

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 (e.g., Botvinick, 2007; Verguts & Notebaert, 2008). 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 spatially interleaved words. Half of the items were congruent (the interleaved words had the same identity), and the other half were incongruent (the interleaved words had different identities). Following the naming phase, participants completed a surprise recognition memory test. In this test phase, recognition memory was better for incongruent than for congruent items. In Experiment 2, context was only partially reinstated at test, and again recognition memory was better for incongruent than for congruent items. In Experiment 3, all of the items contained two different words, but in one condition the words were presented close together and interleaved, while in the other condition the two words were spatially separated. Recognition memory was better for the interleaved than for the separated items. This result rules out an interpretation of the congruency effects on recognition in Experiments 1 and 2 that hinges on stronger relational encoding for items that have two different words. Together, the results support the view that selective attention demands for incongruent items lead to encoding that improves recognition.

Introduction

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 specific learning mechanisms in contexts used to measure cognitive control (e.g., Botvinick, 2007; Verguts & Notebaert, 2008). Despite this increased focus on how learning processes are sensitive to the type of conflict that occurs in selective attention contexts, the relation between conventional measures of selective attention and explicit remembering has received little direct study. The following section describes some recent research that motivated us to look at this issue directly.

Selective Attention and Episodic Specificity

In the flanker task (Eriksen & Eriksen, 1974), responses are slower when targets are flanked by incongruent (e.g., HSHHH) than by congruent distractors (e.g., SSSSS). Gratton et al. (1992) noted that such flanker congruency effects vary as a function of the immediately preceding trial type, with smaller congruency effects following incongruent trials than following congruent trials. This trial-to-trial modulation of the congruency effect, referred to here as a sequential congruency effect, has now been observed in a host of other tasks, including the Stroop (Kerns et al., 2004) and Simon tasks (Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002).

One interpretation of sequential congruency effects is that they reflect 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 during incongruent than during congruent 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 incongruent 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, then preparation for conflict ought to be high following incongruent trials, leading to smaller congruency effects following incongruent trials than following congruent trials. Moreover, as incongruent-

incongruent trial transitions are more frequent in blocks with a high proportion of incongruent trials, carryover of preparation from one incongruent trial to the next also offers an explanation of proportion congruent effects (smaller congruency effects in blocks with a relatively high proportion of incongruent trials) in Stroop and Stroop-like tasks (Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; Tzelgov, Henik, & Berger, 1992; for a review see Bugg & Crump, 2012).

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 to a modification of the conflict monitoring theory. Botvinick (2007) proposed that the use of limited capacity cognitive resources in response to conflict is aversive. As a result, the experience of conflict leads to avoidance learning, reducing the likelihood that a particular processing pathway is used in the future. For example, word-reading in a Stroop task may lead to conflict, which then reduces the dependence on the word-reading pathway in the future. The function of this avoidance learning is 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 the sequential congruency and proportion congruency effects are a manifestation 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. For example, for the word BLUE presented in red (Stroop, 1935), the task requirement to identify the colour and ignore the word may lead to broad tuning that favours processing of a colour identification pathway relative to a word reading pathway (MacLeod & Dunbar, 1988). By this view, adaptations that occur in response to conflict with that particular Stroop item ought to impact performance for any following item that involves these same broad colour identification and word reading pathways.

An alternative view that has received increasing support is that adaptations in cognitive control are shaped by learning processes that are more specific and targeted. By this alternative view, the requirement to respond to the word BLUE in red could result in learning that favours processing of the colour dimension relative to the word dimension for that particular item, but not for other items. This idea gained initial support from findings of item-specific proportion congruency effects in the Stroop task (Jacoby, Lindsay, & Hessels, 2003; see also Blais, Robidoux, Risko, & Besner, 2007; Bugg, Jacoby, & Toth, 2008; for a review see Bugg & Crump, 2012). Jacoby et

al. (2003) manipulated the relative proportions of congruent and incongruent items separately for different sets of Stroop items. Despite these item sets being randomly intermixed, congruency effects were larger for the high proportion congruent item set than for the low proportion congruent item set.

In this case, learning related to cognitive control is specific to the Stroop item, but in theory the specificity could be tied to the task one performs, or any of a wide range of contextual features associated with the item. Indeed, context-specific proportion congruent effects, in which proportion congruency is associated with task-irrelevant stimulus dimensions, have also been reported for the Stroop (Crump, Gong, & Milliken, 2006) and flanker tasks (Cañadas, Rodríguez-Bailón, Milliken, & Lupiáñez, 2013; Corballis & Gratton, 2003; Lehle & Hübner, 2008; Vietze & Wendt, 2009; Wendt & Kiesel, 2011; Wendt, Kluwe, & Vietze, 2008).

Evidence favouring the view that adaptations in cognitive control involve relatively specific learning processes has also accrued in studies of sequential congruency effects. For example, it has now been reported that sequential congruency effects can be task-specific, with sequential congruency effects observed for task-repetitions but not task-switches from one trial to the next (Kiesel, Kunde, & Hoffmann, 2006); context-specific, with sequential congruency effects occurring when superficial contextual cues repeat but not when such cues switch from one trial to the next (Spapé & Hommel, 2008); and conflict-type specific, with sequential congruency effects 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).

