, and Target→Target benefits will not occur. This variable system is used to explain the Lowe (1979) finding that negative priming is induced by overall expected task difficulty. Houghton et al (1994) believed that those results could be accounted for by adjusting the degree to which inhibitory and excitatory mechanisms will be used.

However, the fact remains that the congruency principle follows from the theory as long as the fundamental Target→Target benefits and Distractor→Target costs, in relation to the control condition, are found. This is because, while inhibitory and excitatory mechanisms are not necessarily involved in every case, it is the case that whenever a Distractor→Target cost is found then an inhibitory mechanism is expected to have caused it. And, whenever a Target→Target benefit occurs then it is an excitatory mechanism that was responsible. Therefore, in any situation where a Distractor→Target cost occurs, and a Target→Target benefit

occurs then a congruency principle is strongly predicted across the other related conditions using the same rationale as in the original selective inhibition theory. However, the exceptions available in the original selective inhibition theory for a Target→Distractor benefit are not available to the model. There is no late selection exception, therefore the model more strongly predicts a congruency principle than the theory as long as Target→Target benefits and Distractor→Target costs occur. But, as was stated previously, under this model those conditions are necessary in order to be certain that one is examining negative priming in the first place.

As an extension, examination of the Control condition with respect to the model reveals that in fact a congruency principle could be supported without the Control condition falling between congruent and incongruent. This is because, even if inhibition occurs, it is possible that it does not exceed the activation generated from the stimulation, either completely, or in time to cause the resting level of the inhibited distractor to be suppressed below Control. Therefore, the model could be supported as long as the congruency principle is supported even if the Distractor→Target performance is not worse than Control. Note that this is not logically incompatible with stating that the model strongly predicts the congruency principle when there are Target→Target benefits and Distractor→Target costs with respect to Control. It is a separate assertion that, should the congruency principle be followed in the data, it is not necessarily true that the Control condition will be centered between congruent and incongruent relationships.

### Dual Channel

This is a variation of the selective inhibition theory that postulates separate channels for processing of locations and identities (Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993). All predictions are the same as for the above selective inhibition theory except that the rules change as an individual ages. The dual channel account was proposed to account for findings of preserved negative priming in spatial location while identity negative priming disappears with age. The Control condition should fall between congruent and incongruent trials, just as with the selective inhibition theory.

This theory will not be discussed extensively here because no aged participants are tested and therefore it cannot be verified. But, it is important to note that the originators of the theory found enough differences between findings in location and identity negative priming experiments to at least postulate different mechanisms within a single theory. This is support for the heterogeneity of negative priming findings proposed here. And the effect of aging might plausibly be used to provide converging evidence in favour of memorial influences since memory is known to decline with age; though, of course, inhibitory function is asserted to decline as well.

### Episodic Retrieval

The first memory based theory of negative priming was proposed by Neill & Valdes (1992). It was inspired by Logan's (1988, 2002) automaticity theory and it relegates attention to a passive role with respect to the negative priming effect.

Episodic retrieval causes negative priming through incompatibilities between the stored memories of an item and its present display. On the prime trial one records the target as something to respond to and the distractor as something to ignore. This memory is crucial to developing the faster, automatic processing of stimuli that typically occurs with repeated encounters with the same stimuli. When stimuli are repeated the previous episodes are retrieved and usually help performance. However, if on the probe trial the previous distractor is presented as a target then the memory that it was to be ignored will be in conflict with the present task and a cost in performance will occur.

A congruency principle follows very strongly from this theory. In fact, the theory is a description of a congruency principle with interactions between the contents of retrieved memories and present stimulation as the proposed mechanism for the congruency.

The theory has never been significantly altered to account for exceptions to the pattern of data predicted by any congruency principle. For example, the Target→Distractor benefit that Neill (1978) tried to explain is considered an anomaly under this theory and a condition that just yields variable results from time to time, which is true in the literature. But, if it were found that it is not just an exception, but the general case, that a congruency principle is not upheld, then the episodic retrieval hypothesis would have to be rejected. Or, if the congruency principle was consistently violated in just one class of negative priming experiments, then the generality of the episodic retrieval theory in explaining negative priming would be challenged.

An interesting twist with the episodic retrieval theory is that Control condition performance is thought to be generated by a separate mechanism from related conditions. Under the automaticity theory prior episodes are used to attempt to improve performance. However, in the Control condition there is no relationship to the immediately prior episode and the new response has to be calculated.

There is no a priori reason to believe that incompatible conditions will necessarily be slower than the Control condition. If episodes are recalled to help in performance then the fact that an item has a "do not respond" code when it is now a target item will only partially impede performance. The general recognition of the stimuli and other factors should be facilitated by the episodic retrieval. Recognizing this fact, performance may be speeded for incongruent conditions, relative to Control, under the episodic retrieval theory. The episodic retrieval theory is thus uncommitted with respect to the position of the Control condition. This is in contrast to the very strong prediction that the congruency principle will be upheld.

### Transfer-Inappropriate Processing

Neill & Mathis' (2000) Transfer-Inappropriate Processing (TIP) theory is based on the Transfer Appropriate Processing (TAP) theory (Morris, Bransford, & Franks, 1977), which in turn is related to Tulving's encoding specificity principle (Tulving, 1984) and may be thought of as a generalization of the episodic retrieval theory. The TAP theory proposes that ubiquitous repetition effects found in psychology (starting at Ebbinghaus, 1885) are determined by the appropriateness of the relationship

between current events and past events. This can be generalized to many domains and in order to understand what is meant, an example is needed. If one is asked to rhyme words, then subsequent recognition of those words will be better if rhyming is again the task. Here the recognition is appropriate to the initial encoding. Neill & Mathis (1998) suggested a corollary of this process in which TIP caused performance to be poorer. Recall of the previous instance of the item interferes with current processing requirements because it is inappropriate for the present task. Both TAP and TIP are used to explain typical results in a negative priming experiment and this is often referred to as the TIP/TAP theory.

TIP/TAP explains negative priming in a manner that strongly predicts that the congruency principle must be upheld. On the prime trial the target is processed as a to-be-responded-to item while the distractor is processed as an item to which no response is made. On the probe trial the appropriate transfer would be to repeat these responses. Therefore, trials on which the target or distractor repeat (Repeat, Target→Target, and Distractor→Distractor) will all benefit from appropriate transfer and performance will be better than for the newly calculated Control trial. TIP occurs whenever the probe stimulus needs to be processed in a way that differs from its presentation on the prime trial. Therefore, Distractor→Target, Target→Distractor, and Switch trials will all have poorer performance than Control.

For the specific case of negative priming this theory is nearly identical to Episodic Retrieval Theory. However, it differs in that it is more general and is applied by the authors to many cases of behavioural reductions in

performance. It need not be the case that ignoring a prime stimulus is the processing that is inappropriate for the probe. Any current processing incompatible with a prior event suffices to hurt performance. By generalizing the Episodic Retrieval theory in this way Neil & Mathis sought to explain various other phenomena where items are repeated and performance efficiency is reduced.

Unfortunately, it is not clarified why the TIP should necessarily be poorer than Control. It is true that it should be poorer than TAP, but for some reason it is just assumed that processing a brand new trial will be better than processing one that generates TIP. This may not be the case because some of the properties of the stimulus may facilitate perception of the item even while the incompatible processing hinders generating the appropriate response. Therefore, even though TIP/TAP theory strongly predicts a true congruency principle it makes no stronger predictions about the relative position of the Control condition than does Episodic Retrieval theory. It may just be that all congruent relationships are faster than incongruent relationships, in the order predicted by the congruency principle, but that Control performance may not lie between the two.

TIP/TAP is more appropriately called a description than a psychological theory. That is admitted by the authors who simply state that some phenomena only need to be described. For example, if you teach half of a sample of students geology and the other half biology and then give them all a geology test, one need not postulate a psychological theory to explain why some students do worse in the test than others. Because of this property, the TIP/TAP explanation provides few details with regard to

psychological mechanism.

One might notice that the congruency principle bears a resemblance to TIP/TAP in terms of explanatory power. However, the congruency principle is not meant as an explanation. It is only a way to categorize and think about data that are generated when sequences of events are studied. This can then potentially be used to generate more elaborate and well formed relationships between the complex data and theory.

### Hesitation

This innovative explanation of negative priming was first proposed by Milliken et al (1998). It relies on the same principle of automaticity (Logan, 1988) that is used in the episodic retrieval theory. However, the mental events that occur to generate the deficit in performance seen as negative priming are very different from those encountered in episodic retrieval.

Milliken starts by stating that there are two ways in which the processing of the current target item can occur. It can be a calculated process in which one determines the identity and responses on each trial. The other method by which the target is processed is through automatic retrieval of previous similar episodes. If the target was recently encountered then performance will be enhanced because the processing will be, at least partially, automated. This process explains Target→Target benefits and how new Control trials are calculated. Up to this point things are very similar to the episodic retrieval theory of negative priming.

However, the Distractor→Target deficit is explained uniquely as a hesitation caused by indecision. There must be a method by which one



decides whether the target item should be processed automatically or whether the response has to be calculated. If this occurred immediately then there would only be two performance levels; fast automatic processing would occur in the Target→Target condition while in those conditions where the current target was not presented on the prime trial performance will be calculated and slower. However, the decision as to whether the target response should be calculated or retrieved is sometimes difficult. This is because, for example, in the Distractor→Target condition the current target was recently presented, but not as a target. There is a similarity to a recent trial for which an automaticity benefit should accrue, but it cannot. Automatic responses compete to control performance, and the decision to make the proper calculated response is delayed because of this competition.

This explanation was supported by experiments wherein the items presented were merely masked stimuli and the participant was not required to respond to them at all. Because there is no automatic response for these stimuli, repeating them cannot help. However, because they were masked and difficult to discern they bore a resemblance to a subsequent and identical unmasked stimulus. In Milliken's hesitation theory performance is poorer because the similarity to a recent stimulus causes a delay in the computed processing while the system decides whether a recent automatic candidate is a better choice.

As with most of the other theorists, Milliken et al (1998) do not explain the other conditions discussed here; therefore, the hesitation theory's predictions of the likely outcome with respect to a congruency principle must be deduced. However, in this instance extra assumptions are required

to get to a full explanation.

The main points of hesitation theory are that a processed target is well remembered and will lead to benefits from automaticity if it is repeated; and that an item will be partially remembered, and lead to hesitations, if it is not an identical repetition but is related to the prime. Therefore, Repeat and Target→Target performance should be better than Control. However, the Distractor→Distractor condition presents somewhat of a conundrum. A probe trial related only to the prime distractor should cause a hesitation effect. But, once that is resolved there should be automaticity rather than calculating that no response be made to the distractor.

I propose that a repeated distractor (Distractor→Distractor) does not cause a hesitation effect, but an automaticity benefit. Under the hesitation theory the main reason a hesitation effect occurs in Distractor→Target is because, not only has the target been seen before, but it has also been transformed, obscuring its present status. In Distractor→Distractor the prior episode of the distractor has not been transformed and therefore performance should be accelerated by automaticity into processing it as the item not to be responded toward. Furthermore, similar confusion to that predicted in the Distractor→Target condition should occur when the target is transformed into a distractor (Target→Distractor). If this is true then one can predict that a congruency principle should also be upheld for the mismatch hypothesis except for one case. There is no reason to believe that the Switch condition will be any poorer than Distractor→Target. That is because there isn't a linear relationship between congruency and performance. An incongruency that requires a recalculation should take the

same amount of time as any delayed recalculation. The only way one might generate a difference between Switch and Distractor→Target is to propose that there is some probability that indecision occurs that varies between the conditions.

The difficult thing about making a strong prediction of congruency with the hesitation hypothesis is that it is unclear what exactly leads to the hesitation. One might weight the fact that an item was previously a distractor more than the fact that it was transformed. And, there is no prediction of a monotonic relationship between increasing incongruency and hesitation in the relationship. That is because, at some point, the incongruency may not cause the hesitation, and a calculation of a response will be initiated immediately. In that case performance in the more incongruent condition may become as good as in the Control condition.

As with selective inhibition, the congruency principle strongly predicts that the Control performance will lie between the congruent and incongruent items because incongruent performance is based on the same processes as Control, but with an added hesitation. However, the relative positions of congruent and incongruent items around the control are very hard to pinpoint.

### Perceptual Mismatch

The perceptual mismatch theory of negative priming is specifically designed to deal with the fact discovered by Park & Kanwisher (1994) that selection is neither necessary nor sufficient to generate negative priming, at least within a particular paradigm.

Using the location negative priming paradigm, where one must indicate the location of a target while ignoring a distractor in another location (Tipper et al 1990), it was discovered that even without overt selection on the prime negative priming could occur. It was proposed that the negative priming effect is entirely caused by mismatches between the prime and probe stimuli.

Again, the theory here strongly predicts a congruency principle. In fact, it is extremely similar to the episodic retrieval theory in this respect. However, instead of making the congruency mechanism one related to the action performed on an item, it is presumed to be a perceptual one. Perceptual congruencies assist performance while perceptual incongruencies hurt performance. In typical negative priming experiments these two covary. In atypical negative priming experiments, where the rules of selection may change from prime to probe or there is some other method used by which the Distractor→Target transition does not result in a perceptual mismatch, this theory is moot and possibly refuted (Milliken et al, 1994; Tipper et al, 1995). In fact, while the refutation of perceptual mismatch in these papers is strong, the theory is still included here as an example of the consensus in the literature about the congruency principle. Moreover, as suggested earlier, there are problems drawing strong inferences from studies with rule changes, which may decrease our confidence in their ability to reject this theory. Furthermore, the generality of the lack of a perceptual mismatch effect has not been thoroughly tested.

The control trial is interesting in this theory. Under the tested paradigm of location negative priming, there will be no matches or

mismatches between prime and probe on the Control. Therefore, for location negative priming it is quite reasonable to expect it to fall between the benefits that congruent trials receive, and the costs that incongruent trials receive. However, in other paradigms, such as Stroop and letter identification, there are often perceptual mismatches in the Control condition. Therefore, if perceptual mismatch is the mechanism causing negative priming, it is quite possible that in other paradigms there will be no negative priming, as defined by Distractor→Target worse than Control.

### Selection-Feature Mismatch

MacDonald et al (1999), following the path of the perceptual mismatch hypothesis (Park & Kanwisher, 1995), proposed that negative priming is caused by a Selection-Feature Mismatch mechanism. Unlike Park & Kanwisher, the mismatch was not the perceptual properties of the stimulus, but a selection feature. This theory focuses on a common feature of negative priming experiments. They are often constructed such that identical stimuli (e.g., letters) may have different selection features (e.g., colour or location) from trial to trial. In Stroop a given colour may be represented with the target selection feature (actual colour) or the distractor selection feature (as a word). In the typical experiment this selection feature will mismatch between prime and probe on Distractor→Target trials when the stimulus content remains the same. Because most negative priming experiments base the selection on a perceptual feature there will be no distinction between predictions from the two theories in many tasks.

That is also the case for the congruency principle. Again, whenever

there is a match (congruency) between the current selection features and prime features, there will be an improvement in performance. Whenever there is a mismatch (incongruency) performance will be reduced.

This view doesn't suffer the same problems with interpreting control conditions as does perceptual mismatch. That is because the specific mismatch between the selection features of the prime distractor and its current status as a target are what cause the negative priming and not the perceptual features in general. For example, a red "A" could be a target on the prime with a green "B" distractor. On the probe one might present a red "B" target. In that instance there is a perceptual feature mismatch between the prime and probe targets and a selection-feature mismatch. However, in the control condition there may be a red "C" target. In that instance there is still a perceptual mismatch, but there is no selection feature mismatch since the stimulus was not present on the prime to even have a selection feature.

### Three proposals

One might note that many of the theories above are restatements of a congruency principle with different psychological mechanisms proposed to explain the congruency effect. The difference between those theories and the congruency principle lies in the level of description. By adopting the congruency principle one can attempt to address entire classes of theories instead of being concerned about the details of each individual one. If an entire class of theories predicts a particular data pattern then one can either support or reject that entire class with simple experiments, without getting into the details of the plausibility of the individual mechanisms. This path

of experimentation is reminiscent of Broadbent's (1958, p. 307-309) proposal that one attempt to reduce entire classes of theories in a sort of binary reduction method.

The following three propositions are put forward here as following from what has been written so far. It is proposed that the finding of Distractor→Target being worse than Control is not sufficient to demonstrate that negative priming has been caused by the prime distractor. It is further proposed that the congruency principle is, by consensus of the theorists, a more powerful data pattern under which to find negative priming, and makes the traditional Distractor→Target cost relative to Control unnecessary as well as insufficient. Finally, it is proposed that the selective inhibition hypothesis is the most important hypothesis in the negative priming literature.

Distractor→Target effect is not sufficient to demonstrate negative priming

Finding that the Distractor→Target condition performance is worse than that of the Control condition has in the past been the only measure of negative priming. It is proposed here that it is not sufficient to establish that the negative priming was caused by some property unique to the ignored distractor or the relationship between the current target and the previous distractor. There are several other conditions needed as controls for this situation. The Target→Target condition can verify whether the cost is specific to the distractor, or if it is merely stimulation that causes the cost in performance. If one ignores the target and distractor nomenclature with respect to the prime, then the Distractor→Target and Target→Target

conditions are not different and may be rewritten as Stimulus→Target conditions. If there were a deficit in performance in both of those conditions then the cost would not be attributed to anything about the target distractor distinction. Minimally, one must demonstrate that there is not a cost in the Target→Target condition in order to assert that a cost in the Distractor→Target condition is specifically related to the distractor. Note, that even though the Selective Inhibition Model allows for there not to be a Target→Target benefit, it does not allow for there to be a Target→Target cost.

There are further conditions that are important in establishing the cause of the negative priming effect and eliminating confounds. If one were to only run the Control and Distractor→Target condition then there is a prediction based on stimulation one can make. Without establishing identities one can always know that if something is repeated from the prime trial then it will be the target. This will still be true if the Target→Target condition is run as well. The best way to eliminate this heuristic is to add trials that violate it. The Distractor→Distractor and Target→Distractor trials balance the prime and probe relationships such that there is no way to know whether a relationship is to the current target or distractor.

Finally, the repeat and switch trials are important for primarily theoretical reasons. Many hypotheses one might generate about negative priming logically come to the conclusion that performance in Repeat and Switch should be at the extremes of the differences noted in the Target→Target and Distractor→Target conditions. Therefore, these trials can be run to further verify those hypotheses.



Thus far it has been suggested that each of the possible prime and probe relationships is necessary. Moreover, they are also convenient. In the process of designing an experiment to test negative priming one will be confronted with the potential confounds introduced by leaving any of the possible relationships out. By leaving them all in, one easily removes any confounds in the experiment based on biased or predictive sequencing. One might be tempted to remove a condition based on the fact that there is no sound hypothesis about what should occur in a condition. But, a theoretical concern should always be overridden by a methodological one, else the evidence collected to verify the theory is corrupt. Neill (1977) ran all possible conditions by selecting probes completely randomly with replacement. One can only guess why he did not report all the conditions based on theoretical considerations. However, that did not affect the methodological concerns. It is important to note that every condition naturally occurs when a random sequence is selected.

### Congruency is a critical data pattern

While it has been discussed how the Distractor→Target cost relative to Control is not sufficient to demonstrate negative priming, it also turns out that it is not necessary. When describing the various theories that explain negative priming and their relationship to the congruency principle it was explained that the Control condition may not necessarily be between the congruent and incongruent trials in performance. In fact, under some theories there is no reason for it to have any relationship to the performance in the related trials. With the Episodic Retrieval, TIP/TAP, Perceptual

Mismatch, and Selection-Feature Mismatch theories there is no reason to believe that Control will necessarily be faster than Distractor→Target. Furthermore, it is highly probable that it will be in fact as slow as Distractor→Target, or slower, in both Perceptual Mismatch, and Selection-Feature Mismatch.

The second proposal is affirmed by the commonality in various negative priming theories in their support for the congruency principle. This could be further broken down into strong and weak violations. For example, a Target→Distractor violation of the congruency principle (e.g., Target→Distractor faster than control) would be considered a weak violation. There are various ways a selective inhibition theory might be construed to easily account for this, but those construals should then be propagated across all conditions. If it is assumed that the Target→Distractor benefit was caused by late selection mechanisms wherein having recently identified the current distractor causes it to be dismissed more easily, then the impact of that on the Switch conditions should be assessed. One might propose that following the same mechanism the Switch condition performance should be better than Distractor→Target.

A strong violation of the congruency principle might be that Distractor→Target or Switch performance may be more efficient than Distractor→Distractor, or even Target→Target. Alternatively, another strong violation may be that there is a cost in the Target→Target or Repeat conditions. Every explanation of negative priming explicitly predicts that these conditions will not be worse than any of the incongruent conditions.

A match to the congruency principle is a good measure of whether

costs in the Distractor→Target condition are really caused by the distractor and whether one is in fact observing negative priming from ignored distractors.

### Selective inhibition hypothesis is important

The final proposal is based on my study of the history of negative priming. When selective inhibition was considered the most likely cause of negative priming, it was a very hot topic. Every experiment on clinical or developmental populations with negative priming has been about testing inhibition mechanisms (e.g. Beech, Powell, McWilliam, & Claridge, 1990; Kieley & Hartley, 1997; Stuss, Toth, Franchi, Alexander, Tipper, & Craik, 1999). However, the selective inhibition theory is currently not the most popular.

The fall in popularity of selective inhibition is partially the result of some failed logic in the interpretation of some negative priming results by its strongest proponents (also suggested by Tipper, 2001). As was previously stated here, negative priming necessarily involves memory at some level. All priming methods implicitly have this feature. Whether one is talking about decaying traces of perceptual information or conscious recall there is some sort of memory component involved. Even if one wants to class a trace as something other than memory, it cannot be denied that the trace will be connected to information stored in a memory and prompt activation of that information, or vice versa. Therefore, the demonstration that memory manipulations influence negative priming may be uninteresting with respect to causal explanations of negative priming. MacDonald &

Joordens (2000) state that negative priming was "Touted as a paradigm for exploring processes of selective inhibition" but, "apparently negative priming sheds more light on automatic-retrieval processes." (p. 1495). If one manipulates retrieval processes this is exactly what one will find. Such research does nothing to address the fact that attention may be the cause of the eventual effects found through retrieval processes. To deny retrieval processes is just blind ignorance of the method being used. But, relying exclusively on the finding that the negative priming effect is malleable when modifying memory in order to assert that attention is uninvolved in negative priming is equally myopic.

