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**SEPARATE SPECIFIC AND NONSPECIFIC INFLUENCES ON THE
REPETITION EFFECT: IMPLICATIONS FOR AGING**

By

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A Thesis

Submitted to the School of Graduate Studies

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SPECIFIC AND NONSPECIFIC INFLUENCES ON THE REPETITION EFFECT

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Abstract

The research reported in this thesis focuses on the cognitive processes that contribute to the repetition effect in a forced-choice discrimination task. The five experiments reported in the first manuscript suggest that the repetition effect is determined by two separate memorial influences. One influence is specific to the link between perception and action while the other influence reflects the prior action independent of the perceptual stimulus to which that action was made. The critical observation is that these two influences, specific and nonspecific, can work in concert or in opposition to modulate the repetition effect. The four experiments reported in the second manuscript focus on how these two processes, specific and nonspecific, change with age. There are two critical findings reported in this second manuscript: 1) the relative contribution of these two influences changes with age and 2) manipulating the testing time in young adults appears to be an excellent model for the study of aging. A further contribution of this thesis is that it illustrates the danger in assuming that repetition effects are process pure cognitive measures. Instead, it may be more appropriate for cognitive psychologists to focus on analytic techniques that allow the influence of separate processes on performance to be studied.

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Chapter 1

Introduction

Some time ago, there was an occasion when my dog Winston, who is normally full of energy, whimpered and crawled under the bed. Shortly after, there was a torrential rain storm during which water poured through the open windows of the house. As I cleaned up water puddles on the floors, I had the thought that Winston may have known the storm was coming well before I did.

A few months later, I saw Winston display this same behavior once again. He whimpered and went to hide under the bed. This time, I saved time and energy. I knew that although the weather looked fine outside, a storm might be approaching. Therefore, I went around the house and closed all of the windows. Sure enough, within a few minutes, another big storm hit. Clearly, I had benefited from the fact that the same sequence of events had occurred before. As I perceived Winston's behavior of going to hide under the bed, this led me quickly to the appropriate action. I closed the windows before big water puddles developed on the floor.

A cognitive psychologist who hears the story about my dog Winston would be interested in several questions. For example, how similar must the prior learning experience be to the current experience, for an individual to benefit from repetition? What if Winston hid under the dining room table? Would this be a situation where I

would think to go and close the windows? What if I went to visit a relative and their dog hid under the bed, would I think to go and close the windows? I might not if I thought that their dog Elmo just had a nervous disposition or Elmo didn't like visitors. A general question that cognitive psychologists have struggled with is how similar do the initial and subsequent events have to be for the effects of learning to be expressed in performance.

Learning and memory are fundamentally dependent on sensitivity to repetition. To better understand learning and memory, the repetition method has been used to study the processes that underlie our ability to detect that a present event is the same as, or somewhat similar to, previously experienced events. The repetition method can be used to better understand the nature of memory representations and processes that influence behavior. What exactly is remembered from your first experience that guides your behavior on subsequent occasions? Moreover, how do these processes change as we get older? Surprisingly, such seemingly simple questions have brought about a long debate in cognitive psychology that continues to this day. This debate has to a certain extent divided cognitive psychology researchers into two theoretical camps about how memory for prior experiences guides current behavior. In the remainder of this Introduction, I will first describe the basic views of each of these two theoretical camps. Second, I will then propose that it is process pure assumptions about observed performance in repetition tasks that has perpetuated this debate and has led to more questions than answers. Finally, I will then propose that the theoretical framework and evidence presented in this thesis may help to resolve some of these issues.

The Abstractionist versus Episodic Debate

Some cognitive psychologists have favored a theoretical approach that assumes that, at least in part, memory consists of a collection of abstract mental representations. By this *abstractionist model*, a repetition effect can be understood by referring to the activation state of these abstract mental representations (Morton, 1969). Behavior is guided by the relative states of excitatory and inhibitory mechanisms that affect these mental representations. The purpose of excitation of these representations is to produce relevant, goal-directed behavior and the purpose of inhibition of other representations is to prevent distraction.

In a recent review article, Bowers (2000) summarized a large body of empirical evidence that supports abstractionist theories. Just as an example, in a simple word identification experiment, a participant might read the word 'TABLE' and then later be required to read 'TABLE', 'table' or 'FLUTE'. If performance were particularly fast for 'TABLE' or 'table', compared to 'FLUTE', then an important inference might be made. It would be inferred that while the perceptual qualities of 'TABLE' and 'table' differ, both of these stimuli result in excitation of the internal abstract mental representation for all table stimuli. Therefore, fast performance to both 'TABLE' and 'table' may be taken as evidence that the activation state of an abstract mental representation is responsible for the repetition effect (Bowers, Vigliocco & Haan, 1998).

In contrast to the abstractionist account of the repetition effect, *episodic retrieval* accounts assume that the repetition effect is caused by memory retrieval of specific prior experiences. By this view, all aspects of a prior experience, such as the stimulus, the

action, and the context of the experience, are encoded as part of the memory episode.

Note that this episodic explanation assumes that repetition effects should be fairly specific to stimuli that match in perceptual detail with a prior presented item.

In a recent review article, Tenpenny (1995) summarized a large amount of experimental evidence that supports the episodic retrieval viewpoint. For example, classification performance has been shown to be influenced by the similarity of the test stimuli to the individual stimuli seen during learning (Brooks, 1976). To relate this example back to the simple word identification experiment described above, a participant might read the word 'TABLE'. Following this first stimulus, the participant may then be very fast to read the stimulus 'TABLE', compared to a control item such as 'FLUTE', as the stimulus fully overlaps with the prior episode. However, the participant may be quite slow to read the test stimulus '*tAbLe*' as this item does not perceptually overlap with the prior experience. Similar experiments have varied other surface features, such as type font, handwriting, and type orientation, to demonstrate reliance on specific prior processing episodes. In general, episodic retrieval accounts of the repetition effect predict that transfer should depend on a match between specific aspects of an initial and subsequent presentations (Jacoby & Brooks, 1984; Kahneman, Treisman & Gibbs, 1992; Logan, 1988; Neill, Valdes, Terry & Gorfein, 1992; Whittlesea & Jacoby, 1990).

In brief, the important distinction between the abstractionist and episodic accounts of memory representations is that an episodic retrieval explanation necessitates perceptual specificity of repetition effects whereas the abstractionist account does not. With the episodic retrieval explanation, encoding of the first event includes the perceptual details

of the stimulus, such as when the word 'TABLE' is written in capital letters. Repetition of the exact same stimulus should assist retrieval of the appropriate prior episode that includes this perceptual stimulus. In other words, the stimulus '*tAbLe*' would not be the best cue to elicit retrieval of a prior episode that includes the stimulus 'TABLE', as there are perceptual differences between these two stimuli. In contrast, the abstractionist account suggests that repetition of perceptual details should not matter. By this view, the repetition effect reflects activation of the abstract mental representation for 'table'. Therefore, stimuli such as 'TABLE', '*table*', or '*tAbLe*' would all excite the same abstract mental representation. Using the terminology of this thesis, specific and nonspecific memory influences on performance distinguish these two theoretical views (Tenpenny, 1995).

The Process Pure Assumption

As experimental evidence from studies of the repetition effect have accumulated, it has become increasingly clear that the specificity of repetition effects does not unequivocally favor one theoretical view over the other. An abstractionist account needs to accommodate perceptual specificity effects observed in some experiments, while the episodic retrieval account needs to accommodate findings of generalization across perceptual differences observed in other experiments. However, the process pure assumption has been adopted in numerous experiments. This assumption implies that an observed difference in performance between two conditions in an experiment is a measure of one cognitive process. The process pure assumption slows theoretical

progress when the observed effects of repetition are not distinguished from the inferred underlying processes that are purported to be contributing to performance.

In the word identification experiment described earlier, I gave the example of the first stimulus, 'TABLE', followed by the second stimulus '*tAbLe*'. What exactly should the response time to '*tAbLe*' be compared to? Cognitive psychologists have generally assumed that the subject's response time to '*tAbLe*' should be compared to the same subject's response time to some appropriate control item, and that the difference in performance between these two conditions, repeated and not repeated, measure a process that is responsible for the repetition effect. However, this may be a mistaken assumption. The observed difference between two conditions may not reflect a single underlying process, but instead two or more processes that contribute jointly to performance. Multiple processes could account for the considerable variability in perceptual specificity observed in various experiments. Some patterns of data appear to fit the abstractionist account while others fit the episodic retrieval account. One possibility is that data that appear to fit well with the abstractionist account do so because the task predominantly taps into memory influences that are not specific to a particular instantiation of a prior event. Similarly, data that appear to fit well with the episodic retrieval account do so because the task predominantly taps into memory influences that are specific to a particular instantiation of a prior event. If this is the case, then a better understanding of performance may be gained from separating the contributions of multiple processes to a task, rather than assuming that the repetition effect measures just one process.

Specific and Nonspecific Influences

Is it possible that both perceptually specific and nonspecific influences jointly contribute to performance in a cognitive task? A similar issue was addressed in the categorization literature as Whittlesea, Brooks and Westcott (1994) provided some compelling evidence that specific and general influences can both contribute to performance in a categorization task. These authors observed that people often utilize general knowledge about categories as well as specific knowledge about members of a category. In a series of experiments, they encouraged their participants to encode a stimulus both as a unique entity, processing its perceptual features, as well as encode the same stimulus, that was treated as an example of the general class, by having participants analyze the typicality of each feature for the item's category. The experiments demonstrated that the processing demands of the transfer task can control the relative contributions of specific and general knowledge to performance.

Beyond the approach of Whittlesea et al. (1994) in the categorization literature, similar approaches have been adopted by memory researchers who have separated multiple processes that contribute to performance (Atkinson & Juola, 1974; Jacoby, 1991; Mandler, 1980; Ratcliff & McKoon, 1995). Therefore, this thesis focuses on the contribution of specific and nonspecific memory influences to performance in a single task. Two specific goals are addressed in this thesis. The first goal was to demonstrate that both specific and nonspecific memory influences contribute to performance in a simple two-alternative forced-choice task. In Chapter 2, demonstrations are provided that two memorial processes, specific and nonspecific, both influence performance, and that

these two processes appear to be independent from one another. Furthermore, this first manuscript will address how the specific and nonspecific influences can be separately measured so that the researcher can better understand how each influence alters performance.

The second goal of this thesis is to examine how these two memorial influences change with increasing age. The individual differences literature has also been struggling with the best way to understand the observed variability in repetition effects. However, many studies in this literature depend on a process-pure assumption about observed performance. In Chapter 3, the approach presented focuses on understanding how perceptually specific and nonspecific influences from memory both affect performance in younger and older adults. In addition, this manuscript provides evidence of how testing younger subjects at their optimal and nonoptimal times of day may provide a model for the study of cognitive changes associated with aging.

Inferential Statistics

Data collection involved the recording of a participant's reaction time to all types of trials as well as the participant's accuracy percentages for the various types of trials. Inferential statistics were used to address the question of how perceptually specific and nonspecific influences from memory both affect performance. In general, the inferential statistics reported were either the t statistic or the F statistic. Both statistics measure the signal to noise ratio in an experiment. The number that corresponds to the signal, the difference between two experimental groups (t statistic) or more than two experimental

groups (F statistic), would be divided by the noise, the variability in scores among individuals within each group. A critical alpha level of .05 was used in all experiments. Therefore, any p values reported as less than .05 indicate statistical significance.

Chapter 2

The following manuscript has been submitted to the Journal of Experimental Psychology: Learning, Memory, and Cognition, on February 16, 2001. All references, tables and figures from this paper are self-contained in Chapter 2.

**Specific and nonspecific transfer:
The repetition effect in forced-choice discrimination tasks**

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Abstract

The research reported in this article focuses on processes that contribute to the repetition effect in forced-choice discrimination tasks. Early research on this issue (e.g., Bertelson, 1965) attempted to distinguish between two possible sources for the repetition effect: stimulus repetition (perception) and response repetition (action). The data from these early studies favored neither of these possibilities unequivocally. An alternative view is that the locus of repetition effects is in response selection, the stage of processing during which perception and action are linked. By this view, faster stimulus repetitions than response alternations occur when the link between perception and action on one trial can be retrieved and used to respond to the following trial, in effect bypassing the analysis usually required at the response selection stage (Fletcher & Rabbitt, 1978; Pashler & Baylis, 1991). In contrast to a strong version of this response selection bypass account, the results of the experiments reported here suggest that both a nonspecific response repetition influence, and a more perceptually specific episodic influence, jointly determine the repetition effect. A critical observation is that these two influences can work in concert or in opposition to modulate response repetition effects. Implications for other priming paradigms that posit mixtures of specific and nonspecific influences on performance are discussed.

Specific and nonspecific transfer:

The repetition effect in forced-choice discrimination tasks

Repetition effects in relatively simple performance tasks are a widely used tool to study learning and memory processes. The study of trial-to-trial repetition effects can be traced back to research that examined performance in two-alternative forced-choice tasks (Bertelson, 1965; Smith, 1968). This research showed that response repetitions to targets that match the immediately previous target are faster than response alternations to targets that mismatch the immediately previous target. This result led to attempts to specify the locus of this repetition effect. Conceivably, target repetition could have an effect anywhere from early sensory processing all the way to execution of the motor response.

One method used to specify the processing locus of the repetition effect involves assigning more than one stimulus to each response. For example, the letters A and B might be assigned to one button-press response while the letters C and D are assigned to another button-press response. A useful property of this method is that it allows response repetition effects to be measured both with and without stimulus repetition. Note that if the letter A appears as a target in consecutive displays, the resulting response repetition effect could contain components of both stimulus repetition and response repetition. In contrast, if the letter A appears as a target in one display, and the letter B appears as a target in a following display, then the resulting response repetition effect should no longer contain a component associated with stimulus repetition. In principle then, this method holds promise for identifying the processing locus of the repetition effect. If a robust

repetition effect is observed in the absence of stimulus repetition, then it would appear that repetition of the response, rather than repetition of the stimulus, underlies the repetition effect.

In practice however, this method has not provided a clear answer to whether stimulus repetition or response repetition is responsible for the repetition effect. In some experiments, repetition effects have not depended on the identity of targets in consecutive displays (Bertelson, 1965), while in other experiments, repetition effects have depended strongly on the identity of targets in consecutive displays (Smith, 1968). We use the term 'perceptual specificity' throughout this article to refer to the extent to which the repetition effect depends on the presentation of identical consecutive targets. Thus, the appropriate conclusion from these early studies is that the perceptual specificity of the repetition effect appears not to be fixed, but instead varies depending on the task.

To address this variability in perceptual specificity, Pashler and Baylis (1991) proposed that the repetition effect is associated neither with early perceptual nor late response stages of processing, but with response selection; that is, the stage of processing during which perception is linked with action. According to this view, response to a target can be selected by retrieving the perception-action link from the immediately preceding trial. Use of this memory representation benefits performance because it allows the participant to bypass the slower analytic processing that would be otherwise necessary to select a response. Variability in perceptual specificity of the repetition effect then follows from an assumption that the link between perception and action that is retrieved can vary in specificity.

For example, consider two response categories, one with members A and B and the other with members 1 and 2. Presentation of the letter A as a prime could result in strengthening of a specific link between the letter A and an action, or in strengthening of a higher order link between the category LETTER and an action. Consequently, when the letter B appears following the prime letter A, the response repetition effect will depend on whether the link strengthened involves the letter A and an action or the prime category LETTER and an action. Importantly, Pashler and Baylis viewed both of these links as integral to response selection. In this way, they were able to attribute both specific and nonspecific (categorical) components of the repetition effect to the bypassing of analytic response selection processes.

This analysis suggests that specific and nonspecific components of the repetition effect may share a dependent relation. Such a dependent relation would occur, for example, if the relative strength of encoding of specific and nonspecific information depended on attention, and if attention were a limited resource. Returning to our example, attention to the higher order link between the specific letter A and an action could result in less strengthening of the link between the category LETTER and an action. Consequently, increases in the specific component of the repetition effect would be accompanied by decreases in the nonspecific component of the repetition effect. Indeed, although Pashler and Baylis (1991) did not address this issue directly, the results from their experiments appear to show this type of dependence. In several of their experiments, manipulations that increased the nonspecific component of the repetition effect also appeared to decrease the specific component of the repetition effect.

In this article, we examine the relation between specific and nonspecific components of the repetition effect directly. To our knowledge, this issue has not been addressed in prior studies of the repetition effect in forced-choice discrimination tasks. More important, an understanding of the joint contributions of specific and nonspecific memory influences to performance has become critical to theoretical progress in a variety of other research domains that use the repetition method (see Tenpenny, 1995; Bowers, 2000; see also Neill, 1997; Conway, 1999). As such, although the present research uses a forced-choice discrimination method, the theoretical issues addressed are of general importance. The experiments in the first empirical section of the article address the possibility that specific and nonspecific influences can contribute independently to the repetition effect. Our research strategy was to examine whether specific and nonspecific contributions to the repetition effect can be dissociated. Indeed, the results suggest that both the specific and nonspecific components of the repetition effect can be affected selectively, leaving the other component unchanged. In the second and third empirical sections of the article, we focus on the processing bases of the specific and nonspecific components of the repetition effect.

Historical Background

Bertelson (1965) was the first to systematically address the source of the repetition effect. In his study, the digit 2 was assigned to a button-press response with one hand, and the digit 5 was assigned to a button-press response with the other hand. With this procedure, response repetitions were faster than response alternations. To address

whether this effect was mediated by repetition of the response itself, Bertelson (1965) conducted a second study in which the digits 2 and 4 were assigned to one response and the digits 5 and 7 were assigned to a second response. To the extent that the response repetition effect occurs because of repetition of the response itself, it should not matter whether that response is elicited by identical stimuli or by different stimuli on consecutive trials. In contrast, if the repetition effect is determined either by early perceptual processes or by more central processes involved in stimulus categorization, then it may be larger when the same stimulus elicits a repeated response than when a different stimulus elicits a repeated response.