Together, these findings demonstrate that adaptations that occur in response to conflict might best be conceptualized as involving learning that is specific to task, conflict type, and context, rather than as an adjustment that generally heightens cognitive control, or that up-regulates one broad processing pathway relative to another. In line with this idea, Verguts and Notebaert (2008) introduced a computational model of cognitive control with a learning mechanism capable of handling findings of specificity in both sequential congruency and proportion congruency effects. 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 specific 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

Lately, there has been a shift in interest toward specific learning processes in studies of cognitive control. This shift in interest has been supported by findings reflecting item-specificity and context-specificity in proportion congruent effects, and by findings of task-specificity, context-specificity, and conflict-type specificity in trial-to-trial adaptation effects. It seems possible that cognitive control adaptations that impact performance in tasks that tap memory implicitly might also impact performance in tasks that require explicit remembering. Yet, prior to conducting the present study, we were aware of no prior research that addressed this issue directly (but see Krebs, Boehler, De Belder, & Egner, 2013). To examine this issue, we tested in three experiments 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 recognition memory may be superior for incongruent than congruent items.

Experiment 1

The method used in this experiment required participants to read aloud one of two spatially interleaved words in a naming phase, and then tested recognition of those words in a test phase. Half of the named items were incongruent (the two interleaved words were different) while the other half of the named items were congruent (the two interleaved words were the same). Critically, any particular word appeared in only one naming trial (either once in the case of incongruent items, or twice in the case of congruent items). Following the naming phase, participants were asked to complete a surprise recognition memory test. The recognition test required participants to decide if each item was old or new, and then for each old judgment to indicate whether it was driven by a feeling of remembering or knowing (Tulving, 1985; Yonelinas, 2002). It should be noted that all old items were presented in the exact same manner at test in which they were seen during the naming phase. If the presence of conflict during naming leads to better encoding of an item, then recognition ought to be more sensitive for incongruent than for congruent items. As the remember/know data were gathered for exploratory purposes and did not add any clarity to the results, they are reported only in Appendix A.

Method

Participants. Twenty-four participants (20 females; mean age = 20 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 naming 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, and both were displayed against a black background. Each word subtended 0.8° of visual angle vertically and 5.9° horizontally. The two words together measured 1.0° vertically and 6.5° horizontally. A total of 360 five-letter words were used in the experiment, all of which were high frequency nouns (Kučera & Francis, 1967).



Fig. 1. Depiction of stimuli in Experiments 1 and 2. The item on the left is an example of a congruent item, in which the two interleaved words were the same. The item on the right is an incongruent item, in which the two words were different. The location of the words were counterbalanced within each condition, so that the target red word was in the top position for half of the congruent and incongruent items, and in the bottom position for the other half of the items.

Procedure. The experiment consisted of two phases, a naming phase and a surprise recognition memory test phase. In the naming phase, participants saw a red word spatially interleaved with a green word on every trial, and were to read the red word aloud as quickly and accurately as possible. Each trial in the naming phase began with a central fixation cross presented for 2000 ms, followed by a word pair presented for 1000 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.

Responses in the naming phase were coded by the experimenter as correct, incorrect, or a spoil, by pressing "1", "2", or "3", respectively, on the computer keyboard. Responses were coded as incorrect if a participant named

aloud, in whole or in part, a word other than the target. Responses were coded as a spoil if a spurious noise was suspected to have set off the microphone before a response was made (e.g., coughing or stuttering before responding).

Following the naming 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 was a surprise 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 2000 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”, respectively. 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 naming 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 (those from the naming phase) were presented exactly as they appeared in the naming phase; that is, old items were the same two words presented in the same colours and in the same spatial positions during naming 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 B). 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 naming 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 counterbalanced for naming phase items and for new test phase items.

Results

Naming phase. RTs for correctly named targets and error rates from the naming phase were both analyzed. Correct RTs were submitted to an outlier procedure (Van Selst & Jolicoeur, 1994), eliminating 2.2% 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 (690 ms) than for congruent items (592 ms), $t(23) = 7.40$, $p < .001$, $d = 2.13$, and participants made significantly more errors for incongruent items (.044) than for congruent items (.009), $t(23) = 5.00$, $p < .001$, $d = 1.44$.

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

Experiment	Congruent	Incongruent
1	592 (.009)	690 (.044)
2	594 (.006)	702 (.049)
	Separated	Interleaved
3	633 (.017)	726 (.035)

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 naming phase were not included in the test phase analyses, both here and in all following experiments.