The current logic in the literature is that either attention or memory is the primary cause of negative priming. If attention is the cause, one shouldn't see effects of memory, and if memory is the cause one shouldn't see effects of attention. However, there is a very large difference between attributing a cause and stating that there should be no involvement. In one direction, where attention is the cause, it must be accepted that memory is involved. In that case one cannot rule out attention by measuring memory. One can only rule out attention by measuring attention. On the other hand, theories where memory is the cause do not require attentional involvement at all and would be unparsimonious if they did (Macleod, in press). Therefore, a demonstration of attentional effects would conflict with those theories. Because attention has been the prime non memorial process proposed to explain negative priming from distractors, and memory is a necessary part of the priming process, then refuting the attention hypothesis is the most important endeavor for memory proponents.

A brief look at the specific kinds of experimental manipulations that have been used to refute the selective inhibition theory and the selective inhibition model is in order at this point (both are elaborations of a selective inhibition hypothesis). There has been much discussion of this in the negative priming literature. One may interpret the focus on refuting the selective inhibition hypothesis in one of two ways. The selective inhibition hypothesis is either a very important idea, or the selective inhibition hypothesis merely has proponents who are persistent. It has been made clear here that the current reason for discussing the selective inhibition hypothesis is its potential importance. This is true whether or not its proponents are persistent.

The effect of changes between prime and probe context is considered refutation of the selective inhibition hypothesis (Fox & deFockert, 1998; Neill, 1997). It has been demonstrated that similarity between prime and probe context is important for negative priming to be revealed. Stimulus intensity and distractor onset variables have been used to demonstrate this. For example, if the stimulus intensity changes from prime to probe then negative priming will be reduced or eliminated. This is considered evidence that negative priming is not caused by selective attention because the effect can be eliminated by changing the likelihood that the prime episode is recalled. Given that negative priming, however it is discussed, is necessarily partially a memorial phenomenon, disrupting the link between the probe stimulus and the prime events will necessarily modify the relevance of the prime and the likelihood that it will be recalled. The finding that context matters for the strength of the negative priming effect does not directly

address how the negative priming effect is caused. What is it about the trace left by the prime that causes negative priming? It may well be that the distractor is inhibited but that the change in context causes the system to disinhibit that channel because it is no longer adaptive to maintain the original state. This would be even more likely if the inhibition were of individual instances of stimuli to a greater degree than more abstract representations of stimuli. This makes sense given that it is the suppression of a specific instance of a stimulus being ignored that is adaptive. If one suppressed the concept of the colour red in a Stroop paradigm rather than specific instance of the colour red, then that would be maladaptive in a new context. Finally, because only the Control, Distractor→Target, and, in Neill (1997), Target→Target conditions were run, one cannot verify whether the negative priming effects were simply reduced or the nature of the prime→probe relationship was changed.

Moore (1994) has most notably pointed out another reason to doubt the validity of the selective inhibition hypothesis. The inhibition of a distractor should be independent of other stimuli. Therefore, on a Distractor→Target probe trial it should not matter if the currently inhibited target is accompanied by a distractor. However, distractors are usually required on the probe in order for the negative priming to be observed. Leaving aside the fact that the location paradigm is an exception here (Neill et al, 1994; Frame, Klein & Christie, 1993), this is very similar to the context argument above. Similarly, this finding does not, by itself, challenge selective inhibition because it can be explained in a variety of ways within the selective inhibition framework. For example, a ceiling

effect in performance when there is no distractor on the probe may mask suppression of the current target. Or, as mentioned previously, the task may not be sensitive enough to detect negative priming without a distractor. It is not a direct attack on the idea that the distractor was inhibited on the prime; rather it can be thought of as a manipulation of whether that inhibition will matter on the probe.

Other experimenters have demonstrated that negative priming is very dependent on the context without completely abandoning a selective inhibition hypothesis (Lowe, 1979). In Lowe (1979) the context manipulation was whether difficult selection was expected or not. Negative priming only occurred on easier selection trials when difficult selection was anticipated as a potential event. If the effect is manipulated by the *expectation* of selection rather than the actual selection, then mustn't it necessarily be tied to attention? This is certainly true if one's definition of attention includes that it is the primary mental faculty that is manipulated by expectations. A cueing experiment is just an experiment about the manipulation of expectations.

If one takes the position that the cost in negative priming is primarily caused by the processing of a prime distractor then the selective inhibition theory is very important. That is because it is the only theory that attributes the cause of negative priming how the prime distractor is processed as an attentional distractor. The breadth of the importance of a paradigm that can be used to determine what happens to items that are not overtly responded to cannot be overstated.

### The Current Experiments

Given the present three proposals, and the goal of examining heterogeneity in negative priming, a number of factors must be considered in deciding what experiments to undertake.

Testing the congruency principle on some known negative priming paradigms is important. It is best to test the more popular paradigms as they have the most wide reaching influence in the literature. Furthermore, variations of those paradigms in which negative priming has not been found are important to observe the effectiveness of the congruency principle as a tool for assessing the presence of negative priming. Sometimes the Distractor→Target performance is not worse than Control, but given that the Control is not needed to confirm the congruency principle maybe we will find that negative priming is occurring anyway by using an analysis of congruency.

In addition, it would be good to test negative priming when the influence of hypothesized selective inhibition is the strongest. It is accepted that there may be memorial effects that cause negative priming, as well as influence the degree to which selective inhibition may be observed. Simple perceptual mismatch is an example of a very plausible hypothesis, and may operate in some cases. Therefore, in order to test a congruency explanation and a selective inhibition hypothesis it is necessary to start with a paradigm that does not produce negative priming, and then generate negative priming through the manipulation of attention. The attentional manipulation will be one where the participant is biased toward maintaining the prime selection set (i.e., attend the prime target and ignore the prime distractor). A bias in



the design of the experiment toward target repetitions will generate this. If the participant is biased toward maintaining the prime's attention set, and suppressing the distractor is a necessary part of that attention set, then negative priming should increase when there is a bias toward maintaining attention on the prime target. By selecting a paradigm where negative priming has not been observed and then introducing this bias in order to generate a negative priming effect large enough so that it can be observed one can be more certain that the effect is being caused by selective inhibition.

Others (Lowe, 1979; Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994) have suggested that a bias in the experimental design like that described above is a memorial manipulation and have already demonstrated that it may produce more robust negative priming (as typically measured). They proposed that the participant is more likely to refer to the prime episode to facilitate probe processing. This comes from priming research where the proportion of related trials ( $r-p$  or relatedness proportion) is known to modify priming effects, especially at long SOAs (Neely, 1990).

It may be true that individuals tend to use the prime event to help in probe processing when there are many target repetitions. But, while this appears to be a memorial manipulation, that is a misrepresentation of what is really going on. Or rather, it is unparsimonious. The prime target will be better remembered because the individual is maintaining attention on the prime target. Attention is preceding and guiding any memory effect here and to discuss it primarily as a memory effect is a case of the tail wagging the dog. There may be a memorial effect, but it is not the primary effect of

the manipulation. The method is little different from attentional cueing experiments (Posner & Snyder, 1975).

More important, the biasing manipulation is not strictly analogous to the r-p effect found in the priming literature. Negative priming is about the relationship between the prime distractor and the probe target. The r-p between the prime distractor and probe target is not inflated simply by increasing the number of target repetitions or likelihood of a target repetition. The r-p under study is only affected by increasing the number of Distractor→Target trials.

The possibility of a memorial effect contaminating an attention effect is the sad side effect of the priming paradigm. But, it is also true of the attentional cueing paradigm where one must remember a cue in order to orient. The present experiments are more similar to the latter, and this similarity permits the confident use of bias (cueing) in the present experiments in order to establish negative priming effects in paradigms where there previously was no Distractor→Target cost. In this way one can attribute the bulk of the cost to the attention.

The three paradigms to be explored here will be location negative priming, letter identity negative priming with two items and fixed locations, and Stroop negative priming with button presses.

The letter identity negative priming paradigm was first used by Tipper & Cranston (1985). Following up a trend in Tipper & Cranston's data, Ruthruff & Miller (1995) verified that if there are two letters and they do not change location then there is no cost in the Distractor→Target condition and therefore no negative priming. Given that negative priming can occur in this

kind of paradigm when the items change location from prime to probe, and that an attentional manipulation can enhance a negative priming effect, it is believed that a negative priming effect could be recovered in the letter identity, fixed location paradigm if an attentional manipulation was used. This is not hypothesized because of the similarity between moving items from trial to trial and biasing toward target repetitions. Rather, the paradigm is considered a good candidate for revealing an effect because of the general fact that negative priming can be uncovered with other manipulations. Furthermore, when letter identity is used and the items move there are good experiments (Neumann & DeSchepper, 1991; Stadler & Hogan, 1996) whose results are consistent with the predicted congruency principle. Comparing the results of an attentionally induced negative priming effect with a similar one that occurs through another manipulation may reveal information about the attentional component of the negative priming effect. Finally, testing the congruency principle in an unbiased experiment replicating Ruthruff & Miller (1995) may reveal information about the sufficiency of the Distractor→Target minus Control condition measure used to uncover negative priming in those experiments.

The button press Stroop paradigm is another paradigm in which the negative priming effect does not usually occur. Neill & Westbury (1987) generated a negative priming effect in this paradigm by having participants operate at increased levels of accuracy. It has never been carefully explored exactly what this accuracy manipulation did to the negative priming effect in these experiments. One hypothesis may be that it caused individuals to maintain attention on the prime target, similar to a biasing manipulation.

Therefore, accuracy and Target→Target biasing manipulations will be examined. There is already data in the literature on the vocal Stroop negative priming effect where the congruency principle can be explored (although somewhat biased in design, Lowe, 1979). Data collected here can be compared to those data.

Location negative priming is chosen as a candidate for testing the congruency principle for several reasons. It is a very popular paradigm primarily because of its claimed ecological validity. It has been shown to diverge from the other negative priming paradigms (Fox, 1995; Kane et al, 1997), and may have a unique cause for the Distractor→Target cost. And, in the first test to see if Target→Target showed poorer performance than Control the design was biased (Tipper et al, 1990). By looking at every condition in the location negative priming paradigm further insights into the cause of location negative priming may be found. The Distractor→Target cost may or may not be accompanied by a pattern of data that follows the congruency principle. The location paradigm is unique among those presented here because negative priming is expected in the design that is going to be used because it is usually found in location negative priming paradigms. For these same reasons a biased version of the experiments will not be presented. Negative priming, as measured by Distractor→Target minus Control, already exists and the gamut of related conditions is being examined in order to establish whether they conform to a congruency principle and can inform one about the nature of the cost. This is very different from how the other two paradigms will be explored. But, the presentation is necessary to reveal the extent of heterogeneity in negative

priming Differences between only two paradigms do not make a heterogeneous phenomenon and a third is needed.

### Rationale for Order of Exposition of the Current Experiments

These paradigms will be presented in this manuscript in an order that helps relate the main points of the paper best. The experiments across the three paradigms were often run in parallel so reporting the experiments in the order they were performed isn't appropriate. Furthermore, one of the purposes of carrying out the current experiments was to look at heterogeneity. Being intentionally heterogeneous experiments they are a little difficult to stitch into a single story.

The congruency principle was only upheld in letter identity experiments. Therefore, it will be presented first in order to better follow up and reinforce much of the description of congruency in this introduction. Following that will be the Stroop paradigm. This is primarily because the Stroop studies were conducted in a manner similar to the letter identity studies. A variation of the paradigm was used that does not produce conventional negative priming, and then this was followed up with a biased version in order to attempt to recover it. However, with Stroop a pattern supporting the congruency principle was not found. Furthermore, it was difficult to resurrect any conventional negative priming in the paradigm. Finally, the location paradigm will be presented. This paradigm also did not reflect the congruency principle, but does generate an interesting and explainable set of data. Because negative priming occurred robustly in the basic design, and it could be determined that this paradigm was not about

negative priming, but was about IOR (to be explained later), a biased version was not carried out. It may seem after reading these experiments that they are somewhat unrelated, based on results. But, it is important to remember that exploring heterogeneity is the point of these experiments and that based on method they are highly related. Results from simplified versions of these experiments are often reported as studies of the same psychological mechanisms. It will be made clear that such a view is very difficult to support given a more complete design.

### Methods of Data Analysis

The data collected here have all been subjected to an outlier reduction procedure using a non recursive moving criterion based on cell size (Van Selst & Jolicoeur, 1994). In addition, even though planned contrasts are often justifiable for the effects under study it was decided that the simpler approach of using a very liberal post hoc comparison be used. Therefore, all contrasts use Fisher's protected least significant difference (PLSD). If an effect arises that was marginal with the PLSD but is uncovered using a justifiable planned contrast the contrast will be reported. Furthermore, a lack of an effect in a particular condition will be verified in multiple ways, such as via non parametric statistics. One comparison that will be emphasized is the difference between the Distractor→Target condition and relevant Control condition. However, as was argued above, this will not be the only measure examined. All important differences between the unrelated Control condition and the related conditions will be examined in order to confirm that negative priming has, or has not, occurred. In addition,

the six related conditions will be examined to see whether or not they fit the pattern predicted by the congruency principle. If the performance for the six conditions matches the congruency principle, and fit or non-fit is the only important decision to make at that point, then fit will be assumed significant because the chances of a specific predicted pattern occurring by chance are 1:720. This will normally be performed on RTs with ties potentially being broken by referring to accuracies. However, a single tie between two adjacent conditions could be considered still adhering to the congruency principle because the odds of our single predicted pattern and all possible single adjacent ties is 6:720. If further analysis of agreement with the congruency principle is needed then average rank order correlations with the predicted order will be used. This will allow one to estimate the agreement of the effect with the prediction. Furthermore, the B coefficient from a linear regression can be used to estimate the magnitude of the congruency effect (slope), should any be found. When it is appropriate to determine the relative goodness-of-fit of two groups to the congruency principle both the correlations, and regressions can be compared. The individual participant correlations between observed and predicted ranks, transformed using Fisher's Z (in order to normalize the distribution), can be averaged within each group and compared using a T or F test. In the event that the rank correlations result in correlations of 1 a non parametric test could be used because the Z transform cannot be used on such data. A multiple regression of the observed data on the predicted ranks and the two groups to be compared can be used to compare the size of the effects. A significant interaction between group and rank would be indicative of a significant

difference in the magnitude of the congruency effect across groups.

### Fixed Location Letter Identity Experiments

Letter identity experiments are those wherein one must identify a target letter accompanied by one or more distractor letters. The target letter is usually indicated by a colour (Tipper & Cranston, 1985) or by a bar marker (e.g., Fox, 1994). Two previous studies that tested all of the prime-probe relationships in this paradigm conformed to the congruency principle (Neumann & Deschepper, 1991; Stadler and Hogan, 1996). In those experiments the order of related trials was the same as that predicted by the congruency principle (Repeat < Target→Target < Distractor→Distractor < Target→Distractor < Distractor→Target < Switch).

An interesting anomaly in the letter identity paradigm is that no negative priming is found if the target letter does not change location and there is one target and one distractor. In an experiment where participants required to respond with the identity of a letter in a target colour Ruthruff & Miller (1995) found that if the location of the target on the prime repeated on the probe then negative priming did not occur. However, if the items changed location then it did. In other studies the items in these experiments typically change location from prime to probe, thus necessitating the colour or bar marker to indicate which item is the target item.

There is no good explanation in the literature for this finding and it has not been followed up. Some might argue that the selection task is too easy in this condition and that negative priming is not measurable because of that. However, this has not been formally tested. Furthermore, there has



been no explanation of this finding by the Hesitation theory or any of the Mismatch theories. All of these theories predict that there should be some negative priming effect there.

Given that negative priming really should be occurring in the letter identity paradigm then perhaps this is an opportunity to attempt to induce a negative priming effect that is primarily caused by attentional orienting. Specifically, a replication of Ruthruff & Miller (1995) will be attempted. This will be followed by a similar experiment with the prime target predicting the probe target identity.

### Experiment 1

This experiment was conducted to determine whether the original finding of Ruthruff & Miller (1995) is replicable and to show that the current implementation of an experiment exploring negative priming does not reveal the effect using a letter identification task, with one distractor, when the target does not change location. This replication is important to make comparisons to the literature and to the condition where attention is manipulated.

In addition to the replication, the proposal that an attentional manipulation can induce negative priming (Lowe, 1979; Kane et al, 1997) is tested. In Ruthruff & Miller (1995) there was no expectation that the target would repeat. In this experiment an attention manipulation will be used that encourages the participant to maintain attention on the prime target identity when the probe target appears. This is done by increasing the probability that targets will repeat. If this manipulation causes negative priming, then

the new induced negative priming effect is caused by attention. This differs from negative priming effects that are found without a specific manipulation and therefore may be caused by any of a number of factors.

## Method

### Participants

Forty participants volunteered from a first year introductory Psychology class. Fifteen were in the unbiased condition while 25 participated in the biased condition.

### Apparatus

The stimuli were generated by a Macintosh IIX computer and displayed on a Macintosh, High Resolution, 13" Monitor. Responses were recorded by the computer through a National Instruments NB-MIO-16h board with a custom key pad for timed responses and a foot pedal used for trial advance. Responses were latched to a timer on the board through a custom circuit designed by the experimenter to insure accurate recordings of reaction times within less than 1 msec of a button press. The software used was written in Pascal by the experimenter and run on System 7.1.

The stimuli consisted of two letters in Monaco font that were positioned 0.6 degrees apart centered horizontally with the target letter always on the right. They were from the set "A", "B", "C", and "D".

In the unbiased condition the 7 conditions described in Table 1 were run. The 144 trials selected covered each possible prime and probe relationship and possible stimulus presentation excluding instances where identical letters could be presented at the same time. Prior to running in the experimental block, subjects were first run in a practice block consisting of

36 trials selected randomly from the original 144 such that the proportions of various relationships was the same as in the full set.

In the test block each possible identity of targets and distractors across prime and probe trials was presented once, in random order. These were categorized into 7 conditions. The following three conditions would be classified as congruent. If the target repeated identity from prime to probe and the distractor repeated as well this was called a 'Repeat' condition (12 trials). If only the target repeated while the distractor changed identity then this was called a 'Target→Target' condition (24 trials). The distractor could repeat from prime to probe while the target changed, resulting in a Distractor→Distractor condition (24 trials). The next three conditions were classified as incongruent. If the prime target appeared as the distractor on the probe this was called the Target→Distractor condition (24 trials). If the prime Distractor appeared as the target on the probe this was called Distractor→Target (24 trials). This last condition is often called the "ignored repetition" or "negative priming" condition by others. There was the possibility that the prime target and distractor would switch positions on the probe; this was called the Switch condition (12 trials). The final condition was called Control and neither of the identities on the probe were the same as ones presented on the prime (24 trials). This is the same categorization of possible events used by Lowe (1979) in the Stroop task. However, unlike Lowe each possible event occurs once and is then classified into a condition. Lowe presented each *condition* with equal probability whereas in this experiment each event is presented with equal probability (e.g., Stadler & Hogan, 1996).

In the biased condition only the Distractor→Target, Control, and Target→Target conditions were used. This inflated the probability of a target repetition event from 0.25 to 0.33. This method of biasing was used because it is often the incidental method of bias found in the literature.

### Procedure

A trial began with the pressing of the foot pedal. Once it was released a 1500 msec warning interval elapsed until the onset of the prime stimuli. The prime stimuli remained until the participant made a response by pressing a button or for 1995 msec. After the prime response or the 1995 msec period elapsed the stimuli were erased for a 360 msec interval called the response-stimulus interval (RSI). After the RSI the probe stimuli appeared until a response or for 1995 msec.

After both responses were made in the trial, or both 1995 msec presentation durations timed out, there was a feedback display containing the reaction time for the prime above fixation and the reaction time for the probe below fixation. In the case of errors either of these reaction times could be replaced with the word 'Wrong' or, in the case of a failure to respond in 1995 msec, with the phrase 'Respond Sooner'. This method of trial presentation limited the effects of trials outside the prime-probe pairing from influencing performance by breaking things up with manual prime trial initiation after receiving feedback.

### Results

The results are shown in Figure 2. The analyses are reported first for reaction times followed by error rates.

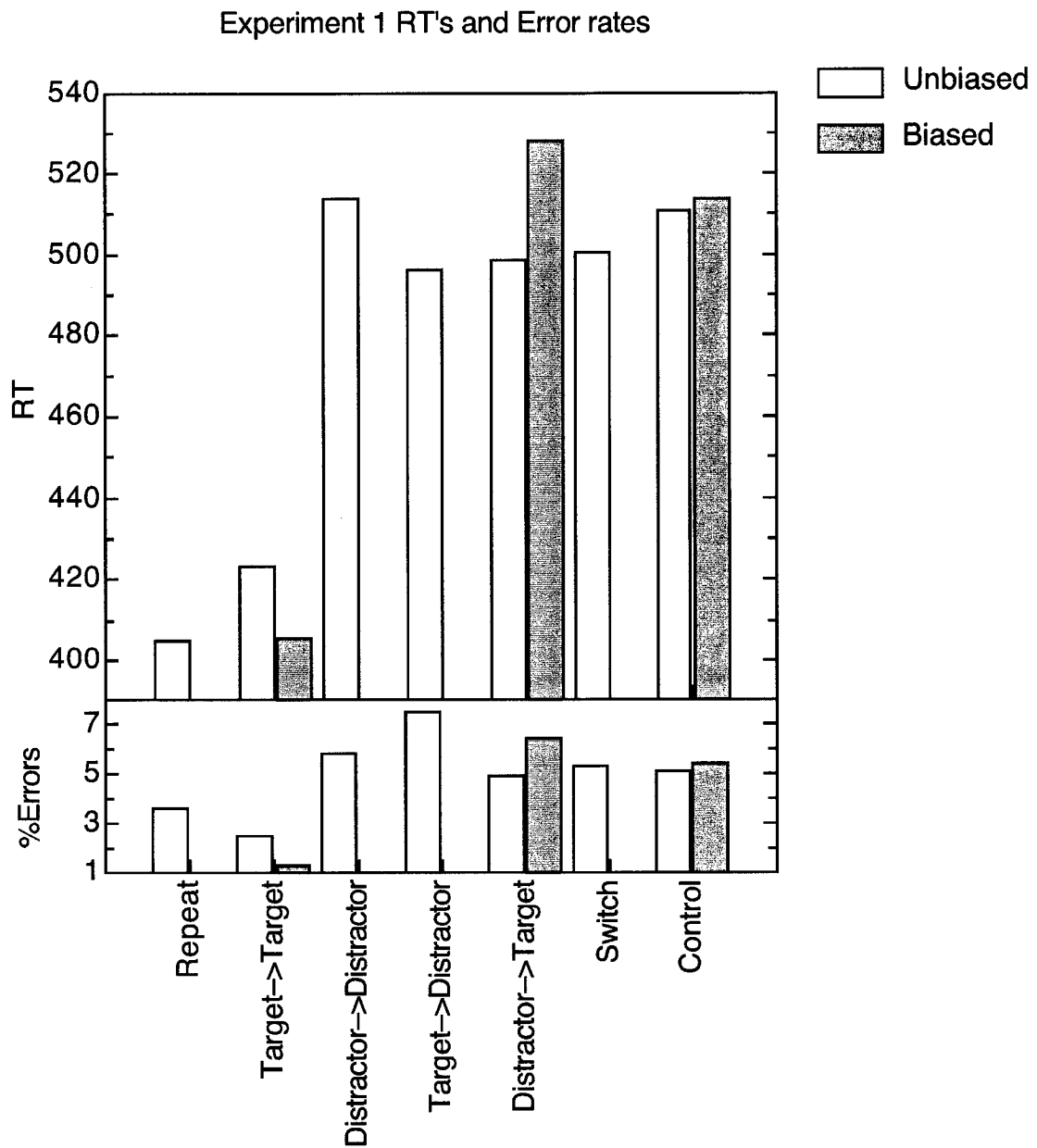
### Reaction Times

Separate ANOVAs were run for the effects of conditions in the biased and unbiased groups. They were both significant with  $F(6, 84) = 32.13$ ,  $p < 0.001$ ,  $MSE = 928.93$ ,  $PLSD = 22.13$ , for unbiased, and  $F(2, 48) = 141.95$ ,  $p < 0.001$ ,  $MSE = 793.28$ ,  $PLSD = 16.02$ , for biased. The only condition numerically slower than Control in the unbiased condition is Distractor→Distractor, but this is only by 1 msec and not significant. The slower Distractor→Distractor performance tends to violate the congruency principle, but it is the only point out of 6 that does.