The results from Bertelson's (1965) study indicated that the repetition effect was only slightly smaller when a different stimulus elicited a repeated response than when an identical stimulus elicited a repeated response. This result is consistent with the view that a large component of the response repetition effect is related to repetition of the response itself. However, Smith (1968) noted an alternative explanation for this result. Specifically, the digits 2 and 4 that were assigned to one response may have been coded as EVEN (or LOW) while the digits 5 and 7 that were assigned to the other response may have been coded as ODD (or HIGH). If the digits were categorized in this manner, then Bertelson's (1965) inference that the repetition effect is response-related may not have been correct. To address this issue, Smith (1968) conducted a similar study, but assigned the green number 1 and red number 2 to one response and the green number 2 and red number 1 to a second response. With this procedure, response repetitions were faster than response alternations only when an identical stimulus was presented on consecutive

trials. Furthermore, repeated responses for non-identical items were actually slower than alternating responses.

Two aspects of these results are particularly noteworthy in the present context. First, the finding that response repetitions were faster following identical than non-identical primes in some experimental contexts (Smith, 1968) but not others (Bertelson, 1965) predates a related pattern of findings in the wider literature on priming effects. In particular, variability in the perceptual specificity of priming effects in naming, lexical decision, and other tasks is now well-documented (see Tenpenny, 1995; Bowers, 2000 for reviews). Second, the finding of slower response repetitions following non-identical/same-category primes than response alternations following non-identical/different-category primes is critical because it rules out a purely perceptual account of the repetition effect. Specifically, if response repetitions following non-identical primes had been neither faster nor slower than response alternations, then it could be argued that, at least under some conditions, the repetition effect is determined entirely by the perceptual match between consecutive items. Instead, the particularly slow response repetitions following non-identical/same-category primes require an explanation that takes into account how a perceptual stimulus is categorized.

To explain a similar set of findings in forced-choice discrimination tasks, Fletcher and Rabbitt (1978) proposed a response selection bypass account for the repetition effect. According to the bypass account, the appearance of a stimulus that is identical to the prior prime produces a bias to repeat the prior response, while a stimulus that is non-identical to the prior prime produces a bias to make a different response. The notion underlying

the bypass account is that, under many experimental conditions, information provided by the perceptual match between consecutive stimuli is often sufficient to determine a response. If a target stimulus matches that displayed in the prior trial, and if the stimulus-response mapping rule is identical for those two trials, then the prior response can be repeated for the current target without engaging in the analytic processing usually required to link perception with action.

Bias and the Repetition Effect

Fletcher and Rabbitt's (1978; see also Pashler & Baylis, 1991; Terry, Valdes, & Neill, 1995) proposal that a bias is responsible for the repetition effect merits further consideration. One type of bias in two-alternative forced choice tasks is a bias that favors one of two responses over the other. Such a response bias results simply in faster performance when the task requires the favored response than when the task requires the disfavored response. Note that this type of bias can be set for an entire task context, such as when WORD responses are favored over NONWORD responses in a lexical decision task.

However, the bias proposed by Fletcher and Rabbitt (1978) to explain the perceptual specificity of repetition effects is not a simple response bias. Rather, they proposed that when a test stimulus matches the preceding prime, participants are biased to repeat their response, whereas when a test stimulus mismatches a prior prime, participants are biased to make a different response. Two differences from a simple response bias are noteworthy. First, the Fletcher and Rabbitt bias is determined flexibly in response to the

match between a current probe item and the preceding prime item, rather than inflexibly for the task context as a whole. Second, this flexible bias is determined both by response-related factors and by stimulus-related factors. In other words, to be biased to make a different response upon perceiving a different stimulus implies memory for both the perceptual identity of the prime and the response that was made to that prime.

To make this second point clear, the Fletcher and Rabbitt (1978) bias can be contrasted with a bias that is also determined flexibly in response to matches with a prior prime, but that does not depend on matches that involve both perception and action. Returning to our earlier example, consider a task in which participants make one response to either of the letters A or B, and a different response to either of the numbers 1 or 2. On trials in which the prime is the number 1 and the probe is the number 2, the Fletcher and Rabbitt bias results in a tendency to favor response alternation. Now consider the consequences of a bias that contains information about the prime response but not the prime identity that led to that response. In this case, the perceptual mismatch process that produces the tendency to alternate responses would be absent, leaving available only categorical (1 and 2 are both NUMBERS) or response (1 and 2 require the same response) properties to bias response. However, the categorical/response similarity for consecutive items 1 and 2 would bias performance in favor of response repetition rather than response alternation.

One point of note in this example is that a memory representation can conceivably bias current performance in more than one way. The bias proposed by Fletcher and Rabbitt (1978) implicates a specific memory representation that contains information

about both the prime stimulus and how it was responded to. The second memory-based bias described above implicates a less specific memory representation that retains categorical (e.g., NUMBER) and/or response information for the prior prime. This approach to interpreting biasing effects of prior experiences on current performance is consistent with proposals made more recently by Pashler and Baylis (1991). They suggested that there is an intimate tie between the perceptual specificity of repetition effects in two-alternative forced choice tasks and memory for specific prior experiences, or episodic memory.

A second point of note is that the two biasing effects of memory described above can produce opposite effects on performance. For the trial type used in the above example (i.e., 1 followed by 2), one bias produces a tendency favoring response alternation, while the other bias produces a tendency favoring response repetition. Consequently, the repetition effect that occurs in this condition will depend on which of these two biases predominates in performance. This issue is similar to that addressed by Ratcliff and McKoon (1995) in studies of priming that involved POSSIBLE/IMPOSSIBLE decisions about line drawings of nonsense objects. Ratcliff and McKoon demonstrated that if an impossible test item is presented earlier as a prime item, its familiarity at the time of test will introduce a bias to respond POSSIBLE. However, this bias to respond POSSIBLE will be opposed by explicit retrieval of specific properties of the object that lead the participant to respond IMPOSSIBLE. When these two processes jointly contribute to the response to an impossible object, their effects cancel one another, and a priming effect is often not observed. However, decreasing the

contribution of the episodic-based influence, by introducing a response deadline or a memory load, increases the relative contribution of the familiarity-based bias, as evidenced by reliable priming for both possible and impossible objects. The notion that memory for a prime can exert two separate and opposing influences on performance also plays a central role in this article.

The present research

Logic similar to that of Ratcliff and McKoon (1995) can be applied to the study of repetition effects in two-alternative forced-choice tasks. In particular, we examine the possibility that specific and nonspecific memory influences independently contribute to repetition effects. We assume that a link between a perceptual stimulus and the response category to which it is assigned provides the basis for a specific memory influence on performance. In contrast, the basis for a nonspecific influence on performance is a representation of the response category to which a stimulus was assigned independent of the specific stimulus that led to that assignment. As described above, this logic sets up conditions in which these two memory influences can produce either identical or opposite influences on performance.

For example, when two identical stimuli appear on consecutive trials (the same stimulus condition), both the specific and nonspecific memory influences produce a tendency to repeat the prior response. In contrast, when two different stimuli from the same category appear on consecutive trials (the same response condition), the specific memory influence produces a tendency to make a different response (Fletcher & Rabbitt,

1978), while the nonspecific memory influence produces a tendency to repeat the prior response. Assuming that the nonspecific influence contributes identically to these two conditions, its contribution to performance can be controlled for by subtracting a performance measure for the stimulus repetition condition from that for the response repetition condition. The remaining difference score should then provide a measure of the specific memory influence on performance. This logic is similar to that used by Lindsay and Jacoby (1994) to examine separate contributions of word reading and color naming to Stroop performance. In the Stroop domain, the contribution of color naming to performance is assumed to be identical in congruent and incongruent conditions. In contrast, word reading opposes color naming in the incongruent condition and works in concert with color naming in the congruent condition. As such, the contribution of word reading to performance can be estimated by subtracting a performance measure for the incongruent condition from that for the congruent condition. By analogy, the specific component of the repetition effect can be estimated by the difference in performance between same response (specific and nonspecific influences in opposition) and same stimulus (specific and nonspecific influences in concert) conditions.

This analytic approach allowed us to address two issues. First, we evaluated whether the independence logic applies to performance in two-alternative forced-choice tasks by examining whether specific and nonspecific contributions to the repetition effect could be dissociated. If these two memory influences can contribute independently to the repetition effect, then there ought to be variables that affect the specific memory influence while leaving the nonspecific memory influence unchanged. Similarly, there ought to be

variables that affect the nonspecific memory influence while leaving the specific memory influence unchanged. Indeed, the results of Experiments 1A, 1B, and 2 demonstrate such a dissociation. Second, beyond demonstrating such a dissociation, we examined in more detail the processes underlying specific and nonspecific components of the repetition effect. Experiments 3 and 4 focused on the processing basis of the nonspecific component of the repetition effect, while Experiment 5 focused on the processing basis of the specific component of the repetition effect.

Experiments 1A & 1B: The repetition effect and nonspecific transfer

The two-alternative forced choice task used in all of the experiments reported in this article required participants to categorize a single colored rectangle in each of two consecutive displays. The colors red, yellow, blue and green were randomly assigned to two categories. In Experiments 1A and 1B, the only difference between the procedures of the two experiments concerned the nature of the response (vocal versus manual) made by participants. The results of these experiments provided the initial evidence that the nonspecific component of the repetition effect can be affected selectively, leaving the specific component of the repetition effect unchanged.

Method

Participants

Sixteen undergraduate students (14 females) from an introductory psychology course at McMaster University participated in Experiment 1A for course credit. A

separate group of sixteen undergraduate students (10 females) from the same source participated in Experiment 1B. The mean age of participants in the two groups was 19.3 years and 19.1 years, respectively. All subjects had normal or corrected-to-normal visual acuity and normal color vision.

Apparatus and Stimuli

Stimuli were presented on a Sony color monitor that was connected to an IBM 486 micro-computer. Micro Experimental Laboratory (MEL) software was used (Schneider, 1988) to display the stimuli and collect the data. Participants were seated approximately 60 cm from the monitor. In Experiment 1A, responses were spoken aloud into a microphone placed just in front of the participant. This microphone was connected to a voice activated relay that permitted the timing of onset of the participant's vocal response. In Experiment 1B, responses were made by pressing one of two buttons on the keyboard placed in front of participants.

Each trial consisted of three displays. The first display was a white fixation cross displayed in the center of the black background of the computer monitor. The fixation cross subtended a visual angle of 0.7° horizontally and 0.7° vertically. The second display was called the prime stimulus, and consisted of a rectangular color patch presented in the center of the computer screen. The color patch subtended a visual angle of 3.4° horizontally and 0.7° vertically. The third display was called the probe stimulus, and again consisted of a rectangular color patch. The colors in which the prime and probe could appear were red, yellow, blue and green. The MEL RGB palette coordinates used

to present these colors were (63, 0, 0) for red, (0, 63, 63) for yellow, (0, 0, 63) for blue, and (0, 63, 0) for green.

Procedure

Participants were required to categorize the color of the rectangle that appeared in the prime display, and then do so again for the color that appeared in the probe display. In Experiment 1A, the participants were asked to categorize the rectangles vocally. The two categories were arbitrarily called CAT and DOG, with the intention that the category labels be no more systematically related to the colors than would two keys on the keyboard. For one half of the participants, red and yellow rectangles were given the category label CAT and blue and green rectangles were given the category label DOG. For the remaining participants, blue and green were given the category label CAT and red and yellow were given the category label DOG. In Experiment 1B, participants were asked to categorize the rectangles manually rather than vocally. The participants categorized the rectangles using the “m” and “x” keys with their index fingers on the computer keyboard. For half of the participants, red and yellow rectangles were categorized by pressing the “m” key with their right index finger. The blue and green rectangles were categorized by pressing the “x” key with their left index finger. The other half of the participants had the reverse response assignment.

Each of these experiments consisted of one block of 32 practice trials followed by ten blocks of 32 experimental trials. Each of the four prime colors was paired with each of the four probe colors for a total of 16 combinations. Each of these combinations was repeated twice, to give 32 trials within a block. At the beginning of each block of trials,

instructions to press 'b' to begin the next block appeared. Each trial within a block contained the following sequence of events: (1) a fixation cross appeared on the screen until the subject pressed the spacebar, (2) a 500 ms blank interval, (3) the prime display presented until the participant responded, (4) a 500 ms blank interval, and (5) the probe display presented until the participant responded. Participants were instructed to respond to the color patch in the prime display by categorizing its color and to respond to the color patch in the probe display by categorizing its color. The instructions emphasized that responses should be fast as well as accurate.

After each trial in Experiment 1A, the accuracy of the vocal response was coded by the experimenter on the keyboard, which then triggered either the word 'correct' or the word 'incorrect' to appear on the screen, together with the fixation cross for the next trial. As participants responded manually in Experiment 1B, the computer coded the manual key press responses for accuracy and the word 'correct' or the word 'incorrect' appeared on the screen with the fixation cross after each trial. As the experimenter was not required to code manual answers for accuracy, the experimenter was not present in the room with participants in Experiment 1B. The sequence of events for each trial is presented in Figure 1.

Insert Figure 1 About Here

Response times were measured as the latency between onset of the color patch and the onset of the participant's voice (in Experiment 1A) or the onset of the participant's key press (in Experiment 1B). In all experiments, an error was recorded if the participant categorized the probe incorrectly. A trial was recorded as a spoil if the prime was categorized incorrectly, if the voice key was activated by a sound other than the onset of the participant's response (in Experiment 1A), or if the voice key did not pick up the onset of the response for either the prime or the probe (in Experiment 1A).

There were three conditions of importance in these experiments. In the same stimulus condition, the prime display and the probe display consisted of patches of the same color. In the same response condition, the prime and probe patches were different colors but required the same categorization response. In the different condition, the patches were from different categories and required different responses. The color of the prime provided no predictive information regarding the color of the probe. As such, half of the trials belonged to the different condition, one quarter of the trials belonged to the same stimulus condition, and one quarter of the trials belonged to the same response condition.

Results and Discussion

Correct response times (RTs) to the probe display were first subjected to an outlier elimination procedure on a cell by cell basis to eliminate from further analysis any RTs that were unusually large or small. Van Selst and Jolicoeur's (1994) modified recursive outlier elimination procedure was used to ensure that more observations were not

systematically excluded from cells that contained fewer observations. This procedure discarded 1.6% of the observations from further analysis in Experiment 1A and 3.7% of the observations from further analysis in Experiment 1B. Using the remaining observations, mean RTs were computed for each of the three conditions (same stimulus, same response, different). Mean RTs and error percentages for each condition are displayed in Table 1. Also displayed in Table 1 are two difference scores of interest. The difference in performance between same stimulus and different conditions is referred to as the *stimulus repetition effect*, while the difference in performance between same response and different conditions is referred to as the *response repetition effect*.

Insert Table 1 About Here

For Experiment 1A, mean RTs and error percentages were submitted to repeated measures analyses of variance in which repetition condition was the lone within-subject variable. The analysis of RTs revealed a significant effect of repetition condition, $F(2,30) = 45.24$, $MSE = 69255.53$, $p < .001$. Post-hoc comparisons were computed by Tukey's Honestly Significant Difference (HSD) test. This analysis revealed that RTs in the three conditions were all significantly different from each other, $p < .05$. Responses were fastest in the same stimulus condition (495 ms), slower in the different condition (588 ms), and slowest in the same response condition (622 ms). The effect of repetition condition was also significant in the analysis of error percentages, $F(2,30) = 15.08$, MSE

= 108.96, $p < .001$. Post-hoc comparisons revealed that more errors were made in the same response condition than in both the same stimulus and different conditions, $p < .05$.

For Experiment 1B, the mean RTs and error percentages were also submitted to repeated measures analyses of variance in which repetition condition was the lone within-subject variable. The analysis of RTs revealed a significant effect of repetition condition, $F(2,30) = 21.20$, $MSE = 4126.46$, $p < .001$. Post-hoc comparisons revealed that RTs were significantly faster in the same stimulus condition than in both the same response and different conditions, $p < .05$, but not significantly different in the same response and different conditions (see Table 1). The overall effect of repetition condition was significant in the analysis of error percentages, $F(2,30) = 6.11$, $MSE = 2.77$, $p < .01$. Post-hoc comparisons on the error percentages paralleled the findings in the RT data, with only the same response and different conditions not differing significantly from one another.

To summarize, a reliable repetition effect was observed in both experiments. However, response repetitions were faster than response alternations only when identical stimuli were presented in consecutive displays. This result suggests that there is a significant specific component to the repetition effect. Further, in Experiment 1A but not in Experiment 1B, this specificity resulted in a response repetition effect that was significantly less than zero. At first blush, this observation suggests that the specific component of the repetition effect may have been greater in Experiment 1A than in Experiment 1B. However, an examination of the stimulus repetition effects reveals that they also differ across the two experiments, and in the same direction as the response repetition effects. That is, both the stimulus repetition and response repetition effects are

more positive in Experiment 1B than in Experiment 1A. The most parsimonious explanation for this pattern of repetition effects is that there is a larger nonspecific component to the repetition effect in Experiment 1B than in Experiment 1A, and this nonspecific component opposes the specific component in the response repetition condition. As a result, the response repetition effect is significant and negative only in Experiment 1A.

This interpretation is supported by separate estimates of the specific component of the repetition effect. Recall that this specific component can be estimated by subtracting a performance measure for an “in concert” condition (the stimulus repetition condition) from that for an “in opposition” condition (the response repetition condition; see Lindsay & Jacoby, 1994). These measures of the specific component of the repetition effect are presented in Table 2, and reveal very close agreement across Experiments 1A and 1B. Thus, it appears that the response modality difference across the experiments affected the nonspecific component of the repetition effect while leaving the specific component unchanged.

