EFFECTS OF CONGRUENCY ON EPISODIC LEARNING

SELECTIVE ATTENTION AND RECOGNITION: EFFECTS OF CONGRUENCY ON EPISODIC LEARNING

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Abstract

Recent research on cognitive control has focused on the learning consequences of high selective attention demands in selective attention tasks. The current study extends these ideas by examining the influence of selective attention demands on remembering. In Experiment 1, participants read aloud the red word in a pair of red and green interleaved words. Half of the items were congruent (the interleaved words were the same), and the other half were incongruent (the interleaved words were different). Following the study phase, participants completed a recognition memory test with a remember/know classification. A mirror effect was observed in the recognition memory data, with better memory for incongruent than for congruent items. In Experiment 2, context was only partially reinstated at test, and again better memory for incongruent compared to congruent items was observed. However, the processes supporting recognition decisions varied depending on context reinstatement, with only full context reinstatement resulting in differences in recollection for congruent and incongruent items. These results demonstrate that selective attention process demands associated with incongruent items affect episodic learning.

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Preface

The following thesis contains three chapters. Chapter 2 is the final draft of a manuscript being submitted for publication. Chapter 1 is an introduction to further expand on the ideas that motivated the research in this thesis. Chapter 3 outlines the broad implications of the results obtained, as well as possible lines of future research.

Chapter 2 is a manuscript titled "Selective attention and recognition: Effects of congruency on episodic learning". The order of authorship is: Rosner, T.M., D'Angelo, M.C., MacLellan, E., & Milliken, B. My role in this manuscript included experimental design, data collection, data analysis, and writing the manuscript.

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CHAPTER 1: Introduction

Selective attention tasks are traditionally used to study perception and changes in behaviour in the present (MacLeod, 1991). Recently, it has been proposed that selectively attending to relevant information when encountering conflicting stimuli can lead to small, incremental changes in learning (e.g. Botvinick, 2007; Verguts & Notebaert, 2008). However, it has yet to be examined if this processing results in episodic learning. The goal of the current study was to determine if events that demand selective attention are better remembered than events that do not, and if so, which memory processes are contributing to differences in remembering.

The need for cognitive control can be observed in selective attention tasks, such as the Stroop (Stroop, 1935) and flanker tasks (Eriksen & Eriksen, 1974). In both of these tasks, participants are instructed to respond to target information, which is presented along with irrelevant distractor information. For example, in the Stroop task, participants are told to respond to the colour in which a word is written. It is found that participants tend to respond slower to incongruent trials (such as RED written in blue) when compared to congruent trials (such as RED written in red). The difference in response time between congruent and incongruent trials is called the Stroop effect, and is thought to be a measure of how long it takes to increase cognitive control for the more difficult trial types (MacLeod, 1991). Botvinick, Braver, Barch, Carter, and Cohen (2001) have proposed the conflict monitoring theory of cognitive control, suggesting that the anterior cingulate cortex (ACC) plays a role in changing levels of cognitive control. According to this theory, conflict (such as between word and ink colour) is detected by the ACC, which in turn activates the dorsolateral prefrontal cortex (DLPFC), an area involved in cognitive control. Indeed, activation of these areas has been observed during the Stroop task, lending support to the conflict monitoring theory (Kerns et al., 2004).

The implementation of cognitive control can be influenced by context. For example, it has been observed that following incongruent trials in a selective attention task, performance is less affected by irrelevant distractor information (Gratton, Coles, & Donchin, 1992). This effect is sometimes referred to as a sequential congruency effect, and demonstrates that the extent to which cognitive control is engaged on one trial can have observable effects on behaviour on the following trial.

Another influence of context on cognitive control can be observed with the proportion congruency effect. The classic Stroop task contains an equal number of congruent and incongruent trials (Stroop, 1935), but it has been found that changing the proportions of each trial type can influence the size of the Stroop effect, with a higher proportion of congruent trials resulting in a larger Stroop effect (e.g., Lindsay & Jacoby, 1994; Logan & Zbrodoff, 1979; West & Baylis, 1998). It has been suggested that this effect occurs as a high proportion of incongruent trials leads to a higher state of control, so less time is needed to increase cognitive control when an incongruent trial is encountered (Botvinick et al., 2001). The proportion congruency effect demonstrates that global context can impact how cognitive control is implemented across a series of trials.

The ACC has also been implicated in the detection of aversive stimuli and reinforcement learning (Holroyd & Coles, 2002). Botvinick (2007) has integrated these two theories of the role of the ACC, suggesting that conflict is detected as an aversive stimulus in order to adjust responding in a way that reduces the cognitive control needed to complete a task. According to this theory, conflict can lead to both trial-to-trial changes, as well as longer-lasting changes in behaviour as a result of learning. A similar theory has been proposed by Verguts and Notebaert (2008), in which conflict is a mediator in a Hebbian learning system. In this model, the detection of conflict leads to the strengthening of connections between stimulus and response, resulting in improved performance on a task. Their computational model demonstrates that a conflict-moderated Hebbian learning system successfully accounts for sequential congruency and proportion congruency effects, suggesting that learning may be occurring throughout the duration of selective attention tasks.