It is obvious in the biased condition that most of the weight of the significant effect is that the Target→Target condition is faster than the others. This finding insures that any potential costs in Distractor→Distractor conditions are not merely due to stimulation. Additionally, a planned comparison reveals that the Distractor→Target is slower than the Control condition,  $F(1, 24) = 7.3$ ,  $p = 0.01$ ,  $MSE = 330.01$ . Thus, negative priming did occur in the biased condition, by the conventional measure, as predicted.

### Error Rates

ANOVAs for the accuracies revealed no effects in the unbiased group,  $F(6, 84) = 1$ ,  $MSE = 34.71$ , but significant effects in the biased group,  $F(2, 48) = 16.00$ ,  $p < 0.001$ ,  $MSE = 11.22$ . The accuracy effects in the biased group mirror the reaction time effects in that experiment.



**Figure 2.** Reaction times and errors from Experiment 1. This was a fixed location letter identity experiment. Note that there are only 3 conditions that are biased. This is because the bias was generated by removing the other conditions.

### Discussion

The findings of Ruthruff & Miller (1995) are replicated; there was no

negative priming effect when there was no reason to maintain orienting from the prime to the probe. This is true based on a comparison of Distractor→Target to Control, and because a slower Distractor→Distractor condition violated the congruency principle. However, in a biased experiment it was discovered that negative priming is observed despite the constant location when one is biased toward maintaining the attentional set from the prime to the probe. This occurred even though participants were not informed about the probability manipulation.

These findings may open the door toward the reuse of negative priming as a tool to investigate inhibitory mechanisms in attention. In Experiment 2 an attempt to replicate these results in a more complete design will be made. While the current experiment is more harmonious with the way target repetition biases are often incidentally performed in the negative priming literature, the congruency principle cannot be explored in the biased condition because the appropriate conditions have not been run. Furthermore, the condition has contingency problems mentioned earlier with limited designs. For example, if a distractor item from the prime is presented on the probe it will always be a target. This kind of contingency may have actually reduced the observed negative priming effect.

As a final note, it must be mentioned that while the results from the unbiased condition above are not in harmony with those expected by the congruency principle for negative priming this may be due to the low number of participants, speed accuracy tradeoffs, or both. Specifically, the Distractor→Distractor RT performance is not better than Target→Distractor, but the order of accuracy performance is as predicted.

The following experiment will verify this finding with a much larger number of participants.

### Experiment 2

In Experiment 1 all participants responded toward the letter on the right. In case there is something special about the right side due to reading or some other effect a replication was performed in which one half of the participants responded to the letter on the left while the other half responded to the letter on the right.

Furthermore, the biased condition of Experiment 1 was created by simply removing several conditions in an attempt to replicate bias commonly seen in experiments in the negative priming literature. In the present Experiment the biased condition will be created by increasing the number of trials on which targets repeat identity only. In this way one may be able to observe the effects of maintaining an attentional set on the other conditions and assess the congruency principle. In addition, in Experiment 1 the bias was a probability increase for target repetitions from 0.25 to 0.33; but, the bias in Experiment 2 will consist of a target repetition probability increase from 0.25 to 0.50.

Another change from Experiment 1 to Experiment 2 is that there will be no increase in the probability of Distractor→Target conditions. Some have hypothesized (Lowe, 1979) that generating a probabilistic relationship between prime and probe items increases the likelihood that they will be remembered and that a current trial will be compared to a previous one. Therefore, in Experiment 1, where the likelihood of a Distractor→Target



condition was 0.33 it is possible that participants maintained the prime distractor in memory and that this caused the negative priming effect. The transfer inappropriate processing (TIP) theory of Neill & Mathis (1998) would explain this negative priming effect by asserting that one was motivated to remember the prime distractor, but the previous processing that was done on it (do not respond) was incompatible with its current status as a target. This incompatibility may have caused the reduction in performance in the Distractor→Target condition. This explanation is somewhat flawed because it seems reasonable that if one is using the previous distractor then one will use it in the appropriate way, as a predictor for the target. This should reduce negative priming. In any event, the biased condition Distractor→Target events will be very unlikely ( $p = 0.17$ ) in Experiment 2, thus making it unlikely that improved memory for the distractor is the explanation for any negative priming that might occur. In fact, the probability of a prime distractor appearing on a probe trial in any fashion is well below chance.

In Experiment 1 the number of participants in the biased group was double that in the unbiased group. This generated a power difference where it was more likely effects would be found where they were predicted. However, experiments similar to the unbiased group (Ruthruff & Miller, 1995) have also failed to find negative priming. Nevertheless, the numbers of participants in Experiment 2 will be greater in the unbiased group than in the biased.

Finally, in Experiment 2 the interfering effect of distractors will be examined by presenting trials without distractors. Interference effects will

be examined across the biased and unbiased conditions.

A new nomenclature is introduced in this experiment that builds on the one that has been used so far. This is necessary to describe trials in which the presence of a distractor is variable. Because the presence of a distractor on the prime or probe can result in several kinds of unrelated (Control) trials, the conditions in an experiment where distractors may or may not occur are divided into 4 categories. As seen in Table 3 these are based on the presence of a distractor on either the prime or the probe. The letters D and ND indicate distractor present, and no distractor conditions respectively. Furthermore, the D or ND prefix indicates prime distractor presence while the suffix indicates probe distractor presence.

Table 3. These are examples of all of the possible conditions used in Experiment 2 forward. For the Stroop experiments the target is the ink colour and the distractor is the word. For the letter identity experiments the target is the letter with the "-" immediately adjacent while the other letter is the distractor. In the location examples the target is the "0" and the distractor is the "+". Note that all trials are described in relationship to the corresponding prime. "D" indicates that a distractor is present while "ND" indicates that it is not. The "D" or "ND" prefix indicates distractor presence on the prime while the suffix indicates distractor presence on the probe. No distractor primes and related probes are listed first followed by distractor primes and related probes. There are 15 probe conditions all together.

	Letter Identity	Stroop	Location
ND-Prime	-A	XXXX	_ 0 _ _
-----			
ND-Repeat-ND	-A	XXXX	_ 0 _ _
ND-Control-ND	-B	XXXX	0 _ _ _
-----			
ND-Target->Target-D	-AB	BLUE	_ 0 + _
ND-Target->Distractor-D	-BA	GREEN	_ + 0 _
ND-Control-D	-BD	YELLOW	0 _ + _
=====			
D-Prime	-AC	RED	_ 0 _ +
-----			
D-Target->Target-ND	-A	XXXX	_ 0 _ _
D-Distractor->Target-ND	-C	XXXX	_ _ _ 0
D-Control-ND	-B	XXXX	0 _ _ _
-----			
D-Repeat-D	-AC	RED	_ 0 _ +
D-Target->Target-D	-AB	BLUE	_ 0 + _
D-Distractor->Distractor-D	-BC	RED	0 _ + _
D-Target->Distractor-D	-BA	GREEN	_ + 0 _
D-Distractor->Target-D	-CB	BLUE	_ _ + 0
D-Switch-D	-CA	GREEN	_ + _ 0
D-Control-D	-BD	YELLOW	0 _ + _

## Method

### Participants

There were 123 participants selected from an introductory Psychology subject pool. These were divided such that 72 participated in the unbiased experiment, and 51 participated in the biased experiment. The extra participant in the biased group was randomly assigned to the right side.

### Apparatus

A Macintosh LC 630 computer was used for experiment presentation, and data collection. It was positioned 53 cm from the chin rest used by the participant. All letters were presented in Monaco font 0.5° in height. The letters 'A', 'B', 'C', and 'D' were used. Letters were presented in a dark gray area in the center of the black screen that was just large enough to hold both of them. This dark gray area was used instead of a fixation cross because it was predictive of the exact space occupied by the letters and, because it was always present, provided less of a stimulus disruption from trial to trial.

There were many more trials in this experiment than in experiment 1. This is because similar probability manipulations were maintained (i.e., making each possible event happen exactly once), but there was the added possibility of a trial with only one letter presented. A total of 15 conditions were used as opposed to the 7 in Experiment 1. A standard nomenclature for the naming of the probe trials is to place an ND- before the trial name to indicate there was no distractor on the prime, and a D- before the trial name if the prime contained a distractor. If the probe trial itself did not contain a distractor it was followed by a -ND, while the presence of a distractor was indicated by the presence of a -D after the trial name. Thus, a trial called

Distractor→Target in Experiment 1 would be called D–Distractor→Target–D in Experiment 2 because all of the trials in Experiment 1 contained distractors. Naming conventions for trials were otherwise the same for Experiment 2 as Experiment 1.

In the unbiased group each possible event could only happen once. However, in the biased group this was modified by tripling the numbers of trials in all of the conditions where the target could repeat. This increased the number of trials to 384 in the biased condition as compared to 256 in the unbiased condition. In addition, because the probability of a target repetition by chance was 0.25, tripling those trials made the probability of a target repetition 0.5.

### Procedure

The procedure was very similar to Experiment 1 with the following changes. Prior to the start of the experiment participants in each group were randomly assigned to select either the left or the right letter as the target. The participant began each trial with the pressing of the space bar and used the keyboard keys 'F', 'V', 'M', and 'K' to indicate the presence of the target letters 'A', 'B', 'C', and 'D' respectively. After initiating the trial there was an alert time of 750 msec immediately followed by the prime target presentation. The stimulus remained present until response or 1995 msec had passed. After this time there was a 495 msec RSI where only the fixation area was present before the probe stimulus appeared. The probe stimulus remained present until a response was made or 1995 msec passed. Immediately afterward a feedback screen appeared similar to Experiment 1. A new trial was begun by pressing the space bar.

## Results

Several ANOVAs were carried out. The data were sorted by control condition with each set having the same properties of distractor presence on the prime and the probe (see the groupings in Table 3 above). Prime analyses were carried out separately. All of the analyses, RTs and error rates are presented in Table 4. The RTs and error rates for the conditions with distractors on both the prime and probe are presented in Figure 3.

### Reaction Times

On prime trials in the unbiased group there was a main effect of distractor presence. In all probe target repetition conditions (Repeat, and Target→Target) performance was significantly better than the relevant control conditions. There were no other effects in RT for the unbiased group. There was no negative priming.

On prime trials RT in the biased condition group performance mirrored that of the unbiased group in prime performance and all probe ANOVAs except for when there were distractors on both the prime and probe.

When there was a distractor in both the prime and the probe there was a significant effect of condition. Three conditions were faster than control. D-Repeat-D, D-Target→Target-D, and D-Distractor→Distractor-D, as opposed to just the two target repetition conditions in the unbiased group.

There was no significant negative priming in reaction times by conventional measures. However, when examining the order of magnitudes of reaction times the biased condition did follow the congruency principle.

This indicates there was negative priming in the biased condition reaction times. In the unbiased condition, there was a single adjacent tie between D–Target→Distractor–D and D–Distractor→Distractor–D (only 1 msec difference). These are acceptable as detailed in the section on methods of data analysis (p. 65). Permitting one adjacent tie as an acceptable violation of the one predicted pattern still keeps the odds of occurrence at a respectable 6:720. Furthermore, the direction of the performance tends toward confirming the congruency principle in the accuracies.

### Error Rates

There was no effect of distractor presence on prime trials in the error rates whether participants were in the biased or the unbiased group. When there was no distractor present on the prime or the probe Repeat was more accurate than control in both biased and unbiased conditions. However, target repetitions only improved performance in the biased condition when either the prime or probe contained a distractor but not both.

When there was a distractor on both the prime and probe trials there was an improvement in the D–Repeat–D condition for both unbiased and biased participants. There was also a cost relative to D–Control–D in the D–Switch–D condition for both groups of participants. But, only in the biased group was D–Target→Target–D more accurate than D–Control–D. In addition performance was impoverished in the condition that normally is used to measure the negative priming effect, D–Distractor→Target–D in the biased group only.

Given that Distractor→Target was worse than Control, then there was negative priming in the accuracies of the biased condition by the

conventional measurement. This replicates the findings of Experiment 1.

The results of the conditions in which primes and probes appeared on both target and distractor, and in which interesting effects other than mere target repetition advantages were found, are presented in Figure 3. The accuracies in the unbiased condition followed the congruency principle at every point and are used to bolster the claim that the congruency principle was supported in the RTs. However, in the biased condition the Switch error rate was slightly better than Distractor→Target. Nonetheless, this is a very small difference and not significant. It does not bring into question the congruency principle observed in RTs.

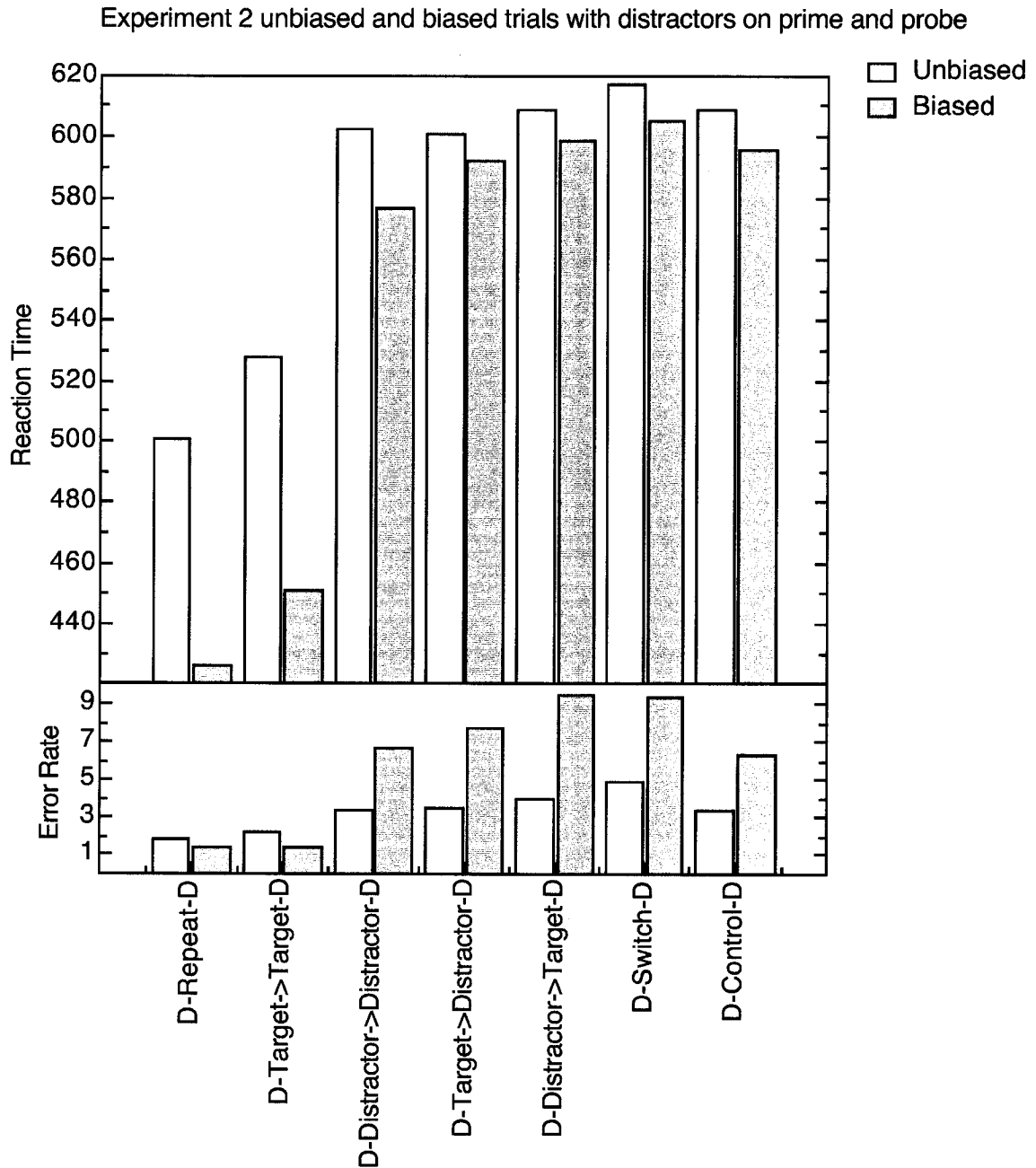


**Table 4.** Reaction times, error rates, and ANOVAs from all conditions of Experiment 2. The first section is the unbiased condition, and the second section is the biased condition. Bold indicates a significant difference from the corresponding Control condition, or in the case of primes a significant difference from D-Prime.

Unbiased	RT	analysis	Errors	analysis
ND-Prime	<b>578</b>	F(1,71)= 164.5, p<0.001	4.73	F(1,71)= 0.109, p=0.74
D-Prime	619	MSE = 369.6	4.62	MSE = 4.17
ND-Repeat-ND	<b>468</b>	F(1,71)= 109.4, p<0.001	<b>0.69</b>	F(1,71)= 7.33, p=0.009
ND-Control-ND	568	MSE = 3274.1	2.83	MSE = 22.14
ND-Target->Target-D	<b>556</b>	F(2,142)= 62.7, p<0.001	3.10	F(2,142)= 1.12, p=0.33
ND-Target->Distractor-D	623	MSE = 1940.3	2.94	MSE = 25.17
ND-Control-D	627	PLSD = 14.5	4.10	PLSD = 1.65
D-Target->Target-ND	<b>506</b>	F(2,142)= 74.3, p<0.001	2.06	F(2,142)= 2.21, p=0.11
D-Distractor->Target-ND	587	MSE = 1901.1	3.98	MSE = 31.21
D-Control-ND	577	PLSD = 14.4	3.32	PLSD = 1.94
D-Repeat-D	<b>501</b>	F(6,426)= 123, p<0.001	<b>1.77</b>	F(6,426)= 4.46, p<0.001
D-Target->Target-D	<b>528</b>	MSE = 1257.1	2.21	MSE = 17.67
D-Distractor->Distractor-D	602	PLSD = 11.6	3.30	PLSD = 1.37
D-Target->Distractor-D	601		3.48	
D-Distractor->Target	609		3.96	
D-Switch-D	617		<b>4.91</b>	
D-Control-D	609		3.32	

Table 4 (continued)

Biased	RT	analysis	Errors	analysis
ND-Prime	<b>552</b>	F(1,50)= 138.1, p<0.001	6.25	F(1,50)= 0.76, p=0.39
D-Prime	590	MSE = 268.6	5.98	MSE = 2.46
ND-Repeat-ND	<b>398</b>	F(1,50)= 416.8, p<0.001	<b>0.49</b>	F(1,50)= 27.87, p<0.001
ND-Control-ND	559	MSE = 1587.0	6.90	MSE = 37.61
ND-Target->Target-D	<b>477</b>	F(2,100)= 146.0, p<0.00	<b>2.66</b>	F(2,100)= 6.54, p=0.002
ND-Target->Distractor-D	594	MSE = 1672.5	6.64	MSE = 35.32
ND-Control-D	601	PLSD = 16.07	5.96	PLSD = 2.33
D-Target->Target-ND	<b>435</b>	F(2,100)= 263.8, p<0.00	<b>1.50</b>	F(2,100)= 13.71, p<0.00
D-Distractor->Target-ND	558	MSE = 1013.5	5.80	MSE = 30.31
D-Control-ND	562	PLSD = 12.5	6.91	PLSD = 2.16
D-Repeat-D	<b>426</b>	F(6,300)= 286, p<0.001	<b>1.34</b>	F(6,300)= 18.00, p<0.00
D-Target->Target-D	<b>451</b>	MSE = 1051.7	<b>1.41</b>	MSE = 31.48
D-Distractor->Distractor-D	<b>577</b>	PLSD = 12.6	6.70	PLSD = 2.19
D-Target->Distractor-D	592		7.76	
D-Distractor->Target-D	599		<b>9.52</b>	
D-Switch-D	605		<b>9.39</b>	
D-Control-D	596		6.29	



**Figure 3.** Reaction times and accuracies from Experiment 2 for trials in which the distractor appeared on both the prime and the probe. The biased condition is when the participant was biased to expect the target identity from the prime to reoccur on the probe. Note that the data follow a congruency principle whether the participant is biased or not. But, only when the participant biased is conventional negative priming observed.

## Discussion

The null findings of Ruthruff & Miller (1995) using a fixed position letter identity paradigm were replicated again. However, Ruthruff & Miller (1995) did not use a D–Switch–D condition and did not run the conditions required to observe the congruency principle. Therefore, while the data from Ruthruff & Miller (1995) are upheld, where the conditions match those used here, their conclusion is not supported by the extra information in the present experiment. A small degree of negative priming found in accuracies in the unbiased condition when comparing the D–Switch–D condition and the D–Control–D condition. Furthermore, in the unbiased condition, which was not supposed to show negative priming, there was support for the congruency principle in the accuracies and it was only violated by 1 msec in the reaction times. This principle is strongly supported by the consensus of negative priming theorists about what should be found if one runs all of the relationships in a negative priming experiment. Therefore, while the data support Ruthruff & Miller's null finding, the conclusion is that there was negative priming.

Initially this experiment was run anticipating that negative priming would be present in the biased condition but absent in the unbiased condition, as was found in Experiment 1. Even though there was no spontaneous generation of negative priming when participants were biased toward target repetitions, negative priming did appear to be increased through the attentional cueing. This is similar to the findings of Lowe (1979), in Stroop experiments. In the current biased condition there was a deficit in performance in both the D–Distractor–>Target–D, and

D–Switch–D conditions with respect to D–Control–D, whereas this was only true for the D–Switch–D with unbiased participants. Furthermore, there appears to be a slightly steeper slope matching the congruency principle (even ignoring target repetitions) in the biased than the unbiased condition.