Insert Table 2 About Here

Experiment 2: Dissociating specific and nonspecific transfer

The results of Experiments 1A and 1B provide preliminary evidence that the repetition effect has both specific and nonspecific components, and that the nonspecific component can be affected selectively. If the specific and nonspecific components of the

repetition effect can contribute independently to performance, then it ought to be possible to show that the specific component also can be affected selectively.

To address this issue, four groups of participants completed the same task as in Experiments 1A and 1B. Two groups of participants categorized the colored rectangles as in the previous experiments, giving the response “CAT” or the response “DOG” to each stimulus, while the other two groups categorized the colored rectangles with manual responses on the keyboard. The purpose of this manipulation was to replicate within a single experiment the results observed across Experiments 1A and 1B. For one of the two groups in each response type condition, the proportion of trials in each of the repetition conditions was the same as in the previous experiments. However, for the other group in each response type condition, there were three times more same stimulus trials than same response trials. The purpose of this proportion manipulation was to examine whether it would affect the specific component of the repetition effect selectively. Note that this proportion manipulation did not affect the overall probability of trials in which the same response was required for consecutive items, which remained at .50. Rather, this proportion manipulation raised to an above-chance level the probability that the specific color would match in consecutive displays.

Method

Participants

Sixty-four undergraduate students (49 females) from the same source as the previous experiments participated in the study (mean age of 19.1 years). Participants

were randomly assigned to one of four groups. All participants had normal or corrected-to-normal visual acuity and normal color vision.

Apparatus and Stimuli

All apparatus and stimuli in this experiment were identical to the previous experiments.

Procedure and Design

The procedure and design for this experiment were the same as in Experiments 1A and 1B, with the following exceptions. First, response type was included as a between-subjects variable, rather than being tested in two separate experiments. Participants who made vocal responses categorized the colored rectangles using the labels “CAT” and “DOG” as in Experiment 1A. Participants who made manual responses categorized the colors using the “m” and “n” keys on the computer keyboard with two fingers on their dominant hand (a small change from the “m” and “x” keys used in Experiment 1B). The second between-subjects variable was proportion repeated, which was factorially crossed with the response type variable to create four groups. In the .250 repeated condition, the proportion of same stimulus trials was .250, the proportion of same response trials was .250, and the proportion of different trials was .500, as in Experiments 1A and 1B. In the .375 repeated proportion condition, the proportion of same stimulus trials was .375, the proportion of same response trials was .125, and the proportion of different trials was .500. Note that this proportion manipulation introduced a predictive relation between the colors of the prime and probe, but not between the response required for the prime and probe.

The assignment of colors to response categories was counterbalanced such that each color was paired in a response category with each of the other colors for approximately one-third of the participants. This change was implemented in this and following experiments to avoid any concerns that the particular color assignments used in Experiments 1A and 1B contributed to the response repetition effects observed.

Results and Discussion

Correct RTs were subjected to the same outlier elimination procedure as used in Experiments 1A and 1B. This procedure discarded 3.6% of the observations from further analysis. Using the remaining observations, mean RTs were computed for each proportion repeated (.250/.375), response type (manual/vocal), and repetition condition (same stimulus, same response, and different). Mean RTs and error percentages in each condition, as well as the stimulus repetition and response repetition effects, are displayed in Table 3.

Insert Table 3 About Here

Response times

Inspection of the mean RTs suggests that the repetition effect was positive in sign in all four groups only when the prime and probe matched in color. Overall, responses were fastest in the same stimulus condition and slowest in the same response condition.

As in Experiments 1A and 1B, the response type manipulation appeared to affect the stimulus repetition and response repetition effects similarly, with both being more positive for manual than for vocal responses. In contrast, the proportion repeated manipulation appeared to modulate the response repetition effect without also affecting the stimulus repetition effect. These observations were confirmed by the following analyses.

Mean correct RTs were submitted to a 2x2x3 factorial ANOVA that treated response type (manual/vocal) and proportion repeated (.250/.375) as between-subjects variables, and repetition condition (same stimulus/same response/different) as a within-subject variable. This analysis revealed a significant main effect of repetition condition, $F(2,120) = 165.92$, $MSE = 1633.90$, $p < .001$. A Tukey test indicated that RTs in the three conditions were all significantly different from each other. Responses were fastest in the same stimulus condition, and slowest in the same response condition (see Table 3).

Proportion repeated effects. The overall analysis also revealed a significant interaction between proportion repeated and repetition condition, $F(2,120) = 5.00$, $MSE = 1633.90$, $p < .01$. To identify the source of this interaction, two 2x2 ANOVAs were conducted. The first analysis focused on response repetition effects for the .250 and .375 repeated groups. In this ANOVA, proportion repeated (.250/.375) was treated as a between-subjects factor and repetition condition (same response/different) was treated as a within-subject factor. There was a significant interaction between proportion repeated and repetition condition, $F(1,62) = 7.08$, $MSE = 1687.74$, $p < .01$. The means in Table 3 reveal that response repetition effects were significantly more negative for the .375

repeated groups than for the .250 repeated groups. The second analysis focused on stimulus repetition effects for the .250 and .375 repeated groups. For this ANOVA, proportion repeated (.250/.375) was treated as a between-subjects factor and repetition condition (same stimulus/different) was treated as a within-subject factor. In this analysis, the proportion repeated by repetition condition interaction did not approach significance, $F < 1$.

Recall that response repetition and stimulus repetition effects that are affected similarly by a variable implicate a nonspecific memory influence on performance (compare Experiments 1A and 1B). In this light, it is noteworthy that the proportion repeated variable affected response repetition and stimulus repetition effects differently. This result suggests that the proportion repeated variable affected the specific component of the repetition effect. We proposed that the specific component of the repetition effect can be measured by subtracting a performance measure for the stimulus repetition condition from that for the response repetition condition. Indeed, the specificity measures presented in Table 2 indicate that the specific component of the repetition effect was affected selectively by the proportion repeated variable, with larger measures of specificity associated with the higher proportion repeated condition.

Response type effects. The main effect of response type was significant, $F(1,60) = 5.12$, $MSE = 16389.28$, $p < .05$. Responses were faster for the groups that responded manually than for the groups that responded vocally. The interaction between response type and repetition condition did not reach conventional levels of significance, $p < .11$. However, given the results of Experiments 1A and 1B, we had an a priori interest in

testing two orthogonal components of this interaction. One component of the interaction compares the mean of the two conditions in which a repeated response is required (i.e., the mean of same stimulus and same response conditions) to the different condition, across the two response types. We refer to this difference score as an overall repetition effect. Note that this is the component of the interaction that should be sensitive to a nonspecific memory influence. A contrast that focused on this component of the interaction revealed that the overall repetition effect differed for manual and vocal responses, $F(1,62) = 5.38$, $MSE = 922.08$, $p < .03$. The overall repetition effect was significantly more positive (i.e., faster response repetitions than response alternations) for manual than for vocal responses. A second component of the response type by repetition condition interaction examines differences between the same stimulus and same response conditions across the two response types. This is the component of the interaction that should be sensitive to a specific memory influence. A contrast that focused on this component of the interaction revealed no significant difference between vocal and manual response types, $F < 1$.

As in Experiments 1A and 1B, the response type manipulation affected the stimulus repetition and response repetition effects similarly. This selective shift in the nonspecific component of the repetition effect is captured by the two contrasts described above. Whereas the manual response type condition produced an overall repetition effect that was more positive than for the vocal responses, the specific component of the repetition effect was not affected by response type (see Table 2).

Errors

The analysis of error percentages revealed a pattern of results similar to the RTs. There was a significant main effect of repetition condition, $F(2,120) = 57.73$, $MSE = 8.22$, $p < .001$. A post-hoc Tukey HSD test revealed that more errors were made in the response repetition condition than in both the stimulus repetition and different conditions. The proportion repeated by repetition condition interaction was significant, $F(2,120) = 3.82$, $MSE = 8.22$, $p < .03$. The pattern of errors for this interaction was very similar to that for the RTs (see Table 3). The interaction between response type and repetition condition was also significant, $F(2,120) = 6.26$, $MSE = 8.22$, $p < .01$. As was the case for the RTs, the response type manipulation appeared to affect performance differently for the conditions that did and did not require a response repetition. In the stimulus repetition and response repetition conditions, fewer errors were made for manual responses than for vocal responses, whereas the opposite effect occurred for the different condition. The only other significant effect in the analysis was the interaction between response type and repeated proportion, $F(1,60) = 4.18$, $MSE = 18.18$, $p < .05$. In the .250 repeated condition, more errors were made for vocal than for manual responses, while the opposite pattern of errors was observed in the .375 repeated proportion condition.

Summary

Response type affected performance in a manner similar to Experiments 1A and 1B. In particular, differences in the response repetition effect were mirrored by differences in the stimulus repetition effect. As such, the effect of response type on the repetition effect reflects a nonspecific influence of memory. Contrary to the effect of

response type, the proportion repeated variable modulated the response repetition effect but left the stimulus repetition effect unchanged. The effect of proportion repeated on the repetition effect therefore reflects a specific influence of memory. Together, these results demonstrate a dissociation between the specific and nonspecific components of the repetition effect. Response type influenced the nonspecific component but not the specific component, while proportion repeated influenced the specific component but not the nonspecific component.

Having demonstrated this dissociation, our attention turned to experiments that would provide a better understanding of the processing basis of the specific/nonspecific distinction. Experiments 3 and 4 examine the nonspecific component of the repetition effect, and Experiments 5 and 6 examine the specific component of the repetition effect.

Experiment 3: Nonspecific transfer and response modality

In Experiments 1A, 1B and 2, the nonspecific component of the repetition effect was affected by whether the responses were made vocally, using the category labels CAT and DOG, or manually, using two keys on the keyboard. In this experiment, we examined whether the difference in nonspecific transfer in prior experiments was due to the difference between vocal and manual response modalities per se, or to some other factor that differed between the response categories that were used. For example, the two sets of response categories also differed in that the labels CAT and DOG are inherently meaningful, while the response keys on a keyboard are not meaningful. To test whether the nonspecific component of the repetition effect is sensitive to the meaningfulness of

response categories, rather than to a static difference between vocal and manual response modalities, both groups in this experiment used vocal response categories. However, participants in one group used the vocal category labels CAT and DOG, while participants in the other group used the vocal category labels C and D. If meaningfulness of category labels is critical, then the nonspecific component of the repetition effect should differ across the two groups in this study, in spite of both groups responding vocally.

Method

Participants

Thirty-two undergraduate students (28 females) from an introductory psychology course at McMaster University participated for course credit (mean age of 19.4 years). All subjects had normal or corrected-to-normal visual acuity and normal color vision.

Apparatus and Stimuli

All apparatus and stimuli in this experiment were identical to the previous experiments.

Procedure

The design of this experiment was similar to Experiments 1A and 1B. Participants were randomly assigned to one of two groups and asked to categorize the rectangles vocally. The first group categorized the colors as “CAT” and “DOG” and the second group categorized the colors as “C” and “D”. Color assignments were randomized as described in Experiment 2. One further procedural change was

introduced. Participants did not initiate each trial with a button press. Instead, a trial began 1000 ms after the experimenter coded the accuracy of the prior trial. This change in procedure was adopted to ensure that participants in the two response type groups had comparable inter-trial intervals. All other aspects of the procedure were identical to Experiments 1A and 1B.

Results and Discussion

Correct RTs to probes were subjected to the same outlier elimination procedure as in previous experiments (Van Selst & Jolicoeur, 1994). This procedure discarded 2.3% of the observations. Using the remaining observations, mean RTs were computed for each of the three repetition conditions (same stimulus, same response, and different). Mean RTs and error percentages for each condition, as well as the stimulus repetition and response repetition effects, are displayed in Table 4.

Insert Table 4 About Here

Response times

Inspection of the mean RTs suggests that both the stimulus repetition effect and the response repetition effect were more positive for the C/D than for the CAT/DOG group. In other words, response type appeared to affect equally the two conditions in which a repeated response was required. These observations were confirmed by a 2x3

factorial ANOVA that treated response type as a between-subjects factor (CAT/DOG versus C/D) and repetition condition (same stimulus, same response, different) as a within-subject factor. This analysis revealed a significant main effect of repetition condition, $F(2,60) = 132.58$, $MSE = 625.94$, $p < .001$. A Tukey test indicated that RTs in the three conditions were all significantly different from each other. Responses were fastest in the same stimulus condition, and slowest in the same response condition.

More important, there was a significant interaction between response type and repetition condition, $F(2,60) = 4.50$, $MSE = 625.94$, $p < .02$. To address the source of this interaction, we focused on the two orthogonal components of the interaction that were of primary interest, as in Experiment 2. The first contrast focused on the overall repetition effect across the two response types; that is, the difference between conditions in which a repeated response was required (the mean of same stimulus and same response conditions) and the condition in which a response alternation was required. This analysis revealed a difference in the overall repetition effect for CAT/DOG and C/D response types, $F(1,30) = 15.73$, $MSE = 261.76$, $p < .001$. The overall repetition effect was significantly more positive (i.e., faster response repetitions than response alternations) for C/D than for CAT/DOG responses. The second contrast focused on the difference between same stimulus and same response conditions across the two response types. Again, this component of the interaction reflects the specific component of the repetition effect. The analysis revealed no significant difference between CAT/DOG and C/D response types, $F < 1$.

Errors

In the overall analysis of error percentages, there was a significant main effect of repetition condition, $F(2,60) = 33.93$, $MSE = 4.19$, $p < .001$. A Tukey test indicated that more errors were made in the response repetition condition than in both the stimulus repetition and different conditions.

Summary

The response type manipulation affected the stimulus repetition and response repetition effects similarly. The C/D response type condition produced an overall repetition effect that was more positive than the CAT/DOG response type condition. At the same time, the specific component of the repetition effect was not affected by response type (see Table 2). The similarity between the results of this experiment and those of Experiments 1B and 2 suggest that differences in response modality per se were not responsible for the response type effects observed in those experiments. Rather, it appears that the meaningfulness of response categories in some way influences the nonspecific component of the repetition effect.

Experiment 4: Nonspecific transfer and response category distinctiveness

One way in which the meaningfulness of response categories could contribute to the repetition effect is through the effect of meaning on category distinctiveness. In other words, meaning could be a stimulus dimension that contributes to the relative distinctiveness of response categories. To appreciate how performance might be

influenced by the distinctiveness of response categories, two approaches to solving the color categorization task must be considered.

One approach to solving the task involves identifying the target color, and then using that color as a cue to retrieve the correct response category from memory. This process of retrieving an appropriate response category from memory might reasonably be expected to depend on the distinctiveness of the response categories; the more distinctive the response categories, the more efficient the retrieval. A second approach to solving the task would be to use categorical information as a memory cue, and then to evaluate the match between that categorical information and the target color. For example, participants could maintain an active representation of the colors red and yellow together with the response associated with these colors. The target color could then be compared to this representation, with a good match constituting verification of that response category and a poor match initiating a similar verification routine for the alternate category. What is noteworthy about this second response selection strategy is that it implicates categorical encoding processes that would reasonably be expected to produce nonspecific transfer. If this second response selection strategy were used more under conditions in which the first response selection strategy is inefficient, then reducing the distinctiveness of response categories would naturally result in an increase in nonspecific transfer.

Although this theoretical framework is speculative, it would be supported by further evidence that it is the distinctiveness of the response categories that affects the nonspecific component of the repetition effect. We propose that the distinctiveness of

response categories was manipulated in Experiment 3 by using one pair of vocal response categories that were relatively rich in meaning (CAT/DOG) and a second pair of vocal response categories that had less meaningful labels (C/D). In the present experiment, we capitalized on the notion that meaning is just one of many dimensions that can contribute to the distinctiveness of two response categories, and that it ought to be possible to use some other dimension to vary the distinctiveness of two manual response categories. To this end, we asked participants to categorize colors using manual key press responses, as in Experiment 1B, but two distinct auditory tones were added to the response categories. Thus, although the nominal task was to press the “z” key for either of two colors and the “m” key for either of the other two colors, each of the keypress responses was consistently paired with either a 1000 Hertz or a 1500 Hertz tone.

Method

Participants

Thirty-two undergraduate students (26 females) from an introductory psychology course at McMaster University participated for course credit (mean age of 19.5 years). All subjects had normal or corrected-to-normal visual acuity and normal color vision.

Apparatus and Stimuli

All apparatus and stimuli in this experiment were identical to the previous experiments.

Procedure

The design of this experiment was similar to Experiment 1B. Participants were randomly assigned to one of two groups and asked to categorize the colored rectangles manually. Both groups categorized the rectangles by pressing the “z” and “m” keys on the computer keyboard. However, for one of the two groups a 1000 Hertz tone was presented for 50 ms immediately following each “z” button press and a 1500 Hertz tone was presented for 50 ms immediately following each “m” button press. Color assignments to responses were counterbalanced as described in Experiment 2 and the inter-trial interval was 1000 ms as described in Experiment 3. All other aspects of the procedure were identical to Experiment 1B.

Results and Discussion

Correct probe RTs were subjected to the same outlier procedure as in previous experiments, which resulted in the elimination of 3.4% of the observations. Using the remaining observations, mean RTs were computed for each of the three conditions (same stimulus, same response, and different). Mean RTs and error percentages for each condition, as well as the stimulus repetition and response repetition effects, are displayed in Table 5.