Additionally, the theory proposed by Verguts and Notebaert (2008) can explain other behavioural consequences of selective attention that both the original and modified conflict monitoring models have difficulty handling. For example, the item-specific proportion congruency (ISPC) effect is observed when individual items have varying levels of proportion congruency (Jacoby, Lindsay, & Hessels, 2003). For example, if the word RED is presented in a congruent context 25% of the time and the word BLUE in a congruent context 75% of the time, the Stroop effect will be larger for the word BLUE when compared to RED. This effect cannot be explained by the conflict monitoring theory or its extension; according to these theories, control is implemented globally, rather than on an item-by-item basis, yet the ISPC effect suggests that control may be recruited differently for different items. However, the model of cognitive control proposed by Verguts and Notebaert does account for specific learning, and can easily explain the ISPC effect.

Learning in response to conflict has to date been discussed as if the learning that occurs is slow and gradual. However, the goal of the present study was to examine if conflict can trigger learning that is more episodic in nature. According to the instance theory of automatization (Logan, 1988), the accumulation of episodes of a specific experience is what allows for learning and automaticity when performing a task. Instance theory assumes that paying attention to a stimulus allows it to be encoded, though how well it is encoded is dependent on how well the information is attended. Logan (1988) also suggests that attending to a stimulus leads to the retrieval of similar instances. Assuming multiple instances of a stimulus have been encoded, retrieval of those instances can facilitate a more automatic or efficient response when that stimulus is once again encountered. The proposition that the retrieval of previous instances can facilitate responding has been supported by studies examining episodic integration (e.g. Hommel, 1998; Kahnneman, Treisman, & Gibbs, 1992), with faster responses observed when integration is possible. It is possible that the presence of conflict and the increased need for selective attention leads to better encoding of a stimulus compared to when selective attention demands are lessened. If this were the case, it would be expected that incongruent trials in a Stroop task would be encoded better when compared to congruent trials, and this enhanced encoding would allow for more efficient responding to those trial types.

Episodic learning in response to the need for cognitive control can account for many of the effects observed in selective attention tasks. Previous work demonstrates that episodic integration can explain sequential congruency effects (see Egner, 2007 for review). Episodic learning can also account for the proportion congruency effect; if incongruent trials are encountered often (such as in a low proportion congruent condition), many of these instances will be encoded, leading to overall faster responding to incongruent trials and a reduction in the observed Stroop effect. However, in a high proportion congruent condition, instances of incongruent items will be scarce, resulting in less facilitation when incongruent items are encountered and a larger Stroop effect. The ISPC effect can also be explained by episodic learning, as specific items being presented in a low proportion congruent condition means that there are more incongruent instances of those items compared to items in a high proportion congruent condition, leading to greater response facilitation.

The goal of this study was to demonstrate that episodic learning occurs in the presence of conflict by having participants complete a recognition memory task following a selective attention task. Unlike traditional selective attention tasks, the one employed used a stimulus set that allowed for every item presented to be unique. Finding that incongruent items are better remembered than congruent items would support an episodic learning hypothesis, as each item would only be presented once in the study phase. Finding no difference in memory between incongruent and congruent items would suggest that there is no effect of conflict on episodic learning, and that any learning that does occur in the presence of conflict is gradual in nature, requiring multiple exposures to a stimulus.

CHAPTER 2: Selective attention and recognition: Effects of congruency on episodic learning

Selective attention tasks (Eriksen & Eriksen, 1974; Simon, 1969; Stroop 1935) have gained increasing use as tools to study cognitive control. Gratton, Coles and Donchin (1992) were the first to report that congruency effects in selective attention tasks vary as a function of the congruency of the immediately preceding trial. The proposal that these effects reflect a form of trial-to-trial adaptation in cognitive control (Botvinick, Braver, Barch, Carter, & Cohen, 2001) has stimulated a great deal of research over the past decade or so, with a particular focus lately on the role of learning in contexts used to measure cognitive control (e.g. Botvinick, 2007; Verguts & Notebaert, 2008). Cognitive control is also known to play a role in remembering (e.g., Jacoby, 1991), yet the relation between cognitive control in both selective attention and remembering has received little direct study. The following section describes some recent research that motivated us to look at this issue directly.

Sequential Congruency Effects: Specificity in Trial-to-Trial Adaptations

In the flanker task (Eriksen & Eriksen, 1974), responses are slower when targets are flanked by incompatible (e.g. HHSHH) than by compatible distractors (e.g. SSSSS). Gratton et al. (1992) noted that such flanker effects vary as a function of the immediately preceding trial type. Specifically, flanker interference tends to be smaller following incompatible trials than following compatible trials. This trial-to-trial modulation of the compatibility (or congruency) effect, referred to here as a sequential congruency effect

(SCE), has now been observed in a host of other tasks, including the Stroop (Kerns et al., 2004) and Simon tasks (Stürmer, Luethold, Soetens, Schröter, & Sommer, 2002).