Up until this point the predictive power of a low probability event has been generally used to prove or disprove the significance of the congruency principle. However, if it is not statistically tested there is no way to compare the strength of the agreement with the congruency principle across experiments, except descriptively. Such a comparison is desirable here between the biased and unbiased conditions. In this particular instance it would be unfair to compare all six related conditions across the bias manipulation. An attentional manipulation was used in one of the groups that should generate a benefit for target repetitions, and a cost when targets do not repeat (Posner & Snyder, 1975). This attentional manipulation by itself should increase any slope across all the conditions if they already follow the congruency principle because the cueing manipulation almost perfectly covaries with the congruency manipulation (Distractor→Distractor being the exception). However, in the four conditions where the targets do not repeat, the attentional manipulation does not directly cause any relative change in performance among these conditions. They would all have reduced performance because the target did not repeat. Therefore, only the slope across the four non target repetition conditions can be compared. In addition, there were typically null effects found in comparisons of reaction times within participants in this experiment and one can only expect a

similar result if comparisons are made across participants. A conservative and more justified comparison, in this particular instance, would be to compare the correlations with the congruency principle in the error rates. It is conservative because the congruency effect is not perfectly represented in the biased condition, the one that is predicted to have the steeper slope. And, it is justified because the conventional measure of negative priming only appears in accuracies.

The correlation between observed and predicted rank order was calculated for each participant and then transformed to a Fisher's Z score. These were then compared using a T test across the unbiased and biased conditions. The differences in mean correlations were significant,  $t(111.8) = 2.88$ ,  $p = 0.005$ , with the average correlation greater in the biased condition,  $r = 0.49$ , than the unbiased condition,  $r = 0.25$ . Both of the slopes are significant and show a numerical difference in the expected direction in separate linear regressions,  $b = 0.53$ ,  $p = 0.03$  for unbiased and  $b = 0.98$ ,  $p = 0.04$  for biased. But, there was no interaction between the two,  $b = 0.45$ ,  $p = 0.37$ . Therefore, as described on p. 65, the agreement between the congruency principle and the obtained data was stronger in the biased condition but the magnitude of the effect was not.

It is important to emphasize here that if one were to just analyze the typically analyzed results in this experiment one would find that in fact there was no negative priming in the unbiased condition. Is this a conclusion that one would wish to accept? If the current analysis of the general consensus of the congruency principle is to be believed then the answer is no. Therefore, it has been found that negative priming can occur without a

Distractor→Target cost.

Another interesting discovery is that there was no change in how well the data reflected a sensitivity to congruency across the biased and unbiased conditions, but there was an increase in the typical negative priming measure. When introducing what the various theories had to say about negative priming it was striking to discover that memory theories of the effect fail to make a prediction for the relative performance of the Control condition. Attentional theories generally place the Control condition squarely between congruent and incongruent trials. From the current data it appears that there is a memory driven negative priming effect that can be observed when enough conditions are run such that the congruency pattern can be analyzed. In any event, when the Control condition does not fall between congruent and incongruent conditions one must conclude that any adherence to the congruency principle is not due to attention. But, an attentional manipulation can have a further effect such that the Control condition is shifted in between congruent and incongruent. Therefore, the congruency principle can be used to find the negative priming effect, but in this instance one can make a stronger suggestion that the conventionally measured negative priming found in the biased condition is due to selective inhibition.

Another interesting effect that has occurred here is that error rates are highest in the condition with the most negative priming. Error rates in all of the non target repetition conditions when there is an attentional bias are higher than those same conditions without an attentional bias. This tends to cast doubt on the generalizability of maintaining low error rates as a way to

insure that negative priming occurs (Neill & Westbury, 1987) even though that is often used as an explanation for a lack of an effect. And, many theorists mention the high accuracy finding of Neill & Westbury as a general principle of negative priming. Some also focus on the extended reaction times that high accuracies also produce, yet again, the reaction times in the biased condition are faster than in the unbiased condition; but the negative priming effect is as strong or stronger when reaction times are faster.

It is important to note that it is not unprecedented to have some negative priming in an experiment where letter identities are used and items do not change location (e.g., Fox, 1998; Fox & DeFockert, 1998). However, in all of those instances there were two flanking distractors, one on either side of the target. That is why it is explicitly mentioned in the present experiments that items do not change location from prime to probe and there is one distractor.

While Fox (1998; Fox & DeFockert, 1998) has previously generated negative priming that could be seen with a conventional measure with stationary targets and distractors from prime to probe it is interesting that this effect was sensitive to attentional manipulations. They found that grouping of items or selection difficulty influenced the negative priming effect in those paradigms. From the present data we would predict that negative priming would be present in all conditions based on congruency but that the attentional manipulations would modify the relative position of Control so that negative priming would be observed with more conventional measures.



Because the congruency principle has been generally supported in letter identity experiments it is very difficult to use it to distinguish among negative priming theories. It may well be that the biasing that enhances negative priming does so because it increases the memory for prime distractors, as others have suggested. However, it is my position that this is a rather weak attribution. An attentional manipulation more strongly manipulates attention than memory. In fact, it might well be argued that the ignored item will be remembered less well because, to paraphrase James' famous description of attention, "greater attention on some items should entail greater withdrawal from others." In other words, attempting to maintain attention on the prime target from prime to probe should *reduce* the memory trace of the prime distractor, not enhance it. Therefore, if negative priming is increased by such a procedure it is because of increased attentional suppression, not because of a better memory for the prime distractor.

It is a little more understandable that a biased trial sequence was originally given a memorial explanation for negative priming in the Stroop task (Lowe, 1979). In that instance the memories of the prime and probe may not be as easily disentangled from one another because the target and distractor properties are of a single item. However, in spite of the uniqueness of Stroop stimuli, it must be the case that if the participant is biased toward target repetitions then their memory of the prime distractor will be reduced.

### Stroop Button Press Experiments

The second class of experiments to be explored here is Stroop experiments using a button press response. From all theoretical accounts negative priming should be expected in this paradigm, and it does happen with a vocal response. But, it is not found with a button press response. This unexpected absence of NP is akin to that seen in the fixed location two letter identification task explored in Experiments 2 and 3. One manipulation that caused negative priming in this paradigm was having the individual maintain high accuracy (Neill & Westbury, 1987).

It is presently hypothesized that high accuracy requests may have generated negative priming because high accuracy engendered an attentional bias. One of the ways to maintain high accuracy may have been to generate a degree of target repetition bias. If that is the case then either manipulation (high accuracy instructions or a high probability of target repetitions) should be able to generate negative priming. Furthermore, when negative priming is generated then the general pattern of data should follow the congruency principle.

One may note that there is a finding in the literature that may contradict the present prediction of support for the congruency principle, or more precisely, suggest a different position for the Control condition with respect to related conditions. An interesting effect in vocal Stroop experiments is that the Target→Distractor condition is faster than Control (Neill, 1978). In addition, Lowe (1979) showed that the Switch performance was not worse than the Distractor→Target, moreover, it was numerically better. Since both of those conditions contain a

Target→Distractor property it may well be that the congruency principle was not upheld. However, for the time being, it is expected that if the congruency principle is supported in this paradigm the Control condition may be worse than Target→Distractor. The Switch findings of Lowe (1979) may have been an anomaly and, not being significant, may have been merely the result of noise.

In this series of experiments bias is manipulated in both of the ways it was generated in the letter identity experiments. This was done not only so that a demonstration of the effects of bias in a commonly used, but nevertheless flawed, design could be showcased, but because a complete pattern of results is needed to verify the congruency principle. As was done in Experiment 2, no distractor conditions are run in most of these experiments. Therefore, instead of the base seven conditions (six related and one unrelated) there are 15 conditions with four classes of probe trials, each with its own Control condition in most of the experiments, just as in Experiment 2 and shown in Table 3.

### Experiment 3

In Stroop negative priming where button presses are used for the response there have been repeated failures to generate negative priming (Neill, 1977; Neill & Westbury, 1987). Neill & Westbury hit upon a manipulation that causes the effect to be generated. If the participant is asked to maintain a high level of accuracy then the negative priming effect reappears; Distractor→Target performance is worse than that in the Control condition. This pattern was replicated twice in the Neill & Westbury paper,

but there are no published replications outside of that work.

Neill & Westbury (1987) conservatively attributed the cause of the negative priming effect appearing with the accuracy emphasis to greater inhibition required when generating a more accurate response. However, later theorists have reinterpreted this finding to be a timing issue. It is not just that attempting to be more accurate generates more inhibition of the distractor, but that the extra time taken when one is more accurate allows for the inhibition to accrue and its effects to be revealed.

This experiment is an attempt to see if a bias can generate the same effects as did requesting high accuracy. According to Neill & Westbury (1987), high accuracy causes the individual to attempt to suppress the distracting information more strongly. If our hypothesis is correct about bias, that maintaining an attentional set toward the target item necessitates maintaining inhibition of the distractor, then negative priming will occur in biased designs as well. There is some precedent for bias being important in vocal Stroop tasks (Lowe, 1985; Kieley & Hartley, 1997). The following is a simple biased negative priming study deliberately designed with only three conditions, Target→Target, Distractor→Target, and Control, just as in the biased condition of Experiment 1. Again, this is for reference to the literature, where it is common to run only these conditions with equal probability.

## Method

### Participants

12 participants were run in an experiment that was biased (see the

biased condition of Experiment 1, for a similar design). All were rewarded with one credit point toward their introductory psychology course.

### Apparatus

The computer setup was the same as that of Experiment 2. The number, and arrangement of trials was the same as the biased condition of Experiment 1. This was a Stroop-like (1935) experiment in which words were presented one at a time on a computer screen. The response was to make a button press indicating the colour of the word. The possible words, and colours, were 'RED', 'GREEN', 'BLUE', and 'YELLOW'. While the participants were required to ignore the words they were to respond by pressing either the 'F', 'V', 'M', or 'K' keys respectively. The keys were not labeled with colours and participants were given the instructions by placing their hands on the keys and touching each finger to indicate the appropriate response. The actual letters on the keys were not mentioned to participants.

### Procedure

The procedure was identical to the biased condition of Experiment 1 except that the target response was indicating the colour of the word by pressing the corresponding button instead of the identity of a letter.

### Results

The prime RT was 759 msec and the prime error rate was 3.75%.

The probe data are presented in Figure 4. It is clear from the figure that performance in the Distractor→Target condition is not numerically poorer than Control in RT. There is a main effect of condition,  $F(2,22) =$

41.48,  $p < 0.001$ ,  $MSE = 5110.5$ ,  $PLSD = 50.5$ . This is primarily driven by the Target→Target performance. Confirming that this is not just a power issue, only 4 participants had Distractor→Target RTs that were slower than Control RT. In accuracies the graphs tell a different story and it appears that perhaps negative priming has occurred given that there is a main effect,  $F(2,22) = 3.66$ ,  $p = 0.04$ ,  $MSE = 21.73$ ,  $PLSD = 3.95$ . The Distractor→Target cost is not significant (2.2% difference) but that might be a power issue. This was tested by examining individual participants' performance. Only 5 of the 12 participants had Distractor→Target error rates that were worse than Control. The pictured results are strongly biased by one participant who had a 20% error rate in Distractor→Target.

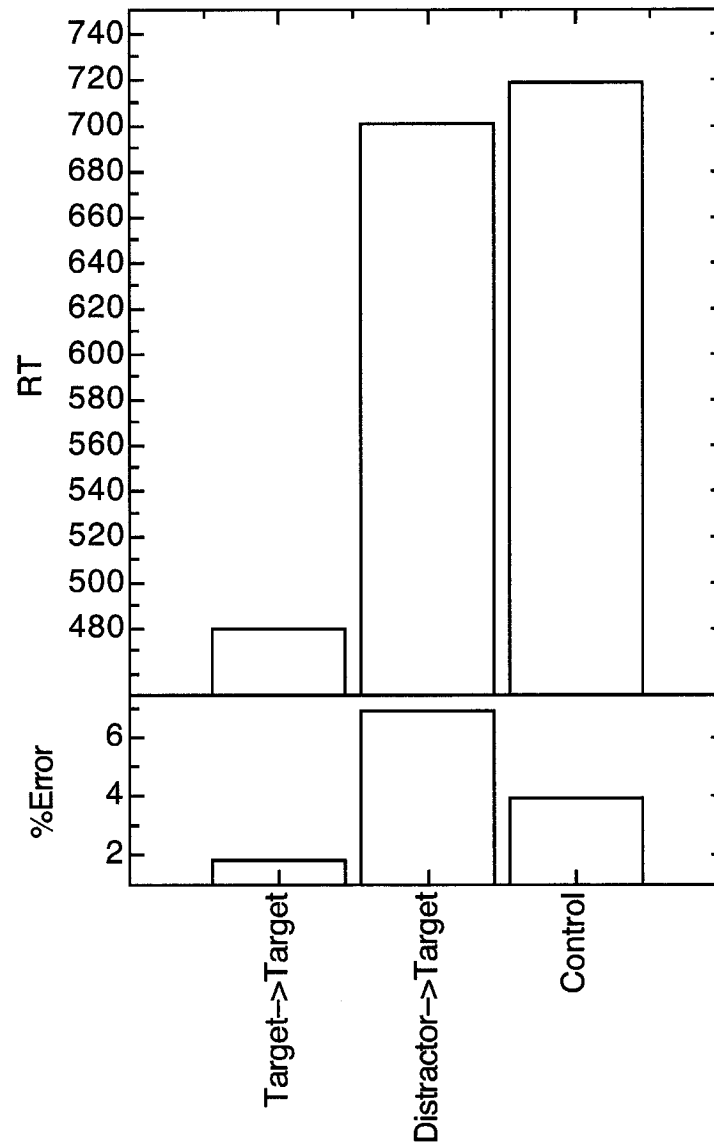


Figure 4. RT and error rates for Experiment 3. This is a Stroop button press experiment with only these conditions run in a biased way.

#### Discussion

Apparently a biased experimental design alone cannot produce negative priming with Stroop and button presses.

The Neill & Westbury (1987) findings that NP in the Stroop button

press task can be generated by using high accuracy requirements have not been replicated outside their laboratory. In order to further explore attentional manipulations in Stroop with button press responses it was decided that a replication of the original Neill & Westbury experiment be conducted. There are several attempts to do this in the following experiments.

#### Experiment 4

Neill & Westbury (1987) found that negative priming does not occur in a Stroop paradigm, wherein button presses are used for the response, unless one is required to respond very accurately. This is an attempt to replicate that experiment.

#### Method

##### Participants

There were 26 participants, 12 in the balanced accuracy condition (i.e., be both fast and accurate), and 14 in the high accuracy instruction condition (i.e., be as accurate as possible).

##### Apparatus

The computer setup, number, and arrangement of trials were the same as Experiment 2 in the unbiased condition. Stimuli were the same as in Experiment 2.

##### Procedure

The procedure was identical to that of Experiment 3 except for the following exceptions. Participants were first selected for either the unbiased



high accuracy condition, or unbiased balanced accuracy instruction condition. If they were in the balanced accuracy instruction condition participants were asked to respond to the stimuli with both speed and accuracy. If they were in the high accuracy condition participants were strongly encouraged to respond to the stimuli making as few errors as possible and ignoring how long it took.

### Results

The accuracy instruction was successful in reducing error rates on the prime conditions with distractors, 2.51% v. 5.37%,  $F(1,24) = 4.56$ ,  $p = 0.04$ . This was marginally true for probe accuracies, 2.79% v. 4.72%,  $F(1,24) = 2.63$ ,  $p = 0.055$  (one way). Because there is only a marginal effect of a probe accuracy across the instructions some non parametric tests were performed. A Mann-Whitney U test was performed and revealed a significant effect of the high accuracy request on probe trials,  $Z = 1.98$ ,  $p = 0.045$ .

In all of the probe trials in which the prime or the probe did not contain a distractor the only effect that occurred was that target repetition improved performance. Those will not be discussed further. The analyses and means for all conditions can be seen in Table 5. The balanced accuracy group is presented there followed by the high accuracy group.

The data from trials in which there was a distractor on both the prime and the probe are shown in Figure 5. In reaction time there were main effects of condition for the balanced accuracy and high accuracy conditions.

Note that the original hypothesis of a high accuracy instruction engendering a bias favoring repetitions, as seen in the increasing target

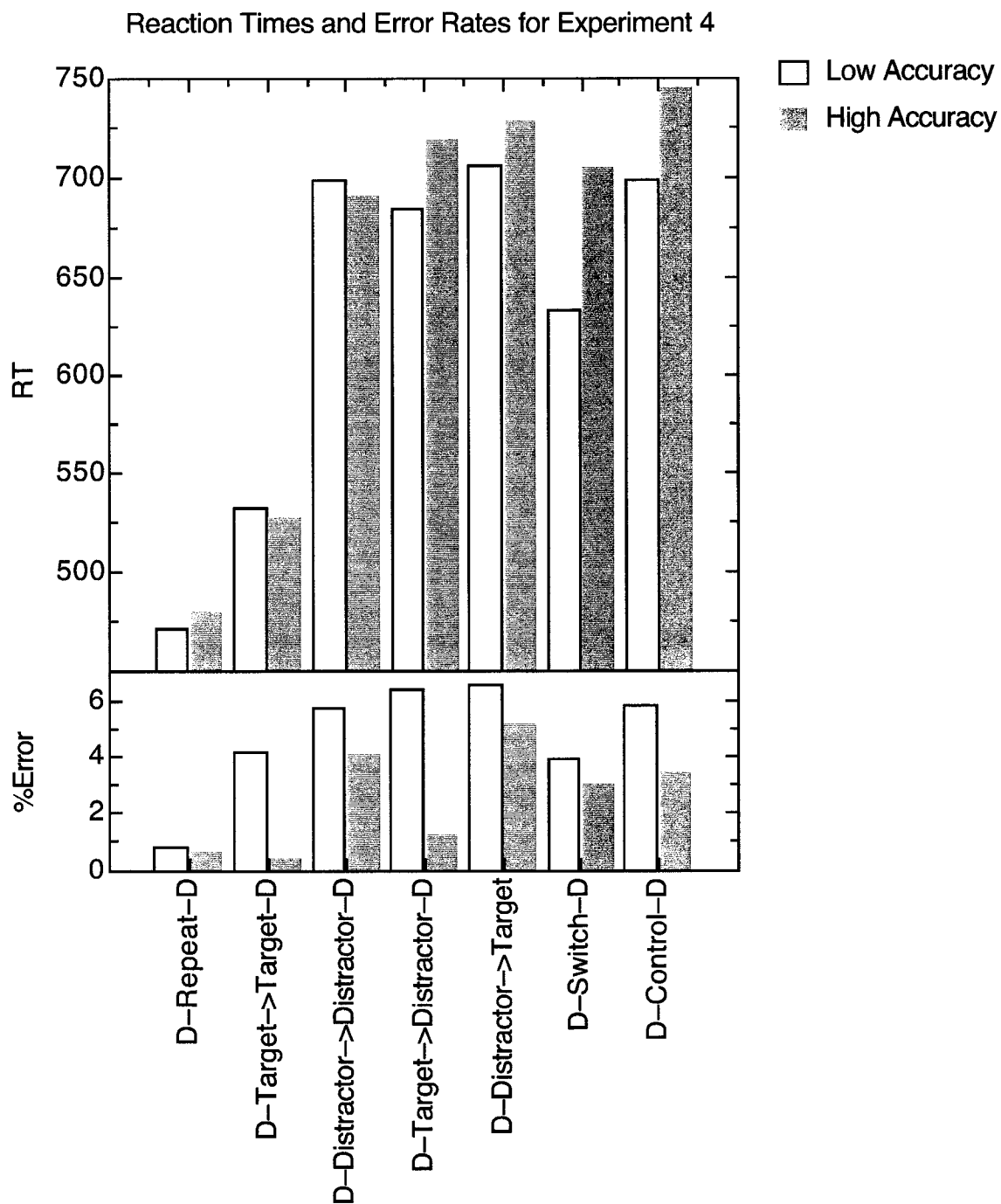
repetition effects, was partially upheld. There is definitely a trend in this direction. However, high accuracy instructions did not generate a negative priming effect. In fact, the trends are in the wrong direction. The congruency principle is not upheld, primarily because of the superior performance of the D–Switch–D condition which is supposed to be the one in which participants perform worst. The D–Control–D condition was numerically poorer than all of the other conditions when high accuracy was requested.

**Table 5.** Reaction times, error rates, and ANOVAs from all conditions of Experiment 4. The first section is the balanced accuracy instruction condition, and the second section is the high accuracy instruction condition. Bold indicates a significant difference from the Control condition, or in the case of primes a significant difference from D-Prime for the ND-Prime condition.

Balanced Accuracy		RT	analysis	Errors	analysis
ND-Prime	<b>681</b>	F(1,11)= 25.0, p<0.001	<b>3.80</b>	F(1,11)= 6.79, p=0.024	
D-Prime	759	MSE = 1459.8	5.37	MSE = 2.18	
ND-Repeat-ND	<b>449</b>	F(1,11)= 112, p<0.001	<b>0.00</b>	F(1,11)= 6.43, p=0.028	
ND-Control-ND	636	MSE = 1866.2	4.43	MSE = 18.33	
ND-Target->Target-D	<b>510</b>	F(2,22)= 54.9, p<0.001	3.20	F(2,22)= 0.81, p=0.84	
ND-Target->Distractor-D	704	MSE = 3005.0	4.65	MSE = 44.68	
ND-Control-D	722	PLSD = 46.4	3.27	PLSD = 5.66	
D-Target->Target-ND	<b>502</b>	F(2,22)= 25.6, p<0.001	<b>0.69</b>	F(2,22)= 2.82, p=0.081	
D-Distractor->Target-ND	648	MSE = 2911.6	3.88	MSE = 19.41	
D-Control-ND	628	PLSD = 45.69	4.75	PLSD = 3.73	
D-Repeat-D	<b>472</b>	F(6,66)= 35.6, p<0.001	<b>0.76</b>	F(6,66)= 2.07, p=0.069	
D-Target->Target-D	<b>532</b>	MSE = 2948.3	4.12	MSE = 24.20	
D-Distractor->Distractor-D	699	PLSD = 44.3	5.69	PLSD = 4.01	
D-Target->Distractor-D	684		6.36		
D-Distractor->Target	706		6.57		
D-Switch-D	<b>633</b>		3.88		
D-Control-D	699		5.80		

Table 5 (continued)

High Accuracy	RT	analysis	Errors	analysis
ND-Prime	<b>731</b>	F(1,13)= 10.1, p=0.007	2.02	F(1,13)= 1.62, p=0.23
D-Prime	773	MSE = 1183.7	2.51	MSE = 1.02
ND-Repeat-ND	<b>486</b>	F(1,13)= 27.3, p<0.001	4.17	F(1,13)= 0.03, p=0.86
ND-Control-ND	671	MSE = 8739.4	3.63	MSE = 61.78
ND-Target->Target-D	<b>523</b>	F(2,26)= 31.27, p<0.001	1.79	F(2,26)= 1.54, p=0.23
ND-Target->Distractor-D	700	MSE = 6038.8	1.84	MSE = 20.93
ND-Control-D	742	PLSD = 60.37	4.44	PLSD = 3.56
D-Target->Target-ND	<b>500</b>	F(2,26)= 39.9, p<0.001	0.59	F(2,26)= 2.12, p=0.14
D-Distractor->Target-ND	660	MSE = 3258.6	3.27	MSE = 13.20
D-Control-ND	674	PLSD = 44.4	2.73	PLSD = 2.82
D-Repeat-D	<b>481</b>	F(6,78)= 34.7, p<0.001	<b>0.59</b>	F(6,78)= 3.48, p=0.004
D-Target->Target-D	<b>528</b>	MSE = 4537.5	<b>0.36</b>	MSE = 13.61
D-Distractor->Distractor-D	<b>690</b>	PLSD = 50.7	4.06	PLSD = 2.78
D-Target->Distractor-D	719		1.23	
D-Distractor->Target	728		5.14	
D-Switch-D	704		3.03	
D-Control-D	745		3.41	



**Figure 5.** The RT and error rates for Experiment 4. It is a Stroop button press experiment with equal even probabilities. Only conditions where both targets and distractors are present are shown. Requesting high accuracy did not generate data that reflect a negative priming process either from a simple Distractor->Target - Control perspective or from the perspective of

confirming the congruency principle.