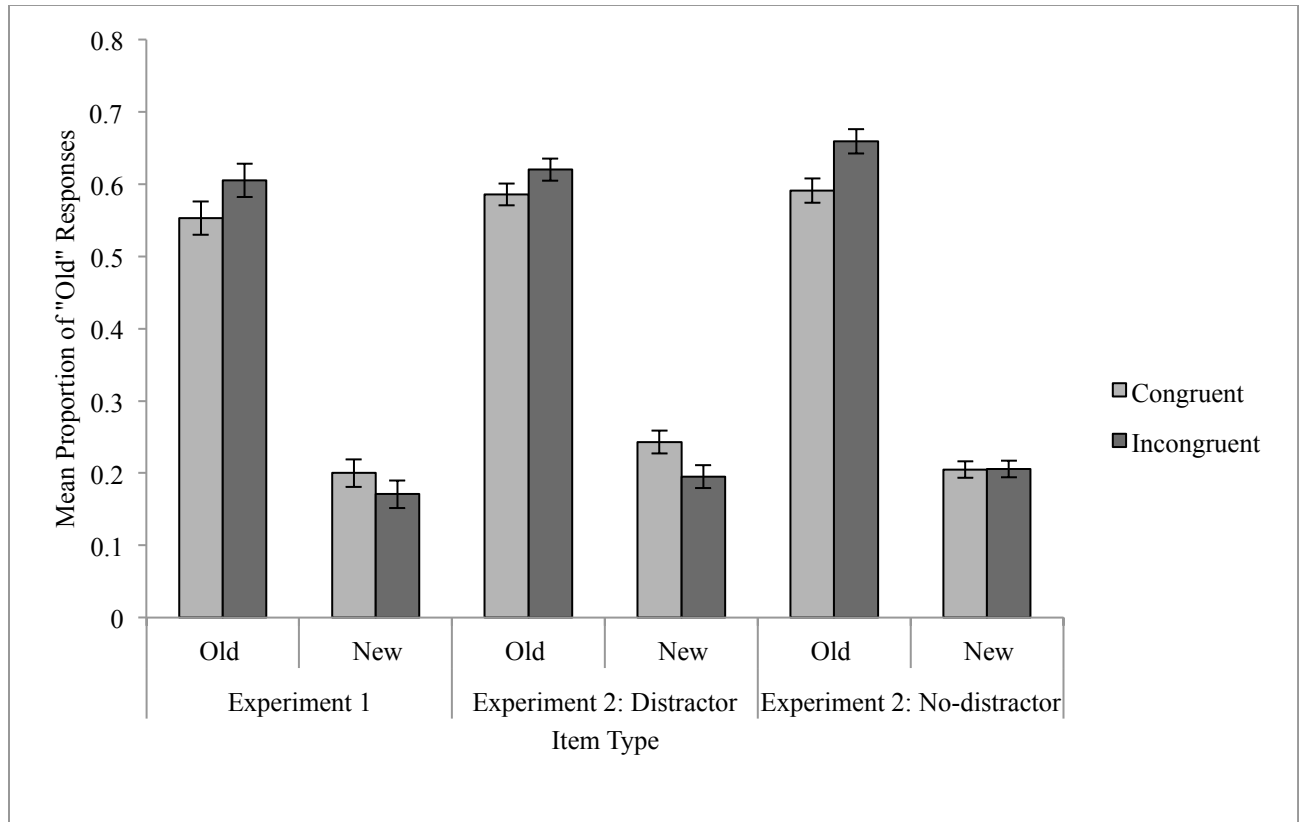


Fig. 2. Mean proportion of “old” responses to old and new items as a function of congruency for Experiments 1 and 2. Error bars reflect the standard error of the mean corrected for between-subject variability (Morey, 2008).

The analysis revealed a significant main effect of item type, $F(1,23) = 275.13, p < .001, \eta_p^2 = .92$, with more “old” responses to old items (.579) than to new items (.185). More important, the interaction between congruency and item type was significant, $F(1,23) = 9.43, p = .005, \eta_p^2 = .29$, with the difference between hits and false alarms being larger for incongruent than for congruent items. To examine this interaction more closely, two-tailed paired sample t-tests were used to examine the simple main effect of congruency for old and new items. For old items, the effect of congruency was significant, $t(23) = 2.26, p = .034, d = 0.65$, with a higher hit rate for incongruent items (.605) than for congruent items (.553). For new items, the effect of congruency was not significant, $t(23) = 1.51, p = .144, d = 0.44$, though numerically there was a greater false alarm rate for congruent (.200) than for incongruent items (.171).

Signal detection analyses were also computed using d-prime to measure sensitivity and beta to measure response bias (Stanislaw & Todorov, 1999). A two-tailed paired sample t-test revealed that d-prime, and therefore sensitivity, was greater for incongruent (1.41) than for congruent items (1.07), $t(23) = 3.78, p < .001, d = 1.09$. There

was also a significant effect of beta, with greater beta values for incongruent (3.21) than for congruent items (1.96), $t(23) = 2.28, p = .032, d = 0.66$. This effect reflects a stronger tendency to respond “new” for incongruent than for congruent items.

Discussion

The goal of Experiment 1 was to examine whether selective attention during the naming phase would affect recognition performance at test. The results from the naming 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, as indicated both by a larger difference between hit and false alarm rates for incongruent than congruent items, as well as by significantly larger values of d' for incongruent than for congruent items. Indeed, the results were in line with the mirror effect, a robust pattern of data observed in the recognition memory literature, in which the more memorable class of items in a recognition memory task produces both higher hit rates and lower false alarm rates (Glanzer & Adams, 1985). In the current experiment, the incongruent items were the more memorable class of items, and hit rates were significantly higher for incongruent than for congruent items. Although the other half of the mirror effect, that for false alarms, was not statistically significant, the pattern of means was consistent in direction with the mirror effect (i.e., a numerically lower false alarm rate for incongruent than for congruent items). In all, the results of this experiment are consistent with the idea that encountering incongruent items in the naming phase results in episodic learning that supports recognition of those items in the test phase.

Experiment 2

In Experiment 1, congruency of items during the naming phase matched that in the test phase. In other words, if an item was congruent in the naming phase, that same item was also congruent in the test phase. Thus, better recognition for incongruent than congruent items could conceivably be due to incongruency during the naming phase, incongruency during the test phase, or both. Experiment 2 was conducted to address this issue, as well as to replicate the results of Experiment 1. Two groups experienced the same naming 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. If recognition is better for incongruent than congruent items in both conditions, then this result would support the view that the effect owes to the influence of congruency of items during encoding. In contrast, if recognition is better for incongruent than congruent items

only in the test condition with distractors, then this result would support the view that the effect owes either to the effect of congruency at the time of retrieval, or to the joint influence of congruency at encoding and retrieval.