One interpretation of SCEs is that they reflect trial-to-trial adaptations in cognitive control processes (Botvinick et al., 2001; but see Hommel, Proctor, & Vu, 2004; Mayr, Awh, & Laurey, 2003 for alternatives), with the anterior cingulate cortex (ACC) playing a key role in detecting the need for such adaptations. Indeed, it is well-established that the ACC is more active on incompatible than on compatible trials (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Kerns, 2006; Kerns et al., 2004). Botvinick et al. (2001) have suggested that the ACC detects conflict on incompatible trials, signaling the dorsolateral prefrontal cortex (DLPFC) to increase control. Increased DLPFC activity is then presumed to focus attention on task-relevant stimulus attributes, which facilitates correct responses on the current trial. Assuming that this adaptation to conflict persists across time, it can also explain why congruency effects tend to be smaller following incongruent than congruent trials.

In the original variant of the conflict monitoring model (Botvinick et al., 2001), there was no obvious role for learning. However, studies indicating that the ACC plays an important role in reinforcement learning (Holroyd & Coles, 2002) led Botvinick (2007) to modify the conflict monitoring theory. In line with a long-held learning principle known as the *law of least work* (Hull, 1943), Botvinick proposed that conflict may be aversive and lead to avoidance learning because it uses up limited cognitive resources. The function of avoidance learning would be to ensure that conflict experienced at one point in time is not re-experienced at a later point in time. In this way, conflict in the present can lead to changes that reduce resource use in the future, and SCEs may be one example of this broad principle.

The modification of the conflict monitoring theory offered by Botvinick (2007) describes learning at a relatively broad level: that of tuning processing pathways in accord with task strategies. Yet, quite a few studies have demonstrated specificity in SCEs: task specificity, with SCEs observed for task-repetitions but not task-switches from one trial to the next (Kiesel, Kunde, & Hoffmann, 2006); context specificity, with SCEs occurring when superficial contextual cues repeat but not when such cues switch from one trial to the next (Spapé & Hommel, 2008); and conflict-type specificity, with SCEs observed when conflict type (e.g., Stroop or Simon) repeats but not when conflict type switches from one trial to the next (Egner, 2008; Funes, Lupiáñez, & Humphreys, 2010; Notebaert & Verguts, 2008). These findings demonstrate the specificity of cognitive control, highlighting a need to integrate a more specific form of learning into cognitive control models.

In response, Verguts and Notebaert (2008) introduced a computational model of cognitive control with a learning mechanism capable of handling findings of specificity in SCEs, as well as in proportion congruency effects (e.g., Jacoby, Lindsay, & Hessels 2003; see also Blais, Robidoux, & Besner, 2007; Crump, Gong, & Milliken, 2006). This model uses a conflict-moderated Hebbian learning mechanism to strengthen the binding between active representations in a task. This learning mechanism is thereby sensitive to items or contexts that are associated with conflict, which in turn allows it to predict item- and context-specific cognitive control effects.

The Present Study

Although there has been a shift in interest toward specific learning processes in studies of cognitive control, to our knowledge there has been no research on the possible relation between these specific learning mechanisms and actual remembering. Rather, the learning processes that have been integrated into accounts of cognitive control describe incremental changes in learning, which across many trials result in some measurable change in behaviour. In contrast, learning that occurs in response to conflict could be instance-based (Logan, 1988), and therefore could conceivably impact explicit remembering. The test of this issue is whether, after a single exposure, incongruent items are better remembered than congruent items.

In the following two experiments, we asked whether recognition memory performance would be affected by the congruency of distractor words presented together with target words at the time of encoding. If incongruent encoding contexts cue learning processes that enhance episodic learning, then it seemed possible that recognition memory would be superior for incongruent than congruent items.

Experiment 1

The method used in this experiment required participants to read aloud one of two interleaved words in a study phase, and then tested recognition of those words in a test phase. Half of the study items were incongruent (the two interleaved words were different) while the other half of the items were congruent (the two interleaved words were the same). Critically, any particular word appeared only once in the study phase as either a target or distractor. Following the study phase, participants were asked to complete a recognition memory test. To determine the relative contributions of recollection and familiarity to recognition performance, participants were asked to perform a remember/know judgment for items judged as old in the recognition phase (Tulving, 1985; Yonelinas, 2002).

Method

Participants. Twenty participants (16 females; mean age = 19 years) from the McMaster University student pool completed the experiment in exchange for course credit. All participants had normal or corrected-to-normal vision and spoke English fluently.

Apparatus and stimuli. The experimental program was run on a Dell computer using Presentation® experimental software (v.16.3, www.neurobs.com). The stimuli were displayed on a 24-inch BENQ LED monitor, and responses were made via a keyboard and microphone. Participants were tested individually, and sat approximately 50 cm from the monitor.

On each trial in both the study and test phases, two interleaved words were presented in the middle of the display, as shown in Figure 1 (Milliken & Joordens, 1996). One of the two words was red and the other was green, displayed against a black background. Each word subtended 0.8º of visual angle vertically and 5.9º horizontally. The two words together measured 1.0º vertically and 6.5º horizontally. A total of 360 five-letter words were used in the experiment, all of which were high frequency nouns or adjectives (Kucera & Francis, 1967).

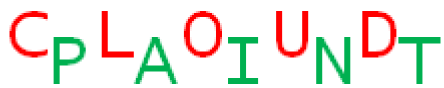

Figure 1. Example of experimental stimuli.