### Discussion

Participants in Neill & Westbury (1987) had error rates in the Control condition with distractor of 10.3% for lax accuracy instructions and 4.3% for strict. In spite of the fact that the current accuracy rates were lower than 4.3% in both conditions there was no negative priming found. Perhaps the failure to replicate Neill & Westbury was due to less aggressive motivation to maintain high accuracies than they used. Given that Neill & Westbury's explanation for their results relies heavily on the motivation to maintain high accuracy it is important that a higher motivation be tested here.

One caveat is that the accuracy rates in the current experiments are not entirely comparable to Neill & Westbury (1987). Performance generally improves after a stimulus change at a steep rate for a few hundred milliseconds (Klein & Kerr, 1974). In the current experiments there is a 330 msec offset after a prime response before the probe stimulus comes on. But, in Neill & Westbury this response to stimulus interval (RSI) was usually 0 msec. Therefore, their participants may have been less accurate because they were less well prepared when the probe stimulus came on.

Because the actual accuracy rates are not truly comparable between Experiment 4 and Neill & Westbury in terms of reflecting a motivation to maintain accuracy, it is important to attempt to better equate these variables methodologically.

### Experiment 5

This experiment was conducted to attempt to replicate Neill & Westbury's (1987) finding of NP by using a higher emphasis on accuracy and biasing participants towards maintaining the attention state from prime in anticipation of the probe.

Participants in this experiment received an inordinately large number of target repetitions. Fully one half of the time the target is repeated. This change was made because it is believed that the normal instance of runs of trials that occurs in a long random sequence like that used by Neill & Westbury (1987) may have caused individuals to expect target repetitions. When trials are discretely paired this illusion of increased target repetitions may not have occurred. Therefore, putting in such a bias in a paired trial design should allow us to replicate those original findings.

Of course this manipulation may have all of the effects that biasing has been predicted to have earlier in this document. The participant may be motivated to maintain attention both on the prime target, and away from the prime distractor. This may enhance or bring out any negative priming effect as it did in Experiments 1 and 2. Furthermore, Lowe (1979) demonstrated in a vocal Stroop paradigm that bias enhanced the negative priming effect.

In order to convince participants to respond as accurately as possible a 2s warning was presented after every probe in which there was an error on either the prime or the probe. This is more similar to Neill & Westbury's original accuracy manipulation procedure.

## Method

### Participants

There were 12 participants in this experiment who were rewarded with one credit point toward their introductory psychology course.

### Apparatus

All apparatus was the same as Experiment 4.

### Procedure

The procedure was identical to the high accuracy condition of Experiment 4 except that the probability of a target repeating was increased to 0.5. This was accomplished by tripling the number of all trials where targets repeat. A 2s warning was put in before feedback after every probe trial where an error occurred on either the prime or the probe. This was considered an increased incentive to maintain high accuracy.

## Results

In the prime condition participants were significantly hampered in performance by the presence of an interfering word in reaction time,  $F(1,11) = 10.65$ ,  $p = 0.008$ ,  $MSE = 1850.31$ , but not in error rates,  $F < 1$ . Without a distractor RT was 645 msec and error rate was 3.66%. With a distractor the RT increased to 703 msec while the error rate remained a similar 3.12%.

All conditions that did not contain a distractor on either the prime or the probe only had one significant effect, that target repetitions were faster than Control.

Considering only the conditions where a distractor appeared on both



the prime and the probe, as can be seen in Figure 6, statistical tests on this particular set of data are rather pointless for investigating negative priming. Every condition was numerically faster than D-Control-D. In addition, the congruency principle is violated. Switch conditions are faster and more accurate than all other incongruent conditions. The Switch is even faster than the Distractor->Distractor condition. However, for further analysis it is important to note that there was a significant effect of condition in both RT,  $F(6,66) = 66.21, p < 0.001, MSE = 2590.94, PLSD = 44.38$  and error rate,  $F(6,66) = 3.67, p = 0.003, MSE = 12.60, PLSD = 2.89$ . More complete analyses are presented in Table 6.

**Table 6.** All RTs and error rates from Experiment 5. This was a Stroop button press experiment with participants biased to expect target repetitions and encouraged to maintain high accuracy.

Experiment 5				
	RT	analysis	Errors	analysis
ND-Prime	<b>645</b>	F(1,11)= 10.7, p=0.008	3.66	F(1,11)= 0.97, p=0.522
D-Prime	703	MSE = 1851.3	3.26	MSE = 1.02
ND-Repeat-ND	<b>386</b>	F(1,11)= 107, p<0.001	0.00	F(1,11)= 4.72, p=0.053
ND-Control-ND	627	MSE = 3251.5	3.54	MSE = 15.88
ND-Target->Target-D	<b>427</b>	F(2,22)= 61.9, p<0.001	1.20	F(2,22)= 2.37, p=0.12
ND-Target->Distractor-D	653	MSE = 3648.0	5.00	MSE = 18.48
ND-Control-D	675	PLSD = 51.1	2.84	PLSD = 3.64
D-Target->Target-ND	<b>420</b>	F(2,22)= 71.6, p<0.001	<b>0.23</b>	F(2,22)= 5.28, p=0.013
D-Distractor->Target-ND	609	MSE = 2175.9	4.99	MSE = 16.09
D-Control-ND	624	PLSD = 39.5	4.68	PLSD = 3.40
D-Repeat-D	<b>401</b>	F(6,66)= 66.2, p<0.001	<b>0.73</b>	F(6,66)= 3.67, p=0.003
D-Target->Target-D	<b>427</b>	MSE = 2950.9	<b>0.82</b>	MSE = 12.60
D-Distractor->Distractor-D	658	PLSD = 44.3	3.30	PLSD = 2.89
D-Target->Distractor-D	<b>654</b>		<b>1.81</b>	
D-Distractor->Target	699		4.85	
D-Switch-D	<b>639</b>		<b>2.08</b>	
D-Control-D	703		5.20	

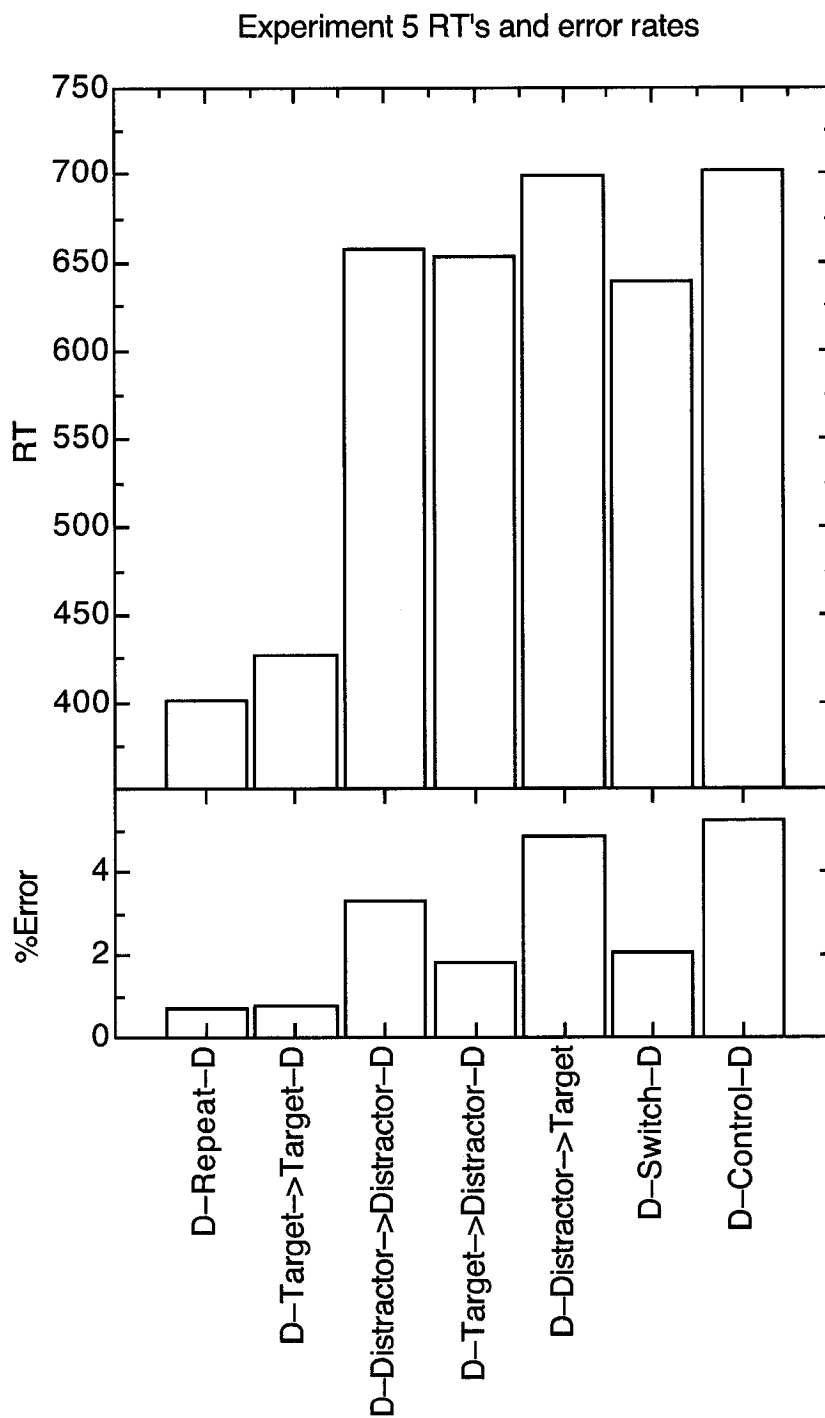


Figure 6. Reaction times and error rates for Experiment 5. In this experiment participants are biased to expect that the current target will repeat and should maintain that attentional set. Furthermore, they were encouraged to maintain high accuracy by pausing the progress of the experiment for 2s whenever an error occurred.

## Discussion

Lowe (1979) demonstrated that negative priming in a vocal Stroop negative priming paradigm is sensitive to target repetitions. He found that if a target was likely to repeat, then the negative priming effect was more robust. Together with Experiment 5, this experiment demonstrates that the opposite may be true for button press Stroop negative priming. If the Switch condition can be taken as one that can also be used to measure negative priming it is telling that the advantage over Control is greater in this experiment than the previous unbiased ones.

Perhaps the Neill & Westbury (1987) pattern is not replicable. The preceding non replications certainly lead one to believe that this is true. However, in the interests of fairness there are several design parameters in the present experiments that differ from Neill & Westbury (1987).

A couple of further replications will be performed in which an attempt to very closely replicate Neill & Westbury (1987) will be made.

### Experiment 6 a, b, c

These experiments were conducted to attempt to replicate Neill & Westbury's (1987) finding of NP with a high emphasis on accuracy while also modifying other properties to more closely match those of Neill & Westbury. The bias manipulations are removed and all stimulus events are equally likely to occur using random selection without replacement. This is the same trial probability used in the earlier unbiased attempt at replication in Experiment 4.

In Experiment 6a participants were convinced to respond as accurately as possible with a 2s warning presented after every probe in which there was an error on either the prime or the probe, just as in Experiment 5. This is more similar to Neill & Westbury's original accuracy manipulation procedure without the target repetition bias introduced in Experiment 5.

In Experiment 6b the method was identical to Experiment 6a except that the RSI was reduced to 30 msec. This was very similar to the most commonly used RSI in Neill & Westbury (1987). In one experiment they used both shorter (0 msec) and longer (500 msec) RSIs mixed in a block. It is possible that the 330 msec RSI used in experiments thus far allowed the participant to attain a level of preparedness that was not found by Neill & Westbury. With their short RSI their participants would have been at a generally significantly lower level of alertness than with the present RSI. In addition, in the experiment that included a 500 msec RSI, the extreme differences between that and a 0 msec RSI may have caused neither the 0 or 500 msec RSI to provide optimal preparedness. The bulk of the approximately 100 msec difference between Neill & Westbury's average RTs and the ones reported here are likely due to this alertness difference. The longer RSI used by Neill & Westbury would have allowed for better alertness on the part of the participants, and it did significantly reduce RTs over the 0 msec RSI condition. However, because the 500 msec RSI was presented mixed with 0 msec RSI trials, and 500 msec is long enough for alertness to begin to decline (Klein & Kerr, 1974), participants may not have been quite as prepared as they are in the present experiments. In order to see

if reduced preparedness is necessary to generate a negative priming effect, Experiment 6b and c will both use 30 msec RSIs. Furthermore, because of the reduction in alertness it is predicted that the overall RT will be considerably longer in Experiment 6b and c than in Experiment 6a.

Experiment 6c was identical to Experiment 6b except that an 8s time-out was used instead of 2s. While asking for high accuracy in the present experiments there may also be somewhat of a conflict with a speed requirement. In the previous experiments the trial time-out was 2s. Whereas this is far above the mean RT, and rarely is exceeded during test trials, the time-out may often be encountered in practice trials. Those encounters with a trial termination may have encouraged participants to go faster than participants without a time-out would have gone (as in Neill & Westbury, 1987). The current software was not designed to easily handle an unlimited trial time, but it was assumed that 8s would be long enough to achieve a similar effect. It is predicted that the overall RT in Experiment 6c will be longer than that in 6a, or 6b.

Finally, a larger number of participants were run to reduce the chance of a Type II error.

## Method

### Participants

There were 26 participants in Experiment 6a, 20 in Experiment 6b, and 14 in Experiment 6c. All 60 participants were from first year Psychology courses and were rewarded with one credit point toward their course mark for participation.

### Apparatus

All apparatus was the same as Experiment 4.

### Procedure

The procedure of Experiment 6a was identical to the high accuracy group of Experiment 4 except that if an error was made there was a message that forced the participant to wait for 2s after the probe trial. This seems to be a strong inducement not to make errors and one that was very similar to the method used by Neill & Westbury. Experiment 6b was identical to 6a except that the RSI was reduced from 330 msec to 30 msec. Experiment 6c was identical to Experiment 6b except that the trial time-out was increased from 2s to 8s.

### Results

There were effects across Experiments but they did not interact with an analysis of negative priming. There were no significant main effects across experiments in either reaction times or accuracies and only one significant interaction with reaction times when both primes and probe contained distractors,  $F(12, 342) = 2.44$ ,  $p < 0.01$ ,  $MSE = 3437$ . This is shown in Figure 7. The interaction was caused by the fact that in Experiment 6c with the 8s time-out RT increased, but only for trials in which the target did not repeat. The RT for trials where the target repeated in Experiment 6c was numerically faster than in Experiment 6a or 6b. Otherwise, the general pattern of results did not differ across experiments. It is notable that the decrease in RSI from 330 msec to 30 msec did not appreciably increase RT. However, it did appear to raise error rates, but this was not statistically significant. Another notable between-experiment

finding is that the 2s delay to encourage error reduction did not make the accuracy numerically greater than that in the high accuracy instruction condition of Experiment 4. In fact, the general pattern of performance is nearly identical to the high accuracy condition of Experiment 4 and likely the only difference in significant effects is due to the extra power of running 60 participants in the present experiment as opposed to 14 participants in the high accuracy condition of Experiment 4. Again, the only significant finding in all of the conditions where there was no distractor on the prime, probe, or both, was that target repetitions were faster. Those conditions will not be discussed further but the data can be seen in Table 7. Error rates were in general very low.

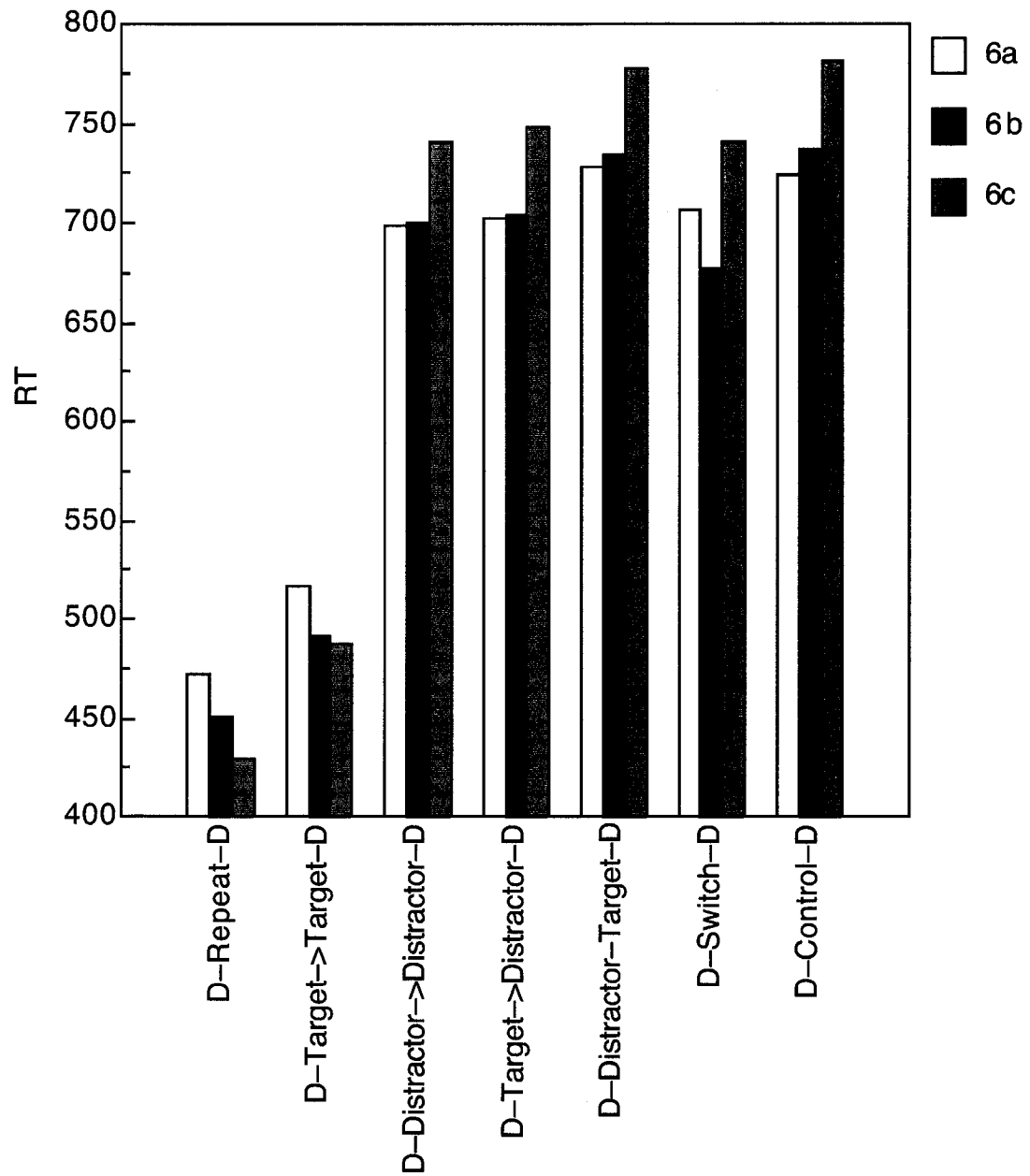
The data with distractors on both the prime and probe collapsed across Experiments 6a, 6b, and 6c are presented in Figure 8. There was a main effect of condition in RTs,  $F(6, 354) = 242.6$ ,  $p < 0.001$ ,  $MSE = 3604.0$ ,  $PLSD = 21.6$ . The negative priming measured by the difference between D-Distractor→Target-D and D-Control-D is not in the right direction. In addition, there are violations of the congruency principle similar to what was found in Experiment 5. The D-Switch-D condition is faster than the D-Distractor→Target-D and even the D-Control-D condition. In addition, the predicted result of D-Target→Distractor-D being faster than D-Control-D also occurred.

In errors there was a trend for D-Distractor→Target-D to be worse than D-Control-D. There was a main effect of condition,  $F(6,354) = 14.73$ ,  $p < 0.001$ ,  $MSE = 9.63$ ,  $PLSD = 1.11$ , the negative priming effect, as measured against Control, was significant. D-Distractor→Distractor-D,



and D-Switch-D condition performance was also worse than Control. The congruency principle was clearly violated in error rates with D-Distractor->Distractor-D performance being significantly worse than all other conditions, and Switch performance tending to be better than Distractor->Target.

