# ASSESSING THE DURABILITY AND TIME COURSE OF STIMULUS-DRIVEN CONTROL

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Assessing the Durability and Time Course of Stimulus-driven Control

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## LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| RT | Response Time |
| CSPC | Context Specific Proportion Congruence |
| ANOVA | Analysis of Variance |
| RSI | Response Stimulus Interval |

# SUMMARY

The term cognitive control refers to a variety of mental processes that support goal-directed behavior. In the current dissertation, I focus on the role of cognitive control in situations where a weaker (but task-relevant) source of information must be selected over a stronger (but task-irrelevant) source of information. The efficiency with which individuals select information in the face of distraction has classically been viewed as a function of static control settings tied to task instructions. Recent evidence suggests, however, that variations in the efficiency of cognitive control can be induced by variations in stimulus experience and that multiple control settings may be maintained for a single task. To date, little is known about the mechanisms that support this more flexible form of control. Across six experiments, I find evidence for the formation of multiple control settings that are relatively long lasting but fragile. Multiple control settings can be maintained within a single experiment and can last over relatively long periods of time, however, without the proper contextual support these control settings fall apart. These results emphasize the important role of stimulus experience in studies of cognitive control.

# CHAPTER 1

# INTRODUCTION

The term cognitive control has come to include a wide variety of mental processes that support goal-directed behavior (e.g. Botvinick, Braver, Barch, Carter, & Cohen, 2001; Braver, Reynolds, & Donaldson, 2003; Ochsner & Gross, 2005). Here, I focus on the role of cognitive control in selective attention, where a weaker (but task-relevant) source of information must be selected over a stronger (but task-irrelevant) source of information. Sitting on a public bus you are immediately reminded of the variety of stimuli confronting you at any one time: the sound of people talking, the sight of cars passing by, and the smell of the person next to you. Now imagine you decide to read a newspaper on that bus. The conversation, the cars, and the person next to you are now irrelevant sources of information and the newspaper is now the relevant source of information. Reading on the bus demonstrates a fundamental function of cognitive control: the biasing of information processing in the service of internally generated goals (Miller & Cohen, 2001; Posner & Snyder, 1975).

## Measuring the Influence of Cognitive Control

In the laboratory, cognitive control in selective attention is commonly studied using interference tasks (Eriksen & Eriksen, 1974; Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002), of which the paradigmatic example is the Stroop task (MacLeod, 1991; Stroop, 1935). In Stroop, participants respond to stimuli consisting of color words (e.g. BLUE) presented in a color (e.g. blue or green) and are instructed to name the color in which the word appears. The color can be consistent (congruent) or inconsistent (incongruent) with the meaning of the word. Performance is generally slower and less accurate on incongruent relative to congruent trials suggesting an inability to fully inhibit processing of the word dimension (MacLeod, 1991). To measure how successful participants are at selecting the weaker (but task-relevant) color dimension over the stronger (but task-irrelevant) word dimension, response times (RTs) for incongruent and congruent trials can be compared. The difference in RT for incongruent minus congruent trials is referred to as the congruency effect, and the size of this effect is influenced by a variety of experimental factors (for reviews see: Logan, 1980; MacLeod, 1991).

In connectionist models, cognitive control is implemented through the activation of processing units corresponding to task-goals that bias the relative contributions of stimulus dimensions. In the case of the Stroop task, the task-goal is to ignore the word and report the color (Cohen, Dunbar, & McClelland, 1990; Cohen & Huston, 1994; Cohen & Servan-Schreiber, 1992). When the task-goal is active, color information dominates performance and when the task-goal is inactive, word information dominates performance. Therefore, small congruency effects are associated with high levels of control and large congruency effects are associated with low levels of control (Botvinick et al., 2001; Egner, 2007; Verguts & Notebaert, 2009). Consistent with this account, word information influences performance to a greater degree relative to controls in groups presumed to have difficulty actively maintaining task-goals such as those with Alzheimer's disease (Spieler, Balota, & Faust, 1996), schizophrenia (Cohen & Servan-Schreiber, 1992), and low working memory capacity (Kane & Engle, 2003; Unsworth, Redick, Spillers, & Brewer, 2012).

In addition to variations in Stroop performance across different groups, variations in the size of the congruency effect can be observed within individual participants, suggesting the activation of task-goals may vary over the course of a single experimental session (Blais, Harris, Guerrero, & Bunge, 2012; Crump, Gong, & Milliken, 2006; Jacoby, Lindsay, & Hessels, 2003). As De Jong, Berendsen, and Cools (1999) point out, "the processing demands of the standard Stroop task may not induce or force subjects to bring to bear their ability to prevent formally irrelevant information from biasing processing" (p. 383). This leads to an important question in the cognitive control literature; what aspects of experience within a task support the implementation and maintenance of cognitive control?

## The Influence of Conflict on Cognitive Control Performance

The conflict monitoring framework provides one such mechanism for how stimulus experience influences the implementation and maintenance of cognitive control (Botvinick et al., 2001; Botvinick, Braver, Yeung, Ullsperger, Carter, & Cohen, 2004; Botvinick, Cohen, Carter, 2004). The importance of preventing conflict in mental processing has been identified previously (Navon & Miller, 1987; Norman & Shallice, 1986), however the conflict monitoring framework views the occurrence of conflict as a piece of information that can be used to monitor and adjust control in order to avoid conflict in the future (for a related idea see Berlyne, 1960). When an individual is presented with a stimulus that requires a single response, conflict occurs when multiple responses are active. The experience of conflict is taken as evidence for inadequate control, and as a result signals the need to tighten control on upcoming trials.

In the Stroop task, the co-activation of multiple responses typically occurs on incongruent trials (Botvinick et al, 2001; Yeung, Botvinick, & Cohen, 2004). Behaviorally, conflict monitoring is supported by the reduction in the size of the congruency effect following incongruent relative to congruent trials (Gratton, Coles, & Donchin, 1992; Kerns, Cohen, MacDonald III, Cho, Stenger, & Carter, 2004). Importantly, this *conflict adaptation* effect occurs in the absence of specific stimulus overlap from trial N to trial N+1 (Hutcheon & Spieler, 2014; Notebaert, Gevers, Verbruggen, & Liefooghe, 2006; Ullsperger, Bylsma, & Botvinick, 2005, but see: Mayr & Awh, 2003; Mayr, Awh, & Laurey, 2009). Thus, the occurrence of conflict leads to the activation of the task-goal that weights the contribution of the color and word dimensions.