Insert Table 5 About Here

Response times

Inspection of the mean RTs suggests that both the stimulus repetition and response repetition effects were more positive for the Z/M group than for the Z/M + tones group. To confirm this observation, RTs were submitted to a 2x3 factorial ANOVA that treated response type as a between-subjects factor (ZM versus ZM + tones) and repetition condition (same stimulus, same response, different) as a within-subject factor. This analysis revealed a significant main effect of repetition condition, $F(2,60) = 88.67$, $MSE = 1106.70$, $p < .001$. More important, there was a significant interaction between response type and repetition condition, $F(2,60) = 3.12$, $MSE = 1106.70$, $p < .05$.

Our a priori interest was in the same two orthogonal components of the interaction as were analyzed in previous experiments. The first contrast revealed that the overall repetition effect (mean of the stimulus repetition and response repetition conditions minus different condition) was significantly more positive for the Z/M group than for the Z/M + tones group, $F(1,30) = 4.84$, $MSE = 997.44$, $p < .04$. The second contrast revealed that the difference between same stimulus and same response conditions did not differ across the Z/M and Z/M + tones groups, $F < 1$.

Errors

In the analysis of error percentages, there was a significant main effect of repetition condition, $F(2,60) = 29.99$, $MSE = 7.43$, $p < .001$. A Tukey test indicated that the mean errors for all three repetition conditions were significantly different from one another.

Summary

As in Experiment 3, the response type manipulation produced similar modulations of the stimulus repetition and response repetition effects. In this case, the Z/M response type condition produced repetition effects that were more positive than for the Z/M + tones response type condition. At the same time, the specific component of the repetition effect was not affected by response type (see Table 2). As such, the results of this experiment provide further support for the view that response type differences in Experiments 1 and 2 were not due to a difference between vocal and manual response modalities. Rather, the distinctiveness of response categories appears to play a critical role in determining the nonspecific component of the repetition effect. In this experiment, the addition of distinctive tones to two response categories was sufficient to modulate the nonspecific component of the repetition effect. Together with the results of Experiment 3, the present results are consistent with the view that distinct response categories encourage a response selection strategy that discourages the use of categorical information.

Experiment 5: Specific transfer and episodic retrieval

The motivation for the final experiment was to pursue the proposal of Pashler and Baylis (1991) that the specificity of the repetition effect in forced-choice discrimination tasks is related to episodic memory. We proposed above that the specific component of the repetition effect can be measured as the difference in performance between the same stimulus and same response conditions. If this specific component of the repetition effect

is related to episodic memory, then it ought to be sensitive to variables that are known to affect episodic memory.

Neill, Valdes, Terry, and Gorfein (1992) followed similar logic in assessing the contribution of episodic memory to the negative priming effect. In their study, they examined the sensitivity of negative priming to the temporal discriminability of the prime episode. Following Baddeley (1976), they varied temporal discriminability by manipulating two temporal intervals: (1) the temporal interval between the response to the prime stimulus and onset of the current probe stimulus (i.e., the response-stimulus interval, or RSI), and (2) the temporal interval between response to the probe for the prior trial and onset of the prime stimulus for the current trial (i.e., the prior response-stimulus interval, or PRSI). According to Baddeley (1976), the temporal discriminability of the prime episode should be greatest, and thus the likelihood of its retrieval highest, when the RSI is short and the PRSI is long. Indeed, Neill et al. (1992) observed the largest negative priming effect in a condition that had a short RSI (500 ms) and long PRSI (4000 ms), and the smallest negative priming effect in a condition with a long RSI (4000 ms) and short PRSI (500 ms).

Following Neill et al. (1992), participants in Experiments 5 were randomly assigned to one of four groups defined by the factorial combination of short and long RSI durations and short and long PRSI durations. The short duration was 500 ms and the long duration was 4000 ms, thus resulting in groups with the following RSI-PRSI intervals: 500-500, 500-4000, 4000-500, and 4000-4000. If the perceptual specificity of the repetition effect is related to episodic memory, then the performance difference between

same stimulus and same response conditions (see Table 2) should vary across these four groups, being largest in the 500-4000 condition and smallest in the 4000-500 condition. Participants in Experiments 5 made their responses manually and were assigned to one of two proportion conditions. For half of the participants the proportions of same stimulus and same response trials were both .250, whereas for the other half of the participants the proportion of same stimulus trials was .375 and the proportion of same response trials was .125. Recall that in Experiment 2, this proportion manipulation selectively affected the specific component of the repetition effect. As such, both the temporal discriminability and proportion repeated manipulations were expected to affect the specific component of the repetition effect in this experiment.

Method

Participants

One hundred twenty-eight undergraduate students (102 females) from the same source as the previous experiments participated in Experiment 5 (mean age of 20.0 years).

Apparatus and Stimuli

All apparatus and stimuli in this experiment were identical to the previous experiments.

Procedure

The design of this experiment was similar to Experiment 2. Participants made manual responses by categorizing the colors using the “M” and “X” keys on the computer

keyboard with their index fingers of their right and left hands. The color assignments for these two experiments were counterbalanced as described in Experiment 2. For half of the participants (64 students), a .250 repeated proportion condition was utilized as described in Experiment 2. The proportion of same stimulus trials was .250, the proportion of same response trials was .250, and the proportion of different trials was .500. For the other half of the participants (64 students), a .375 repeated proportion condition was utilized as described in Experiment 2. The proportion of same stimulus trials was .375, the proportion of same response trials was .125, and the proportion of different trials was .500. In this experiment, participants were also randomly assigned to one of four groups ($n=32/\text{group}$). The four groups were defined by the factorial combination of two variables; RSI and PRSI. RSI refers to the temporal interval between response to the current prime stimulus and onset of the current probe stimulus, while PRSI refers to the temporal interval between response to the prior probe stimulus and onset of the current prime stimulus. Both of these variables had two levels: 500 ms and 4000 ms. The four groups were therefore given the labels 500-500, 500-4000, 4000-500, and 4000-4000, referring to RSI and PRSI for each condition, respectively.

Results and Discussion

Correct RTs were subjected to the same outlier procedure as described in the previous experiments. This procedure eliminated 3.2% of the observations. Using the remaining observations, mean RTs were computed for each repetition condition in each of the two proportion groups and each of the four temporal interval groups. Mean RTs in

each condition, as well as the stimulus repetition and response repetition effects, are displayed in Table 6A for the .250 proportion manipulation and in Table 6B for the .375 proportion manipulation. Perceptual specificity measures are presented in Table 2. Inspection of these data suggests that the temporal discriminability manipulation as well as the proportion manipulation influenced the measures of perceptual specificity in the predicted manner. Increasing the proportion of same stimulus trials increased the perceptual specificity difference score. Furthermore, the measure of perceptual specificity was largest in 500-4000 condition and smallest in the 4000-500 condition, for both proportion manipulations. These observations were confirmed in the following analyses.

Insert Tables 6A and 6B About Here

Response times

Mean RTs for each condition were submitted to a 2x2x2x3 factorial ANOVA that treated proportion repeated (.250/.375), RSI (500/4000 ms) and PRSI (500/4000 ms) as between-subjects variables and repetition condition (same stimulus/same response/different) as a within-subject variable. This analysis revealed a significant main effect of RSI, $F(1,120) = 58.58$, $MSE = 37907.22$, $p < .001$. Responses were faster in the 500 ms RSI condition than in the 4000 ms RSI condition. The interaction between RSI and PRSI was also significant, indicating that this RSI effect was larger in the 4000 ms

PRSI condition than in the 500 ms PRSI condition, $F(1,120) = 4.71$, $MSE = 37907.22$, $p < .05$. There was a significant main effect of repetition condition, $F(2,240) = 194.38$, $MSE = 1342.03$, $p < .001$. A Tukey test indicated that RTs in the three repetition conditions were all significantly different from each other, $p < .05$. Repetition condition interacted significantly with proportion repeated, $F(2,240) = 7.61$, $MSE = 1342.03$, $p < .001$, with RSI, $F(2,240) = 22.90$, $MSE = 1342.03$, $p < .001$, and with PRSI, $F(2,240) = 7.69$, $MSE = 1342.03$, $p < .001$.

Given the specific aim of the present study, these interactions were examined further using the differences between the same stimulus and same response conditions as the dependent variable. This measure of perceptual specificity was submitted to a 2x2x2 factorial ANOVA that treated proportion repeated, RSI and PRSI as between-subjects variables. This analysis revealed a significant main effect of proportion repeated, $F(1,120) = 9.52$, $MSE = 3763.22$, $p < .005$. The perceptual specificity effect was larger for the .375 proportion condition than for the .250 proportion condition. This analysis also revealed a significant main effect of RSI, $F(1,120) = 27.17$, $MSE = 3763.22$, $p < .001$. The perceptual specificity effect was larger for the short RSI condition than for the long RSI condition. Finally, there was a significant main effect of PRSI, $F(1,120) = 9.73$, $MSE = 3763.22$, $p < .01$. The perceptual specificity effect was larger for the long PRSI condition than for the short PRSI condition. There were no significant interactions in this analysis.

The only other significant effect in the overall analysis was the interaction between RSI, PRSI, and repetition condition, $F(2,240) = 3.28$, $MSE = 1342.03$, $p < .05$. This interaction appears due to a slightly larger effect of PRSI on repetition effects in the

long RSI than in the short RSI condition. However, the means in Table 2 indicate that this three-way interaction does not compromise the predicted ordering of perceptual specificity effects across the four RSI x PRSI conditions.

Errors

In the overall analysis of error percentages, a similar pattern of results was observed. There was a significant main effect of repetition condition, $F(2,240) = 63.28$, $MSE = 9.48$, $p < .001$. A Tukey test revealed that more errors were made in the same response condition than in both the same stimulus and different conditions. Repetition condition interacted significantly with proportion repeated, $F(2,240) = 5.18$, $MSE = 9.48$, $p < .01$, with RSI, $F(2,240) = 14.17$, $MSE = 9.48$, $p < .001$, and with PRSI, $F(2,240) = 5.35$, $MSE = 9.48$, $p < .01$. The means in Tables 6A and 6B indicate that the pattern of errors is similar to that in the analysis of RTs. In particular, the difference between same stimulus and same response conditions is numerically largest in the 500-4000 condition and smallest in the 4000-500 condition. The only other significant effect in the analysis was the main effect of proportion repeated, $F(1,120) = 6.17$, $MSE = 25.90$, $p < .02$. More errors were made in the .375 proportion repeated condition than in the .250 proportion repeated condition.

Summary

Two properties of the present results are consistent with the proposal that the specific component of the repetition effect is related to episodic memory (Pashler & Baylis, 1991). First, as in Experiment 2, the specific component of the repetition effect was sensitive to the proportion of same stimulus trials. Second, and more important, the

specific component of the repetition effect was affected both by the interval following the prime and by the interval preceding the prime. These two effects resulted in the largest specificity effect when the RSI was short and the PRSI was long, and the smallest specificity effect when the RSI was long and the PRSI was short. This result suggests that the specific component of the repetition effect is sensitive to the temporal discriminability, and thus retrievability, of the prime episode.

General Discussion

To summarize the argument presented in this paper, there appear to be independent specific and nonspecific influences on performance in two-alternative forced-choice tasks. When two identical stimuli appear on consecutive trials (the same stimulus condition), both specific and nonspecific memory influences produce a tendency to repeat the prior response. In contrast, when two different stimuli from the same category appear on consecutive trials (the same response condition), the specific memory influence produces a tendency to make a different response, while the nonspecific memory influence produces a tendency to repeat the prior response. Assuming that the nonspecific influence contributes identically to these two conditions, its contribution to performance can be discounted by subtracting a performance measure for the same stimulus condition from that for the same response condition. This difference then provides a measure of the specific memory influence on performance.

This analytic approach allowed us to address two issues. First, we evaluated whether specific and nonspecific memory influences contribute separately to performance

in two-alternative forced-choice tasks by examining whether they could be dissociated. If these two memory influences contribute separately to the repetition effect, then there ought to be variables that affect the specific memory influence while leaving the nonspecific memory influence unchanged, and vice versa. Indeed, the results of Experiments 1A, 1B, and 2 demonstrate such a dissociation. Second, we examined in more detail the processes responsible for specific and nonspecific components of the repetition effect. Experiments 3 and 4 focused on the processing basis of the nonspecific component of the repetition effect. These experiments showed that changes in the nonspecific component of the repetition effect are best attributed to differences in the relative discriminability of the response categories rather than to differences in response modality. Presumably, greater discriminability of response categories encourages a perceptual analytic strategy, whereby responses are selected by using color as a cue to retrieve a response category from memory. In contrast, when the discriminability of response categories is lower, the prior response category may be used as a cue to evaluate its match with a subsequent target color. Experiment 5 focused on the processing basis of the specific component of the repetition effect. This final experiment found support for Pashler and Baylis' (1991) proposal that the specific component of the repetition effect reflects the retrieval of a memory episode.

The view presented in this article can be considered an extension of the logic forwarded by Ratcliff and McKoon (1995) to explain repetition effects in a possible/impossible object decision task. These authors argued that repetition effects are sometimes observed only for possible objects because of a bias to respond possible to

familiar objects regardless of whether they are possible or impossible. If retrieval of specific information about how a prime was categorized also contributes to performance, then these two influences should work in concert for familiar possible objects and in opposition for familiar impossible objects. Consequently, repetition benefits are consistently observed for possible objects, but depend on the relative contributions of the two memory influences for impossible objects. The parallel to the framework used to describe the present results is a close one. Here, we have proposed that specific and nonspecific memory influences contribute separately to performance, and that these processes work in concert in the same stimulus condition, but in opposition in the same response condition. An interference effect involving the same response condition, which we call the response repetition effect, sometimes occurs and other times does not occur, which parallels the critical finding that priming for impossible objects sometimes occurs and other times does not occur (Ratcliff & McKoon, 1995). In both studies, whether this effect occurs depends on the relative contributions of two opposing memory influences to performance.

Beyond the parallel to the Ratcliff and McKoon (1995) study, there may be other empirical domains to which the present analytic approach would apply. For example, the notion that an interference effect can depend on the relative contributions of two or more processes, one of which involves episodic memory, has become central in the literature on negative priming. Negative priming is typically measured by asking participants to respond to a target and ignore a distractor in both of two consecutive displays. Responses are often slowed when the target in one display matches the distractor in the prior display

(Neill, 1977; Tipper, 1985; see Fox, 1995; May, Kane, & Hasher, 1995 for reviews). An early consensus that this effect measures an inhibition process used to ignore competing distractors (Neill, 1977; Tipper & Cranston, 1985; but see Lowe, 1979) was challenged by Neill, Valdes, Terry, and Gorfain (1992). Neill et al. proposed that the negative priming effect occurs because response information is encoded as part of the prime episode (e.g., an 'ignore this stimulus' tag may be linked to the prime distractor). In turn, onset of a probe may cue the retrieval of similar such episodes, producing a conflict when a currently attended item matches a previously ignored item (see also Neill & Mathis, 1998 for a revised version of this theory).

Indeed, there is now good evidence that episodic memory can contribute to negative priming (Fox & deFockert, 1998; Neill, 1997). However, there are also studies in which negative priming is not as sensitive to variables that ought to affect episodic memory as would be predicted by the episodic explanatory framework (Conway, 1999; Hasher, Zacks, Stoltzfus, Kane & Connelly, 1996). One approach to resolving such discrepancies is to assume that negative priming – that is, the difference in performance between ignored repetition and baseline conditions – is not a pure measure of the contribution of episodic memory to performance. Indeed, following the logic introduced here, a negative priming effect might not be observed under conditions in which retrieval of an interfering episodic memory contributes robustly to performance. That is, if there exists a nonspecific memory influence that is of similar magnitude and opposes the interfering episodic influence, one might observe no negative priming despite a robust contribution to performance from episodic memory. Following the present logic a step

further, inclusion of an attended repetition condition (probe target matches prime target), in which episodic memory works in concert with required response selection processes, would allow measurement of both the facilitating and interfering effects of episodic memory on performance. The difference in performance between the attended and ignored repetition conditions might then provide a better measure of the contribution of episodic memory to performance (see Lindsay & Jacoby, 1994 for a similar argument in the Stroop domain). Unfortunately, the assumption that negative priming is process pure has resulted in many studies in which the attended repetition condition is not included.

The present findings may also be related to recent discussions of the cause of task switching costs. In particular, Allport and Wylie (2000) proposed an alternative to the view that task switching costs reflect the time required to switch control settings to those appropriate for a new task (Rogers & Monsell, 1995). Given the stimulus-specificity of so called task switching costs, and that such costs occur even with many intervening trials between the old and new task, Allport and Wylie suggested that retrieval of prior learned stimulus-response (S-R) mappings may underlie task switching costs. Our proposal that differences in performance between the same stimulus and same response conditions reflect the relative utilities of retrieval of the prior S-R mapping is perfectly consistent Allport and Wylie's (2000) claims. Indeed, the task that we used could be modified slightly by asking participants to name the colors in the first display, and to categorize the colors (RED/YELLOW = left response – BLUE/GREEN = right response) in the following display. This procedure would now have a task switching requirement, and the retrieval of prior S-R mappings would no longer work to the participant's advantage

when identical colors appear in consecutive displays. Indeed, we have conducted this experiment, and performance is worst for trials with the same color in consecutive displays.

In summary, the research reported in this article focuses on processes that contribute to the repetition effect in forced-choice discrimination tasks. While early research on this issue (e.g., Bertelson, 1965) attempted to distinguish between two possible sources for the repetition effect, perception or action, the data from these early studies favored neither of these possibilities unequivocally. Instead, more evidence supported the alternative view that the locus of repetition effects is in response selection, the stage of processing during which perception and action are linked (Fletcher & Rabbitt, 1978; Pashler & Baylis, 1991). The results of the experiments reported in this article further extend this current view. The perceptual specificity of the repetition effect results from the reliance on the prior perception-action link. This specific component of the repetition effect does appear to be episodic in nature. Furthermore, the experiments reported also demonstrate that there is another independent influence on performance, a nonspecific response repetition influence. Therefore, both a perceptually specific episodic influence and a nonspecific response repetition influence jointly determine the repetition effect.