## Experiment 6a, b, c between experiment interaction

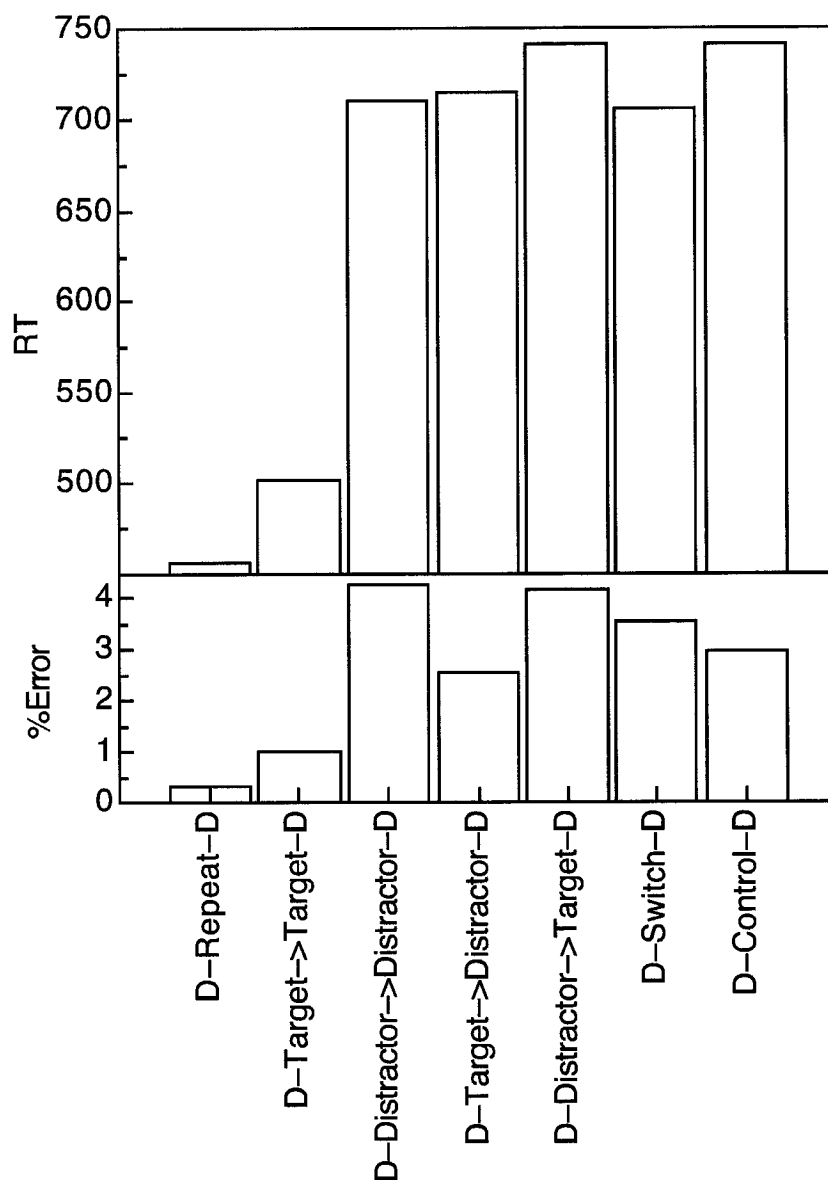


**Figure 7.** Reaction times from the one analysis where there is an interaction between experiment and condition in Experiment 6a, b, c.

**Table 7.** Collapsed data and analyses across experiments 6a, b, c.

Experiment 6a,b,c	RT	analysis	Errors	analysis
ND-Prime	<b>717</b>	F(1,59)= 144, p<0.001	3.47	F(1,59)= 0.03, p=0.857
D-Prime	785	MSE = 959.7	3.42	MSE = 2.08
ND-Repeat-ND	<b>442</b>	F(1,59)= 329, p<0.001	<b>0.24</b>	F(1,59)= 43.13, p<0.001
ND-Control-ND	681	MSE = 5229.2	4.60	MSE = 13.26
ND-Target->Target-D	<b>504</b>	F(2,118)= 207, p<0.001	<b>0.65</b>	F(2,118)= 16.29, p<0.00
ND-Target->Distractor-D	722	MSE = 4815.6	3.58	MSE = 9.26
ND-Control-D	732	PLSD = 25.1	3.17	PLSD = 1.10
D-Target->Target-ND	<b>480</b>	F(2,118)= 184, p<0.001	<b>0.42</b>	F(2,118)= 19.79, p<0.00
D-Distractor->Target-ND	661	MSE = 4130.2	3.59	MSE = 10.61
D-Control-ND	686	PLSD = 23.2	3.73	PLSD = 1.18
D-Repeat-D	<b>455</b>	F(6,354)= 243, p<0.001	<b>0.31</b>	F(6,354)= 14.73, p<0.00
D-Target->Target-D	<b>501</b>	MSE = 3604.0	<b>0.98</b>	MSE = 9.63
D-Distractor->Distractor-D	<b>710</b>	PLSD = 21.6	<b>4.28</b>	PLSD = 1.11
D-Target->Distractor-D	<b>714</b>		2.55	
D-Distractor->Target	742		<b>4.20</b>	
D-Switch-D	<b>705</b>		<b>3.53</b>	
D-Control-D	742		2.98	

Experiment 6a, b, c RTs and Error Rates



**Figure 8.** RTs and error rates for the seven conditions that contain a distractor on both the prime and the probe in Experiment 6a, b, c. There are three experiments collapsed here that are similar to Experiment 4. All also have the 2s pause after errors in the experiment introduced in Experiment 5 to encourage high accuracy. Two (7b, c) have an RSI of only 30 msec vs. 330 msec. And, one of those (6c) also has a maximum response time of 8s instead of 2s in all previous experiments.

## Discussion

There was a partial failure to replicate Neill & Westbury (1987). There was a Distractor→Target cost relative to the Control condition but this only occurred in accuracies. This is an odd result given that the participants were strongly encouraged to focus on maintaining high accuracy. That instruction should have caused most of the performance effects to occur in reaction times, as was found in Neill & Westbury. In fact, an alternative explanation of their results has always been that the request to maintain high accuracy caused participants to move all of the variance in their performance into reaction time and that a very noisy result appeared in the reaction times that would otherwise require much more power to find. Furthermore, the effect size is considerably lower in the present experiments. Neill & Westbury found negative priming in three separate experiments that had a total N smaller than that of the present combined experiment. Separately, none of the present experiments (6a, b, c) had significant negative priming in accuracies and they needed to be combined for the effect to be revealed. A small difference in accuracies that is only significant when the three experiments are combined is not nearly as powerful as an effect found with three separate experiments, each containing roughly equivalent numbers of participants as any of the individual experiments here.

Another interesting finding was that the reduction in RSI alone did not increase RTs or have a significant effect on error rates. Given previous alertness studies it was surprising that this did not change performance by a larger amount. Klein & Kerr (1974) found the steepest effects of alertness

occurred within the first 100 msec.

Because there is only a partial weak replication here another experiment was performed that more closely approximated Neill & Westbury (1987). In all of the experiments presented thus far trials are presented in prime-probe pairs. Each pair of trials is self initiated. Neill & Westbury avoided this design in order to preclude participants from noticing prime-probe relationships. They ran the trials in sequences with no breaks or separation in between prime and probe. The only feedback was a pause whenever an error occurred. In the next experiment the prime-probe pairing used in the previous experiment is not employed and the sequence of trials is much more similar to Neill & Westbury.

### Experiment 7

This experiment is an attempt to replicate Neill & Westbury as exactly as possible. It is essentially identical to Experiment 6c except that there are no paired trials. The participant just sees a long series of trials.

#### Method

##### Participants

12 Dalhousie University undergraduate students served as volunteer participants. They received one credit point toward their introductory psychology class as remuneration.

##### Apparatus

The computer generating the experiment was changed to another Macintosh of near identical specifications, a Centris 650. The monitor was

the same.

### Procedure

The procedure was nearly identical to Experiment 6c except for the following modifications. Only error feedback was given and it was given immediately following the trial that the error occurred on. Trials were no longer self paced and ran for blocks of 100 before giving participants a rest. The sequence of trials included all the pairs used in Experiment 6, but the pairing was completely invisible to the participant

### Results

There was a main effect of distractor presence on prime RTs, with the mean of no distractor trials faster than primes with distractors. There was no effect of distractor presence on error rates.

The only effect that was significant on probe trials when there was no distractor on the prime, probe, or both, was that target repetitions improved performance. Those trials will not be discussed further. However, all of the RTs, error rates, and analyses are in Table 8.

The data from the trials that contained a distractor on both prime and probe are presented in Figure 9. There was a main effect of condition in both RT and error rate, as analyses in Table 8 reveal.

As in the previous experiments, there was no negative priming from either a comparison of D-Distractor->Target-D and D-Control-D or an examination of the congruency effect. This time D-Distractor->Target-D was faster than D-Control-D and not significantly less accurate with only a very small numerical difference (2.15 v. 2.31). All of the accuracy

differences were very small, with only the D-Repeat-D condition exceeding the others in performance with a mean error rate of 0%.

The overall RTs are much greater than that found in the other experiments here with paired trials.

**Table 8.** The RTs, error rates, and analyses from Experiment 7. This was a Stroop experiment much like Experiment 6c but with a continuous run of trials rather than discrete prime and probe pairs. The bold numbers are significantly different from the Control condition in the group. Or, in the case of the primes, significantly different from D-Prime.

Experiment 7	RT	analysis	Errors	analysis
ND-Prime	<b>810</b>	F(1,13)= 23.8, p<0.001	2.09	F(1,13)= 2.77, p=0.120
D-Prime	880	MSE = 1445.7	1.57	MSE = 0.68
ND-Repeat-ND	<b>538</b>	F(1,13)= 80.6, p<0.001	<b>0.00</b>	F(1,13)= 9.65, p=0.008
ND-Control-ND	863	MSE = 9172.7	3.36	MSE = 8.19
ND-Target->Target-D	<b>658</b>	F(2,26)= 51.1, p<0.001	1.31	F(2,26)= 0.57, p=0.575
ND-Target->Distractor-D	972	MSE = 9709.5	0.88	MSE = 2.74
ND-Control-D	995	PLSD = 76.6	1.54	PLSD = 1.29
D-Target->Target-ND	<b>605</b>	F(2,26)= 79.3, p<0.001	1.12	F(2,26)= 1.65, p=0.212
D-Distractor->Target-ND	864	MSE = 4406.5	2.22	MSE = 2.57
D-Control-ND	891	PLSD = 51.6	1.70	PLSD = 1.25
D-Repeat-D	<b>571</b>	F(6,78)= 59.5, p<0.001	<b>0.00</b>	F(6,78)= 3.08, p=0.009
D-Target->Target-D	<b>654</b>	MSE = 6973.1	1.46	MSE = 2.92
D-Distractor->Distractor-D	<b>885</b>	PLSD = 62.8	2.12	PLSD = 1.29
D-Target->Distractor-D	967		1.83	
D-Distractor->Target	975		2.31	
D-Switch-D	953		1.22	
D-Control-D	995		2.15	



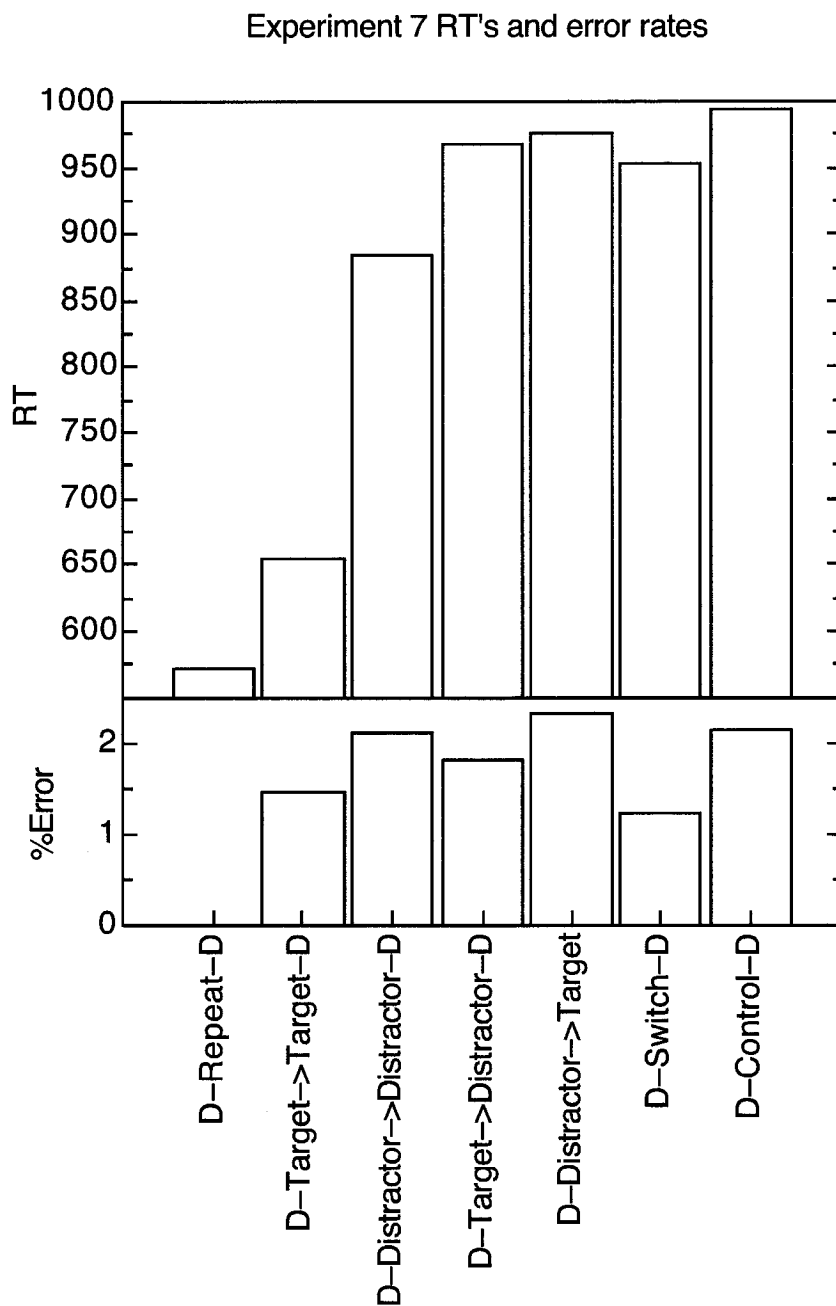


Figure 9. The error rates and reaction times for probe trials where the prime and the probe both contained a distractor in Experiment 7. This experiment is very similar to Experiment 6c but trials happen in one continuous sequence instead of prime-probe pairs.

## Discussion

Every effort has been made to conduct an experiment as similar as possible to those found in Neill & Westbury (1987). Their findings of negative priming in RT, Distractor→Target performance worse than Control performance, were not replicated. Either Neill & Westbury was an instance of a chance occurrence or there was something in the design of the experiments that has not been captured here. In any event, whereas the cause of Neill & Westbury's (1987) pattern has not been ascertained, it is certain that the pattern is not very generalizable or it is very weak.

An interesting finding was the large increase in RT when participants no longer had paired trials with self initiation. This further demonstrates that by pairing the trials and using self initiation individuals can be optimally prepared for the probe trial. It is predicted that if there was a variation in the RSI done as in Experiment 6a to 6b it would have a much larger effect in Experiment 7.

In spite of the present non replication of Neill & Westbury an interesting pattern of results has occurred across the experiments. These will be discussed together in a separate summary of the Stroop experiments.

But, before getting to that there was one more replication attempted. It was based on a personal communication with Neill.

### Experiment 8

I contacted Neill about the non replications of his Neill & Westbury (1987) findings and discussed some details of the experimental design. In Neill (1977) trials were selected at random and any kind of prime-probe relationship could occur, similar to the experimental design used here. It

was assumed that a similar kind of manipulation was performed in Neill & Westbury. However, on personal communication Neill reported that this was not the case. Neill & Westbury only ran the probe conditions they were interested in, Distractor→Target, and Control. All probe trials contained distractors.

In this experiment only the Distractor→Target, and Control conditions were be run. It was otherwise a replication of Experiment 6c. This experiment is only done in an attempt to replicate. In general it is recommended that such a design not be used for reasons described below.

When running D–Control–D, and D–Distractor→Target–D as the only trial possibilities a probability problem occurs. Each of these kinds of trial has an equal possibility of occurring in a completely random sequence. However, when running only these two conditions the salient target then appears related to the prime distractor half of the time. This might generate a bias toward expecting the Distractor→Target condition. Because of this problem Neill & Westbury (1987) doubled the number of Control trials in relation to the Distractor→Target trials so that the three possible targets would be equally likely. However, this has a side effect of biasing the probability of the probe Distractor that can appear toward the unrelated because the probe word can never be a prime item. It also has a side effect of increasing the likelihood of unrelated stimuli occurring on the probe trial in general. In other words, if the prime contains red and blue then participants will rightly expect green and yellow on the probe. This probability manipulation alone may hinder performance in the appearance of a Distractor→Target condition because it is a low probability event.

In addition to probability confounds, there are more serious contingency problems. If a stimulus on the probe is the same as one presented on the prime it is the prime distractor becoming the probe target because the Distractor→Target condition is the only related condition. Another contingency is that, because distractors cannot be anything but new stimuli, the prime can be used as a prefilter for probe items. In fact, while the former contingency caused by having only one kind of related trial may have reduced the negative priming effect by allowing one to easily identify any repeated stimulus as a target, the latter contingency could generate a negative priming effect. Participants could be prefiltering the prime items, both target and distractor, to reduce their interference on the 100 percent of the probe trials where that is a useful strategy. For example, if one sees red and green on the prime then one expects yellow and blue on the probe. That would hurt target selection performance when the prime distractor becomes the target on only 33 percent of the trials. The present findings of increased target repetition effects when high accuracy was requested bolster a claim that participants may use even superstitious, intertrial contingencies.

These kinds of problems are good examples of why it is best to simply run the possible trials at random, whether with replacement or without.

## Method

### Participants

There were 28 participants from the undergraduate subject pool at Dalhousie University.

### Apparatus

The apparatus was identical to Experiment 6c except that the trials that were run all had distractors and the only probe conditions were Distractor→Target, and Control. There were 288 trials, with 96 being Distractor→Target and the remaining Control.

### Procedure

This was identical to Experiment 6c except for the possible trials presented as described above.

### Results

The prime RT was 957 msec and the prime error rate was 2.48%.

There were no significant effects in probe RT,  $t(27) = 1.46$ ,  $p = 0.16$ , or error rates,  $t(27) = 0.39$ ,  $p = 0.70$ , across the two conditions. The direction of RT differences was against finding negative priming with a Distractor→Target RT of 857 msec faster than the Control RT of 867 msec. The error rates were almost the same with Distractor→Target at 2.30% and Control at 2.17%. These data are depicted in Figure 10.

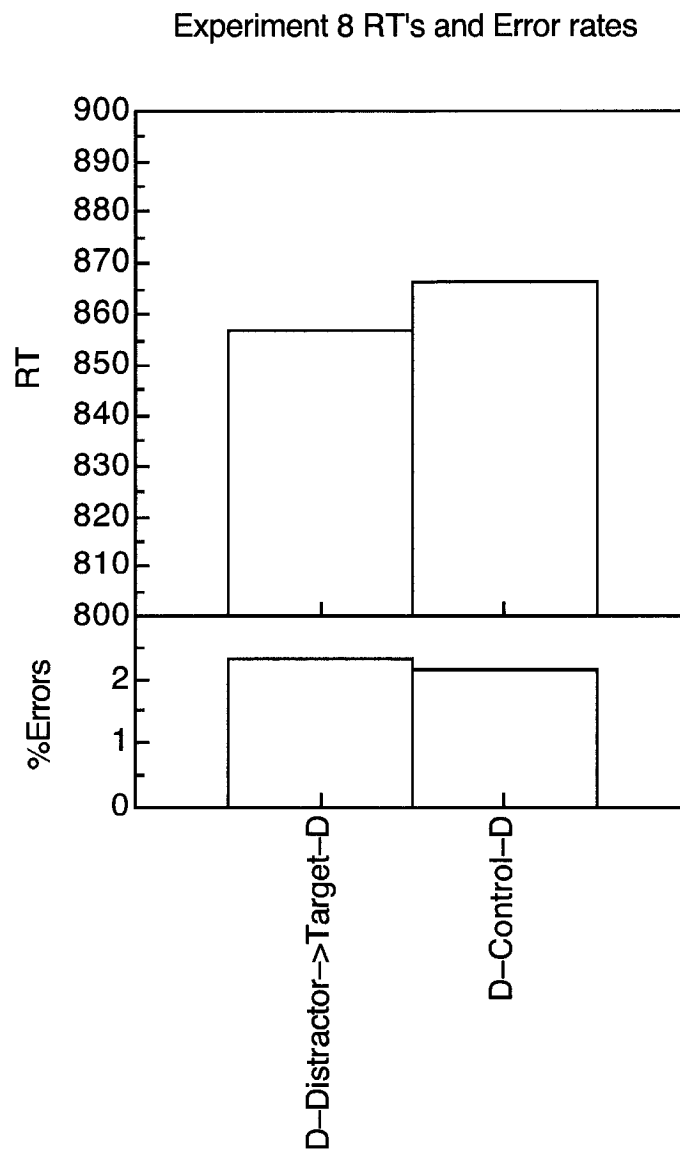


Figure 10. The RTs and error rates from Experiment 8. This was a Stroop experiment like Experiment 6c but with only the conditions above run to more closely replicate Neill & Westbury (1987). There are no statistically reliable differences in the RTs or error rates.

#### Discussion

Running the same two conditions that Neill & Westbury (1987) ran did not resurrect the negative priming effect. But, as described above, any resulting negative priming effect would be suspect even if it were there

because of all the previous non replications and the alternative explanations based on probability and contingency problems when running the reduced set of conditions.

What follows is a summary of the Stroop experiments and a further analysis of the various effects that were found.

### Stroop Experiments Summary

Neill & Westbury (1987) was only partially, and weakly, replicated. D-Distractor->Target-D reaction time was not worse than D-Control-D. This was not just a lack of statistical significance, but on average the numerical performance was better in the D-Distractor->Target-D condition. The fact that the performance in error rates did confirm a small and fleeting negative priming effect will be discussed later. The congruency principle was not confirmed. Therefore, it is not merely an issue with the Control condition failing to have better performance than Distractor->Target because the congruency principle does not necessarily include the Control condition.

A general pattern of performance appeared in these experiments that is rather interesting. Particularly notable is Experiment 6 where several effects were found. There was the standard benefit in both accuracies and reaction times for the trials where a target repeated, with the effect being larger for Repeat trials than Target->Target trials. There was also a benefit in reaction times for the Distractor->Distractor trials. Thus, on the congruent side of the congruency principle predictions were upheld in reaction times. However, accuracies in the Distractor->Distractor condition were worse than for the Switch, Target->Distractor, and Control conditions.

One of two things has occurred in the Distractor→Distractor condition. Either there is a simple speed accuracy tradeoff, or separate factors are affecting speed and accuracy in the related trials. By looking at other trials where there were speed or accuracy differences one may be able to tease this apart. In terms of speed, Target→Distractor and Switch trials were both faster than Control. What do these have in common that could account for the improvement in performance?