Procedure. The experiment consisted of two phases, a study phase and a recognition memory test phase. In the study phase, participants saw a red word interleaved with a green word on every trial, and were to read the red word aloud as quickly and accurately as possible. The study phase involved incidental encoding, as participants were not informed that they would later be asked to recognize the target words. Each trial in the study phase began with a central fixation cross presented for 1000 ms, followed by a word pair presented for 2000 ms. Response times (RTs) were recorded from the onset of the word pair to the onset of the vocal response, as detected by a microphone placed in front of the participant. Following offset of the word pair, a blank screen was presented until the experimenter coded the participants' response, after which the next trial began.

Naming responses in the study phase were coded as incorrect (by pressing "2" on the keyboard) if a participant named aloud, in whole or in part, a word other than the target. Naming responses were coded as a spoil (by pressing "3" on the keyboard) if a spurious noise was suspected to have set off the microphone before a response was made (e.g., coughing or stuttering before responding). Otherwise, naming responses were coded as correct (by pressing "1" on the keyboard).

Following the study phase, participants completed math problems for ten minutes prior to beginning the test phase. Detailed instructions for the test phase were then provided, both verbally and written on screen. The test phase used a recognition memory task with remember/know classifications for items judged as “old”. The remember/know instructions included detailed definitions of the difference between “remembering” and “knowing” (Rajaram, 1993). Rather than using the terms “remember” and “know”, participants were given the labels “Type A” (remember) and “Type B” (know), as prior work suggests that these labels minimize the frequency of remember false alarms and increase overall accuracy (see McCabe & Geraci, 2009).

Each trial in the test phase began with a central fixation cross presented for 1000 ms. The fixation cross was followed by a word pair, and the words “OLD” and “NEW” on the bottom left and right of the screen, respectively. These stimuli remained on screen until participants responded by pressing the left shift button for old, and the right shift button for new. Participants were told to ignore the green distractor when making this decision; the task was to make a recognition decision for the red target word. When an “old” response was made, the word pair stayed on screen, and the words “OLD” and “NEW” were replaced by “TYPE A” and “TYPE B”. Participants pressed the left shift button if their old response was based on a Type A memory (a feeling of remembering) or the right shift button if their old response was based on a Type B memory (a feeling of knowing).

Design. Two hundred and forty unique two-word items were used in the experiment; 120 items were presented in both the study and the test phases, and 120 items were foils presented only in the test phase. Within these two sets of 120 items, half were congruent and half were incongruent. For congruent items, the red and green interleaved words had the same identity. For incongruent items, the red and green interleaved words had different identities. Note that in the test phase, the old items were presented exactly as they appeared in the study phase; that is, old items were the same two words presented in the same colours and in the same spatial positions at study and at test.

The 240 items were constructed using a set of 360 five-letter high frequency words. The 360 words were randomly divided into six lists of 60 words (see Appendix). Four of these lists were used to generate incongruent items (one list for targets and another for distractors, for each of the old and new items). The words that served as target and distractor for a particular item were selected randomly from the lists for each participant. The other two lists were used to generate old and new congruent items. The assignment of lists to each of the six possible roles was counterbalanced across participants.

A total of 60 congruent and 60 incongruent items were intermixed randomly in the study phase. In the test phase, these 120 old items were randomly intermixed with 60 congruent and 60 incongruent new items, for a total of 240 recognition test trials. Whether the red target appeared on top of or below the green distractor was determined randomly for study phase items and for new test phase items.

Results

Study phase. RTs for correctly named targets and error rates from the study phase were both analyzed. Correct RTs were submitted to an outlier procedure (Van Selst & Jolicoeur, 1994), eliminating 2.4% of the RTs from additional analysis, and mean RTs were computed from the remaining observations. Means of these mean RTs and error rates are presented in Table 1. One-tailed paired sample t-tests revealed that responses were significantly slower for incongruent items (728 ms) than for congruent items (622 ms), $t(19) = 9.12$, $p < .001$, $d = 2.88$, and participants made significantly more errors for incongruent items (.031) than for congruent items (.004), $t(19) = 4.46$, $p < .001$, $d = 1.41$.

Table 1.
Mean Response Times (ms) and Error Rates for Word Reading in the Study Phase

Experiment	Congruent	Incongruent
1	622 (.004)	728 (.031)
2	582 (.004)	686 (.047)

Note. Table displays response times with error rates in parentheses.

Test phase. The proportions of items judged "old" served as the dependent variable in a 2 x 2 within-subjects ANOVA that treated congruency (congruent/incongruent) and item type (old/new) as factors. Mean proportions of "old" judgments, collapsed across participants, are presented in Figure 2. Items that were responded to incorrectly during the study phase were not included in the test phase analyses.