Consistent with the occurrence of conflict leading to tightening of control (Botvinick et al., 2001), in *list level* manipulations, the size of the congruency effect is reduced when individuals encounter a high proportion of incongruent trials relative to a high proportion of congruent trials. This list level effect occurs despite participants receiving identical task instructions (Kane & Engle, 2003; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; Mitchell, 2010; West & Baylis, 1998). From a conflict monitoring perspective, the frequent occurrence of incongruent trials provides frequent reactivation of the task-goal resulting in a high level of control. When incongruent trials are infrequent, the reactivation of the task-goal is also infrequent, resulting in lower levels of control (Botvinick et al., 2001; Kane & Engle, 2003; Lindsay & Jacoby, 1994).

Despite the success of the conflict monitoring framework in accounting for conflict adaptation and list level effects, recent evidence suggests that the conflict signal carries more detailed information about the source of conflict. In *item level* manipulations, participants encounter stimulus lists in which certain words and colors appear most frequently as incongruent trials (mostly incongruent items) while other words and colors appear most frequently as congruent trials (mostly congruent items). Importantly, these lists contain an equal proportion of incongruent and congruent trials overall, ensuring that the prior trial will be incongruent or congruent with an equal probability (see Table 1 for an representative stimulus list) (Jacoby et al., 2003; Jacoby, McElree, & Trainham, 1999). Paralleling list level results, mostly incongruent items show smaller congruency effects relative to mostly congruent items and this finding is referred to as the item specific proportion congruence (ISPC) effect (Blais & Bunge, 2010; Bugg, Jacoby, & Toth, 2008; Jacoby et al., 2003).

Table 1. Representative stimulus list for an item level manipulation (adapted from Jacoby et al., 2003).

| | | Color | | | |
|---|---|---|---|---|---|
| Item Type | Word | blue | green | red | yellow |
| Mostly Congruent | | | | | |
| | BLUE | 36 | 12 | | |
| | GREEN | 12 | 36 | | |
| Mostly Incongruent | | | | | |
| | RED | | | 12 | 36 |
| | YELLOW | | | 36 | 12 |

Unlike the original instantiation of conflict monitoring, the ISPC effect is taken as evidence that control is implemented at the item level (e.g. if the word is RED, inhibit processing of the word dimension) rather than the task level (e.g. inhibit processing of the word dimension) (Blais, Robidoux, Risko, & Besner, 2007; Blais & Verguts, 2012; Verguts & Notebaert, 2008; 2009). Since performance varies as a function of item type, participants appear to maintain multiple control settings that are tied to the identity of specific stimuli and are updated by the occurrence of conflict. For mostly incongruent items, the frequent occurrence of conflict leads to the frequent reactivation of control. In contrast, for mostly congruent items, the infrequent occurrence of conflict leads to the infrequent reactivation of control (Bugg & Crump, 2012; Blais et al., 2007; Verguts &

Notebaert, 2008). Note, in item level manipulations stimulus features are colors and words. However, since word information is available early in processing (MacLeod, 1991; MacLeod & Dunbar, 1988), it is generally assumed that word information triggers the implementation of control settings on a given trial (Bugg et al., 2008; Crump et al., 2006).

The ability to maintain multiple control settings in parallel that are updated by the occurrence of conflict is supported by evidence from the task-switching literature. In task-switching paradigms, conflict on trial N does not reduce conflict on trial N+1 if this coincides with a task-switch. However, conflict on trial N does reduce conflict on trial N+1 if this coincides with a task repetition (Akçay & Hazeltine, 2011; Funes, Lupiáñez, & Humphreys, 2010; Hazeltine, Lightman, Schwarb, & Schumacher, 2011; Notebaert & Verguts, 2008; but see Freitas, Bahar, Yang, & Banai, 2007; Kan, Teubner-Rhodes, Drummey, Nutile, Krupa, & Novick 2013). Moreover, conflict adaptation can be observed on the next trial of the same task despite intervening trials of a different task (Akçay & Hazeltine, 2011; Fernandez-Duque & Knight, 2008; Hazeltine et al., 2011). In this way, conflict originating from one source of information results in a change to that weight, reducing input from that source on subsequent trials (Egner, 2008).

Similar to the task-switching results, in item level manipulations conflict adaptation is absent when the word changes from trial N to trial N+1 but can be observed on the next trial in which that word appears despite intervening trials containing different words (Hutcheon & Spieler, 2014). From a control perspective, this is viewed as support that multiple control settings are maintained and tied to specific stimulus dimensions (Blais et al., 2007; Bugg & Crump, 2012; Verguts & Notebaert, 2008)

## The Influence of Contingency Learning on Cognitive Control Performance

The ISPC effect demonstrates that participants are sensitive to variations in experience with specific words and colors. From a control perspective, this experience allows participants to implement different control settings based on the identity of the word (Blais et al., 2007; Verguts & Notebaert, 2008). An alternative possibility is that participants use information about the word to predict the likely response. For example, Musen and Squire (1993) have shown that participants are sensitive to the relationship (contingency) between specific words and specific responses. In one experiment, participants were presented with stimuli consisting of a word and color dimension and were instructed to ignore the word and name the color. For the first half of the experiment, each word was consistently paired with a specific color. Halfway through the experiment words were re-paired with a new color. If participants use information about specific words to predict specific responses, then performance should get worse when the word-color pairings switched. Consistent with a contingency account, performance improved as the number of presentations of words and colors increased, however performance dramatically declined when the pairs were switched (see also: Schmidt, Crump, Cheesman, & Besner, 2007).

Jacoby and colleagues (2003) acknowledged in their original paper that contingency learning could be viewed as an alternative explanation for the ISPC effect. For example, from the stimulus list presented in Table 1, if a participant knows the word is BLUE, they know the likely response is “Blue”. Thus, when presented with a stimulus containing the word BLUE, the use of word information to predict the likely response will lead to relatively fast congruent trials and relatively slow incongruent trials. In contrast, if an individual knows the word is RED, they know the likely response is "Yellow". Here, when presented with a stimulus containing the word RED, the use of word information to predict the likely response will lead to relatively fast incongruent trials and relatively slow congruent trials (Schmidt & Besner, 2008). In other words, variations in the size of the congruency effect attributed to variations in control may instead be driven by the predictive relationships between specific words and specific responses (Schmidt, 2013).