Method

Participants. Forty-eight participants (34 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 24 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

Naming phase. Correct RTs were submitted to the same outlier analysis as in Experiment 1, which eliminated 2.5% 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 conditions, 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 (702 ms) than for congruent items (594 ms), $F(1,46) = 188.70, p < .001, \eta_p^2 = .80$, and higher error rates for incongruent (.049) than congruent items (.006), $F(1,38) = 61.62, p < .001, \eta_p^2 = .57$. As the naming phase was identical for the two groups, it was unsurprising that neither the main effect of group nor the interaction between group and congruency were significant in either analysis, all p '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, $F(1,23) = 188.72, p < .001, \eta_p^2 = .90$, indicating participants responded “old” to old items (.603) more often than to new items (.219). More important, the

analysis revealed a significant interaction between congruency and item type, $F(1,23) = 19.53, p < .001, \eta_p^2 = .50$, 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 old and new items. The analysis of old items revealed a main effect of congruency, $t(23) = 2.27, p = .033, d = 0.65$, with a higher hit rate for incongruent (.620) than congruent (.586) items. The analysis of new items also revealed a significant effect of congruency, $t(23) = 3.03, p = .006, d = .87$, with a lower false alarm rate for incongruent (.195) than congruent items (.243).

Signal detection analyses revealed that d-prime was significantly greater for incongruent (1.31) than for congruent items (1.03), $t(23) = 4.63, p < .001, d = 1.33$. Beta values were also significantly greater for incongruent (2.00) than for congruent items (1.53), $t(23) = 2.26, p = .033, d = 0.65$, again reflecting a stronger tendency to respond “new” for incongruent than for congruent items.

No-distractor group. The main effect of item type was significant, $F(1,23) = 196.37, p < .001, \eta_p^2 = .89$. Participants responded “old” to old items (.626) more often than to new items (.205). A significant interaction between congruency and item type was again observed, $F(1,23) = 10.96, p = .003, \eta_p^2 = .32$, 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, $t(23) = 4.01, p < .001, d = 1.16$ (see Figure 2). The hit rate was higher for incongruent items (.660) than for congruent items (.591).

Signal detection analyses were again conducted, revealing a significant effect of congruency on d-prime, $t(23) = 2.10, p = .047, d = 0.61$, with greater d-prime values for incongruent (1.39) than for congruent items (1.21). There was also a marginal effect of beta, with greater beta values for congruent (2.47) than incongruent items (1.63), $t(23) = 1.79, p = .087, d = 0.52$, revealing a stronger tendency to respond “new” for congruent than for incongruent items.

Discussion

As in Experiment 1, response times and error rates from the naming 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 during naming 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 expressed in a mirror effect, with both higher hit rates and lower false alarm rates for incongruent than congruent items. This recognition advantage for incongruent items was also reflected by significantly greater d-prime values. For the no-distractor group, a similar pattern of data was seen, with a significant interaction between congruency and item type, and significantly greater d-prime values for incongruent than congruent items. The fact that recognition was better for incongruent than for congruent items in both the distractor and no-distractor conditions suggests that processing of incongruent items during the naming phase involves learning processes that support recognition of those same items at test.

Experiment 3

The purpose of Experiment 3 was to address a potential interpretation of the results in Experiments 1 and 2 that does not involve conflict. In particular, it might be argued that recognition was better for incongruent items not because of the conflict produced by an incongruent distractor, but because the incongruent distractor could be used as a cue to produce more distinctive encoding than was possible for a congruent distractor. For example, if the target word was “BOARD” and the distractor was “PAINT”, one might imagine participants using the distractor word to create a distinctive representation, such as the “painting of boards”. This type of distinctive encoding might be more difficult in the congruent condition, in which the participant would have to self-generate a distinctive cue that differed from the target.

To address this concern, participants completed a task similar to that in Experiment 1, in which they named the red word in a pair of red and green words. However, rather than congruent and incongruent items, participants were presented with two different types of “incongruent” items, called “interleaved” and “separated”. The interleaved items were identical to the incongruent items in Experiments 1 and 2, while words in the separated items were presented spatially separate from each other. As both the interleaved and separated items involved presentation of two different words, better memory for interleaved than for separated items would support the claim that conflict during naming enhances encoding.

Method

Participants. Forty-eight participants (35 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 apparatus and stimuli used for Experiment 3 were identical to Experiment 1 with the following exception. The two words in the separated items subtended 2.1° of visual angle vertically, with the vertical space between the two words subtending 0.6° of visual angle, as shown in Figure 3. The interleaved items were identical to the incongruent items in Experiments 1 and 2. A total of 480 five-letter words were used in the experiment, all of which were high frequency nouns (Kučera & Francis, 1967).

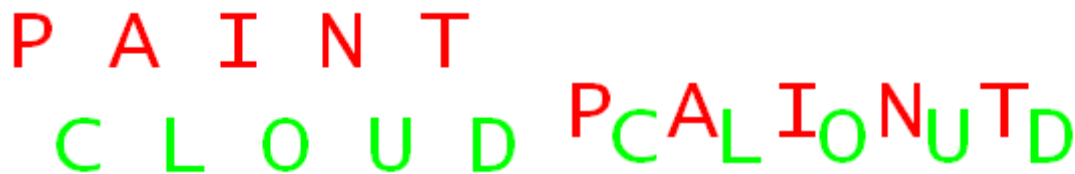


Fig. 3. Depiction of stimuli in Experiment 3. The item on the left is a separated item, in which the two words were spatially separate. The item on the right is an example of an interleaved item, in which the two different words were interleaved. The location of the words were counterbalanced within each condition, so that the target red word was in the top position for half of the separated and interleaved items, and in the bottom position for the other half of the items.