In Stroop experiments one way for the experimenter to facilitate performance is to reduce the amount of interference from the distractor word. This has been done by changing the relative onset of the word and the colour. If the colour precedes the word then of course performance can be improved because response generation can begin before the distractor appears. But, more importantly, if the word precedes the colour by a significant amount then performance will also be facilitated (Dyer, 1971; Glaser & Glaser, 1982; Sugg & McDonald, 1994). It may be that the distractor is easier to ignore if one has already processed it by seeing it before the target or saying it before the target colour. Perhaps, in the current negative priming experiment, when the probe distractor was previously presented as an item on the prime, performance is facilitated in the same way as when a distractor word is presented prior to the target colour. Therefore, Switch, Distractor→Distractor, and Target→Distractor performance are all better than Control. What matters is that a colour had been presented previously; its earlier role, whether target or distractor, seems not to matter. If the current distractor word was previously a target colour on the prime then performance will benefit as much as if it was



presented on the prime as a distractor word. In summary, it only matters that the psychological concept of the colour was processed immediately prior to its current presentation as a distractor word in order to reduce the interference from the distractor.

Further examination of the error rates in Experiment 6 reveals that both the Distractor→Distractor and Distractor→Target conditions were subject to inflated numbers of errors. This was additionally confirmed as a non significant trend in the high accuracy instruction level of Experiment 4. At first one might guess that these inflated error rates are possibly due to the distractor item from the prime being a good cue for the prime target. This would mean that a disproportionately larger number of the errors should be the identity of the prime target.

Table 9 is the listing of the proportion of error sources from Experiment 6. It is hoped that by examining these a better understanding of the source of the deficits in the Distractor→Distractor, and Distractor→Target conditions might be understood. Specifically, it would be interesting to find out whether they had common sources. The distribution of errors is not something that has previously been explored in the Stroop button press negative priming paradigm (or any negative priming paradigm).

Table 9. The proportions of errors, and their distribution, on trials where both the prime and probe contained distractors in Experiment 6. Condition labels were explained in Table 3. Note that the error rates do not match the error rates from the results section of Experiment 6. That is because the ones below are based on total counts of trials from each participant that are not weighted by participant. Note that certain conditions cannot have errors in certain cells while other errors would be classified in multiple cells. If a cell cannot contain an error then it is blank. If an error can be in multiple cells then only one cell contains the errors and the other cells have a reference to that cell.

Conditions	%Errors	ProbeWord	PrimeColour	PrimeWord	Other
D-Repeat-D	0.34	0.400		ProbeWord	0.60
D-Target->Target-D	0.98	0.667		0.148	0.185
D-Distractor->Distractor-D	4.34	0.400	0.200	ProbeWord	0.400
D-Target->Distractor-D	2.46	0.132	ProbeWord	0.368	0.500
D-Distractor->Target-D	4.11	0.675	0.043		0.282
D-Switch-D	3.42	0.085	ProbeWord		0.915
D-Control-D	2.82	0.622	0.054	0.324	

In order to get a baseline of error sources to refer to, the first condition to examine is the Control. In that condition most of the errors, about two thirds in this instance, fall where expected, on the probe distractor. However, the other third of the errors is almost entirely prime distractor word errors, with only 5% of errors being the prime target colour. There may be two causes for this. Perhaps, in the possible events that can occur, a target repetition is less likely than a new stimulus. Therefore, participants may be reluctant to repeat the current response. But, given that there are significant Target->Target benefits, it is more likely that this effect reflects the asymmetry of the Stroop effect (MacLeod, 1991; Melara & Mounts, 1993; Stroop, 1935), i.e., that words interfere with the processing of the colour that they are printed in far more than the reverse. This

asymmetry may make the latent activation of the prime distractor higher than for the target even though a target response is generated.

It is very interesting that there is a general lack of prime target colour errors across all conditions where the prime target colour can be an error. That particular response should be highly available. And, while it is true that a new stimulus is more likely than a target repetition, it is not true that any individual stimulus is more likely than the repeated target. Furthermore, performance in the Repeat, and Target→Target conditions far surpasses that of the conditions where targets do not repeat. If participants were suppressing the prime target response on the probe this should not be the case.

The conditions of concern, and the reason for beginning this analysis, do not appear to have the same error causes. In fact, not only is the RT in the D-Distractor→Target-D condition most similar to the D-Control-D condition, but the same is true for the distribution of the source of errors. Of course, it cannot be identical because the prime distractor, being the correct response, cannot be a source of errors in the D-Distractor→Target-D condition. However, the proportion of use of the Prime target as an error is the same between D-Distractor→Target-D and D-Control-D. In addition, the rest of the errors are attributed to the other potential response that was not presented as a stimulus in the prime and probe; this is an error not available in D-Control-D because across prime and probe all possible stimuli are presented. This finding also tends to refute the suggestion above that the cause for prime-distractor errors in the Control condition is due to latent activation of the prime distractor being

greater than for the target. That is because activation of a colour not even presented in the previous trial should not be higher than the previous target, as a parallel argument would suggest for Distractor→Target performance.

In the D–Distractor→Distractor–D condition the most notable deviation from the D–Control–D condition is that there is a significant increase in the number of errors that would have been correct prime target responses. This is the only condition with any significant proportion of errors that were prime colour responses. It appears that the same prior activation of the distractor that facilitates performance in this condition also brings along with it the prime target activation. One might also expect that D–Target→Target–D errors would be distributed more toward the prime word because that would be carried along with the target repetition activation. However, this did not occur. The difference in these effects may be further evidence of how the nature of the Stroop asymmetry plays out in influence on trial sequences.

One striking condition that bears discussion is the D–Switch–D condition. In that condition almost none of the errors are the expected probe distractor. It is interesting to note that such would also be the prime target response, which tends to be rarely made as an error in general. The bulk of errors are responses for stimuli that were not presented on the prime or the probe. Clearly, in the present response patterns, there is some influence of the prime on performance. It appears, however, that errors in the Switch condition do not consist of accidental recall of prime targets.

Another general observation that is interesting in analyzing the sources of error is that the prime target is almost never an error in any

condition. This is in contrast to what would be expected from both memorial and attentional explanations of the negative priming effect. Because of the increased activation of attention, and general improved memory for targets due to action and attention, one would think that the most available and intrusive response would be that associated with the prime target (when it is a potential source of error). The only time an appreciable number of errors occur that are the prime target is in the D-Distractor->Distractor-D condition. This may primarily be because the prime distractor brings with it enhanced activation of the prime target more so than any other condition where the prime target could be an error.

After considering the overall performance, and the distribution of errors, I believe that a descriptive explanation for these data might be accomplished with a modification in the weight given to components of the congruency principle. There are three factors of the congruency principle. The two that have been discussed so far are the relationship between the prime and probe items, and whether the probe item is a target or a distractor. What has largely gone ignored is whether the prime item is a target or distractor.

Assume that all prior perceptual processing of a stimulus helps future performance with a reappearance of the same stimulus. Further assume that, because the target requires action, and therefore more processing than the distractor, prior target processing will help performance more than prior distractor processing. Now, add in the other properties of the congruency principle. Specifically, congruent relationships will help performance while incongruent may hurt performance, and relationships where the probe item

is a target will influence performance more than when it is a distractor. With these assumptions the Stroop data become much easier to explain.

Repeat and Target→Target will have the most improved performance because they have congruent items processed as targets on both the prime and the probe. What is the next poorest condition? If one varies weighting on the items assumed to be operating above then that answer can change considerably. If improvements in performance because of previous prime perceptual processing are very important, more important than whether the probe item is a target or a distractor, and more important than the congruency in the relationship, then the next conditions will be the ones that contain prime target as distractors. That means that Target→Distractor and Switch should be the next fastest conditions. The next fastest condition will be Distractor→Distractor because it has congruency, but the item was a distractor on both the prime and the probe. Finally, Distractor→Target will be the slowest because even though it is a current target, prime processing is more important (where it was a distractor), and there is an incongruent relationship.

Unfortunately, because most of the current explanations of negative priming have their cause strongly linked to prime-probe congruency none of the negative priming theories is easily modified to fit the above description (except perhaps selective inhibition as described by Neill, 1978).

Another implication of the fact that the present Stroop data defy explanation under any of the current negative priming theories is that negative priming may not be elicited at all in this paradigm. Under the criterion of the congruency hypothesis there is no negative priming in that

paradigm. And, given that a bias toward target repetitions does not enhance the cost in Distractor→Target one cannot claim that the cause here is selective inhibition. Furthermore, memory theorists who wish to propose that negative priming is enhanced when prime targets are predictive of probe targets because they invoke stronger recall of the prime distractor cannot have their cake and eat it too. Experiment 6 seriously impacts their theory as well. Either those who attribute negative priming to memory must abandon the hypothesis that an attentional manipulation will enhance the effect, or take the more reasonable route of accepting that an attentional manipulation enhances memory of the attended target, not of the distractor. If that is accepted then some memory theories might be saved by merely modifying the influence of the prime processing upon the probe, as described above. A memory theory could conceivably explain the present data, but not in any present forms because they all are constructed to predict enhanced conformance to the congruency principle with the attentional manipulation used here.

### Localization Experiment

Thus far negative priming has been examined under letter identification, and Stroop colour word paradigms. In both of these instances the particular experimental design chosen was selected intentionally because it did not generate negative priming. A bias was introduced as an attentional manipulation in order to discover whether an attentional negative priming effect could be generated.

With localization the situation is a little different. Here the primary

goal was to look at the heterogeneity of negative priming. There will be no attentional manipulation. That is primarily because an instance of no negative priming occurring in localization could not be found. The paradigm is explored primarily because it is one of the most popular in negative priming and therefore its similarity to other paradigms, in terms of psychological mechanisms probed by the method, needs to be assessed.

### Experiment 9

Location negative priming was first discovered by Tipper et al (1990). The task in the location paradigm is to indicate the target item's location. Negative priming in this paradigm is thought to be caused by the current target location having been previously occupied by a distractor on the prime trial. This is the fundamental assumption of all negative priming theories. What is explained by the theories is the psychological mechanism through which a previous distractor can cause this reduction in performance.

Location negative priming is one of the more important paradigms because it has been claimed to be one of the more ecologically valid, and it has been extensively used to test negative priming in special populations (Connelly & Hasher, 1993; Kane et al, 1997; McDowd & Filion, 1995; Tipper & McLaren, 1990; Stuss, Toth, Franchi, Alexander, Tipper, & Craik, 1999). In addition it is the only paradigm used to directly test the only computationally explicit model in this literature (Houghton et al, 1996).

However, an alternative to negative priming in the localization paradigm has been proposed and rejected. Tipper et al (1990) suggested that negative priming in the location paradigm might actually be due to inhibition of return (IOR).



It is possible that the negative priming effect that we observed in Experiment 1a might be a form of inhibition of return. Suppose that attention is briefly drawn to a distractor in the prime display (thus producing the interference effect). The mechanism of inhibition of return would then produce the delayed response observed when the probe target appears in the same locus as the distractor in the ignored-repetition condition. If this account is correct, then a delay in response should also be observed when the probe target appears in the same location as the previous prime target in the attended-repetition condition. Indeed, inhibition of return has been observed following a prime that is a relevant stimulus to which a response has been made (Maylor & Hockey, 1985). (Tipper et al, 1990, p. 495-6)

Inhibition of return is, as its name implies, a mechanism whereby spatial attention does not return to previously attended locations (Maylor & Hockey, 1985; Klein & Taylor, 1994; Klein, 2000). By running a Target→Target condition Tipper et al (1990) sought to verify that the negative priming was not merely an IOR effect. However, there was a bias in the design of the experiment such that participants were likely to expect a Target→Target trial. Given that IOR may not occur if one actively maintains attention at a location, the experiment was not a fair test of IOR. The present experiment will have a test of IOR embedded in the design that also tests the congruency principle. If IOR is the cause of the negative priming effect in this paradigm several effects should be found. Unlike the predictions of the Congruency Principle, Target→Target performance should be worse than Control if IOR is the mechanism responsible for the Distractor→Target cost. Furthermore, Distractor→Distractor and Target→Distractor performance should be better than Control.

IOR would cause the Target→Target condition to be worse than Control. In fact, that was what was found in a previous location negative

priming experiment that was very similar to the one conducted here (Frame et al, 1993). However, that result is contradicted by a finding that Target→Target performance was better (Connelly & Hasher, 1995), also in an apparently unbiased design. The current experiment will hopefully clear up some of that controversy.

Another series of experiments by Milliken, Tipper, Houghton & Lupiáñez (2000) also indicates that one may find IOR in a location negative priming paradigm. However, because their method was to make the negative priming paradigm more like an IOR paradigm it is not directly analogous. It is important to note that the transformation was easily done and that the similarities between location IOR and negative priming are made very obvious in that series of experiments.

If IOR were the mechanism causing Distractor→Target costs in the location negative priming paradigm it will generally be true that targets in previously occupied locations will hurt performance (Target→Target, and Distractor→Target worse than control). The converse should also be true for probe distractors. Distractors in previously occupied locations should help performance. The Distractor→Distractor, and Target→Distractor conditions should both be better than Control (this was a trend in Frame et al, 1993). That is because the location occupied by the distractor will be inhibited and therefore the distractor will cause less interference. This beneficial effect should be smaller than the costs that are seen in situations where the probe target appears in the same location as a prime item. That is because having recently suppressed the location of a current distractor can only indirectly affect performance as a subset of the interference caused by

the distractor.

IOR alone predicts that Switch and Repeat performance should be the same. That is because in both conditions the target and distractor occupy inhibited locations. However, there is likely to be some influence from the fact that the target response will be repeated in the Repeat condition, but not the Switch. With the exception of Repeat, all conditions (including Control) involve response changes between the prime and probe. Hence, with regard to response repetition vs switching, the Control provides a reasonable baseline for all but the Repeat condition.

Target only conditions are not run in this experiment. A target only prime condition was originally run by Tipper et al (1990) in order to verify that the distractor did interfere with performance. Distractor interference is a ubiquitous finding and it was thought in this experiment that it was an unnecessary additional complexity to merely verify this finding. Furthermore, it adds a degree of differentiation from Frame et al (1993), and if that work is replicated here generalizability will be greater because of these changes.

## Method

### Participants

Thirteen university students volunteered to be participants in the experiment. They were compensated with a single credit point toward their introductory psychology course.

### Apparatus

All apparatus were the same as in the unbiased condition of Experiment

1 except that instead of letter identity stimuli there were stimuli designed for a localization task.

The stimulus display was presented on a Macintosh high resolution 14" monitor. As seen in the proportional Figure 11, each target location was marked by a square  $1.8^\circ$  across with its center  $1.9^\circ$  from fixation. They were positioned in a cross shape with one above fixation, one to the left, one to the right, and one below. All stimuli were presented in white on a black screen. The target (O) and distractor (+) letters were centered in the squares and were presented in Monaco font, at  $0.95^\circ$  in height.

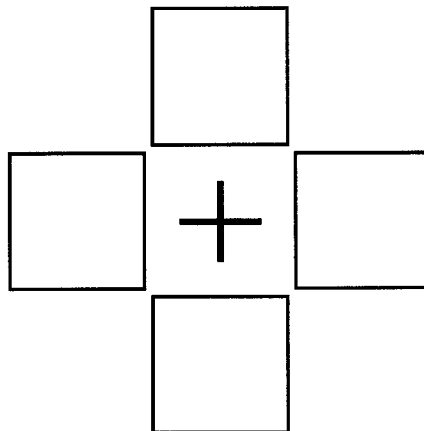


Figure 11. The layout of the fixation cross and location markers for Experiment 1 drawn to scale.

### Procedure

The procedure was very similar to Experiment 1. Each trial consisted of a prime display followed by a probe display. Both reaction time and accuracy were recorded for each display. Each trial, consisting of a prime and probe sequential pair, was initiated by pressing the space bar on the

keyboard followed immediately by a display consisting of the four markers with a fixation cross in the center.

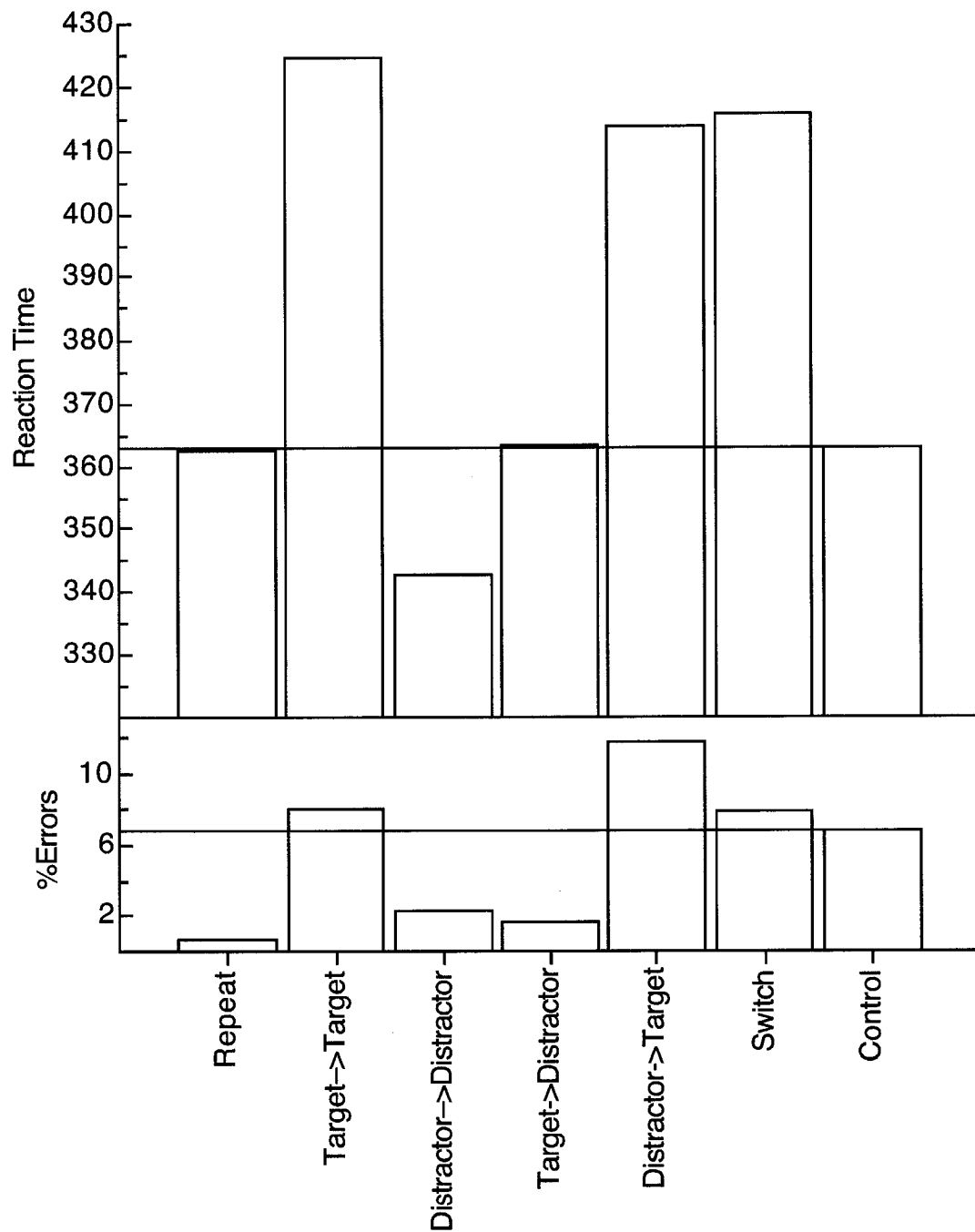
500 msec after the markers appeared, an "0" target was presented in one of these locations. This target was accompanied by a simultaneous "+" distractor appearing in one of the other locations. Participants selected the target on the basis of identity ("0") and responded on the basis of its location by moving the joystick in the direction corresponding to the location on the screen (away for up). Reaction time was recorded from target onset to the time that the joystick was moved far enough to trigger one of the internal switches. After the response to the prime trial, the target and distractor were erased for 345 msec at which time the probe trial was presented (markers and fixation remained on). After the probe response was made, the reaction times to the prime and probe trial were displayed for 1 second (if the participant made an error the word 'WRONG' replaced one of the reaction times). The next pair of prime and probe trials commenced with the pressing of the space bar.

### Results

On prime trials, mean RT was 402 ms and the mean error rate was 1.87%. The probe trial results are shown in Figure 12. The ANOVAs of probe conditions revealed main effects in both RT,  $F(6,72) = 22.52$ ,  $p < 0.001$ ,  $MSE = 632.5$ ,  $PLSD = 19.66$ , and error rates,  $F(6,72) = 6.50$ ,  $p < 0.001$ ,  $MSE = 34.04$ ,  $PLSD = 4.56$ . The pattern of results for probe trials closely matches what would have been predicted if IOR were the cause of location negative priming. In particular, relative to Control: the

Distractor→Target condition (416 ms > 360 ms), the Switch condition (416 ms > 360 ms), and the Target→Target condition (422 ms > 360 ms) showed significant RT costs. None of these RT costs was contradicted by the error rates and there were significantly more errors in the Distractor→Target condition than the control (11.73% > 6.8%). Planned contrasts revealed that when the probe distractor appeared in the location previously occupied by a distractor, Distractor→Distractor, responses were faster,  $F(1,12) = 8.37$ ,  $p < 0.02$ ,  $MSE = 541.2$ , and also more accurate,  $F(1,12) = 8.02$ ,  $p < 0.02$ ,  $MSE=32.83$ , than in the Control condition. When the probe distractor was presented in the location previously occupied by a target, Target→Distractor, performance was not significantly faster, but was more accurate than Control,  $F(1,12) = 6.28$ ,  $p < 0.03$ ,  $MSE=55.74$ . The error rate in the Repeat condition was also significantly lower than control.

## Experiment 9 RT's and Error Rates



**Figure 12.** Reaction time and error data from Experiment 9 probe trials. This is a location negative priming experiment where trials are selected randomly without replacement.

## Discussion

Using a different display, response type, and removing target only trials did not cause the pattern of results for the seven probe condition to differ from Frame et al (1993). These findings also bolster the relevance of the findings of Milliken et al (2000) with respect to conventional negative priming experiments. It appears that IOR is the cause of what was once believed to be location negative priming.

Before continuing, it is important to note a potential reason why Connelly & Hasher (1995) failed to obtain this finding. They appeared to have run a fairly balanced design very similar to Frame et al (1993). The fundamental difference between this experiment and both of those is that in both of those experiments there were no-distractor trials. That is, trials where only a target could appear. It should be noted that on those trials target repetitions (Repeat conditions in that instance) yielded better performance than a control condition that also did not contain a distractor in both studies. Given that both those studies used no distractor trials, that alone should not cause the discrepancy.