Fortunately, it is possible remove the predictive relationship between specific words and responses endemic to item level manipulations. In context level manipulations, participants are presented with a word at fixation immediately followed by a color patch either above or below fixation. Participants are instructed to ignore the word and to name the color of the color patch. All colors (responses) are equally likely to occur at each location and are equally likely to be presented with each word. However, the probability of encountering a congruent or incongruent color patch differs based on location (see Table 2). In one location, the majority of color patches are incongruent and at the other location, the majority of color patches are congruent (Crump et al., 2006). In this way, the nominally irrelevant location dimension is not informative about the likely response but the experience of congruent and incongruent trials differs by location. Similar to the ISPC effect, a context specific proportion congruence (CSPC) effect is observed in which the size of the congruency effect is reduced at mostly incongruent relative to mostly congruent locations (Crump et al., 2006; Crump & Milliken, 2009; Crump, Vaquero, & Milliken, 2008; Heinemann, Kunde, & Kiesel, 2009; King, Korb, & Egner, 2012). Recently, the CSPC effect has been extended to a variety of irrelevant contextual dimensions including color (Vietze & Wendt, 2009) and font type (Bugg et al., 2008).

Table 2. Representative stimulus list for a context level manipulation (adapted from Crump et al., 2006).

| | | Color | | | |
|---|---|---|---|---|---|
| Location Type | Word | blue | green | red | yellow |
| Mostly Congruent | | | | | |
| | BLUE | 36 | 4 | 4 | 4 |
| | GREEN | 4 | 36 | 4 | 4 |
| | RED | 4 | 4 | 36 | 4 |
| | YELLOW | 4 | 4 | 4 | 36 |
| Mostly Incongruent | | | | | |
| | BLUE | 12 | 12 | 12 | 12 |
| | GREEN | 12 | 12 | 12 | 12 |
| | RED | 12 | 12 | 12 | 12 |
| | YELLOW | 12 | 12 | 12 | 12 |

The CSPC effect is difficult for the contingency learning account to explain. If individuals simply use word information to predict the likely response, then there should be no difference in the size of the congruency effect across locations. In order for contingency learning to account for the CSPC effect, it must be argued that individuals use the irrelevant location dimension to predict the likelihood of the word providing the correct response. Viewed in this way, contingency learning is difficult to differentiate from control (see: Schmidt, 2013). From a control perspective, the CSPC effect is simply the outcome of participant's instantiating different control settings at each location.

Further evidence against contingency learning comes from context level transfer manipulations. For example, Crump and Milliken (2009) created a stimulus list containing two sets of stimuli: a context set and a transfer set. In the context set, color patches were likely to be congruent at one location and likely to be incongruent at the other location. In the transfer set, color patches were equally likely to be congruent or incongruent at each location (see Table 3). Stimuli from context and transfer sets were randomly mixed within a single stimulus list. If participants use information about the contingency between the word, location and the correct response, the size of the congruency effect for transfer items should be the same at each location. In contrast, if participants maintain different control settings that apply to all stimuli encountered at that location, then the size of the congruency effect for transfer items should be reduced at the mostly incongruent relative to mostly congruent locations. Consistent with the control account, the size of the congruency effect was reduced at mostly incongruent relative to mostly congruent locations for the context set. Importantly, the size of the congruency effect was also reduced at mostly incongruent relative to mostly congruent locations for the transfer set (Crump & Milliken, 2009; see also: Heinemann et al., 2009). This CSPC transfer effect cannot be accounted for by contingency learning and supports the idea that participants develop control settings that are specific to each location.

## Control Accounts for the CSPC Effect

Context and item level manipulations contribute to our understanding of the architecture of cognitive control. At its core, the function of cognitive control is to make performance easier by biasing information across a range of similar stimuli. What makes stimuli "similar" in a control sense remains unclear. Classically, similarity is defined by task instructions (Miller & Cohen, 2001; Posner & Snyder, 1975). However, the results of item and context level manipulations imply that similar stimuli may be defined by their experience within the task. The exact mechanism by which different control settings become instantiated remains unknown. To date, two alternatives have been proposed in the literature: item level control and stimulus-driven control.

Table 3. Representative block of trials for a context level transfer manipulation (adapted from Crump & Milliken, 2009) used in Experiment 1B.

| | | | Color | | | |
|---|---|---|---|---|---|---|
| Location Type | Probe Set | Word | blue | green | red | yellow |
| Mostly Congruent | | | | | | |
| | Context | BLUE | 11 | 1 | | |
| | | GREEN | 1 | 11 | | |
| | Transfer | RED | | | 6 | 6 |
| | | YELLOW | | | 6 | 6 |
| Mostly Incongruent | | | | | | |
| | Context | BLUE | 1 | 11 | | |
| | | GREEN | 11 | 1 | | |
| | Transfer | RED | | | 6 | 6 |
| | | YELLOW | | | 6 | 6 |

Item level control borrows the basic structure of the original conflict monitoring mechanism. In this account, the occurrence of conflict serves to signal the need to strengthen task-goals tied to specific stimulus features (Blais et al., 2007; Verguts & Notebaert, 2008). In a CSPC manipulation, conflict strengthens control tied to individual locations instead of conflict strengthening a general task-goal as specified by conflict monitoring. At the mostly incongruent location, the frequent occurrence of incongruent trials provides frequent strengthening of the control setting tied to that location. In contrast, at the mostly congruent location, the infrequent occurrence of incongruent trials means that the strengthening of control is also infrequent at that location. The control settings maintained at each location are sensitive to the occurrence of conflict but void of information about specific stimulus features.

While item level control has been shown to account for the CSPC effect (Blais et al., 2007; Verguts & Notebaert, 2008) and in theory can account for the CSPC transfer effect (Verguts & Notebaert, 2009), these effects have also been explained in terms of an episodic learning process referred to as stimulus-driven control (Bugg, 2012; Bugg &

Crump, 2012; Crump et al., 2006; Crump et al., 2008). According to the stimulus-driven control account, information about each trial is encoded into a single memory representation (e.g. Logan, 1988; Hommel, 2000). When a similar stimulus is encountered in the future, previously stored representations are retrieved and influence performance. In addition to information about stimulus dimensions and responses (Hutcheon & Spieler, submitted), these stored representations are thought to include all generalizable aspects of processing (Kolers & Roediger, 1984; Jacoby & Brooks, 1984) including control settings active at the time of encoding (Crump & Milliken, 2009; Crump et al., 2008). The encoding and retrieval of control settings provides a mechanism for the CSPC and CSPC transfer effects. When a stimulus appears at a mostly incongruent location, it leads to the retrieval of a large proportion of trials in which control settings are high. In contrast, when a stimulus appears at a mostly congruent location, it leads to the retrieval of a small proportion of trials in which control settings are high. In this way, control settings are an additional attribute retrieved at the time a stimulus is encountered (Crump & Milliken, 2009).