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Table 1

Mean response times (RT) in milliseconds and error rates (ERR) for Experiments 1A and 1B. The standard error of the difference scores are presented underneath each difference score.

	Response Type			
	Vocal (Exp. 1A)		Manual (Exp. 1B)	
Priming Condition	RT	ERR	RT	ERR
Same Stimulus	495	1.5	473	1.6
Same Response	622	6.3	603	3.6
Different	588	2.2	598	2.8
Stimulus Repetition Effect	+93 (16.6)		+125 (23.5)	
Response Repetition Effect	-34 (9.8)		-5 (13.1)	

Table 2

Summary Table of the Perceptual Specificity Difference Scores for Experiments 1 to 6.

The standard error of the difference scores are presented underneath each difference score.

Perceptual Specificity Scores				
Manipulations of the Response				
Experiment 1	Vocal +127 (14.2)	Manual +130 (28.7)		
Experiment 2 (collapsed across proportion)	Vocal +123 (12.5)	Manual +132 (18.8)		
Experiment 3	Vocal (cat/dog) +97 (10.0)	Vocal (c/d) +103 (11.3)		
Experiment 4	Manual (z/m) +104 (11.5)	Manual (z/m+tones) +93 (9.4)		
Proportion Manipulations & Temporal Discriminability Manipulations				
Experiment 2 (collapsed across response type)	.250 Repeated Stimulus +108 (14.1)	.375 Repeated Stimulus +147 (17.2)		
Experiment 5 RSI/PRSI (.250 Repeated Stimulus)	500/500 +92 (15.2)	500/4000 +97 (14.9)	4000/500 +28 (7.7)	4000/4000 +65 (16.8)
Experiment 5 RSI/PRSI (.375 Repeated Stimulus)	500/500 +120 (16.5)	500/4000 +152 (17.2)	4000/500 +41 (9.0)	4000/4000 +102 (21.0)

Table 3

Mean response times (RT) in milliseconds and error rates (ERR) for the .250 and .375 stimulus repeated conditions with vocal or manual responses in Experiment 2. The standard error of the difference scores are presented underneath each difference score.

Priming Condition	Vocal Response				Manual Response			
	.250 Repeated Stimulus		.375 Repeated Stimulus		.250 Repeated Stimulus		.375 Repeated Stimulus	
	RT	ERR	RT	ERR	RT	ERR	RT	ERR
Same Stimulus	481	1.7	494	0.7	440	0.7	426	1.4
Same Response	586	7.1	635	7.4	550	2.6	579	7.2
Different	553	1.3	566	0.7	540	1.8	528	2.7
Stimulus Repetition Effect	+72 (8.2)		+72 (9.9)		+100 (17.7)		+102 (10.0)	
Response Repetition Effect	-33 (9.0)		-69 (13.0)		-10 (17.2)		-51 (17.2)	

Table 4

Mean response times (RT) in milliseconds and error rates (ERR) for the CAT/DOG or C/D vocal response groups in Experiment 3. The standard error of the difference scores are presented underneath each difference score.

Vocal Response				
CAT/DOG			C/D	
Priming Condition	RT	ERR	RT	ERR
Same Stimulus	499	0.1	480	0.3
Same Response	596	4.5	583	3.6
Different	549	0.4	566	0.9
Stimulus Repetition Effect	+50 (7.9)		+86 (9.5)	
Response Repetition Effect	-47 (7.1)		-17 (6.4)	

Table 5

Mean response times (RT) in milliseconds and error rates (ERR) for the z/m manual response group or the z/m + tones manual response group in Experiment 4. The standard error of the difference scores are presented underneath each difference score.

Manual Response				
	Z/M		Z/M + tones	
Priming Condition	RT	ERR	RT	ERR
Same Stimulus	432	0.8	404	1.0
Same Response	536	6.3	497	6.0
Different	545	2.5	477	4.4
Stimulus Repetition Effect	+113 (16.3)		+73 (7.9)	
Response Repetition Effect	+9 (12.5)		-20 (11.2)	

Table 6A

Mean response times (RT) in milliseconds and error rates (ERR) for the 500/4000 RSI and 500/4000 PRSI conditions with manual responses with .250 stimulus repetitions in Experiment 5. The standard error of the difference scores are presented underneath each difference score.

Priming Condition	RSI = 500 ms				RSI = 4000 ms			
	PRSI = 500 ms		PRSI = 4000		PRSI = 500 ms		PRSI = 4000	
			ms				ms	
	RT	ERR	RT	ERR	RT	ERR	RT	ERR
Same Stimulus	485	1.1	391	0.5	620	1.6	600	0.8
Same Response	550	4.4	488	5.7	648	3.2	665	3.0
Different	544	3.0	481	2.0	639	2.0	649	1.3
Stimulus Repetition	+86		+90		+19		+49	
Effect	(18.4)		(8.3)		(7.8)		(13.6)	
Response Repetition	-6		-7		-9		-16	
Effect	(8.8)		(11.5)		(6.1)		(6.3)	

Table 6B

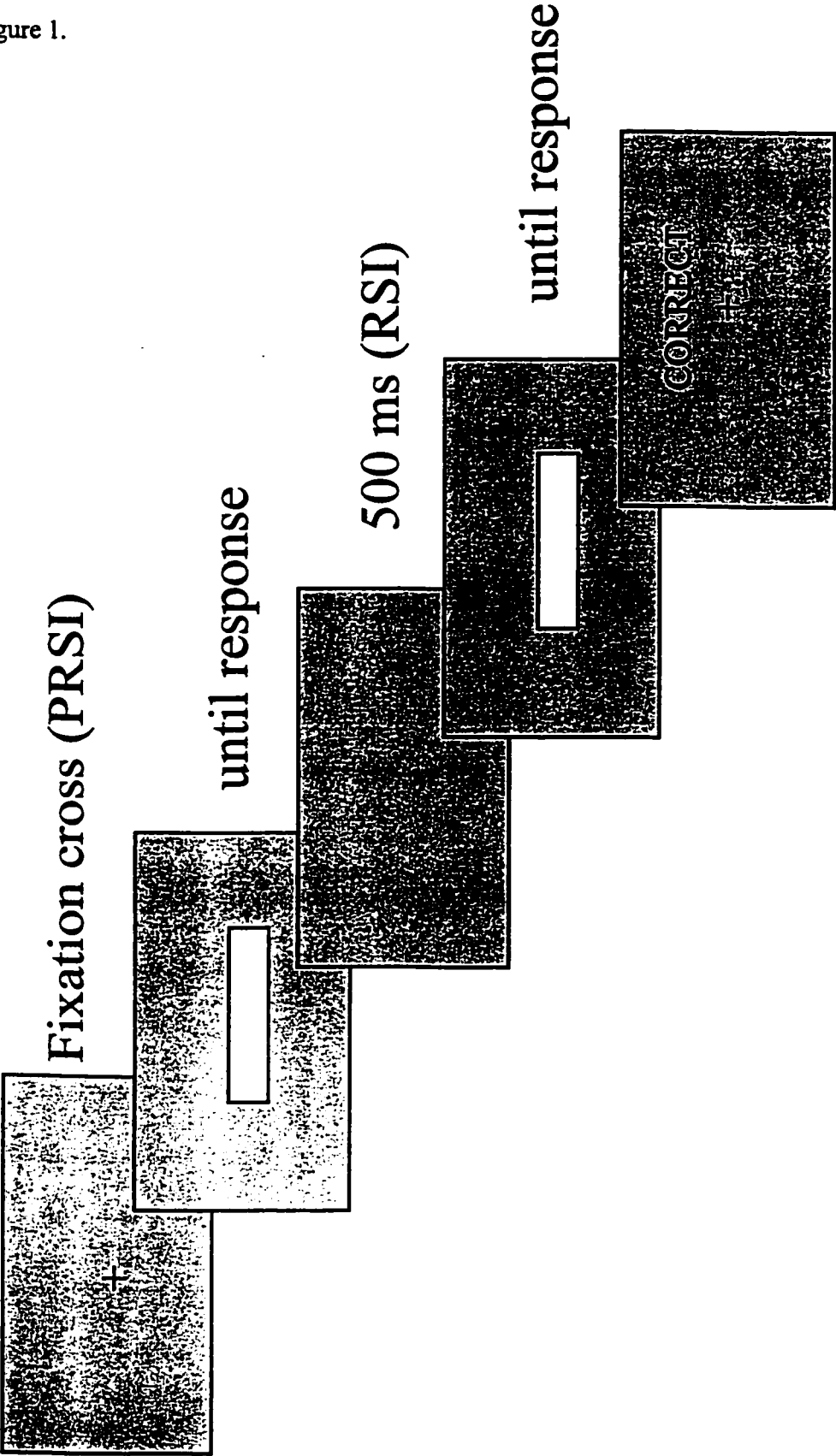
Mean response times (RT) in milliseconds and error rates (ERR) for the 500/4000 RSI and 500/4000 PRSI conditions with manual responses with .375 stimulus repetitions in Experiment 5. The standard error of the difference scores are presented underneath each difference score.

Priming Condition	RSI = 500 ms				RSI = 4000 ms			
	PRSI = 500 ms		PRSI = 4000		PRSI = 500 ms		PRSI = 4000	
			ms				ms	
	RT	ERR	RT	ERR	RT	ERR	RT	ERR
Same Stimulus	413	1.0	385	0.6	566	2.8	611	1.6
Same Response	533	7.2	537	10.8	607	4.4	713	4.8
Different	501	3.5	476	2.4	574	3.2	691	2.0
Stimulus Repetition	+88		+91		+8		+80	
Effect	(16.8)		(11.8)		(6.8)		(16.5)	
Response Repetition	-32		-61		-33		-22	
Effect	(10.7)		(10.8)		(8.8)		(12.5)	

Figure Captions

Figure 1. The sequence of displays for all Experiments. The first of two colored rectangles was displayed on a dark background. The colors were red, yellow, blue or green. On same stimulus trials, the color of the second rectangle, the probe, corresponded with the color of the first, or prime, stimulus. On response repetition trials, the color of the probe was from the same category, but not the same color, as the prime. On different trials, the color of the probe was not the same color nor from the same category as the prime. Participants were required to name the category that the color belonged to as quickly and accurately as possible. (Note: The relative sizes of the stimuli and viewing monitor are not drawn to scale.)

Figure 1.



Chapter 3

The following manuscript has been submitted to the journal, Psychology and Aging, on March 19, 2001. All references, tables and figures from this paper are self-contained in Chapter 3.

To briefly summarize Chapter 1, I outlined the argument that the specificity of repetition effects does not unequivocally favor the abstractionist viewpoint or the episodic retrieval viewpoint. Sometimes observed repetition effects appear perceptually specific, and these findings have been used as evidence to support the episodic retrieval viewpoint. However, other observed repetition effects appear not to be perceptually specific, and these findings have been used as evidence to support the abstractionist viewpoint. Clearly, the abstractionist account needs to accommodate perceptual specificity effects observed in some experiments, while the episodic retrieval account needs to accommodate findings of generalization across perceptual differences observed in other experiments.

Rather than adopting a process-pure assumption regarding repetition effects, I argued in Chapter 2 that a process-pure assumption has slowed theoretical progress in understanding the cause of repetition effects. My approach emphasizes that the observed effects of repetition need to be distinguished from underlying processes that contribute to the repetition effect. In Chapter 2, demonstrations were provided that two memorial

processes, one specific and the other nonspecific, both influence performance. These two processes appear to be independent of one another.

In the cognitive aging literature, the process-pure assumption has also been applied to explain repetition effects. In particular, aging researchers have applied the process pure assumption to explain performance in one particular version of a repetition effect procedure, called the negative priming procedure. The details of the negative priming procedure will be outlined in the introduction of the manuscript in this chapter. However, aging researchers have typically explained negative priming effects by reference to episodic retrieval processes or by reference to processes that act on abstract memory representations. The inference one makes about the effect of aging on performance depends critically on which theoretical camp one ascribes to. For example, sometimes the performance of younger and older adults is observed to be very different in the negative priming literature. These differences have sometimes been attributed to a deficiency in an inhibitory process in older adults. However, this explanation is troublesome to reconcile with other observations that the performance of younger and older adults sometimes appears similar. However, most studies in the aging literature depend on a process-pure assumption about observed performance. Ascribing to either the abstractionist account or the episodic retrieval account limits researchers in how they can account for the variability in older adults' performances in these repetition tasks.

Therefore, the goal of Chapter 3 is to better understand cognitive processing changes that are associated with increasing age using the two-alternative forced-choice task presented in Chapter 2. Instead of adopting the process-pure assumption, the

approach presented focuses on understanding how specific and nonspecific influences from memory both affect performance in younger and older adults. Furthermore, this manuscript also provides evidence of how testing younger subjects at their optimal and nonoptimal times of day may provide a model for the study of cognitive changes associated with aging.

Aging, Testing Time as a Model of Aging, and Repetition Effects

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Abstract

The research reported in this article focuses on two processes that contribute to the repetition effect in a two-alternative forced-choice discrimination task and on how these processes change with age. We demonstrate that two processes, a perceptually specific episodic influence and a nonspecific repetition influence, jointly determine the repetition effect. An analytic technique is presented that allows the researcher to isolate the relative contributions of these two processes to performance. There are two critical findings; 1) the relative contribution of these two influences changes with age and 2) manipulating the time of testing in young adults appears to be an excellent model for the study of aging. The methodology presented may be helpful to researchers who have strived to understand differences in negative priming between younger and older adults.

Aging, Testing Time as a Model of Aging, and Repetition Effects

The research reported in this article concerns cognitive changes that occur with increasing age and how to measure these age-related changes in tasks that rely on attention and automatic (unintended) uses of memory. A two-alternative forced-choice task was used in this study to address two issues. First, we wished to better understand how the relative contributions of two automatic memory influences change with age. Second, we wanted to explore recent suggestions that comparing younger adults tested at their nonoptimal time of day with younger adults tested at their optimal time of day is a useful model for studying how processes change with age (May, 1999; May & Hasher, 1998).

A popular paradigm used to address these issues in aging research measures an effect called negative priming. In a typical negative priming task, participants are presented with trials in paired displays. The first display is called the prime display and the second display is called the probe display. For each display, the participant is asked to selectively respond to a target stimulus (e.g. name a red word) and ignore a distractor stimulus (e.g. a green word). On the critical ignored repetition trial, the participant responds to a target in the probe display that is identical (or related) to the distractor from the prime display. Responses of younger adult subjects on these trials are typically slower than on control trials in which the probe target is unrelated to both the prime target and the prime distractor (Dalrymple-Alford & Budayr, 1966; Lowe, 1979; Neill, 1977; Tipper, 1985). This slowing is known as negative priming (Tipper & Cranston, 1985).

Negative Priming and Aging

The negative priming task has been used as a tool to investigate the cognitive deficits associated with various special populations. In particular, children (Tipper, Bourque, Anderson & Brehaut, 1989), patients with schizophrenia (Beech, Powell, McWilliam & Claridge, 1989; LaPlante, Everett & Thomas, 1992), and patients with frontal lobe lesions (Metzler & Parkin, 2000) have all been documented as producing smaller negative priming effects than appropriate control participants. The present study focuses on the corresponding finding with older adults; in some studies negative priming has not been observed for older adults under conditions in which negative priming is observed reliably for younger adults (Hasher, Stoltzfus, Zacks & Rypma, 1991; Kane, May, Hasher, Rahhal & Stoltzfus, 1997; McDowd & Oseas-Kreger, 1991; Tipper, 1991). Differences in negative priming between older and younger adults is a potentially important observation, as it may help to identify particular processing mechanisms that decline in efficiency with age. For this reason, there has been considerable debate over the processing mechanisms that cause negative priming.

The *inhibitory model* assumes that inhibitory mechanisms protect relevant, goal-directed behavior from distraction. In the context of a negative priming task, inhibitory mechanisms are presumed to suppress the internal representations of distractors. Consequently, when a distractor reappears as a target in a following probe display, the prior inhibition of this item's memory representation results in slowed responding relative to a control condition. Following this logic, absence of negative priming effects in older

adults has been used as evidence that inhibitory mechanisms are less effective or absent with increasing age (Tipper, 1991).

In contrast, the *episodic-retrieval model* attributes negative priming to memory retrieval processes. Presumably, attention to a current probe triggers the retrieval of information about past episodes of similar stimuli. If response information is encoded as part of these episodes, and if this retrieved response information is incompatible with current task demands, then processing that relies on this retrieved episode may well be transfer-inappropriate (Neill & Mathis, 1998; Neill, Valdes, Terry & Gorfein, 1992; Wood & Milliken, 1998; for related episodic memory-based views see Milliken, Joordens, Merikle & Seiffert, 1998; Park & Kanwisher, 1994). The various episodic-retrieval models applied to negative priming were not specifically designed to address aging research (except see Pesta & Sanders, 2000). However, one could account for absent negative priming by suggesting either that older adults encode episodes poorly or that retrieval of these episodes is inefficient or absent.