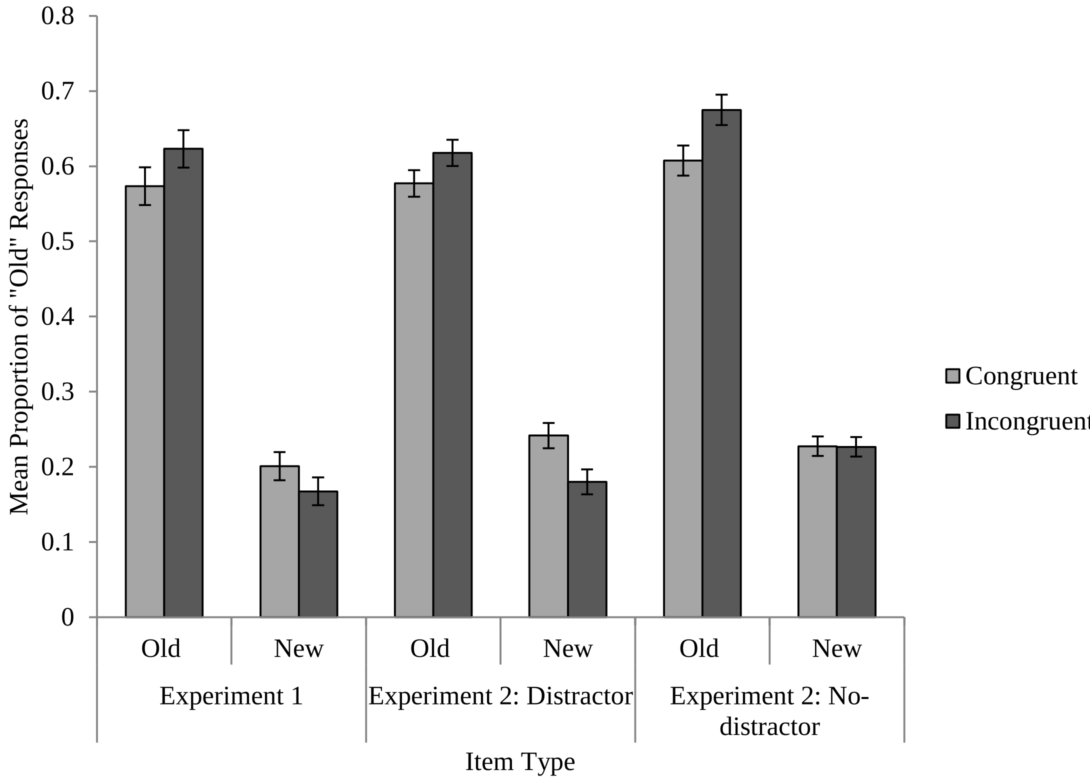

Figure 2. Mean proportion of “old” responses to old and new items as a function of congruency for Experiments 1 and 2. Error bars reflect the standard error of the mean corrected for between-subject variability (Morey, 2008).

The analysis revealed a significant main effect of item type, $F(1,19) = 194.18$, $p < .001$, $\eta_p^2 = .91$, with more “old” responses to old items (.598) than to new items (.184). More important, the interaction between congruency and item type was significant, $F(1,19) = 20.00$, $p < .001$, $\eta_p^2 = .51$, with the difference between hits and false alarms being larger for incongruent than for congruent items. To examine this interaction more closely, the simple main effect of congruency was examined separately for old and new items. For old items, the effect of congruency approached significance, $t(19) = 1.96$, $p =$

.065, *d* = 0.63, with a higher hit rate for incongruent items (.623) than for congruent items (.574). For new items, the effect of congruency also approached significance, $t(19) = 1.79$, $p = .090$, $d = 0.56$, with a lower false alarm rate for incongruent items (.167) than for congruent items (.201).

Separate contributions of recollection and familiarity to recognition were evaluated using the independence remember-know (IRK) procedure (Yonelinas, 2002). The IRK procedure estimates the contribution of recollection by the proportion of trials on which participants make "remember" (R) responses, and estimates the contribution of familiarity by the proportion of trials in which participants make "know" (K) responses on trials in which a remember response is not made (1-R). These estimates of recollection and familiarity were computed separately for hits and false alarms, and statistical analyses were conducted on the hit minus false alarm difference scores, which are displayed in Table 2. Two-tailed paired sample t-tests revealed that recollection was higher for incongruent (.309) than congruent items (.232), $t(19) = 2.95$, $p = .008$, $d = 0.93$, whereas familiarity did not differ significantly for incongruent (.296) and congruent (.252) items, $t(19) = 1.70$, $p = .106$, $d = 0.54$.

Table 2.
The Mean Proportion of "Old" Responses Influenced by Recollection and Familiarity.

	Recollection		Familiarity	
Experiment	Congruent	Incongruent	Congruent	Incongruent
1	.232	.309	.252	.296
2 (Distractor)	.213	.265	.238	.308
2 (No-distractor)	.265	.290	.240	.329

Discussion

The goal of Experiment 1 was to examine whether selective attention at study would affect recognition performance at test. The results from the study phase revealed that incongruent items were named about 100 ms slower than congruent items, suggesting that our selective attention manipulation was effective. Most important, recognition performance was better for incongruent than for congruent items. Indeed, the results were in line with the mirror effect; hit rates tended to be higher and false alarm rates lower for incongruent items than for congruent items (Glanzer & Adams, 1985). Moreover, the results of the IRK analysis revealed that the contribution of recollection to performance was higher for incongruent than for congruent items. In all, the results of this experiment are consistent with the idea that encountering incongruent items at study results in episodic learning that supports recognition of those items at test.

Experiment 2

The goal of Experiment 2 was two-fold. First, we aimed to replicate Experiment 1, and second, we asked whether the result observed in Experiment 1 hinges on reinstatement of the study context (i.e., the distractor) at the time of the recognition test (Tulving & Thomson, 1973). To address these issues, two groups experienced the same study phase as participants in Experiment 1. At test, the two groups differed in that one group was presented with both target and distractor words (as in Experiment 1), whereas the other group was shown only target words.