Across both accounts, control settings represent the weights that are assigned to stimulus dimensions, and distinct control settings are maintained at each location. Two stimuli occurring in the same location should be processed under the same control settings and two stimuli occurring in different locations should be processed under different settings. Putting this together, conflict on the prior trial should only influence performance on the current trial when the location repeats. Item level control and stimulus-driven control accounts both predict that in a CSPC manipulation, conflict adaptation should be observed within but not across locations.

Conflict adaptation effects provide an opportunity to differentiate between the item level control and stimulus-driven control accounts. Are the control settings that bias future processing transiently updated through a conflict monitoring mechanism (Botvinick et al., 2001) as specified by item level control (Blais et al., 2007; Verguts & Notebaert, 2008)? Or are these settings updated through more durable episodic learning representations as specified by stimulus-driven control (Bugg & Crump, 2012; Crump & Milliken, 2009)? Elsewhere, it has been shown that the influence of conflict on future performance is relatively short-lived. In experiments that manipulate the time between trials by varying the response stimulus interval (RSI), the influence of conflict appears to last for 2,000 milliseconds (ms). Specifically, the conflict adaptation effect is present at short (<2,000 ms) but not long (>2,000 ms) RSIs (Blais & Verguts, 2012; Egner, Ely, & Grinband, 2010). Thus, given sufficient time between the occurrence of conflict on the previous trial and processing of the current trial, the influence of conflict disappears. A transient process observed in a context level manipulation would be consistent with item level control and a more durable process would be consistent with stimulus-driven control.

A second way in which item level control and stimulus-driven control accounts differ is the representation that serves to bias performance. In item level control, the control setting built up at that location influences performance on the current trial and these settings are void of specific stimulus information. Thus, the condition of the previous trial at that location should influence performance. In contrast, in the stimulus-driven control account, performance on the current trial is influenced by the retrieval of relatively rich episodic information about the specific stimulus. If information about specific stimuli comes to influence performance, then the condition of the last trial in which the word dimension overlapped should influence performance. This can be thought of in terms of the distinction between proactive and reactive control (Braver, Gray, & Burgess, 2007). Item level control is a proactive process that is applied prior to the occurrence of a stimulus whereas stimulus-driven control is a reactive process that comes on line based on the identity of the current stimulus. The goal of the current dissertation is to better understand the durability and time course of cognitive control.

# CHAPTER 2

## EXPERIMENT 1A

I begin with a conceptual replication of the original context level transfer manipulation (Crump & Milliken, 2009). The purpose of this experiment is to confirm the predictions of both item level control and stimulus-driven control accounts. Specifically, in the presence of multiple control settings the trial-to-trial influence of conflict should be observed when locations repeat but not when locations switch. I begin with a transfer manipulation because there is consensus that the CSPC transfer effect cannot be accounted for by contingency learning (see: Schmidt, 2013). In addition, a replication is warranted because there is only a single report of a CSPC transfer effect in the literature.

There is an aspect of interference tasks such as Stroop that can artificially inflate the observation of conflict adaptation. Stimulus-specific repetition priming could drive the conflict adaptation effect (Mayr & Awh, 2009; Mayr, et al., 2003). Incongruent-incongruent trial transitions and congruent-congruent trial transitions contain some number of specific stimulus repetitions. In contrast, congruent-incongruent and incongruent-congruent transitions do not contain any repetitions. Therefore, incongruent-incongruent and congruent-congruent transitions may be particularly fast due to a repetition benefit that is absent in incongruent-congruent and congruent-incongruent transitions (Hommel, 1998; Pashler & Baylis, 1991). To control for this, researchers typically exclude from analysis all trials in which there is overlap between the stimulus on the current and the stimulus on the previous trial (Kerns et al., 2004). The original CSPC transfer manipulation (Crump & Milliken, 2009) contained two item sets which does not allow for the removal of this stimulus overlap. Here, I implement a manipulation with relatively large stimulus sets. This allows for a more detailed analysis of conflict adaptation within and across locations.

The finding of a CSPC transfer effect is critical evidence that unique control settings are operational at each location. If different control settings are maintained, then a CSPC effect should be observed for both the context and transfer set. Further, conflict adaptation should be observed within but not across locations.

## Method

### *Participants*

Thirty-two participants (19 female, $M$ = 19.15 years, $SD$= 1.39) were recruited from the Georgia Institute of Technology undergraduate population and received course credit for their participation.

### *Materials and Stimuli*

Eprime 2.0 software (Psychology Software Tools, Pittsburgh, PA) was used to control the display of stimuli and record RTs to the nearest ms. Stimuli were displayed on an 18-in color (LCD) monitor. Participants were seated approximately 57 cm from the monitor. A microphone connected to a Psychology Software Tools Serial Response Box™ measured voice onset time.

On every trial, a color-word (prime) was briefly presented, followed by a to-be-named color patch (probe). There were eight color-word primes (BLUE, BROWN, GREEN, ORANGE, PINK, PURPLE, RED, and YELLOW) along with their corresponding color-patch probes (blue, brown, green, orange, pink, purple, red, and yellow). Primes were approximately 1.6° in height and 4.9° in width presented at fixation in Times New Roman font in white against a black background. Color patches consisted of colored rectangles 1.6° in height and 5.2° in width appearing either 5.68° above or below fixation.

Stimuli were separated into two prime/probe sets (Blue/Green/Orange/Pink and Brown/Purple/Red/Yellow). This specific grouping was maintained across participants. For each participant, one set was designated as the context set and one set was designated as the transfer set. Sets were counterbalanced across participants so that each appeared as a transfer set and a context set for half of the participants. Color patches in the context set were equally likely to appear above or below fixation, however at one location (mostly congruent) color patches were likely be congruent and at the other location (mostly incongruent) they were likely to be incongruent. In contrast, color patches from the transfer set were equally likely to appear above or below fixation and were equally likely to be congruent or incongruent at each location. Mostly congruent and mostly incongruent locations were counterbalanced across participants.