Kane et al. (1997) proposed recently that both inhibition and episodic-retrieval can cause negative priming. This dual mechanism hypothesis was offered to account for the finding that older adults sometimes produce negative priming effects that are as robust as those produced by younger adults. In particular, under conditions that accentuate retrieval of the immediately prior episode, Kane et al. found that older adults produced negative priming effects that were equivalent to those of younger adults. One set of conditions in which Kane et al. observed this result was when there was a high proportion of attended repetition trials, which occur when an identical target is responded to in

consecutive displays. In contrast, with a lower proportion of attended repetition trials, negative priming was observed only for the younger adults. Kane et al. concluded that episodic retrieval processes were responsible for negative priming when the proportion of attended repetition trials was high, but that inhibition processes were responsible for negative priming when the proportion of attended repetition trials was low. According to this view, younger and older adults may both produce negative priming when it is episodic retrieval that causes the effect, but only younger adults will produce negative priming when inhibition processes are responsible for negative priming. Although consistent with the general view that older adults suffer from inhibitory processing deficits, an obvious concern is that a single measure of performance (the difference in response times to an ignored repetition trial and a control trial) can reflect inhibition or episodic retrieval. Consequently, the researcher who is attempting to understand what processing changes occur with increasing age is faced with the problem of attributing this effect to one or possibly both of these processes.

This issue has become increasingly important as observations accumulate that older adults do produce negative priming in some variants of the negative priming task. For-example, negative priming has been observed for both younger and older participants in a location-based negative priming task (Connelly & Hasher, 1993). Likewise, there have been several recent reports of negative priming for both younger and older participants in identity-based tasks, such as the Stroop color-word task (Little & Hartley, 2000), letter identification tasks (Gamboz, Russo & Fox, 2000; Grant & Dagenbach, 2000), and a conceptual (semantic) negative priming task (Schooler, Neumann, Caplan, &

Roberts, 1997). A recent meta-analysis on adult age differences in 29 negative priming studies (21 identity negative priming and 8 location negative priming) revealed that both younger and older adults demonstrate negative priming effects, yet the effect is often smaller in the older adults (Verhaeghen & De Meersman, 1998). Thus, although effects of aging do occur in at least some cases, it is impossible to know what these effects imply for cognitive deficits in aging without knowing what the negative priming effect measures in each case.

One purpose of this article is to provide a new analytic technique that allows for the dissociation of two processes that may be similar to the two processes described by Kane et al. (1997) in their dual mechanisms account of negative priming. Recall that Kane et al. suggested that a negative priming effect may reflect inhibition processes under some experimental conditions and episodic retrieval processes under other experimental conditions. In the extreme, this approach assumes that the negative priming effect provides a process-pure measure of either one process or the other, depending on the testing conditions. In contrast, we propose that two processes simultaneously contribute to negative priming effects, and that presence or absence of negative priming in older adults reflects the relative contributions of these two processes on performance. Therefore, an analytical technique is needed to dissociate these two processes.

A second purpose is to identify the processes responsible for negative priming and how the relative contributions of these two processes change with age. To this end, we demonstrate that the idiosyncratic properties of negative priming differences between older and younger adults is paralleled in another task that does not contain the overt

selective attention demands that have led researchers to focus on distractor inhibition processes. We propose that age differences in this task also reflect the relative contributions of two unintentional uses of memory, one specific to the link between perception and action, and the other independent of the link between perception and action.

The Repetition Effect in Two-Alternative Forced-Choice Tasks

The task used in the present study is a two-alternative forced-choice task. Participants were presented with paired displays, a prime and a probe display. Each of these displays contained a single colored rectangle. A rule was given to the participant, such as 'red and yellow rectangles belong to one category and blue and green rectangles belong to the other category'. The participant's task was to give the correct categorical response to the colored rectangle in each display. There are three types of trials in the experiments. On same stimulus trials, the stimulus and response repeat. For example, the participant would make a categorical response to a red rectangle followed by the same categorical response to another red rectangle. On same response trials, the response repeats and the stimulus changes. For example, the participant would make a categorical response to a red rectangle followed by the same response to a perceptually different yellow rectangle. On different trials, both the stimulus and response change. For example, the participant would make a categorical response to a red rectangle followed by a different response to a blue rectangle. Prior observations of younger adult participants with this task have revealed that response times are faster for same stimulus trials than for

different trials. More important, response times are often slower for same response trials than for different trials (Marczinski & Milliken, submitted; see also Pashler & Baylis, 1991; Smith, 1968; Terry, Valdes & Neill, 1994). Henceforth, we refer to this latter effect in two-alternative forced-choice tasks as a response repetition cost.

One of our proposals is that an understanding of response repetition costs in two-alternative forced-choice tasks can inform our understanding of negative priming effects. At the same time, this analogy must overcome an obvious difference in procedures used to measure the effects. The difference between these two paradigms is that it is a response repetition that contributes to the cost in two-alternative forced-choice tasks, and a stimulus repetition that contributes to the cost in negative priming. Although these procedures differ, we argue that there are two fundamental memory influences that contribute to performance in both of these tasks.

Two Influences on Performance

In the two-alternative forced-choice task, there appear to be two influences that contribute to performance. One influence appears to be episodic in nature, in the sense that retrieval of the prior stimulus and its associated response contribute to performance. Note that a similar episodic retrieval explanation has been applied to explain performance in negative priming experiments. In particular, a participant may be slow to respond to a target when a retrieved episode contains inappropriate response information. In effect, we suggest that both negative priming and response repetition costs are caused at least in

part by the retrieval of a prior processing episode that is inappropriate for transfer to the current task (Neill & Mathis, 1998; Wood & Milliken, 1998).

Nonetheless, transfer-inappropriate processing may not be the only process contributing to these effects. In particular, in a two-alternative forced-choice task, a participant might benefit from response repetition independent of the perceptual match between the prior and current stimuli. Similarly, there may be a benefit associated with stimulus repetition in a negative priming experiment that is independent of whether an item was previously attended or ignored.

The nonspecific repetition influence may be similar to what has been described as response perseveration in other literatures. Response perseveration involves an immediate and sometimes inappropriate repetition of a prior response (Sandson & Albert, 1984, 1987; Shindler, Caplan & Hier, 1984). Schizophrenic patients have been observed to perseverate prior responses in the Wisconsin Card Sort Test (Elliott, McKenna, Robbins & Sahakian, 1995). Motor perseverations are often observed in patients with frontal lobe lesions (Annoni, Pegna, Michel, Estade & Landis, 1998). Finally, dementia patients have been observed to perseverate prior responses compared with age-matched controls, with greater severity of dementia associated with greater perseveration (Bayles, Tomoeda, Kaszniak, Stern & Eagans, 1985). Indeed, it has been suggested that inhibition might be the mechanism responsible for suppressing those responses that are highly available from a prior trial (May, 1999).

To make it clear how these two influences could jointly contribute to performance in the present two-alternative forced-choice task, consider first a same stimulus trial.

When two identical stimuli repeat within a trial, both the specific influence (due to retrieval of an appropriate link between perception and action) and the nonspecific influence (due to the perseveration of the last response) produce a tendency to repeat the prior response. In other words, the two influences act in concert. In contrast, when two different stimuli from the same category appear consecutively, the specific influence interferes with the correct response (due to retrieval of an inappropriate link between perception and action) whereas the nonspecific influence (response perseveration) facilitates the correct response. Here, the two influences oppose one another. Following Lindsay and Jacoby's (1994) analysis of Stroop performance, the specific component of the repetition effect can be estimated by the difference in performance between the same response (specific and nonspecific influences in opposition) and same stimulus (specific and nonspecific influences in concert) conditions. Subtraction of these two conditions removes the nonspecific influence that acts similarly in both conditions. Throughout this paper, we refer to this specific influence as the perceptual specificity influence, to emphasize that this contribution to performance depends on a perceptual match between consecutive displays. Furthermore, the nonspecific influence can be gauged by looking at the difference between the trials that require a response alternation (different trials) and trials that require response repetition (the mean of same stimulus and same response trials). Note that the relative contributions of the specific and nonspecific influences dictate whether response repetition costs are observed. Larger relative contributions of the nonspecific repetition influence could potentially override the contribution of the specific influence, resulting in no response repetition cost. However, an experimental

manipulation that increases the contribution of the specific influence could outweigh the opposing nonspecific influence, resulting in a response repetition cost.

The Experiments

A two-alternative forced-choice task is used in all of the experiments reported in this article. The results of the experiments show that response repetition costs behave similarly to negative priming effects with respect to the influence of aging. In Experiment 1, a response repetition cost is observed in our younger participants but is absent in our older participants. In Experiment 2, a manipulation that increases the contribution of the perceptual specificity influence to performance results in response repetition costs for both younger and older participants. Together, the results from Experiments 1 and 2 parallel those observed by Kane et al. (1997). Those authors observed that negative priming was absent in the elderly under conditions that resulted in negative priming in younger participants. However, a manipulation that increased the episodic contribution to performance resulted in negative priming for the older participants. Experiments 3 and 4 of this paper demonstrate a similar set of findings by comparing younger subjects tested at their optimal and nonoptimal time of day. These findings support the view that comparisons of younger subjects at optimal and nonoptimal times of day may be a useful model of how processes change with age (May, 1999; May & Hasher, 1998).

Experiment 1

The two-alternative forced-choice task chosen for all of the experiments reported in this article required participants to categorize a single colored rectangle in each of two consecutive displays. The colors red, yellow, blue and green were used in all experiments. For each participant, two colors were assigned to each of two categories. In Experiment 1, the response repetition costs of younger and older participants were compared. We predicted that costs would be observed for the younger participants but not for the older participants.

Method

Participants

Sixteen older participants (9 females), former alumni of McMaster University, generously volunteered their time to participate in this study and were reimbursed for parking. The mean age of these participants was 76.0 years (range = 71-88). All older participants were tested between 9:00 and 10:00 a.m., their optimal testing time (May & Hasher, 1998). The older adults were asked when they preferred to schedule appointments. All of the older adults claimed that they would prefer to participate in this experiment and schedule other appointments in the morning. All of our older adults were healthy and active members of their community (i.e. they volunteered, had many hobbies, and traveled).

Thirty-two undergraduate students (24 females) from an introductory psychology course at McMaster University participated for course credit. The mean age of these

participants was 18.8 years (range = 18-21). The younger participants were tested between 3:30 and 5:00 p.m., their optimal testing time (May & Hasher, 1998). These younger participants were asked when they preferred to take classes, write essays or take exams. All of these younger participants preferred to do these activities in the afternoon or evening. All of our older and younger subjects had normal or corrected-to-normal visual acuity and normal color vision.

Apparatus and Stimuli

Stimuli were presented on a Sony color monitor that was connected to an IBM 486 micro-computer. Micro Experimental Laboratory (MEL) software was used (Schneider, 1988) to display the stimuli and collect the data. Participants were seated approximately 60 cm from the monitor. Responses were spoken aloud into a microphone that was clipped on to the participant's shirt.

Each trial consisted of three displays. The first display was a white fixation cross displayed at the center of the black background of the computer monitor. The fixation cross subtended a visual angle of 0.7° horizontally and 0.7° vertically. The second display was called the prime stimulus, and consisted of a rectangular color patch presented in the center of the computer screen. The color patch subtended a visual angle of 3.4° horizontally and 0.7° vertically. The third display was called the probe stimulus, and again consisted of a rectangular color patch. The colors in which the prime and probe could appear were red, yellow, blue and green. The MEL RGB palette coordinates used to produce these colors were (63, 0, 0) for red, (0, 63, 63) for yellow, (0, 0, 63) for blue, and (0, 63, 0) for green.

Procedure

Participants were required to vocally categorize the color of the rectangle that appeared in the prime display, and then do so again for the color that appeared in the probe display. The two categories were arbitrarily called “cat” and “dog”, with the intention that the category labels be not systematically related to the colors. Color assignments were counterbalanced so that red and yellow were in one category and blue and green were in the other for approximately one third of the participants. The second third were assigned red and green versus blue and yellow. Finally, the last third were assigned red and blue versus yellow and green.

This experiment consisted of one block of 32 practice trials followed by ten blocks of 32 experimental trials. Each of the four prime colors was paired with each of the four probe colors for a total of 16 combinations. Each of these combinations was repeated twice, to give 32 trials within a block. At the beginning of each block of trials, instructions to press “b” to begin the next block appeared. Each trial within a block contained the following sequence of events: (1) a fixation cross appeared on the screen for 500 ms, (2) a 500 ms blank interval, (3) the prime display presented until the participant responded, (4) a 500 ms blank interval, and (5) a probe display presented until the participant responded. Participants were instructed to respond to the prime and probe displays by saying aloud either ‘cat’ or ‘dog’. The instructions emphasized that responses should be fast as well as accurate.

After each trial in this experiment, the accuracy of the vocal responses was coded by the experimenter on the keyboard, which then triggered either the word ‘correct’ or the

word 'incorrect' to appear on the screen, together with the fixation cross for the next trial.

The sequence of events for each trial is presented in Figure 1.

Insert Figure 1 About Here

Response times were measured as the latency between the onset of the color patch and the onset of the participant's voice. An error was recorded if the participant categorized the probe incorrectly. A trial was recorded as a spoil if the prime was categorized incorrectly, if the voice key was activated by a sound other than the onset of the participant's response, or if the voice key did not pick up the onset of the response for either the prime or the probe.

There were three conditions of importance in these experiments. In the same stimulus condition, the prime display and the probe display consisted of patches of the same color. In the same response condition, the prime and probe patches were different colors but required the same categorization response. In the different condition, the patches were from different categories and required different responses. The color of the prime provided no predictive information regarding the color of the probe. As such, half of the trials belonged to the different condition, one quarter of the trials belonged to the same stimulus condition, and one quarter of the trials belonged to the same response condition.

Results

Correct response times (RTs) to the probe display were first subjected to an outlier elimination procedure on a cell by cell basis to eliminate from further analysis any RTs that were abnormally large or small. Van Selst and Jolicoeur's (1994) modified recursive outlier elimination procedure was used to ensure that more observations were not systematically excluded from cells that contained fewer observations. This procedure discarded 2.2% of the observations from further analysis. Mean RTs were computed for each of the three conditions (same stimulus, same response, and different) using the remaining observations. Finally, the younger subjects were divided into two groups based on a median split of their error rates. This median split was done to produce a group of young adults with comparable error rates to the older adults. The mean RTs and error percentages for each condition, as well as the response repetition effects are displayed in Table 1A. The *response repetition effect* was defined as the difference between the different and same response trials for each group of participants.

Insert Table 1A About Here

All analyses compared the older and the accurate younger groups. However, the inaccurate younger group data are presented in Tables 1A and 1B for the reader's interest. The mean RTs for the older and accurate younger groups were submitted to a 2x3 factorial analysis of variance (ANOVA) that treated age (old/accurate young) as the

between-subjects variable and repetition condition (same stimulus/same response/different) as the within-subject variable. This analysis revealed a significant main effect of repetition condition, $F(2,60) = 74.26$, $MSE = 1833.25$, $p < .001$. A post-hoc Tukey test indicated that RTs in the same stimulus condition were faster than in the same response and the different conditions, $p < .05$. The analysis also revealed a significant interaction between age and repetition condition, $F(2,60) = 4.19$, $MSE = 1833.25$, $p < .02$.

To better understand the nature of this interaction, we compared the response repetition effects for the older and accurate younger groups. As shown in Table 1A, the difference between the response repetition effects for the younger and older groups was statistically significant, $t(30) = 3.21$, $p < .01$. The response repetition effect was significant and negative for the younger group, $t(15) = 3.62$, $p < .001$, but was not different from zero for the older group, $p > .05$.

As described earlier in this paper, we assumed that these response repetition effects reflect a combination of two influences. The *perceptual specificity influence* is defined as the difference in performance between the same stimulus and same response conditions, and can be considered a measure of automatic episodic retrieval. Retrieval on a same stimulus trial should result in transfer-appropriate processing (TAP), as the retrieved episode includes information about the same stimulus and the same response as the current stimulus. Retrieval on a same response trial should result in transfer-inappropriate processing (TIP), as the retrieved episode includes information about a different stimulus yet the response requirements of the retrieved episode and the current stimulus are the same (see Neill & Mathis, 1998, for the TIP-TAP view of negative

priming and other related priming phenomena). Therefore, the perceptual specificity influence is a measure of how TAP of retrieved episodes assists performance and how TIP of retrieved episodes is disadvantageous to performance. The second derived measure of interest is the *nonspecific repetition influence*. This measure captures the extent to which perseveration of a prior response contributes to performance independent of the perceptual match between consecutive stimuli. Therefore, the nonspecific repetition influence is defined as the difference between the different trials and the average of the same stimulus and same response trials. The derived measures of the perceptual specificity influence and the nonspecific repetition influence are displayed in Table 1B.

Insert Table 1B About Here

For the first derived measure, the perceptual specificity influences of the older and accurate younger groups were compared. There was no difference between the older and younger participants on this measure, $p > .50$. For the second derived measure, the nonspecific repetition influences were compared and the older group had significantly larger scores than the accurate younger group, $t(30) = 4.14$, $p < .01$ (see Table 1B).

The error percentages for the older and accurate younger groups were also submitted to a 2x3 factorial ANOVA, the same as described above for the RTs. There was a significant main effect of repetition condition, $F(2,60) = 16.03$, $MSE = 1.04$,

$p < .001$. A post-hoc Tukey test indicated that more errors were made in the same response condition than in the same stimulus and different conditions, $p < .05$. There were no other significant effects in this analysis.

Discussion

The results of Experiment 1 include several interesting findings. First, response repetition costs were observed in the younger adults and were absent in the older adults. This result parallels age differences in negative priming, with the effect present in younger adults and absent in older adults (Kane et al., 1997). Rather than assuming that the response repetition effect is a pure measure of one process, we assumed that two processes contribute to this effect. In particular, response repetition effects may reflect both a specific episodic influence and a nonspecific response perseveration influence. In this experiment, processing of the older adults was characterized by greater contributions of the nonspecific response perseveration influence. In contrast, there was no observed age difference in the contribution of the specific episodic influence to performance.

Experiment 2

Kane et al. (1997) demonstrated that increasing the proportion of target repetitions in a negative priming task resulted in significant negative priming effects for older adults. The authors proposed that episodic retrieval may be induced in experimental contexts when prime-display targets often repeat as the subsequent probe-display targets. In Experiment 2, we explored this issue in the two-alternative forced-choice task by

increasing the proportion of same stimulus trials. We predicted that this manipulation would increase the specific episodic influence on performance, and thus produce response repetition costs for both older and younger adults.