The distinction unique to Connelly & Hasher (1995) is related to the presentation of target only trials. In Frame et al., the stimuli were presented such that each possible event would occur once. This incidentally caused 25% of all trials to be target only. Primes with no distractor could precede probes that may or may not contain distractors, and vice versa. In Connelly & Hasher no distractor trials were organized as a separate entity. The target only prime and probe pairs were mixed with trials in which distractors occurred, but target only prime trials could only be followed by a target only



probe trial, and trials containing distractors were always paired as well. While the proportion of target only trials was the same as in Frame et al., the presentation was not. This obvious pattern in the trial presentation may have caused participants to believe that there were other patterns and they may have been more likely to latch on to target repetition sequences, when they occurred, as something that may be occurring more often than chance. This may have caused Connelly & Hasher not to replicate the Target→Target costs found in the present experiment and Frame et al (1993). It is of note that even though Connelly & Hasher did not replicate the Target→Target costs found in the present experiment, they did not find benefits either.

Another property of Connelly & Hasher (1995) is that the description of the practice is unclear. Whatever was done here may have also contributed to a discrepancy in the findings by setting up a different expectancy for the experimental trials. The present practice was a random subset of the set of experimental trials selected such that the proportions of trials were kept the same.

IOR has been proposed here as the cause of costs seen in the Target→Target, and Distractor→Target conditions. However, performance in the Repeat condition is somewhat anomalous. IOR would predict that performance would be degraded in that condition as well, but it is not. A highly plausible additional mechanism is proposed to explain this: response perseveration. The participant more easily repeats the previous response due to latent activation of those motor pathways and their connection to perception. When a stimulus comes on that is highly similar to a previous

stimulus response perseveration influences performance based on the degree of similarity. In the Distractor→Target, and Target→Target conditions the display is initially perceived as different because there are items present in new locations. This can be determined before identities are assessed (Hillyard & Münte, 1984). Given that the Repeat is identical to the prime then response perseveration dominates IOR in that condition. This practical explanation of the Repeat benefits makes the Switch costs difficult to explain. It could be that IOR causes the performance deficit since response perseveration cannot help. However, the cost could also be because the initial appearance of the display initiates a repetition response before identities are verified. This initial tendency to repeat the response must be overcome once the stimuli are identified and that may be the cause of performance deficits in the Switch condition.

Whereas IOR provides one explanation for aspects of the data pattern reported here, an alternative explanation, one that emphasizes advantages for processing items appearing in new locations, should be considered. It has been shown that new objects, or stimulus properties signifying new objects, exert greater control over attention (i.e., attention is attracted toward them) than other stimuli (Folk & Remington, 1998; Yantis & Hillstrom, 1994). In the present experiments the only decrement in performance that occurred when repeating the previous responses was when the participant needed to filter a distractor that appeared in a location that had been empty on the prime. It can be suggested that when an item is in a new (previously empty) location, there may be automatic orienting toward the new item. When the new item is a distractor, this orienting will hinder performance by

drawing attention away from the target; but when the new item is a target it will benefit performance. If both target and distractor are in new locations (as is the case in the control conditions), they compete and performance falls somewhere in between. This proposal explains costs in Distractor→Target and Target→Target conditions because distractors in new locations with targets in old locations will reduce performance. It also explains benefits in Distractor→Distractor conditions and Target→Distractor conditions because a target in a new location will attract attention away from a distractor in an old location and reduce the interference from that distractor.

Under this explanation Repeat and Switch conditions are not explained because the new item mechanism cannot function. However, the response perseveration mechanism that was used to explain the benefits on Repeat trials can be reused to explain the costs on Switch trials as follows: Where there are no new items then there is nothing to attract attention away from the current locations and response perseveration will help on Repeat trials and hinder performance on Switch trials. The new item explanation has the advantage that the response perseveration mechanism is never directly competing with the mechanism that causes the costs in performance, like it does with IOR.

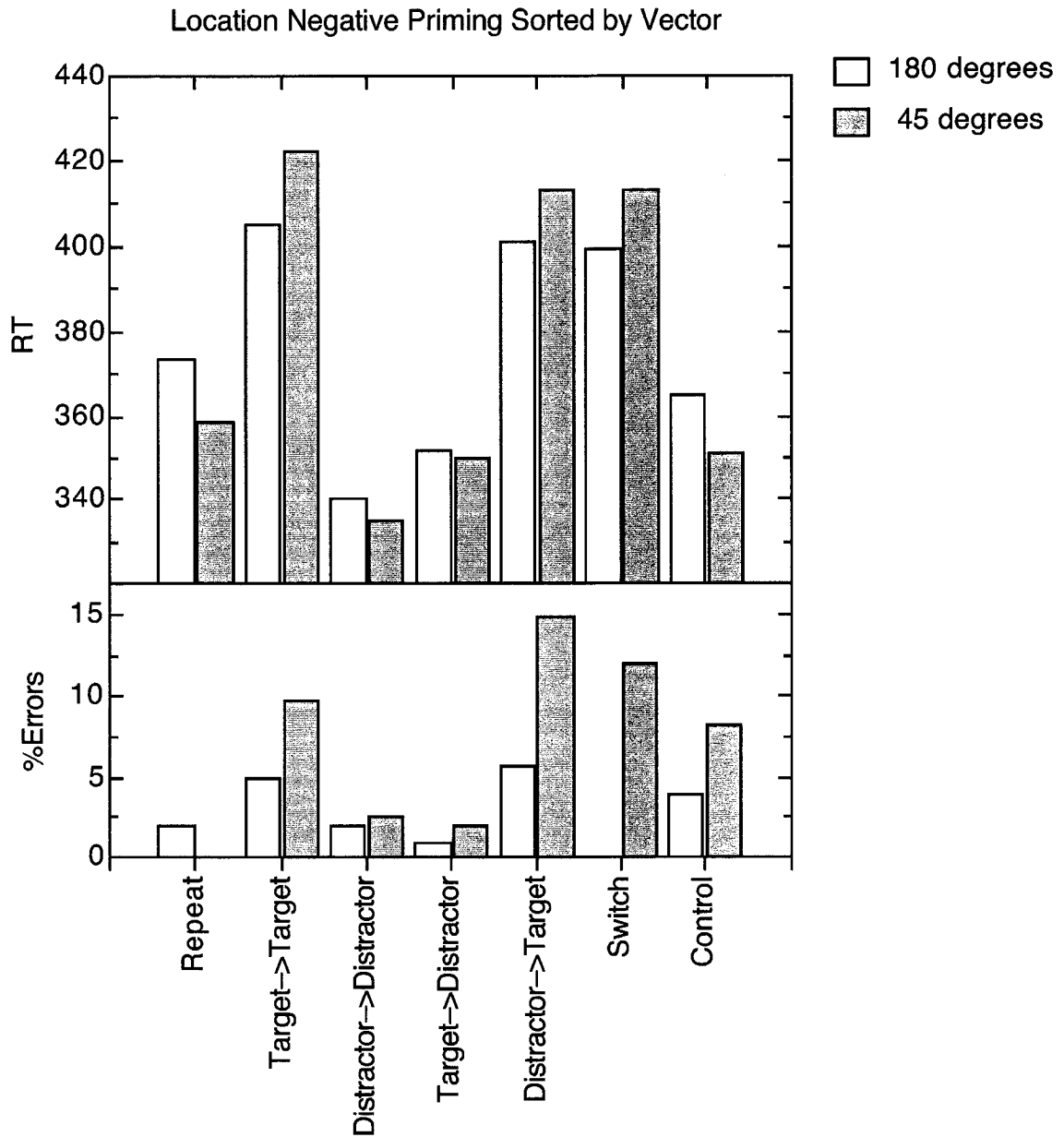
One functional interpretation of IOR is that it serves to bias attention from previously inspected locations (Posner & Cohen, 1984; Klein & MacInnes, 1999; Klein, 2000). If that interpretation is correct, then the new object and IOR accounts for the costs we have observed in Distractor→Target and Target→Target conditions can be seen as two sides of the same coin.

The new item hypothesis appears simpler than IOR and both hypotheses explain all of the findings in this experiment. But, the findings of Frame et al (1993) allow one to be more skeptical of the new item hypothesis because of extra conditions they ran. Frame et al ran no distractor conditions and all the possible additional relationships that could occur, just as was done in several experiments in Stroop and letter identities in this thesis. With that kind of manipulation one then has a Distractor→Target condition without a distractor on the probe. With no probe distractor in a new location there is nothing to draw attention away from the probe target and no negative priming should occur. However, Frame et al did find a cost in Distractor→Target with no distractor on the probe. This finding suggests that inhibition of the previously occupied locations is the cause for costs in the location paradigm and not attention being attracted to previously unoccupied locations.

One strategy for verifying the IOR hypothesis is to test the data for similarities to findings in the IOR literature. A result that could be examined in the present experiments is the vector component of IOR (Klein et al in preparation). Klein et al (in preparation) tested IOR in a paradigm with multiple simultaneous cues that could be positioned in any of 8 places circling fixation. A cue vector was calculated for each trial that consisted of summing the cue directions. If two cues are adjacent then there is a strong cue vector in a direction between those cues. If the cues are opposite then the cue vector is 0. It was found that IOR was strongest when the net cue vector was strongest, and non existent when the net cue vector was low. A similar analysis can be performed on the results from the present

experiment. Considering the prime's target and distractor as "cue" elements that generate IOR, there are two possible cue vectors. When the prime distractor and target are adjacent to each other the cue vector will be strong, while when they are opposite each other the cue vector will be weak. It is predicted that the Target→Target and Distractor→Target costs will be diminished in the weak vector condition because less IOR will have occurred. However, it is not predicted that the costs will go to 0 as they do in Klein (in preparation) because the items must be attended in the present experiments while Klein used a cue-target paradigm where the cues are meaningless and meant to be explicitly ignored.

Figure 13 reveals that that is exactly what has happened. There is a significant main effect of condition,  $F(6, 72) = 19.551$ ,  $p < 0.001$ ,  $MSE = 1293.54$ , and an interaction between condition and vector in the reaction times,  $F(6, 72) = 2.729$ ,  $p < 0.02$ ,  $MSE = 416.43$ . This is also true in the error rates, (main effect of condition =  $F(6, 72) = 5.44$ ,  $p = 0.001$ ,  $MSE = 57.56$ , interaction =  $F(6, 72) = 3.70$ ,  $p < 0.003$ ,  $MSE = 43.0$ ) for which there is also a main effect of vector,  $F(1, 12) = 38.46$ ,  $p < 0.001$ ,  $MSE = 21.43$ . The magnitudes of all costs and benefits with respect to the Control condition are reduced when the prime target and distractor are on opposite sides of fixation (180 degrees). This is the expected result if the effects in this experiment were caused by (or partially caused by) the same mechanisms as cause IOR in attentional cueing experiments.



**Figure 13.** The data from Experiment 9 sorted by the angle between the prime target and distractor. A 90 degree angle between target and distractor generated more IOR than a 180 degree angle.

Furthermore, the overall magnitudes in the error rates when the IOR is less also decrease, revealing an increase in performance. A general improvement in performance is expected if IOR is reduced because IOR

costs are greater than IOR benefits. This is because IOR benefits can only come from the degree to which inhibiting a distractor improves performance while IOR costs come from direct inhibiting of the target. If IOR is reduced then overall performance should increase. This result was found.

In Klein (in preparation) there was no IOR when the cues were opposite one another while in the current experiments there still are effects of IOR. This is likely due to the fact that in the present experiments the prime items must be attended, especially the target, while in the cueing experiments, where this hypothesis was first tested, the cues are supposed to be ignored (although they likely draw attention). This difference may have affected the current results and allowed an IOR effect to be revealed where there would have been none if no response was required on the prime.

The most important thing to note at this point is that in the paradigm used to test location negative priming it appears that the costs in the Distractor→Target condition are not caused by the prime distractor, but by any prime stimulus. It is also important to note that IOR is likely the cause of this cost.

This finding is both problematic and beneficial for the negative priming literature. It is problematic in that there are tests of negative priming with brain damage using the location paradigm that need to be reinterpreted (e.g., Stuss et al, 1999). Furthermore, the only direct tests of the selective inhibition model all use the location negative priming paradigm (Houghton et al, 1996). Thus, a careful reanalysis of several findings in the negative priming literature needs to be undertaken.

The benefits stem from the fact that others have already indicated that

there are findings unique to the location negative priming paradigm (Fox, 1995). It is the only paradigm in which it has been found that a probe distractor is unnecessary to produce the negative priming effect (Frame et al, 1993; Neill et al, 1994). If this is recast as an IOR effect then there may be no instance where negative priming occurs without a probe distractor. Another exception found in location negative priming is that the elderly show negative priming in the location task but not in identity tasks (Connelly & Hasher, 1993; Kane et al, 1997). Excluding these findings from the negative priming literature makes that literature more homogeneous. Upon reanalysis of location negative priming one may gain insights into the functioning of IOR. Furthermore, reexamining negative priming and excluding findings from the location paradigm may reveal more simplicity in the functioning of negative priming.

### General Discussion

Three popular negative priming paradigms have been examined. Each of these paradigms will be discussed further in turn, but the general story is clear. Claiming that a given priming paradigm where there are Distractor→Target costs with respect to an unrelated control condition is comparable to another is unwarranted without further examining other prime-probe relationships. Furthermore, failing to find a Distractor→Target cost does not in itself mean that negative priming has not occurred. Given the finding that negative priming effects are more heterogeneous than once believed, then it is also true that the goal of unifying what are essentially heterogeneous effects within the negative priming literature has had the



negative side effect of causing the field to fail to notice diversity, and hence, to miss some interesting implications.

The location negative priming paradigm was found not to generate negative priming from ignored distractors at all, but rather IOR. This was demonstrated by running all of the possible relationships and examining them in total. The results are not similar at all to other published results of the complete sets of priming relationships in letter identities (Neumann & DeSchepper, 1991; Stadler & Hogan, 1996), and vocal Stroop (Lowe, 1979). Furthermore, this was found without resorting to a paradigm that deviates significantly from traditional location negative priming experiments. For example, Milliken, Tipper, Houghton, & Lupiáñez. (2000) claimed to have found that location negative priming was caused by IOR, but their paradigm definitely looked like an IOR paradigm. They called it a distractor only negative priming paradigm, but there is no real distinction between this and a cue - target IOR paradigm. The present experiments had selection on the prime and the probe and were identical in design to standard negative priming experiments that use localization as the task. Furthermore, because of the richness of data that is provided by running all the relationships it was found that IOR could even be detected on the probe distractor because interference was reduced when distractors occupied inhibited locations.

The primary reason for the conclusion that IOR is responsible for the negative priming effect in the localization paradigm is that the explanation most conveniently fits the data. Under IOR it is assumed that both the prime and probe stimuli are attended but under negative priming it is assumed that only the target is attended and the distractor is not. Except for an easily

explainable exception (Repeat) there was no distinction between how prime stimuli influenced probe processing based on the processing requirements of the individual stimuli as targets and distractors.

But even though IOR provides the best explanation, one cannot absolutely exclude the idea that there may be some influences of the prime target and distractor distinction on probe performance. The Repeat condition exception, where performance improves when targets are presented in a previously occupied location, is an example of exactly this sort of thing. Therefore, it is best to conclude that the bulk of the influence on performance in all but a few select conditions is most appropriately explained by IOR. There still may be other effects of the prime processing that influence performance in a weaker manner. The important issue is not whether there is some effect that could be related to prime processing, as opposed to stimulation, but whether the traditional manipulations and examinations of negative priming using the spatial location paradigm are fair tests of negative priming. Most certainly they are not. One cannot test populations with this paradigm or make simple manipulations without incidentally making the test primarily about IOR and not negative priming. Any negative priming that might be found in the spatial localization paradigm is strongly influenced by IOR and the entire effect may even be caused by it.

The letter identity paradigm, wherein participants report one of two letter identities, was one known not to generate negative priming if the target and distractor stimuli did not change location from prime to probe. The null findings of Ruthruff & Miller (1995) that support this claim were

replicated, but the conclusions were not. This is because Ruthruff & Miller did not use the congruency principle to verify the evidence of negative priming. In the present experiments the congruency principle was supported in letter identity negative priming. Therefore, letter identity negative priming appears to be more robust than originally believed and follows the congruency principle across a wide range of manipulations.

If an attentional manipulation was used to encourage the participants to maintain their attentional focus on the prime target when the probe appeared, then negative priming, as conventionally measured, reappeared. This negative priming paradigm, when biased, also still confirmed the congruency principle, just like the unbiased experiment, and the D-Distractor->Target-D condition was worse than D-Control-D. This is the same finding as the one found in the unbiased version of the experiment where targets change locations from prime to probe. Given that the congruency principle was supported, this paradigm is the most worthy of being called a negative priming paradigm by consensus of the theorists about the expected pattern of results. If one wants to examine what happens to negative priming under a variety of manipulations or when testing specific populations, such as in developmental or patient studies, then using letter identity will insure that one is studying negative priming from ignored distractors. Furthermore, if one wishes to be sure that an attentional negative priming effect is being examined then it is best to run a biased letter identity experiment and focus on the conventional Distractor->Target - Control measurement (this should be not taken as a suggestion that the other conditions can be excluded).

Furthermore, in spite of the fact that all of the theories predict the congruency principle, the letter identity experiments, here and in the literature, lend strong support to selective attention playing a crucial role. In those experiments negative priming has been strongest when items changed location from prime to probe (Tipper & Cranston, 1985), even if the prime and probe shared no locations in common (Fox, 1995), thus eliminating an IOR like explanation. This runs contrary to an episodic retrieval explanation where commonality between the prime and probe such as fixed positions for the items, should enhance retrieval. However, under an attentional explanation selection should be more difficult and the state of the selection mechanisms should more strongly influence performance when items change location. Episodic retrieval may certainly influence performance in letter identity negative priming. However, it is not merely the review of a retrieved trace in this paradigm that causes the effect, but an attentional state attached to the items.

The finding that negative priming occurs when high accuracy is requested in a paradigm using Stroop colour word stimuli and a button press response could not be fully replicated (Neill & Westbury, 1987). While one may be able to claim a negative priming effect in these Stroop experiments based on the significant accuracy effects in Experiment 6, there is no support for the congruency principle, just as in the location experiments, and unlike the letter identity experiments. Furthermore, the particular pattern of failure does not fall into a neat IOR explanation like the location experiments. Is this really negative priming? If one looks at the theories available to explain negative priming and attempts to work backwards and

understand all of these results the answer would be no. As was outlined in the discussion, the general consensus is that the congruency principle describes a pattern of data that is, by consensus, indicative of negative priming. The button press Stroop data violate that principle.

But, my current, more conservative, view is that there may be some form of negative priming here, as defined by costs caused by the current target item having recently been a distractor. But the negative priming behaves very differently from that found in letter identity experiments. Further investigation of this paradigm may reveal exactly what this cost is and lead to a better understanding of the Stroop task, and consequently selection.

One of the most important take home messages is that manipulations in one of these paradigms are not necessarily generalizable to the other, and perhaps many other negative priming paradigms. It may be that we have all been looking at a variety of effects, IOR in the location condition, perhaps NP with one cause in the letter identity paradigm and a different primary cause in the Stroop button press paradigm, and then attempting to form homogeneous explanations for the effects. Unified theories of negative priming are an unwarranted endeavor given the present findings. And, in general, one must be careful what negative priming findings one wishes to bring together in order to understand them better. It would be nice if there were some principle one could use to guide decisions about what are similar and dissimilar negative priming paradigms.

Some might argue that IOR is unique because it is purely a spatial effect (Klein, 2001). It does not occur across other dimensions. Therefore,

location negative priming, being caused by IOR, is unique and can be excluded from efforts to unify negative priming explanations. In the present experiments it appears that IOR is unique because it depends primarily on stimulation and not the classification of targets and distractors. This is an important distinction if one wants to attribute the cause of negative priming to ignored distractors.

But, what of the letter identity and Stroop button press paradigms? Or, even the vocal Stroop paradigm? Are these part of a single group that includes the letter identity studies, or are there significant differences among them? It is interesting that there are commonalities and distinctions across these paradigms in odd places. For example, it is vocal Stroop where it was first found that biasing participants toward an expectation for the target to repeat increased the negative priming effect (Lowe, 1979). That was replicated using letter identities here. However, in button press Stroop just the opposite effect occurred. The results in the biased experiment look the least like negative priming results. So, there is a commonality between vocal Stroop negative priming and letter identity negative priming. However, letter identity negative priming follows the congruency principle while vocal Stroop negative priming violates the congruency principle in a way somewhat similar to the way that button press Stroop does. In both of those the Target→Distractor condition is fast, and the Switch condition tends to show better performance than the Distractor→Target condition (see Lowe, 1979; Neill, 1978). These commonalities and differences are mentioned here to convey the message that coming up with a class of negative priming experiments that are tapping a single mechanism may be

very difficult.

It is proposed that the tool to be used when examining negative priming is the congruency principle. If the pattern of data that arises from an analysis of the sequence effects follows the congruency principle then costs when prime distractors become probe targets can be called negative priming. More importantly, a data pattern that follows the congruency principle can be said to be representative of a negative priming effect even when there is no Distractor→Target - Control cost. However, if the congruency principle is not followed then any costs must be explained more fully. By this principle the only negative priming paradigm, examined thus far, that one can use to address negative priming theories is letter identity negative priming. Future experiments should expand the range of available paradigms, and some reference to the qualities unique to the letter identity paradigm would be useful in guiding research into discovering other true negative priming paradigms.

There are two primary differences between the letter identity negative priming experiments and other negative priming paradigms. Letter identity negative priming has a balanced interference task where the target could switch with the distractor and the instructions and interference would be little affected. This is very unlike Stroop negative priming experiments of any kind. In addition, the task required, while simple, is not automatically prompted by low level stimulation. This differs from the localization response where the response is automatically activated by the low level stimulation of both the target and the distractor. This is likely a strong contributing factor to the effects in the localization paradigm being primarily

due to stimulation.

Using the assessment above one might seek out other paradigms that also generate negative priming, as defined by the congruency principle. Perhaps negative priming using word identification may be a negative priming effect that follows the congruency principle because, other than the actual stimuli used, the paradigm is very similar to letter identity negative priming. Picture naming negative priming may also follow the congruency principle, but this may be violated when there is a combination picture and word naming task. In general, any task where the target and distractor are the same kind of stimulus, the task is to identify the target, and the selection criterion, but not task, is some low level stimulus property such as location or colour, may produce the best negative priming results.

#### Conclusion

Negative priming cannot be measured solely by a Distractor→Target versus Control difference. The folly of using exclusively that metric to assess the occurrence of negative priming has resulted in several serious problems in the negative priming literature. Negative priming may be missed when it has occurred because the related condition performance follows the congruency principle even though Distractor→Target performance is not worse than Control. The second problem is that there may be many reasons for a Distractor→Target performance cost and these cannot be easily differentiated without running more conditions. Sometimes the cost is not due to the current target having been a distractor in the past, but to some other reason altogether.

It is strongly recommended that future negative priming research



takes into account the varied relationships between the prime and probe and carefully considers the congruency principle as a guide for analyzing the resulting complex sets of data.

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