In each experimental block, stimuli from the context set presented at the mostly congruent location consisted of color patches with their corresponding words on 15 trials and in the remaining three members of the set on one trial each. In contrast, stimuli from the context set at the mostly incongruent location consisted of color patches presented with their corresponding word on three trials and with the remaining three members of the set on five trials each. Stimuli from the transfer set consisted of color patches presented with their corresponding words on nine trials and with the three remaining members of the set on three trials each at both the mostly congruent and mostly incongruent location. Overall, there were an equal number of context and transfer trials and these trials were randomly mixed within experimental blocks. A representative block of trials is presented in Table 4.

Table 4. Representative block of trials from the context level transfer manipulation implemented in Experiment 1A.

| | | | Color | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Location Type** | **Probe Type** | **Word** | blue | green | orange | pink | brown | purple | red | yellow |
| **Mostly Congruent** | Context | BLUE | 15 | 1 | 1 | 1 | | | | |
| | | GREEN | 1 | 15 | 1 | 1 | | | | |
| | | ORANGE | 1 | 1 | 15 | 1 | | | | |
| | | PINK | 1 | 1 | 1 | 15 | | | | |
| | Transfer | BROWN | | | | | 9 | 3 | 3 | 3 |
| | | PURPLE | | | | | 3 | 9 | 3 | 3 |
| | | RED | | | | | 3 | 3 | 9 | 3 |
| | | YELLOW | | | | | 3 | 3 | 3 | 9 |
| **Mostly Incongruent** | Context | BLUE | 3 | 5 | 5 | 5 | | | | |
| | | GREEN | 5 | 3 | 5 | 5 | | | | |
| | | ORANGE | 5 | 5 | 3 | 5 | | | | |
| | | PINK | 5 | 5 | 5 | 3 | | | | |
| | Transfer | BROWN | | | | | 9 | 3 | 3 | 3 |
| | | PURPLE | | | | | 3 | 9 | 3 | 3 |
| | | RED | | | | | 3 | 3 | 9 | 3 |
| | | YELLOW | | | | | 3 | 3 | 3 | 9 |

Participants completed 16 practice trials consisting of one congruent trial and one incongruent trial for each of the eight color patches. A fully counterbalanced block required 288 trials. Participants performed two blocks for a total of 576 trials. To make the task more manageable for participants, a rest was given after every 144 trials.

*Procedure*

Participants were instructed to ignore the color-word prime and name the color patch probe as quickly as possible while maintaining an accuracy rate of over 90%. The following sequence of events occurred on every trial: a) a fixation cross appeared at the center of the screen for 1000 ms, b) a blank screen appeared for 250 ms, c) the prime word was presented centrally for 100 ms, d) a color patch probe was displayed either above or below fixation and remained on the screen until a vocal response was detected, e) the screen cleared for the 1000 ms intertrial interval (see Figure 1 for a representative congruent and incongruent trial).

Participants were tested individually while seated next to an experimenter who coded correct responses, incorrect responses, and voice key errors. The entire experimental session lasted approximately 1 hour.

## Results

An alpha level of 0.05 was used for all reported results. Prior to all analyses, voice key errors, RTs less than 200 ms and RTs greater than 2500 ms were excluded. This procedure resulted in the exclusion of less than 2.1% of all trials.

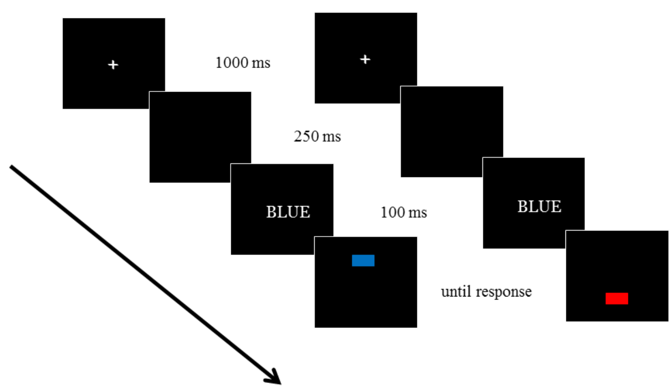


Figure 1. Example of a congruent (left) and incongruent (right) trial in a context level manipulation. This trial structure was used for Experiments 1A, 1B, 1C, and 2. In Experiment 3, the fixation duration varied between (550 ms, 2400 ms, and 4,250 ms).

*Response Time*

To test for the presence of a CSPC effect, all remaining correct trials were analyzed in a 2 Set (context, transfer) X 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures analysis of variance (ANOVA). As seen in Figure 2, congruent trials were faster than incongruent trials, F(1,31) = 142.13, $\eta^2$ = 0.821, and stimuli from the context set were responded to faster than stimuli from the transfer set, F(1, 31) = 5.36, $\eta^2$ = 0.147. However, the size of the congruency effect was not different across locations. Thus, a CSPC effect was not observed in the current experiment. No additional effects were significant.

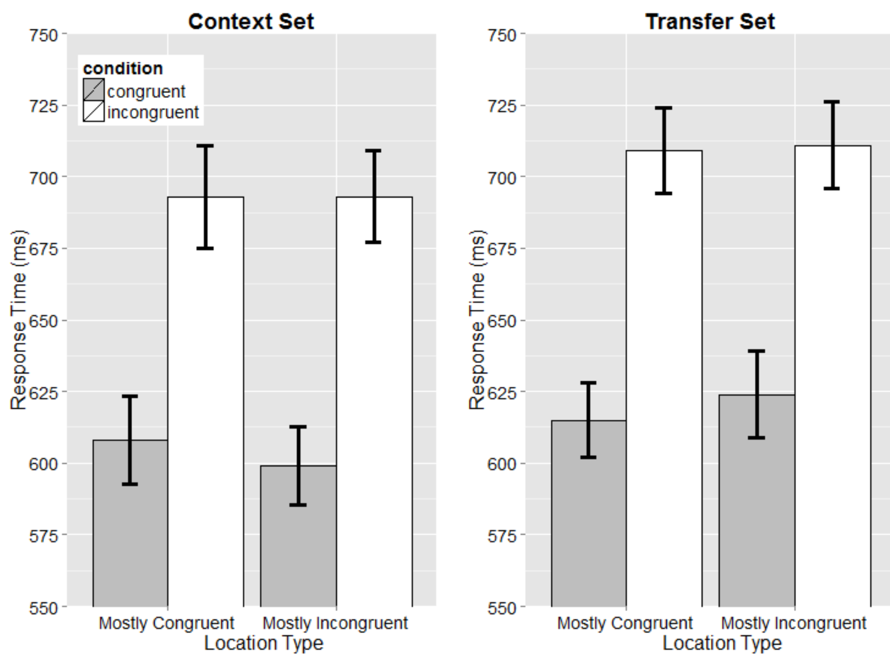


Figure 2. Mean color-naming response latencies with 95% confidence intervals from the 4-item set context level manipulation in Experiment 1A.