Method

Participants. Forty participants (29 females; mean age = 19) from the McMaster University student pool completed the experiment in exchange for course credit. All participants had normal or corrected-to-normal vision and spoke English fluently. Participants were randomly assigned to the distractor or to the no-distractor at test condition, with 20 participants in each group.

Apparatus, stimuli, procedure, and design. The apparatus, stimuli, procedure, and design used for Experiment 2 were identical to Experiment 1 with the following exception. At test, the no-distractor group was presented with a red target word only, rather than a red target and green distractor word pair.

Results

Study phase. Correct RTs were submitted to the same outlier analysis as in Experiment 1, which eliminated 2.6% of the observations from further analysis. Mean RTs were computed from the remaining observations, and these mean RTs and error rates were analyzed with a 2 x 2 mixed-factor ANOVA that treated group (distractor/no-distractor) as a between-subjects factor, and congruency (congruent/incongruent) as a within-subjects factor. Means of mean RTs and error rates, collapsed across participants, are displayed in Table 1.

The analyses of the RTs and error rates both revealed a main effect of congruency, with slower responses for incongruent (686 ms) than for congruent items (582 ms), $F(1,38) = 149.74$, $p < .001$, $\eta_p^2 = .80$, and more errors for incongruent (.047) than congruent items (.004), $F(1,38) = 47.73$, $p < .001$, $\eta_p^2 = .56$. As expected, neither the main effect of group nor the interaction between group and congruency were significant in either analysis, all *F's* < 1.

Test phase. Note that for the distractor condition, congruency was a meaningful variable for both old and new items, whereas for the no-distractor condition, congruency was a meaningful variable only for old items. For this reason, proportions of items judged "old" were submitted to separate 2 x 2 (item type x congruency) within-subjects ANOVAs for the distractor and no-distractor groups. Congruency was dummy coded for the new items in the no-distractor condition.

Distractor group. The main effect of item type was significant, $F(1,19) = 157.06$, $p < .001$, $\eta_p^2 = .90$. Participants responded "old" to old items (.597) more often than to new items (.211). More important, the analysis revealed a significant interaction between congruency and item type, $F(1,19) = 28.56$, $p < .001$, $\eta_p^2 = .60$, with the difference between hits and false alarms being larger for incongruent than for congruent items (see Figure 2). To examine this interaction further, the simple main effect of congruency was analyzed separately for new and old items. The analysis of old items revealed a main effect of congruency, $t(19) = 2.31$, $p = .032$, $d = 0.73$, with a higher hit rate for incongruent (.618) than congruent (.577) items. The analysis of new items also revealed a significant effect of congruency, $t(19) = 3.69$, $p = .001$, $d = 1.17$, with a lower false alarm rate for incongruent (.180) than congruent (.242) items.

The contributions of recollection and familiarity to recognition were computed in the same manner as in Experiment 1 (see Table 2). There was a significant effect of congruency on recollection, $t(19) = 2.74$, $p = .013$, $d = 0.87$, with recollection being higher for incongruent items (.265) than for congruent items (.213). There was also a significant effect of congruency on familiarity, $t(19) = 2.90$, $p = .009$, $d = 0.92$, with familiarity also being higher for incongruent items (.308) than for congruent items (.238).

No-distractor group. The main effect of item type was significant, $F(1,19) = 188.79$, $p < .001$, $\eta_p^2 = .91$. Participants responded "old" to old items (.641) more often than to new items (.227). A significant interaction between congruency and item type was again observed, $F(1,19) = 7.80$, $p = .011$, $\eta_p^2 = .29$, with the difference between hits and false alarms being larger for incongruent than for congruent items. As congruency was dummy coded for the new items, this interaction was carried by the significant simple main effect of congruency for old items, $t(19) = 3.36$, $p = .003$, $d = 1.06$ (see Figure 2). The hit rate was higher for incongruent items (.675) than for congruent items (.608).

In the analyses of recollection and familiarity (see Table 2), in contrast to the results of Experiment 1 and the distractor condition of the present experiment, recollection did not differ between congruent (.265) and incongruent items (.290), $t(19) = 1.17$, $p = .255$, $d = 0.37$. However, congruency did affect estimates of familiarity, $t(19) = 2.62$, $p = .017$, $d = 0.83$, with familiarity being higher for incongruent items (.329) than for congruent items (.240).

Discussion

As in Experiment 1, RTs and error rates from the study phase indicated that our selective attention manipulation was effective. Responses were slower and error rates were higher for incongruent than for congruent items. Importantly, this effect of selective attention at study was accompanied by better performance for incongruent items in the recognition test for both the distractor and no-distractor groups. For the distractor group, the recognition advantage for incongruent items was again expressed in a mirror effect, with both higher hit rates and lower false alarm rates for incongruent than congruent items. These results are again consistent with the view that encountering incongruent items at study involves learning processes that support recognition of those same items at test.