Method

Participants

Sixteen older participants (9 females), none of whom participated in Experiment 1, generously volunteered their time to participate in this study and were reimbursed for parking. The participants were alumni of McMaster University, and the mean age of these participants was 76.4 years (range = 69-83). Thirty-two undergraduate students (22 females) from an introductory psychology course at McMaster University participated for course credit. The mean age of these participants was 19.1 years (range = 17-22). All subjects had normal or corrected-to-normal visual acuity and normal color vision. Optimal testing times were again utilized in this experiment, as the older adults were tested in the a.m. and the younger adults were tested in the p.m.

Apparatus and Stimuli

All apparatus and stimuli in this experiment were identical to Experiment 1.

Procedure

The design of this experiment was similar to Experiment 1. Participants made vocal responses of “CAT” and “DOG” to categorize the colored rectangles. The proportion of same stimulus trials was .375, the proportion of same response trials was .125, and the proportion of different trials was .500. Note that this proportion

manipulation introduced a predictive relation between the colors of the prime and probe, but not between the response required for the prime and probe. All other aspects of the procedure for this experiment were the same as Experiment 1.

Results

Correct RTs were first subjected to the outlier elimination procedure described in Experiment 1. This procedure discarded 2.0% of the observations from further analysis. Using the remaining observations, mean RTs were computed for each of the repetition conditions (same stimulus, same response, and different). As in Experiment 1, the younger subjects were divided using a median split based on accuracy. Analyses compared the older group with the accurate younger group. Mean RTs in each condition, as well as the response repetition effects are displayed in Table 2A. The derived measures of the perceptual specificity influence and the nonspecific repetition influence are displayed in Table 2B.

Insert Tables 2A and 2B About Here

A 2x3 factorial ANOVA that treated age (old/accurate young) as the between-subjects variable, and repetition condition (same stimulus/same response/different) as the within-subject variable, was performed on the mean RTs. This analysis revealed a significant main effect of repetition condition, $F(2,60) = 52.97$, $MSE = 6081.05$, $p < .001$.

A post-hoc Tukey test indicated that RTs in the three conditions were all significantly different from one another, $p < .05$. The analysis also revealed a significant interaction between age and repetition condition, $F(2,60) = 4.63$, $MSE = 6081.05$, $p < .02$.

To further understand the nature of this interaction, the response repetition effects were compared. The response repetition costs for the older and accurate younger groups were not significantly different from one another, $p > .90$. Both the older group, $t(15) = 2.19$, $p < .05$, and the younger group, $t(15) = 4.20$, $p < .001$ had response repetition effects that were negative in sign and statistically significant.

A better understanding of the interaction is gained from separately analyzing the derived measures of the perceptual specificity influence and the nonspecific repetition influence. First, the perceptual specificity influences were compared for the older and accurate younger groups. There was a marginally significant difference between the older and accurate younger groups on this measure, $t(30) = 2.08$, $p < .06$, as the perceptual specificity scores were larger for the older group than the accurate younger group. Second, the nonspecific repetition influence scores were compared and the older group had significantly larger scores than the accurate younger group, $t(30) = 2.49$, $p < .03$.

The error percentages for the older and accurate younger groups were also submitted to a 2x3 factorial ANOVA, the same as described above for the RTs. There was a significant main effect of repetition condition, $F(2,60) = 24.54$, $MSE = 5.59$, $p < .001$. A post-hoc Tukey test indicated that more errors were made in the same response condition than in the same stimulus and different conditions, $p < .05$. There were no other significant effects in this analysis.

Discussion

The results of this experiment include several interesting findings. First, large response repetition costs were observed for both the younger and older adults. These results contrast with the response repetition effects observed in Experiment 1. In the first experiment, only the younger participants demonstrated response repetition costs. Together, the findings from Experiments 1 and 2 parallel the results observed by Kane et al. (1997). In their experiments, negative priming effects were present for younger participants but absent for older participants. However, when the experiment included an increased proportion of target repetition trials, reliable negative priming effects were observed for the older participants. This parallel between the present result and those of Kane et al. suggest that the processes that underlie response repetition costs may be similar to the processes that underlie negative priming effects.

Examination of the two influences that underlie response repetition effects revealed one result that was similar to Experiment 1. The contribution of the nonspecific repetition influence to performance was greater for the older adults than for the younger adults. However, in contrast to Experiment 1, the specific component was greater for older than younger adults. This finding was not predicted. The general discussion includes some suggestions as to why this finding might have been observed and what it suggests about processing changes that occur with increasing age. The important thing to note is that the equivalent response repetition effects for older and younger adults may

actually be the product of age differences in two processes that have opposite influences on performance.

Experiment 3

In Experiment 3, we followed May and Hasher's (1998) suggestion that comparing younger adults tested at their optimal time (generally the late afternoon) with younger adults tested at their nonoptimal time (generally the early morning) may be an important tool for understanding and predicting processing changes that occur with increasing age (Hasher, Zacks & Rahhal, 1999; Intons-Peterson, Rocchi, West, McLellan & Mackney, 1998; May, 1999; May, Hasher & Stoltzfus, 1993). Circadian arousal does not remain consistent across the day. Instead, there are peaks in circadian arousal. For younger adults, these peaks generally occur in the afternoon or evening. For the elderly, this pattern reverses with the peak occurring in the morning. The previous two experiments compared younger and older adults at their peak processing times. In this experiment, undergraduate students were tested either early in the morning (at their nonoptimal testing time) or late in the afternoon (at their optimal testing time). The goal was to determine whether May and Hasher's circadian arousal hypothesis applies to performance in our two-alternative forced-choice task. The design of this experiment was identical to the design of Experiment 1. The prediction was that the perceptual specificity influence scores would not differ as a function of time of testing. However, the nonspecific repetition influence was predicted to be greater for subjects tested at their nonoptimal time than for subjects tested at their optimal time.

Method

Participants

Forty undergraduate students (24 females) from an introductory psychology course at McMaster University participated for course credit (mean age of 21.9 years). All subjects had normal or corrected-to-normal visual acuity and normal color vision. Participants were asked when they preferred to take classes, write essays, and write exams. Any participant that claimed that he or she preferred to do these tasks first thing in the morning was not used in this study (this was a rare occurrence, consistent with previous normative studies showing that young adults are not morning types, May & Hasher, 1998). Therefore, all participants in this experiment claimed that they would prefer academic-related activities in the afternoon or evening.

Apparatus and Stimuli

All apparatus and stimuli in this experiment were identical to the previous experiments.

Procedure

The design of this experiment was identical to Experiment 1. Half of the participants were tested between 8:30 and 10:00 a.m. (the nonoptimal testing time) and the other half of the participants were tested between 3:30 and 5:00 p.m. (the optimal testing time). All other aspects of the procedure were identical to Experiment 1.

Results

Correct response times (RTs) to the probe display were first subjected to the outlier elimination procedure described in Experiment 1 (Van Selst & Jolicoeur, 1994). This procedure discarded 1.9% of the observations. Using the remaining observations, mean RTs were computed for each of three conditions (same stimulus, same response, and different). Mean RTs and error percentages for each condition, as well as response repetition effects, are displayed in Table 3A. The derived measures of the perceptual specificity influence and the nonspecific repetition influence are displayed in Table 3B.

Insert Tables 3A and 3B About Here

The RTs were analyzed by a 2x3 factorial ANOVA that treated testing time (a.m./p.m.) as a between-subjects factor and repetition condition (same stimulus/same response/different) as a within-subject factor. This analysis revealed a main effect of repetition condition, $F(2,76) = 120.33$, $MSE = 975.29$, $p < .001$. A post-hoc Tukey test indicated that the mean RTs for each repetition condition were all significantly different from one another, $p < .05$. In this analysis, there were no other significant effects.

Although there was not a significant testing time by repetition condition interaction, $p > .30$, we had several a priori predictions based on the findings of Experiment 1. First, we predicted that the response repetition costs would be present for the p.m. group and absent for the a.m. group. Although a direct comparison of the

response repetition effects revealed that they were not significantly different from one another, $t(38) = 1.47$, $p < .16$, the response repetition effect was significant less than zero for the p.m. group, $t(19) = 3.18$, $p < .01$, but not for the a.m. group, $p > .05$.

For the derived measures, there was no difference between the perceptual specificity scores for the a.m. and p.m. testing times, $p > .80$. However, the nonspecific repetition influence scores were larger for the a.m. group than the p.m. group, $t(38) = 2.18$, $p < .05$.

The error percentages for the a.m. and p.m. groups were also submitted to a 2x3 factorial ANOVA, as described above for the RTs. There was a significant main effect of repetition condition, $F(2,76) = 20.84$, $MSE = 8.04$, $p < .001$. A post-hoc Tukey test indicated that more errors were made in the same response condition than in the same stimulus and different conditions, $p < .05$. There were no other significant effects in this analysis.

Discussion

The results of Experiment 3 closely parallel the findings of Experiment 1. Response repetition costs were observed for the younger participants tested at their optimal time of day. The response repetition effects were not significantly different from zero for the younger participants tested at their nonoptimal time of day. Thus, the performance of younger adults tested at their nonoptimal time of day (a.m.) resembled the performance of older adults in Experiment 1 who were tested at their optimal time of day. Our analytic technique allowed us to determine that younger adults tested at optimal and

nonoptimal times exhibited no difference in the perceptual specificity influence. However, the nonspecific repetition influence on performance was larger for the nonoptimal testing time than for the optimal testing time. This result also parallels the results observed in Experiment 1, in which the nonspecific component was larger for older adults than for younger adults. The performance of younger adults at their optimal and nonoptimal testing times does appear to model processing changes with increasing age.

Experiment 4

In this experiment, younger adults tested at their optimal time of day were compared with younger adults tested at their nonoptimal time of day using the same proportion manipulation as described in Experiment 2. There were three predictions. First, the younger adults tested at their nonoptimal time and the younger adults tested at their optimal time should both demonstrate response repetition costs with the higher proportion of same stimulus trials. The proportion manipulation should result in an increased contribution of the specific component of the repetition effect. Therefore, large response repetition costs should be observed with both groups. Second, the nonoptimal group of participants should demonstrate greater contributions of the nonspecific repetition influence to performance than the optimal group of participants. In Experiments 1 and 2, older adults always demonstrated increased contributions of the nonspecific repetition influence compared with the younger participants. Finally, the nonoptimal group of participants should demonstrate greater contributions of the

perceptual specificity influence to performance than the optimal group of participants. This prediction follows the findings observed in Experiment 2, whereby older participants were more sensitive to the proportion manipulation that resulted in larger specific contributions to performance.

Method

Participants

Forty undergraduate students (28 females) from an introductory psychology course at McMaster University participated for course credit (mean age of 18.9 years). All subjects had normal or corrected-to-normal visual acuity and normal color vision. Similar to Experiment 3, participants were asked when they preferred to take classes, write essays, and write exams. Any participant who claimed that he or she preferred to do these tasks first thing in the morning was not used in this study (this was a rare occurrence, consistent with May & Hasher, 1998). Therefore, all participants in this experiment claimed that they preferred to do academic-related activities in the afternoon or evening.

Apparatus and Stimuli

All apparatus and stimuli in this experiment were identical to the previous experiments.

Procedure

The design of this experiment was identical to Experiment 2. Half of the participants were tested between 8:30 and 10:00 a.m. (the nonoptimal testing time) and

the other half of the participants were tested between 3:30 and 5:00 p.m. (the optimal testing time). The proportion of same stimulus trials was .375, the proportion of same response trials was .125, and the proportion of different trials was .500. Note that this proportion manipulation, as in Experiment 2, introduced a predictive relation between the colors of the prime and probe, but not between the responses required for the prime and probe.

Results

Correct response times (RTs) to the probe display were first subjected to the outlier elimination procedure described in Experiment 1 (Van Selst & Jolicoeur, 1994). This procedure discarded 2.0% of the observations. Using the remaining observations, mean RTs were computed for each of three conditions (same stimulus, same response, and different). Mean RTs and error percentages for each condition, as well as the response repetition effects, are displayed in Table 4A. The derived measures of the perceptual specificity influence and the nonspecific repetition influence are displayed in Table 4B.

Insert Tables 4A and 4B About Here

The RTs were analyzed first by a 2x3 factorial ANOVA that treated testing time (a.m./p.m.) as a between-subjects factor and repetition condition (same stimulus/same

response/different) as a within-subject factor. This analysis revealed a main effect of repetition condition, $F(2,76) = 162.33$, $MSE = 1144.83$, $p < .001$. A post-hoc Tukey test indicated that the mean RTs for each repetition condition were all significantly different from one another, $p < .05$. There were no other significant effects.

Although there was no significant testing time by repetition condition interaction, $p > .10$, we tested several a priori predictions based on the findings from Experiment 2. As predicted, a comparison of the response repetition costs for the two groups revealed that they were not different from one another, $p > .50$. Both the a.m. group, $t(19) = 4.97$, $p < .001$, and the p.m. group, $t(19) = 4.91$, $p < .001$, had response repetition effects that were significantly less than zero.

For the derived measures, a comparison of the perceptual specificity scores for the two groups revealed that the a.m. group had larger scores than the p.m. group, $t(38) = 2.15$, $p < .04$. Finally, the nonspecific repetition influence scores were compared and they were not different from one another, $p > .50$.

The error percentages for the a.m. and p.m. groups were also submitted to a 2x3 factorial ANOVA, as described above for the RTs. There was a significant main effect of repetition condition, $F(2,76) = 57.56$, $MSE = 17.51$, $p < .001$. A post-hoc Tukey test indicated that more errors were made in the same response condition than in the same stimulus and different conditions, $p < .05$. There were no other significant effects in this analysis.

Discussion

In large part, the results of Experiment 4 parallel the findings of Experiment 2. Comparisons of the performance of younger adults tested at their nonoptimal time of day (a.m.) with younger adults tested at their optimal time of day (p.m.) resembled the age differences reported in Experiment 2. Large response repetition costs were observed for both groups tested in this experiment. This finding parallels the finding in Experiment 2 that, with a high proportion of same stimulus trials, both older and younger participants produced response repetition costs. Second, the perceptual specificity influence was greater for the participants tested at their nonoptimal time compared to those tested at their optimal time. This finding also parallels the finding in Experiment 2 that the perceptual specificity influence was greater for the older adults than the younger adults. Finally, the nonspecific repetition influence was not statistically different for the optimal and nonoptimal groups. This result differs from the corresponding finding in Experiment 2, perhaps because this effect was also relatively small in Experiment 3.

In summary, although the effects in these two experiments were smaller than those obtained when actually comparing older versus younger participants, Experiments 3 and 4 do provide some evidence that time-of-testing manipulations with younger adults may be a useful model for studying processing changes that occur with increasing age (May & Hasher, 1998). Future research is needed to determine the reliability and validity of this model of aging.

General Discussion

The results of the four experiments presented in this paper suggest the following three conclusions. First, the effect of aging on response repetition effects observed in a two-alternative forced-choice task appear to parallel the effect of aging on negative priming effects. Older adults did not produce a response repetition cost in some experimental contexts (Experiment 1) but did produce a response repetition cost in other contexts (Experiment 2). In contrast, younger adults produced a response repetition cost in both of these experimental contexts. These findings parallel the results observed by Kane et al. (1997), who showed that under some conditions, older adults do not, while younger adults do, produce negative priming. However, when Kane et al. increased the proportion of target repetitions, negative priming was observed in the older adults. The parallel between age effects on response repetition effects in the present study and on negative priming in the Kane et al. study suggest that similar underlying processes are involved in both types of experiments.

The second conclusion that can be drawn from the four experiments presented in this paper is that the response repetition effect is unlikely to be a pure measure of one process in any experimental context. Similarly, negative priming effects are unlikely to be pure measures of either episodic retrieval or inhibition in any particular task context. We have presented an alternative method of understanding two automatic processes in a two-alternative forced-choice task. Across four experiments, we demonstrated how the perceptual specificity influence and the nonspecific repetition influence can jointly contribute to response repetition effects. In Experiment 1, only younger participants

produced a response repetition cost because of the larger contribution of the nonspecific repetition influence for older than for younger participants. However, the perceptual specificity influence was equivalent in the younger and older adults. This finding is consistent with prior suggestions in the aging literature that increasing age is associated with the loss of inhibitory mechanisms that prevent strong prior responses from cluttering up working memory (May & Hasher, 1998). Even under conditions in which we encouraged greater contributions of episodic processes to performance (Experiment 2), the older participants still demonstrated large nonspecific repetition influences in performance. Future research should be directed toward the connection between nonspecific repetition influences and deteriorating inhibitory mechanisms.

The analytic technique that we introduced also led to a novel finding in Experiment 2. In that experiment, we increased the proportion of same stimulus trials, analogous to the target repetition manipulation in the Kane et al. (1997) studies. As these authors suggested, this manipulation is presumed to increase the contribution of episodic retrieval to performance for both younger and older adults. Indeed, our analytic technique revealed that the perceptual specificity influence was large in both younger and older participants when the proportion of same response trials was high. However, the older participants were actually more sensitive to this manipulation than the younger adults. At the same time, this proportion manipulation did not affect the nonspecific repetition influence. In both Experiments 1 and 2, this nonspecific influence was larger for older adults than for younger adults. The observation that response repetition costs were equivalent in younger and older participants in Experiment 2 we therefore attribute to

individual differences in two processes. According to this view, larger contributions for older adults than for younger adults in two automatic influences, one specific and one nonspecific to the link between perception and action, underlie the equivalent response repetition costs for older and younger adults in Experiment 2.