To separately assess the contributions of context and transfer stimuli, two separate 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVAs were conducted for context and transfer sets. Congruent trials were faster than incongruent trials for both the context, F(1, 31) = 107.95, $\eta^2$= 0.776 and transfer sets, F(1, 31) = 155.43, $\eta^2$= 0.833. However, the size of the congruency effect did not depend on location for either set. No other effects were significant, Fs < 1.5. This suggests that the CSPC effect was absent in both the context and transfer set.

In contrast with previous context level transfer manipulations (Crump & Milliken, 2009), in the current experiment I find no evidence for a CSPC effect. Unsurprisingly, due to the absence of a CSPC effect, there is also no evidence for a CSPC transfer effect. One potential explanation for the current result is that these effects take time to build. In fact, in the initial experiment (Crump & Milliken, 2009) the CSPC transfer effect was only found during the second half of experimental trials. Combining performance at the beginning and end of the experiment, as I did here, may have served to dilute the effect. To test whether these effects developed over the course of an experiment, all remaining correct trials were analyzed in a Learning Half (first half, second half) X 2 Set Type (context, transfer) X 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA. Only the effect of congruency was significant, $F(1, 31) = 140.70$, $\eta^2 = 0.819$. Learning Half did not interact with any factors suggesting that the CSPC effect was absent during both the first and second half of the experiment.

Learning Half also did not influence performance when assessing the context and transfer set separately. Analyzing the data in two separate 2 Learning Half (first half, second half) X 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVAs for each set revealed that congruent trials were again faster than incongruent trials for both context, $F(1, 31) = 106.324$, $\eta^2 = 0.774$, and transfer sets, $F(1, 31) = 154.26$, $\eta^2 = 0.832$. In addition, transfer stimuli were responded to faster during the second half compared to the first half of the experiment, $F(1,31) = 6.75$, $\eta^2 = 0.178$. However, the size of the congruency effect did not vary as a function of location during the first or second half of the experiment for either set.

One difference between the current experiment and the previous experiment reporting a CSPC transfer effect is that RTs are numerically slower here (611 ms congruent and 701 ms incongruent) compared to the original report (488 ms and 564 ms respectively) (Crump & Milliken, 2009). However, this is unsurprising as RT is likely to be inflated in this experiment because participants are dealing with a larger number of possible responses (Hick, 1952; Hyman, 1953). Importantly, there does not appear to be a speed-accuracy trade-off as participants in the current study were no more accurate than those in the original study.

Elsewhere it is has been suggested that individual difference variables, such as working memory capacity, may influence the expression of ISPC and CSPC effects (Hutchison, 2011). It is possible that participants in the current sample were simply less sensitive to context level learning compared to the Crump & Milliken (2009) sample. If differences between the working memory capacity in the current sample and the Crump & Milliken sample account for the current results, I should find that individuals who demonstrate a CSPC effect for context items also demonstrate the effect on transfer items. Of the 32 participants in the current experiment, 15 demonstrated a numerical CSPC effect in context items. Of the 15 participants who showed a numerical CSPC effect in context items, 11 showed a CSPC effect in transfer items suggesting that there may be some relationship between the observation of the CSPC and a CSPC transfer effect within participants. However, statistical analysis did not support this conclusion.

As seen in Figure 3, a Pearson's correlation shows that this relationship is not significant across participants, r = 0.04, p>0.8.

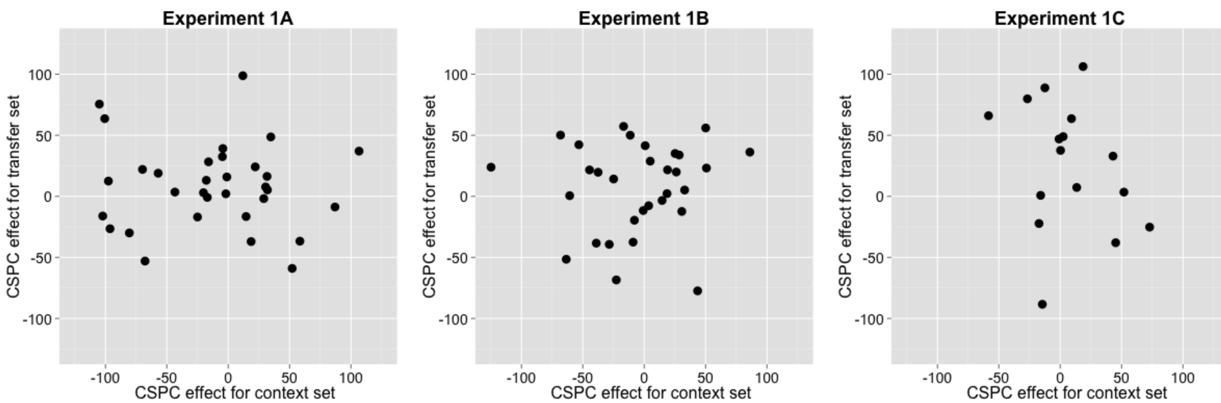


Figure 3. Correlation between the CSPC Transfer effect and CSPC Context effect across Experiments 1A, 1B, and 1C.

Because there is no evidence that participants are implementing different control settings at each location, I do not report the analysis of conflict adaptation effects.

*Accuracy*

Overall, accuracy rate was over 97.5%. Due to the low error rate, statistical analysis of error rates is not presented. However, the results are presented in Table 5.

**Discussion**

In a conceptual replication of the context level transfer manipulation, the congruency effect was similar across two locations differentially predictive of conflict. This is inconsistent with previous reports of the CSPC transfer effect that demonstrated reduced congruency effects at mostly incongruent relatively to mostly congruent locations.