Procedure. The procedure was identical to Experiment 1, with the exception that the congruent condition from Experiment 1 was replaced by the separated condition, and the incongruent condition from Experiment 1 was renamed the interleaved condition. As such, the naming phase and test items contained two different words on every trial.

Design. The design of Experiment 3 was identical to that of Experiment 1 with the following exception. The 240 items were constructed using a set of 480 five-letter high frequency words. The 480 words were randomly divided into eight lists of 60 words (see Appendix C). Four of these lists were used to generate interleaved 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 four lists were used to generate the separated items in the same manner. The assignment of lists to each of the eight possible roles was counterbalanced across participants.

Results

Naming phase. Correct RTs were submitted to the same outlier analysis as in Experiments 1 and 2, eliminating 2.3% of the observations from analysis. Mean RTs were computed from the remaining observations. One-tailed paired-sample t-tests revealed that responses were significantly slower for interleaved (726 ms) than for separated items (633 ms), $t(47) = 13.84$, $p < .001$, $d = 2.82$, and that more errors were made for interleaved (.035) than for separated items (.017), $t(47) = 3.69$, $p < .001$, $d = 0.75$.

Test phase. Similar to Experiment 1, the proportions of “old” responses were analyzed using a 2 x 2 within-subjects ANOVA, with separation (separated/interleaved) and item type (old/new) as factors. Mean proportions of “old” judgments, collapsed across participants, are presented in Figure 4.

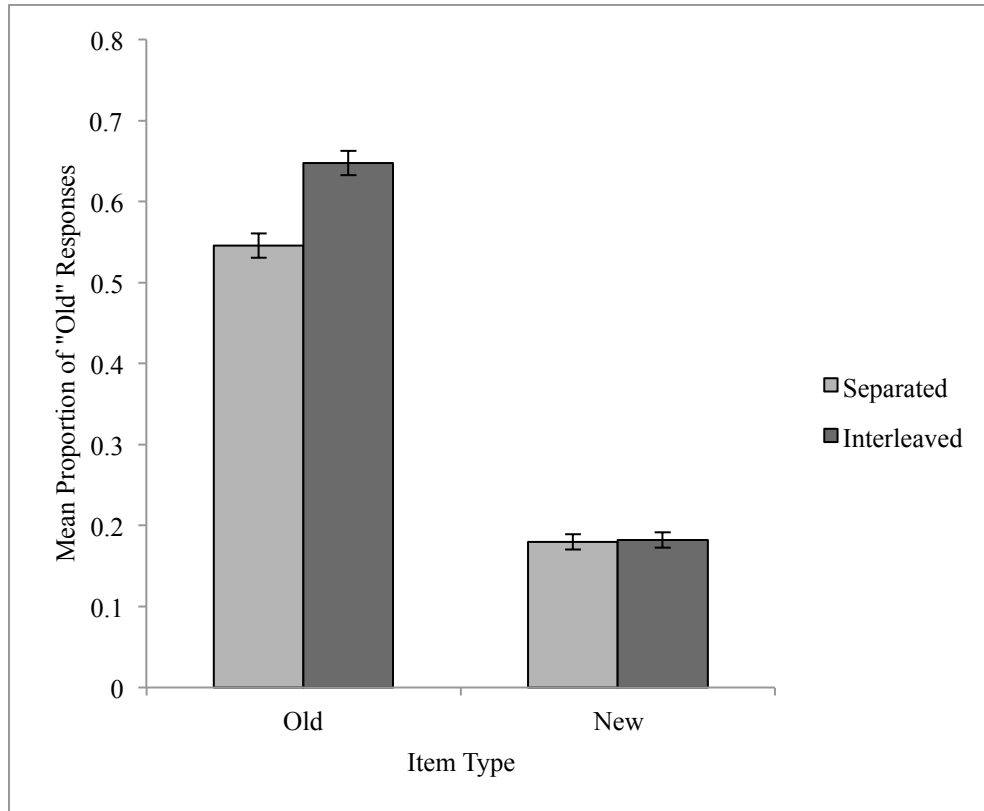


Fig. 4. Mean proportion of “old” responses to old and new items as a function of separation for Experiment 3. Error bars reflect the standard error of the mean corrected for between-subject variability (Morey, 2008).

The main effect of item type was significant, $F(1,47) = 626.11$, $p < .001$, $\eta_p^2 = .93$, indicating that there were more “old” responses to old items (.596) than to new items (.181). There was also a significant interaction between separation and item type, $F(1,47) = 30.65$, $p < .001$, $\eta_p^2 = .39$, revealing a greater difference between hits

and false alarms for interleaved than for separated items. To examine this interaction further, the simple main effect of separation was analyzed for old and new items. The analysis of old items revealed a significant effect of separation, $t(47) = 6.80, p < .001, d = 1.39$, with a greater hit rate for interleaved (.648) than for separated items (.545). The simple main effect of separation for new items was not significant, $p > .1$.

Signal detection analyses revealed a significant effect of d-prime with greater d-prime values for interleaved (1.42) than for separated items (1.15), $t(47) = 4.04, p < .001, d = 0.82$. There was no difference in beta between interleaved (1.89) and separated items (2.33), $t(47) = 1.20, p = .24, d = 0.24$.