One difference between the results for the distractor and no-distractor conditions is worth noting. The recognition advantage for incongruent items appeared to be carried by differences in both recollection and familiarity for the distractor condition, but only by differences in familiarity for the no-distractor condition. The finding that recollection differences between the two congruency conditions depend on reinstatement of the distractor at test is generally consistent with the view that context reinstatement contributes to recollection (Gruppuso, Lindsay, & Masson, 2007; Macken, 2002).

General Discussion

Recent studies that have implicated specific learning processes related to cognitive control led us to ask whether congruency at encoding would affect explicit remembering. Using a large set of unique stimuli, we found that target items named in the context of an incongruent distractor during study were recognized more accurately at test. This effect appears to be supported by both better recollection and familiarity for incongruent items, although recollection was significantly better for incongruent items only when the distractor was reinstated at the time of the recognition test. Additionally, a mirror effect was consistently found in the data, which may have implications for how this ubiquitous pattern found in the recognition memory literature arises. To our knowledge, this is the first study to identify a link between learning processes involved in selective attention contexts and explicit remembering.

Although we are suggesting a potential link between the specificity of cognitive control (Verguts & Notebaert, 2008) and the influence of congruency on the remembering of specific experiences, we should be careful to note that these two empirical findings may or may not be related. It could argued that, although presentation time itself was equated, the additional time required to name incongruent relative to congruent items during the study phase of our experiments resulted in the additional encoding of episodic detail that supported recognition performance. This proposal is consistent with the general view that more difficult encoding conditions often produce better remembering (Lockhart, Craik, & Jacoby, 1976). Furthermore, “difficulty-enhanced” episodic encoding of incongruent items could be entirely separate from learning processes that tune the relative weightings of processing pathways in response to conflict (Botvinick, 2007). If this is the case, then the present results constitute a curious finding, but perhaps not one that links cognitive control adaptations to remembering.

At the same time, an instance-based theory of cognitive control might view the current recognition results as quite sensible. In particular, the same *law of least work* (Hull, 1943) principle that guided Botvinick’s (2007) modification of the conflict monitoring theory would predict that behaviour ought to be guided as much as possible by the automatic retrieval of prior processing episodes. However, when automaticity fails to offer an adequate solution to the current problem, additional learning processes ought to be engaged, the goal of which may be to encode a distinct new instance that can be recruited "automatically" in the future. From this perspective, the function of cognitive control is ultimately to make cognitive control unnecessary. Whether the present data reflect this instance-based notion of cognitive control is an issue that merits further study.

In summary, this study provides preliminary evidence that selective attention has longer-lasting consequences on behaviour than previously believed. If this is the case, selective attention should not only be thought of as having a role in perception, but also triggering processes involved in memory encoding.

CHAPTER 3: General Discussion

The described study demonstrates that the learning consequences of selective attention may be more episodic in nature than previously believed. While it has recently been suggested that higher levels of conflict lead to learning (Botvinick, 2007; Verguts & Notebaert, 2008), the learning discussed implied small, gradual changes in connectivity between stimulus and response. The current study supports an episodic learning account by demonstrating that items with an increased selective attention demand are better remembered during a recognition memory task when compared to items with a smaller selective attention requirement. Importantly, this better memory for incongruent items is seen even though each item in the study was unique; in other words, just a single exposure was enough to result in enhanced memory performance for incongruent items.

These findings suggest that selectively attending to information may trigger processing involved in episodic encoding. Previous studies have demonstrated that episodic integration of events results in improved performance compared to when this integration is not possible (Hommel, 1998; Kahneman, Treisman, & Gibbs, 1992). It is possible that when items that are difficult to process are encountered, such as those that require selective attention, these items are encoded in order to facilitate more efficient performance the next time that item is seen. Encountering the item later on would retrieve the previous instances of that item, and may result in improved performance.

The current study provides, to our knowledge, the first piece of evidence for an episodic account of learning in response to selective attention, leaving a lot of avenues open for future research. Some possible future studies are reviewed below, with studies inspired by both the episodic memory and conflict monitoring literatures.

One important question that needs to be answered is if the effect found is specific to processing in selective attention, or if it is difficulty in perceptual processing in general that leads to better memory for incongruent compared to congruent items. To test this, an experiment could be conducted in which single words are presented that are either intact or degraded, followed by a recognition memory task. If it is processing difficulty in general that results in better memory, then memory performance should be better for the degraded items when compared to those that are intact. A more complex experiment could involve a 2 x 2 design at study, with congruency as one factor and degradation as another factor, in order to examine the effects of both selective attention and perceptual processing difficulty on performance on a recognition memory task.

The importance of context reinstatement at test on recognition test performance could also be further elucidated. In the present study, context at test was manipulated by removing the green distractor word at the time of test; however, the colour and position of the target word remained unchanged. In this case, memory for incongruent items was still better than congruent items, even if context was not fully reinstated. An episodic account would predict that completely changing the context from study to test would result in a null difference in memory performance between incongruent and congruent items. For example, presenting the target word at test in black text in the middle of a white screen may lead to no difference in memory between item types. Obtaining this result would further support an episodic account of learning in response to selective attention, as the effect would be vulnerable to changes in context.

Looking toward the conflict monitoring literature, it would be interesting to examine how proportion congruency manipulations during study affect the memorial consequences of selective attention at test. If it is increasing cognitive control that results in improved memory for incongruent items, it is possible that the memory effect would be smaller in a low proportion congruent condition and larger in a high proportion congruent condition. Manipulating proportion congruency may help uncover the mechanism that leads to better memory for incongruent when compared to congruent items.