The meaning of the current results is unclear. One possibility is that increasing the size of the stimulus-set had some unanticipated effect on the development of different control settings. An alternative possibility is that the CSPC transfer effect does not replicate across studies. In fact, there is only one prior report of the CSPC transfer effect in the literature. To investigate these alternatives, I perform a direct replication of the CSPC transfer effect as reported by Crump & Milliken (2009) in the following experiment.

Table 5. Accuracy rate for context and transfer stimuli as a function of learning half in Experiment 1A.

Context Items

| First Half | | | Second Half | | |
|---|---|---|---|---|---|
| | Condition | | | Condition | |
| Location Type | congruent | incongruent | Location Type | congruent | incongruent |
| mostly congruent | 0.98 | 0.97 | mostly congruent | 0.98 | 0.96 |
| mostly incongruent | 0.97 | 0.98 | mostly incongruent | 0.98 | 0.97 |

Transfer Items

| First Half | | | Second Half | | |
|---|---|---|---|---|---|
| | Condition | | | Condition | |
| Location Type | congruent | incongruent | Location Type | congruent | incongruent |
| mostly congruent | 0.96 | 0.94 | mostly congruent | 0.98 | 0.95 |
| mostly incongruent | 0.98 | 0.94 | mostly incongruent | 0.98 | 0.96 |

## EXPERIMENT 1B

In Experiment 1A, I found no evidence for a CSPC effect or a CSPC transfer effect. However, there were methodological differences between Experiment 1A and the original report of the transfer effect. Due to the theoretical importance of this effect and the lack of published replications, in the current experiment I attempt a direct replication of Crump and Milliken (2009).

### Method

*Participants*

Thirty-two participants (17 female, *M* = 20.41 years, *SD* = 2.28) were recruited from the Georgia Institute of Technology undergraduate population and received course credit for their participation.

*Materials and Stimuli*

The stimulus presentation was identical to that described in Experiment 1A. On every trial, a color-word (prime) was briefly presented, followed by a to-be-named color patch (probe). There were four color-word primes (BLUE, GREEN, RED, and YELLOW) along with their corresponding color-patch probes (blue, green, red, and yellow). Primes were approximately 1.6° in height and 4.9° in width presented at fixation in Times New Roman font in white against a black background. Color patches consisted of colored rectangles 1.6° in height and 5.2° in width appearing either 5.68° above or below fixation.

In each experimental block, stimuli were separated into two prime/probe sets (Blue/Yellow and Green/Red). For each participant, one set was designated as the context set and one set was designated as the transfer set. Sets were counterbalanced across participants such that each appeared as a transfer and context set for half of participants. Color patches in the context set were equally likely to appear above or below fixation, however at one location (mostly congruent) color patches were likely be congruent and at the other location (mostly incongruent) color patches were likely be incongruent. In contrast, color patches from the transfer set were equally likely to appear above or below fixation and were equally likely to be congruent or incongruent at each location. Mostly congruent and mostly incongruent locations were counterbalanced across participants.

Stimuli from the context set presented at the mostly congruent location consisted of color patches with their corresponding words on 11 trials and in the remaining member of the set on one trial each.  In contrast, stimuli from the context set at the mostly incongruent location consisted of color patches presented with their corresponding word on one trial and with the remaining member of the set on 11 trials.  Stimuli from the transfer set consisted of color patches presented with their corresponding words on six trials and with the remaining member of the set on six trials at both the mostly congruent and mostly incongruent location.  Overall, there were an equal number of context and transfer trials and these trials were randomly mixed across the experimental block.  A representative block of trials is presented in Table 3.

Participants completed ten practice trials.  A fully counterbalanced block required 96 trials.  Participants performed four blocks for a total of 384 trials.

*Procedure*

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

**Results**

An alpha level of 0.05 was used for reported results.  Prior to all analyses, voice key errors, RTs less than 200 ms and RTs greater than 2500 ms were excluded.  This procedure resulted in the removal of less than 1.3% of all trials.

*Response Time*

All remaining correct trials were analyzed in 2 Set Type (context, transfer) X 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA.  As seen in Figure 4, congruent trials were faster than incongruent trials, $F(1,31)=130.37$, $\eta^2= 0.808$, but the size of the congruency effect did not differ by location F < 0.2. No other effects were significant. Consistent with the results of Experiment 1A, I find no evidence for a CSPC effect in a context level transfer manipulation.

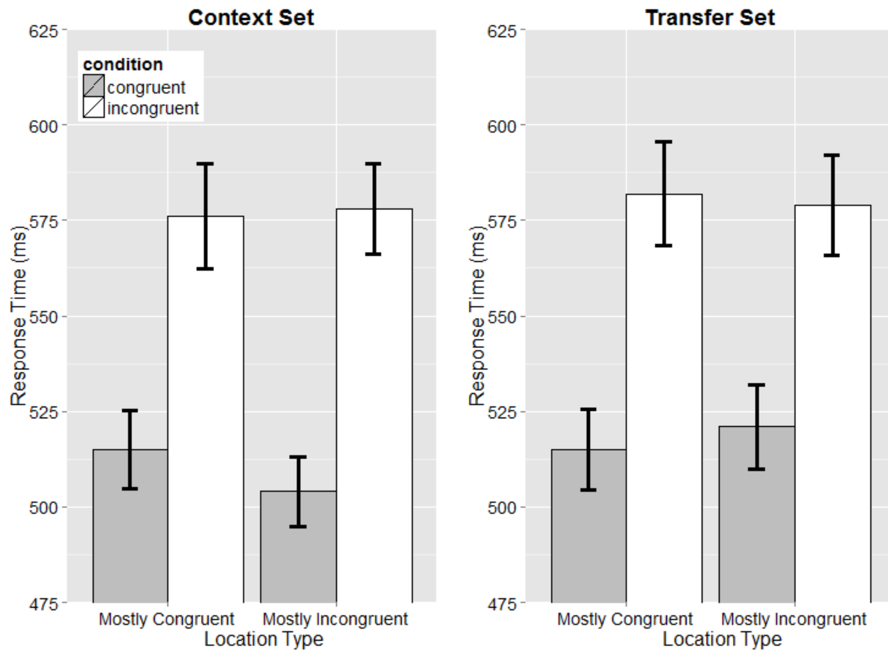


Figure 4. Mean color-naming response latencies with 95% confidence intervals from the direct replication of the context level transfer manipulation in Experiment 1B.