Discussion

Response times and error rates were higher for the interleaved items than for the separated items during naming, consistent with the idea that there was more conflict experienced in naming targets for the interleaved items than for the separated items. Importantly, recognition memory was better for the interleaved items than for the separated items. The recognition advantage for interleaved items is captured both by the larger difference between hits and false alarm rates for the interleaved items than for the separated items, and by the larger values of d-prime for interleaved than for separated items. These results indicate that it was not simply the presence of two different words in the incongruent items that was key to producing the results of Experiments 1 and 2. Rather, it was more likely the higher level of conflict associated with naming one of two different interleaved words, compared to naming one of two identical interleaved words, that led to superior recognition for incongruent items.

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 a high-conflict (incongruent/interleaved) context during naming were recognized more accurately than low-conflict items (congruent/separated). These results identify a link between learning processes involved in selective attention contexts and explicit remembering.

At the outset of our study, we were unaware of any other research examining the relation between congruency effects in selective attention and explicit remembering. However, in a recent functional magnetic resonance imaging study that was independent of ours, Krebs et al. (2013) found a very similar result to ours using a face/word Stroop-like task. Participants were presented with a face overlaid with a word, and were asked to indicate the gender of the face. The trials presented were congruent (e.g., a male face overlaid with the word “man”),

incongruent (e.g., a male face overlaid with the word “woman”), or neutral (e.g., a male face overlaid with the word “house”). Critically, all of the faces presented were unique, and were only seen once during the study phase of the experiment. During the test phase, participants were shown faces and asked to indicate if the face was old or new on a 4-point scale, with “1” being definitely new, “2” being probably new, “3” being probably old, and “4” being definitely old. Krebs et al. found a greater proportion of “definitely old” responses for incongruent than neutral and congruent items. Furthermore, in areas involved in conflict monitoring and cognitive control, such as the dorsal ACC, precuneus, and DLPFC, greater activity was observed for incongruent than congruent and neutral items. Additionally, Krebs et al. found greater activity in the precuneus and DLPFC for incongruent remembered than incongruent forgotten items; no differences in activation were seen for remembered compared to forgotten congruent and neutral items.

For our purpose, it is noteworthy that the selective attention task used by Krebs et al. (2013) was very different from ours, and yet the same key result is reported. Recognition memory showed greater sensitivity for incongruent items than for congruent items. This result appears not to be an unusual quirk of one type of selective attention task, but a result that may occur in selective attention tasks generally. It will be important going forward to gain additional converging evidence that processes engaged to deal with the challenges of incongruent selective attention conditions lead to better explicit memory performance.

An additional recent study of some relevance examined the relation between cognitive control and remembering in a task-switching context (Richter & Yeung, 2012). In this study, participants were presented with a picture overlaid with an unrelated word, and had to classify either the word or the picture for each trial. Richter and Yeung observed better memory for irrelevant information and poorer memory for relevant information on task switches when compared to task repetitions, suggesting perhaps that task switches lead to a broadening of cognitive control. Although it is not entirely clear whether this result is related to the results in our study, it also points broadly to a link between cognitive control in human performance contexts (in this case a task switching context) and remembering.

Selective Attention or Processing Difficulty?

Although we have suggested a potential link between conflict-induced cognitive control and the encoding and explicit remembering of specific experiences, we should be careful to note that these two issues are not necessarily related. For example, “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). This proposal is particularly reasonable given prior studies that have shown that more difficult encoding conditions often produce better remembering (Lockhart, Craik, & Jacoby, 1976). Furthermore, one might argue that, although presentation time itself was equated, the additional time required to name high-conflict relative to low-conflict items during the naming phase of our experiments resulted in the additional encoding of episodic detail that supported recognition performance.

Although this issue cannot be addressed in its entirety in our study, we were interested in whether memory performance was generally related to naming times in the study phase, independent of whether the naming trial was congruent versus incongruent (Experiments 1 and 2) or separated versus interleaved (Experiment 3). To do this, we compared response times during the naming phase for subsequently remembered versus forgotten items for each item type. If longer naming times are directly related to better remembering, then items that were remembered should have been responded to more slowly than those that were forgotten. However, this was not the case; when comparing response times for later remembered or forgotten items using one-tailed paired sample t-tests, no significant differences were observed (all p 's > .1). These analyses offer no support for the view that naming time itself is directly related to the memory benefit for incongruent and interleaved over congruent and separated items.

To examine this issue further, we conducted a second analysis in which response times for each item type were separated into fast versus slow via median split, allowing d-prime values to be compared within item type for the faster and slower responded-to items at study. In Experiments 1 and 2, d-prime values for the slower responded-to incongruent items were higher than for the faster responded-to incongruent items, $p = .003$. However, there was no corresponding effect between the faster and slower responded-to congruent items. In Experiment 3, d-prime values for the slower responded-to interleaved items were higher than for the faster responded-to interleaved items, $p = .008$. Again, there was no corresponding difference for the separated items. These analyses do suggest that recognition performance is related to processes that also impact naming time, in at least some conditions. At some level, this result is not surprising, as engagement in cognitive control ought to both slow responding and enhance remembering under some conditions. The key question is whether speed of responding during study and recognition performance are always directly related. The results of a subsequent analysis were particularly informative in addressing this issue. This analysis compared performance for the slower responded-to congruent items and the faster responded-to incongruent items. In comparing these two sets of items in Experiments 1 and 2, naming times

for the slow congruent items were slower than those for the fast incongruent items, $p < .001$, yet d' -prime remained higher for the fast incongruent items than for the slow congruent items, $p = .002$. A similar analysis of the results of Experiment 3 revealed slower naming times for the slow separated items than for the fast interleaved items, $p < .001$. Here, d' -prime was marginally higher for the fast interleaved items than for the slow separated items, $p = .087$. These results show that speed of responding at study and recognition are not always directly related. Although there are likely to be cognitive control processes that both slow responding at study and lead to better recognition at test, there are also other processes that slow responding at study that are unrelated to those that improve recognition. A key issue in future research will be to tease these processes apart when the aim is to focus specifically on cognitive control.