The final conclusion from the results of these experiments is that we concur with the suggestions of May and Hasher (1998) that comparing the performance of younger adults tested at their optimal and nonoptimal time of day provides a model of how performance changes with age. The processing differences that we observed in Experiments 1 and 2, in which performance of older participants was compared to that of younger participants, were paralleled by the results of Experiments 3 and 4, in which the performance of younger adults at their nonoptimal time of testing was compared to that of younger adults at their optimal time of testing. The nonspecific component of the repetition effect was larger for younger participants tested at their nonoptimal time of day than for participants tested at their optimal time of day. However, this was only observed in Experiment 3, and not in Experiment 4. The specific component of the repetition effect was larger for younger participants tested at their nonoptimal time of day than for participants tested at their optimal time of day, when the proportion of same stimulus trials was high. Both of these processing differences parallel findings with older adults. Although the effects were smaller for the time of day manipulation, the benefit of not having to recruit older adults from the community may favor use of time of day to model aging in some situations, as recruitment of older adults from the community can be a slow and laborious process. Indeed, the use of time of day as a model of aging is increasingly

supported by research findings in both human and animal studies. Recent findings with laboratory rats have also replicated findings that time-of-day influences performance on cognitive tasks in a fashion that resembles the aging process (Winocur & Hasher, 1999).

An issue raised by the results of this study concerns the finding that older adults were more sensitive than younger adults to manipulations that encouraged episodic retrieval. Together with the finding that older adults rely more heavily on nonspecific memory influences suggests that older adults rely more heavily on automatic memorial influences in general. Decreased processing resources associated with increasing age may lead an older participant to rely heavily on any sort of automatic influence from memory, regardless of whether that influence is specific to the link between perception and action or independent of the link between perception and action. Nevertheless, the distinction between specific and nonspecific memory influences on performance is a useful one. In particular, it provides a novel framework for interpreting repetition effects, and for linking individual differences in repetition effects to underlying processes.

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Table 1B

Derived measures of the two influences for older or younger subjects (divided with a median split based on accuracy) in Experiment 1. The standard error of the influence scores are presented underneath each score.

	OLD	ACCURATE YOUNG	INACCURATE YOUNG
Perceptual	+123	+116	+92
Specificity Influence	(16.9)	(20.3)	(10.8)
= SR - SS			
Nonspecific	+72	+19	+26
Repetition Influence	(11.6)	(5.7)	(6.6)
= D - (SS+SR)/2			

Table 2B

Derived measures of the two influences for older or younger subjects (divided with a median split based on accuracy) in Experiment 2. All groups had the proportion manipulation of .375 stimulus repetitions. The standard error of the influence scores are presented underneath each score.

	OLD	ACCURATE YOUNG	INACCURATE YOUNG
Perceptual	+247	+143	+139
Specificity Influence	(43.3)	(25.5)	(20.7)
= SR - SS			
Nonspecific	+65	+17	+12
Repetition Influence	(15.1)	(12.6)	(10.1)
= D - (SS+SR)/2			

Table 3A

Mean response times (RT) in milliseconds and error rates (ERR) for Experiment 3. The standard error of the difference score is presented underneath each difference score.

Testing Time for Young Subjects				
Priming Condition	a.m. (nonoptimal)		p.m. (optimal)	
	RT	ERR	RT	ERR
Same Stimulus (SS)	464	0.4	452	0.4
Same Response (SR)	568	5.1	553	4.6
Different (D)	556	1.2	524	1.6
Response Repetition Effect	-12		-29	
= D - SR	(7.2)		(9.2)	

Table 3B

Derived measures of the two influences for Experiment 3. The standard error of the influence scores are presented underneath each score.

Testing Time for Young Subjects		
	a.m.	p.m.
	(nonoptimal)	(optimal)
Perceptual Specificity	+104	+101
Influence	(11.5)	(12.7)
= SR - SS		
 Nonspecific Repetition	 +40	 +22
Influence	(6.5)	(5.5)
= D - (SS+SR)/2		

Table 4A

Mean response times (RT) in milliseconds and error rates (ERR) for Experiment 4. Both groups had the proportion manipulation of .375 stimulus repetitions. The standard error of the difference score is presented underneath each difference score.

Testing Time for Young Subjects				
Priming Condition	a.m.		p.m.	
	(nonoptimal)		(optimal)	
	RT	ERR	RT	ERR
Same Stimulus (SS)	487	0.1	455	0.0
Same Response (SR)	640	7.8	576	9.1
Different (D)	574	1.2	516	0.4
Response Repetition Effect	-66		-60	
= D - SR	(13.1)		(12.2)	

Table 4B

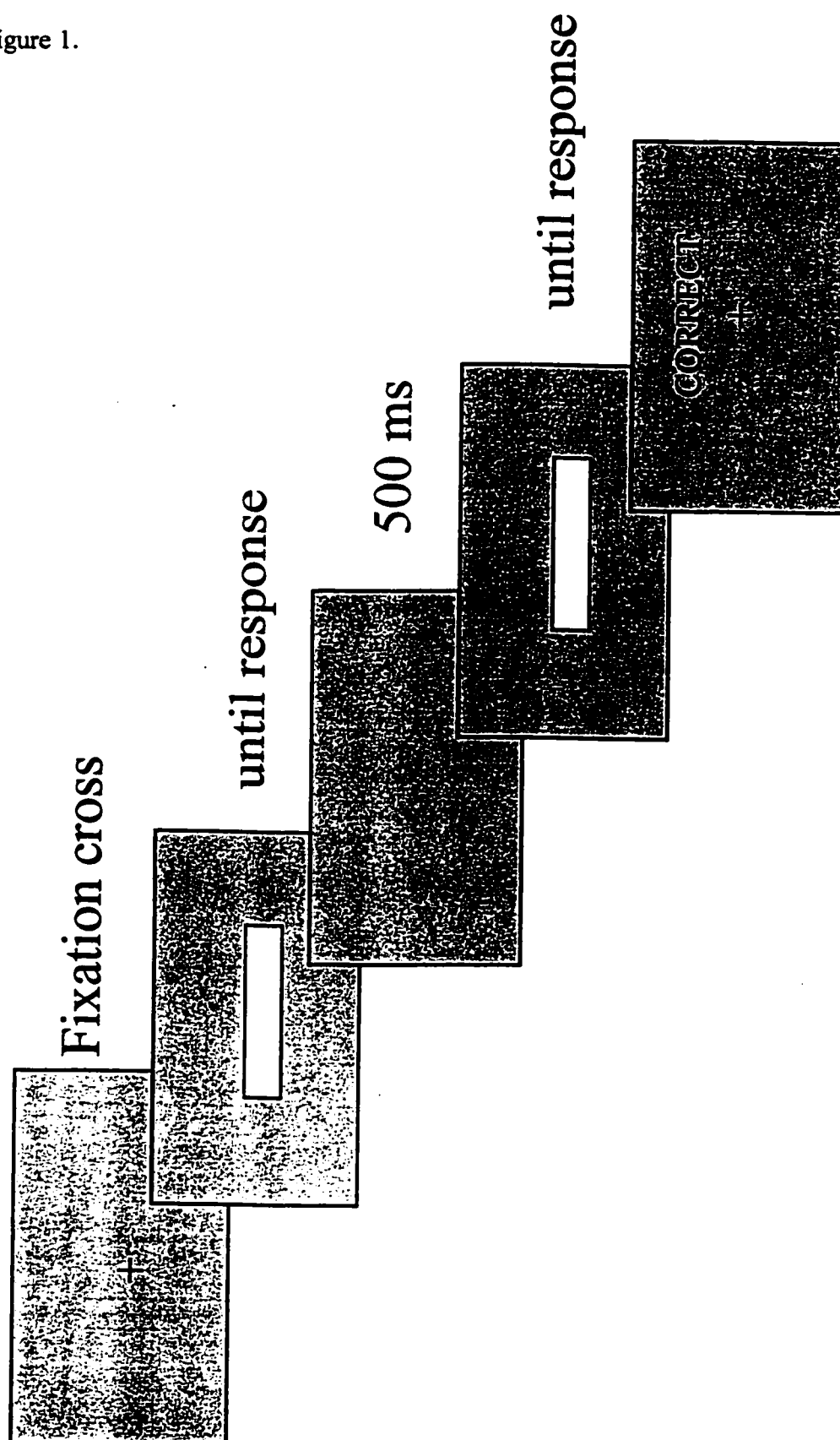
Derived measures of the two influences for Experiment 4. Both groups had the proportion manipulation of .375 stimulus repetitions. The standard error of the influence scores are presented underneath each score.

	Testing Time for Young Subjects	
	a.m.	p.m.
	(nonoptimal)	(optimal)
Perceptual Specificity	+153	+121
Influence	(11.0)	(8.6)
= SR - SS		
Nonspecific Repetition	+11	+1
Influence	(10.1)	(8.9)
= D - (SS+SR)/2		

Figure Captions

Figure 1. The sequence of displays for all Experiments. The first of two colored rectangles was displayed on a dark background. The colors were red, yellow, blue or green. On same stimulus trials, the color of the second rectangle, the probe, corresponded with the color of the first, or prime, stimulus. On same response trials, the color of the probe was from the same category, but not the same color, as the prime. On different trials, the color of the probe was not the same color nor from the same category as the prime. Participants were required to name the category that the color belonged to as quickly and accurately as possible. (Note: The relative sizes of the stimuli and viewing monitor are not drawn to scale.)

Figure 1.



Chapter 4

General Discussion

Summary of the Results

The two manuscripts included in this thesis focused on the cognitive processes that contribute to the repetition effect in a forced-choice discrimination task. The results of the experiments reported in the first manuscript suggest that the repetition effect is determined by two separate and independent memorial influences. One influence is specific to the link between perception and action while the other influence reflects the prior action independent of the perceptual stimulus to which that action was made. These two influences, specific and nonspecific, can work in concert or in opposition to modulate repetition effects. When two identical stimuli appear on consecutive trials (the same stimulus condition), both specific and nonspecific influences produce a tendency to repeat the prior response. In contrast, when two different stimuli from the same category appear on consecutive trials (the same response condition), the specific memory influence produces a tendency to make a different response, while the nonspecific influence produces a tendency to repeat the prior response. The analytic technique provided in the first manuscript illustrated how these two influences might be measured separately.

The logic presented in the first manuscript was then extended to address some applied questions about cognitive changes that occur with aging. The second manuscript

described how the relative contributions of specific and nonspecific influences on the repetition effect change with increasing age. In the recent past, the negative priming paradigm has been used to document age differences in cognition and to make inferences about particular cognitive processes that deteriorate with aging. However, researchers have generally adopted the assumption that a negative priming difference score reflects the contribution of just one process to performance.

In contrast to adopting the process-pure assumption, the approach presented in the second manuscript described how two processes might simultaneously contribute to repetition effects. This approach differs in that there is no assumption that one process or another is contributing to an observed effect. Instead, it is the relative contribution of two influences, specific and nonspecific, that contribute to observed repetition effects. With this approach, the absence of a particular effect of interest in an aging population does not imply that any particular process is absent. For example, in Experiment 1 of Chapter 3, the response repetition effect for older adults was not observed under the same conditions that a large negative response repetition effect was observed for the younger adults. However, this finding with the older adults was not due to a process being absent. Instead, the relative contributions of the two influences change with increasing age. A larger nonspecific than specific influence accounts for the absence of a response repetition effect for the older adults compared with the presence of a response repetition effect for the younger adults. Furthermore, this pattern of results was replicated in Experiment 3 of Chapter 3, when younger adults were tested at either their optimal or their nonoptimal time of day. The nonspecific influence appeared larger for younger

adults tested at their nonoptimal time of day than for younger adults tested at their optimal time of day.

In summary, both manuscripts presented in this thesis focused on how specific and nonspecific memorial influences contribute to the repetition effect. This distinction may be useful in understanding the processing that underlies observed results using other priming paradigms, such as negative priming and perhaps also task switching.

Why two influences?

I have proposed that there are specific and nonspecific memorial influences on performance in a two-alternative forced-choice task. An obvious question that arises is why these two influences contribute separately to performance? One answer to this question begins with the well-documented distinction between two parallel processing pathways for vision (Livingstone & Hubel, 1998; Milner & Goodale, 1996; Ungerleider & Mishkin, 1992). The dorsal and ventral processing streams are two pathways in the brain that have been argued to conduct visual information independently. Most recently, it has been recognized that these two pathways may be best understood by considering the purpose of vision (Milner & Goodale, 1996). In some situations, vision is needed for perception (the ventral stream) while in other cases, vision is needed for action (the dorsal stream). An example might be helpful to clarify the distinction between these two streams. Imagine that you are looking at a wooden block sitting on a table. If your task is predominantly perceptual in nature (e.g. you are looking at the block to determine whether the block is yellow or brown), you would be relying more on the ventral stream

of processing. In contrast, if your task requires action (e.g. you are reaching out to pick up this wooden block), you would be relying more on the dorsal stream of processing. For this task of picking up the block, vision need only be accurate enough to complete the appropriate action.

Milner and Goodale (1996) provided compelling evidence to distinguish between the perception and action functions of these two processing streams. One source of this evidence comes from patients with brain lesions isolated to one processing stream or the other. One case described by these researchers is patient D.F. With a large battery of diagnostic tests, the researchers determined that D.F. demonstrated intact visuomotor behavior despite profound perceptual deficits. For example, when 120 line drawings of everyday objects (such as an apple or a book) were presented to D.F., she was able to correctly name only 11% of these drawings. However, her preserved visuomotor function was indicated by her ability to reach out and grasp those objects with remarkable accuracy. For example, she could easily pick up different sized wooden blocks off a table. Furthermore, she was even able to catch a ball thrown at her by the experimenter. In essence, her deficits were perceptual, but she was able to use vision to guide her actions.

In this thesis, evidence was provided that the effects of repetition can be specific to the link between perception and action or nonspecific and related solely to the prior action. The two memorial influences described in this thesis may reflect the influences of memory involving the ventral and dorsal visual pathways, as described by Milner and Goodale (1996). The effects of repetition that are nonspecific may be due to processing

in the dorsal visual pathway. The effects of repetition that are perceptually specific may be due to processing in the ventral visual pathway or to cross-talk between both the dorsal and ventral pathways. Current innovations in brain imaging could be used to determine if this tentative hypothesis is plausible.

Implications for Aging

In the aging and negative priming literature, the process-pure assumption has resulted in much confusion about whether older adults have inhibitory deficits or deficits in episodic retrieval. However, a measured effect, or lack thereof, may not reflect presence or absence of one process. In this thesis, evidence was presented in support of the view that the relative contribution of nonspecific influences from memory may be larger in older than younger adults. Furthermore, the performance of younger adults tested at their nonoptimal time of day resembled the performance of older adults tested at their optimal time of day. As argued in the Introduction, it may be problematic to assume that a measured effect is a reflection of one process. Instead, both specific and nonspecific influences from memory may influence performance. What appears to change with age is the relative contributions of these two influences. The parallel between the repetition effects described in Chapter 3 and the negative priming effects in other aging papers (e.g. Kane, May, Hasher, Rahhal & Stoltzfus, 1997) suggest that the same underlying processes may contribute to the repetition effect in two-alternative forced-choice tasks and the negative priming effect. Future research should address

directly how specific and nonspecific influences contribute to the observed age differences in the negative priming effect.

In addition, in Experiments 1 and 2 of Chapter 3, there was a selectively greater influence of the nonspecific process in older adults. It is possible that decreased processing resources, associated with either increasing age or testing at a nonoptimal time of day, may result in an inability to rule out nonspecific influences from memory. When resources are readily available, the participant may be able to exclude nonspecific memorial influences on performance. However, when resources are diminished, the participant may be influenced more heavily by nonspecific influences of memory. This finding is consistent with other aging studies in the memory literature. For example, Craik and Simon (1980) investigated the difference between general and context-specific encoding of information. In this study, participants were instructed to recall target words from earlier presented sentences. A sentence could be, "The highlight of the circus was the clumsy BEAR". Cues could be either context-specific (e.g. 'clumsy') or general descriptions of the words (e.g. 'wild animal'). The results were that the younger adults recalled more words given the specific versus general cues. However, the opposite pattern was observed for the older participants. The older adults performed better when they were given general cues. Despite large methodological differences between these memory studies and the two-alternative forced-choice task used in this thesis, the broad statement that older adults rely more heavily on nonspecific or general influences of memory appears to apply well to both domains.

It would be interesting to explore further the hypothesis that older adults rely more heavily on nonspecific influences from memory due to decreased processing resources. One experimental manipulation often utilized in the memory literature to diminish available resources of participants is to divide their attention among two tasks (Troyer, Winocur, Craik & Moscovitch, 1999). Divided attention greatly reduces recognition memory performance in memory tests but has no effect on automatic influences on memory such as familiarity (Jacoby, Lindsay & Toth, 1992; Jacoby, Woloshyn & Kelley, 1989). In a study by Puglisi, Park, Smith and Dudley (1988), the authors compared performance in a divided attention condition and a full attention condition. They observed that there was greater evidence for general encoding of information in the divided attention condition. In contrast, encoding specificity of information was observed in the full attention condition. Assuming that common processes contribute to perceptual, categorical and memory tasks (Jacoby & Brooks, 1984), it can be hypothesized that divided attention would influence repetition effects in a manner similar to testing at nonoptimal time of day or testing older participants. Decreased resources, due to a divided attention manipulation, should result in increased nonspecific influences on the repetition effect.

In conclusion, specific and nonspecific influences jointly determine repetition effects. Individual differences, such as between younger and older participants, may reflect changes in the relative contributions of these two influences. The repetition effect paradigm and the analytic techniques presented in this thesis provide a promising

approach to address questions about the processes that underlie repetition effects and for studying individual differences in these processes.

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