While there are still many more questions to be answered, the present study demonstrates that cognitive control results in learning that is episodic in nature. These results may also have implications for the selective attention literature, as it seems that selectively attending to information may have a greater effect on later behaviour than previously thought.

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Appendix

Word Lists

Word list 1:
BOARD, BRIEF, BROWN, BRUSH, CATCH, CHAIR, CHARM, CLAIM, CLEAN, CLOSE, COUNT, CROWD, DREAM, EARTH, EIGHT, FIELD, FRAME, FRONT, GLASS, GRANT, GREEN, HURRY, IDEAL, LEVEL, LIGHT, LUNCH, MAJOR, ORDER, OTHER, PAUSE, PEACE, PRINT, QUIET, RANGE, RIGHT, SERVE, SHAPE, SHARE, SHEET, SHOUT, SLEEP, SMALL, SPEED, SPORT, STAND, START, STONE, STORE, STUDY, STUFF, SUGAR, TABLE, THICK, THREE, TRADE, TREAT, TRUTH, WAGON, WORLD, YOUTH

Word list 2:
ASIDE, BLOCK, BOUND, CAUSE, CHIEF, COURT, COVER, DANCE, DOUBT, DRESS, DRIVE, DROVE, EVENT, FLASH, FLOOD, FLOOR, FLOUR, FRUIT, GUARD, GUEST, HOTEL, ISSUE, JUICE, LEAST, LEAVE, LOCAL, MIGHT, MOTOR, MUSIC, NIGHT, NORTH, OFFER, PIECE, PLANK, POUND, QUEEN, RADIO, REACH, RIVER, SALAD, SCENE, SENSE, SHORT, SPACE, STAGE, STARE, STICK, STORY, SWEET, TASTE, TEETH, THING, THIRD, TRAIL, TRICK, VALUE, VISIT, WASTE, WATER, WHITE

Word list 3:
BLIND, BRAIN, BREAD, BURST, CABIN, CHECK, CHEEK, CHILD, CLASS, CLIMB, CLOUD, DAILY, DOZEN, DRINK, EMPTY, EXTRA, GROUP, GUESS, HORSE, HOUSE, KNOCK, MARCH, MATCH, MONTH, MOUTH, PAINT, PAPER, PLAIN, PLANE, PLANT, POINT, PORCH, PRESS, QUICK, ROUND, SEVEN, SHARP, SHINE, SIGHT, SLICE, SMART, SOUND, SOUTH, SPOKE, STAIR, STATE, STILL, STOCK, STORM, THANK, THROW, TIMER, TRAIN, TRUST, UNCLE, UNDER, VOICE, WATCH, WHILE, WOMAN

Word list 4:
ANKLE, BIRTH, BOAST, BRICK, BROOK, CHEER, CHILL, CLERK, CLOCK, CLOTH, COACH, COUCH, CRAWL, DRIFT, FEVER, FLAME, FLUSH, GLEAM, GRADE, GRATE, GROWL, INNER, KNIFE, LAYER, LEMON, MORAL, MOVIE, NOBLE, OCEAN, PEACH, PEARL, PILOT, PITCH, PRIZE, PRUNE, PUPIL, ROUGH, SAUCE, SCALE, SCORE, SCRUB, SHIFT, SHIRT, SHRUG, SIXTY, SKIRT, SLOPE, SMELL, SPOON, SPRIG, STAFF, STEAL, STEEP, STERN, STRAW, SWIFT, SWING, TRACE, TRIAL, WHEAT

Word list 5:
AGENT, BASIS, BENCH, BLAST, BLOND, BRAND, BUNCH, CHEST, CHOSE, CLASP, COAST, CRACK, CROWN, CRUMB, CURVE, DEPTH, DOUGH, ELBOW, ELDER, EQUAL, FANCY, FENCE, FROCK, GIANT, GLORY, GLOVE, GRAIN, GRASP, GUIDE, HONEY, LIMIT, MAGIC, NERVE, NOISE, NOVEL, OWNER, PASTE, PENNY, PIANO, PLATE, PROOF, RANCH, ROAST, ROUTE, SCENT, SHORE, SLIDE, SOLID, SPRAY, STAMP, STOVE, THUMB, TOAST, TRACK, TRUNK, TWIST, WAIST, WHIRL, WRECK, WRIST

Word list 6:
ACTOR, ALARM, APPLE, BLANK, BLOOM, CABLE, CANDY, CHAIN, CHASE, CIGAR, CLIFF, CORAL, CRAFT, CRASH, CREEK, CRIME, DELAY, DODGE, DRAIN, FAINT, FLOAT, GRACE, GRASS, GROAN, JELLY, JEWEL, LINEN, METAL, MIDST, MODEL, OLIVE, ONION, PHONE, PURSE, QUART, QUOTE, RIDGE, SCOUT, SHAKE, SHEER, SHELL, SHOOT, SKILL, SPELL, SPLIT, SPOIL, STEAM, STEEL, STOOP, STYLE, TIGER, TITLE, TOTAL, TOUGH, TOWER, TROOP, TRUCK, UPPER, WHEEL, YIELD