Another key issue will be to examine the relation between the results reported here and those in other studies that have looked at the effect of perceptual encoding difficulty on memory performance. Nairne (1988) demonstrated that pattern masked single words during a study phase produced better recognition performance than unmasked single words, an effect that was subsequently replicated and extended by Hirshman & Mulligan (1991; see also Hirshman, Trembath, & Mulligan, 1994; Mulligan, 1996, 1999). Given these results, an important issue for further study is whether the masking effect in these studies is driven by the same mechanism as the selective attention effect we report in our study. If so, then it might imply that a relatively broad mechanism related to encoding difficulty, rather than a specific mechanism dedicated to resolving conflict in selective attention contexts, underlies the results we report here.

Selective Attention in the Mirror

Recognition memory performance in Experiment 1 and in the distractor condition of Experiment 2 was consistent with the well-known mirror effect. The mirror effect is defined by a pattern of data in which the more memorable class of items produces both a higher hit rate and a lower false alarm rate than the less memorable class of items. Mirror effects produced by varying word frequency are perhaps the most well-documented in the memory literature (Glanzer & Adams, 1985). An interesting point to note is that word frequency mirror effects could conceivably be caused by processes related to experience with the naming phase items and test items outside of the experimental context. In particular, low frequency items are less likely than high frequency items to have been experienced recently in an extra-experimental context, and therefore old low frequency items may yield particularly high hit rates because the old low frequency targets are more contextually distinct than old high frequency targets. In

contrast, the mirror effect observed in the present study must be produced by processing of items within the experiment itself. In particular, note that the elevated false alarm rate for congruent relative to incongruent items must owe entirely to the processing of those items in the test context. One possibility is that congruent items are processed more fluently than incongruent items at the time of test, and this fluency is then misattributed to familiarity (Jacoby & Whitehouse, 1989). In a similar vein, the lack of fluency for incongruent items could be experienced as “conflict”, which in turn triggers additional learning, thus explaining the hit rate advantage for incongruent over congruent items.

Conclusion

In summary, this study provides evidence that selective attention processes at encoding have consequences for the remembering of those same items at test. In particular, recognition memory was more accurate for incongruent/interleaved items than for congruent/separated items. Together with the Krebs et al. (2013) study that showed a similar result with a different selective attention task, these data highlight a novel link between cognitive control in selective attention contexts and explicit remembering, which merits continued study. A possible framework for guiding future work might focus on how cognitive control fits with the constructs of automaticity and expertise. In particular, when automaticity fails to offer an adequate solution to a current problem, perhaps cognitive control processes are responsible for new learning, the goal of which is to encode a distinct new instance that can be recruited “automatically” in the future. On this broad issue (but perhaps not in the details), we find ourselves in agreement with Botvinick’s (2007) proposal that the function of a metabolically expensive cognitive control system ought to be to make cognitive control unnecessary. Whether the present data reflect this particular blend of cognitive control and instance-based learning awaits further study.

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Appendix A

Recollection and Familiarity Analyses

Separate contributions of recollection and familiarity to recognition were evaluated using the independence remember-know (IRK) procedure for each experiment (Yonelinas, 2002; Yonelinas & Jacoby, 1995). The IRK procedure estimates the contribution of recollection by the proportion of trials in 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 A1.

Table A1

Estimates of recollection and familiarity derived using the independence remember-know procedure

Experiment	Recollection		Familiarity	
	Congruent	Incongruent	Congruent	Incongruent
1	.213	.263**	.235	.300*
2 (Distractor)	.207	.259**	.248	.301*
2 (No-distractor)	.261	.290	.245	.327**
3	Separated	Interleaved	Separated	Interleaved
	.238	.316***	.229	.311***

Note: Asterisks are placed beside the estimates for the incongruent/interleaved condition when the difference between incongruent/interleaved and congruent/separated estimates is significant (* $p < .05$; ** $p < .01$; *** $p < .001$).

Appendix B

Word Lists: Experiments 1 and 2

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

Appendix C

Word Lists: Experiment 3

Word list 1:

APPLE, BLAST, BRAIN, BRAKE, BRICK, CANAL, CHIEF, CHILL, CLOCK, CLOSE, CLOTH, CRIME, CRUST, CURVE, DAISY, DRAFT, DREAM, EARTH, FEAST, FLOAT, GLOVE, GRAPE, HOUSE, JOINT, LEMON, LEVEL, LILAC, MIDST, MODEL, MUSIC, NERVE, NIECE, NOVEL, ONION, OWNER, PAUSE, PLANT, PRIZE, QUIET, QUOTE, REACH, SALAD, SCALE, SHARP, SHEER, SHELF, SHIRT, STATE, STICK, TABLE, THREE, THUMP, TORCH, TRAIT, TREND, TRUCK, VOICE, WHEAT, YIELD, YOUTH

Word list 2:

AISLE, ANKLE, BLANK, BRUSH, CHECK, CLIMB, COURT, COVER, CRACK, CRAWL, DANCE, DODGE, DRAIN, DRINK, EAGLE, FENCE, FROCK, GLINT, GLOOM, GRAFT, GRASP, GUESS, HURRY, IDEAL, LOCAL, OFFER, OTHER, PEARL, PERCH, PHONE, PIECE, PRIME, PROOF, PRUNE, QUEEN, QUEST, QUICK, RANCH, ROUGH, SHAVE, SHELL, SHORT, SIXTY, SKATE, SLEEP, SMELL, SPOIL, SPOKE, STACK, STOOP, STOUT, STRAW, TASTE, TOPIC, TREAD, TREAT, TRICK, TROOP, UNCLE, VISIT

Word list 3:

ALLEY, BAKER, BLOND, BOUND, CEDAR, CHEEK, CHEST, CIGAR, CLOUD, CORAL, CROWN, DITCH, DOZEN, DRILL, ELDER, EMPTY, EXTRA, FRUIT, GIANT, GRAIN, GRANT, GREEN, GROAN, GROUP, GUIDE, INNER, LUNCH, MERIT, METAL, MOTOR, NIGHT, NORTH, PORCH, QUART, ROUTE, SCREW, SERVE, SHIFT, SHOOT, SHRED, SHRUB, SLICE, SOUND, SPECK, SPORT, STEAM, SUITE, SWARM, SWEET, TITLE, TOOTH, TOTAL, TOWER, TRACK, TRAIL, TRUNK, WASTE, WHITE, WRECK, WRIST

Word list 4:

ASIDE, BREAD, BURST, CANOE, CLAIM, COACH, CROWD, DRESS, DROVE, FANCY, FIELD, FLAME, FLEET, GOOSE, HONEY, HUNCH, JELLY, KNIFE, KNOCK, LEASE, LEAVE, MAJOR, MAPLE, PINCH, PLAIN, POUND, PRESS, PULSE, PUPIL, PUPPY, PURSE, RIGHT, SCENE, SCRUB, SHAKE, SHAPE,

SHARE, SLIDE, SOLID, SPILL, SPLIT, STALL, STARE, STEAL, STONE, STORM, STOVE, STYLE, SURGE,
SWEEP, THEME, THROW, THUMB, TIMER, TOUGH, TRACE, UNDER, WAIST, WHEEL, WIDTH

Word list 5:

ACTOR, ATTIC, BIRTH, BLINK, BROWN, BUNCH, CABLE, CARGO, CHAIR, CHASE, CHILD, CLASP,
CLOAK, COUNT, CROOK, CRUMB, DOUGH, EIGHT, FLOCK, FLOUR, FLUSH, FRAME, FRONT, GRACE,
GRADE, GRILL, HEDGE, HOBBY, HOUND, INDEX, JUICE, LEAST, LIMIT, LINEN, MORAL, OCEAN,
OLIVE, OUNCE, PEACH, PLANE, SAUCE, SHRUG, SMALL, SMART, SNORT, SOUTH, SPELL, SPOON,
STAND, STEEL, STEEP, STEER, STORE, STRAY, SWORD, THING, TOAST, VALUE, WHILE, WHIRL

Word list 6:

AGENT, ALARM, BARGE, BASIS, BLADE, BLEND, BLOCK, BLOOM, BOARD, BRAND, BRASS, BROOK,
CATCH, CAUSE, CHANT, CHARM, CHEER, CHOSE, CLASS, CRASH, DEPTH, DRIFT, ELBOW, ENTRY,
FERRY, GLASS, GRASS, IMAGE, LAYER, MARCH, MEDAL, MIGHT, NOBLE, PENNY, PHASE, PILOT,
PITCH, PLANK, RANGE, SCENT, SCOUT, SCRAP, SHINE, SNIFF, SPEED, STAFF, STAGE, STAIR, START,
STUFF, STUNT, THANK, THIRD, TIGER, TRAIN, TRUTH, TWIST, UPPER, WATER, WOMAN

Word list 7:

AWARD, BLIND, BROIL, CABIN, CANDY, CHAIN, CLUMP, COUCH, COUGH, CRAFT, DOUBT, EQUAL,
EVENT, FAINT, FEVER, FLAKE, FLOOD, FORUM, FROST, GLORY, GRATE, GRAVY, GROWL, GUARD,
GUEST, HORSE, ISSUE, JEWEL, LIGHT, LOBBY, MAGIC, MATCH, MONTH, ORDER, PANEL, PAPER,
PLATE, POINT, PRINT, RADIO, ROUND, SCARF, SCORE, SEVEN, SHEEP, SHORE, SHOUT, SKILL,
SNAKE, SPRIG, STILL, STORY, STRAP, SWAMP, SWIFT, THICK, TRADE, TRIBE, TRUST, TULIP

Word list 8:

APRON, BENCH, BERRY, BOAST, BOOTH, BRACE, BRIEF, CHART, CLEAN, CLERK, CLICK, CLIFF,
COAST, CREEK, DAILY, DELAY, DRIVE, FETCH, FLASH, FLING, FLOOR, FOCUS, GLEAM, GROVE,
HOTEL, LABEL, MOUTH, MOVIE, NOISE, PAINT, PASTE, PEACE, PHOTO, PIANO, RIDGE, RIVER,

ROAST, SENSE, SHEET, SIGHT, SKIRT, SLOPE, SPACE, SPARK, SPICE, SPINE, SPRAY, STAMP, STERN,
STOCK, STUDY, STUMP, SUGAR, SWING, TEETH, TRIAL, VERSE, WAGON, WATCH, WORLD

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