To assess the individual contributions of context and transfer stimuli, two separate 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVAs were conducted for context and transfer sets. Again, congruent trials were faster than incongruent trials for both the context, F(1, 31) = 109.84, $\eta^2$= 0.779 and transfer set, F(1, 31) = 99.18, $\eta^2$= 0.761. No other effects were significant, all Fs < 2. Consistent with the results of Experiment 1A, no CSPC effect or CSPC transfer effect was observed.

To test whether the CSPC effect and CSPC transfer effect are present during the second half of the experiment, all remaining correct trials were analyzed in a 2 Learning

Half (first half, second half) X 2 Set Type (context, transfer) X 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA. The size of the congruency effect was smaller during the second half of the experiment for the context but not transfer set, $F(1, 31) = 7.92$, $\eta^2 = 0.203$. In addition, the context set was faster during the second half of the experiment, $F(1,31) = 9.46$, $\eta^2 = 0.233$. However, there was no evidence for a CSPC effect in either half of the experiment, $Fs < 1.5$.

To assess whether the CSPC effect emerged over the course of the experiment for the context and transfer set, two separate 2 Learning Half (first half, second half) X 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVAs were conducted for the context and transfer sets. For the context set, congruent trials were faster than incongruent trials, $F(1,31) = 109.41$, $\eta^2 = 0.779$, stimuli at the mostly congruent location were responded to faster during the second half of the experiment, $F(1,31) = 6.02$, $\eta^2 = 0.162$, and congruent trials were responded to faster for the first half of the experiment, $F(1,31) = 5.63$, $\eta^2 = 0.153$. For the transfer set, congruent trials were faster than incongruent trials, $F(1,31) = 98.42$, $\eta^2 = 0.760$, and stimuli at the mostly congruent location were responded to faster during the second half of the experiment, $F(1,31) = 4.42$, $\eta^2 = 0.124$. Importantly, the three-way interaction between Learning Half, Location Type, and Congruency did not reach significance for either set, $Fs < 1.5$. When separating the experiment as a function of learning half, there is no evidence for a CSPC effect or CSPC transfer effect.

In Crump and Milliken (2009), the congruent and incongruent trials were faster (488 ms and 564 ms, respectively) than in the current experiment (516 ms and 579 ms).

It is unclear why RTs would be higher in this case, although there does not appear to be a speed-accuracy trade-off as participants in the current study were no more accurate than those in the original study.

If individual differences are driving the absence of the CPSC and CSPC transfer effects, individuals that demonstrate the CSPC effect should also show a CSPC transfer effect. Out of the 32 participants in the current study, 13 demonstrated a numerical CSPC effect in the context set. Of these 13 participants, less than half (6) demonstrated the CSPC effect for the transfer set. To assess the relationship between the CSPC effect in context and transfer sets within individuals statistically, a Pearson's correlation was calculated for CSPC and CSPC transfer effects across participants. As seen in Figure 3, across participants there was no relationship between the presence of a CSPC effect and the presence of a CSPC transfer effect, $r = -0.067$, $p > 0.7$.

As in Experiment 1A, because there is no evidence that participants are implementing different control settings at each location, I do not report the analysis of conflict adaptation effects.

*Accuracy*

The overall accuracy rate was over 98%. Due to the low error rate, statistical analysis on error rates is not presented. However, the results are presented in Table 6.

**Discussion**

Using an identical experimental design as Crump & Milliken (2009), I find no evidence for a CSPC effect or CSPC transfer effect. Across the first two experiments, it seems that the inclusion of a transfer set prevents participants from implementing multiple control settings. That is, the size of the congruency effect is equivalent for mostly congruent and mostly incongruent locations. In the prior two experiments, the context and transfer sets were introduced at the start of the experiment. In the following experiment, I ask what happens if the transfer set is introduced after there is evidence that multiple control settings have been implemented?

Table 6. Accuracy rate for context and transfer stimuli as a function of learning half in Experiment 1B.

Context Items

| First Half | | | Second Half | | |
|---|---|---|---|---|---|
| | Condition | | | Condition | |
| Location Type | congruent | incongruent | Location Type | congruent | incongruent |
| mostly congruent | 0.99 | 0.98 | mostly congruent | 0.99 | 0.96 |
| mostly incongruent | 1.00 | 0.98 | mostly incongruent | 0.99 | 0.98 |

Transfer Items

| First Half | | | Second Half | | |
|---|---|---|---|---|---|
| | Condition | | | Condition | |
| Location Type | congruent | incongruent | Location Type | congruent | incongruent |
| mostly congruent | 0.99 | 0.97 | mostly congruent | 0.99 | 0.96 |
| mostly incongruent | 0.99 | 0.98 | mostly incongruent | 0.98 | 0.96 |

## EXPERIMENT 1C

In the current experiment, I begin with a standard context level manipulation previously shown across multiple studies to induce variations in the size of the congruency effect across locations (Crump et al., 2006; Heinemann et al., 2009; King et al., 2012). After exposing participants to a list containing only a context set, I introduce a transfer set.

### Method

*Participants*

Sixteen participants (9 female, *M* = 19.07 years, *SD* = 1.49) were recruited from the Georgia Institute of Technology undergraduate population and received course credit for their participation.

*Materials and Stimuli*

The stimulus presentation was identical to that described in Experiment 1A with one exception. Because of the high accuracy observed across the first two experiments, voice onset time was recorded but errors and voice key errors were not collected[1].

On every trial, a color-word (prime) was briefly presented, followed by a to-be-named color patch (probe). There were 6 color-word primes (BLUE, GREEN, ORANGE, PINK, RED, and YELLOW) along with their corresponding color-patch probes (blue, green, orange, pink, red, and yellow). Primes were approximately 1.6° in height and 4.9° in width presented at fixation in Times New Roman font in white against a black background. Color patches consisted of colored rectangles 1.6° in height and 5.2° in width appearing either 5.68° above or below fixation.

In each experimental block, stimuli were separated into two prime/probe sets. For each participant, one set was designated as the context set and contained four prime/probes (e.g. Blue, Green, Orange, Pink) and one set was designated as the transfer set and contained two prime/probes (e.g. Red, Yellow). The composition of sets was counterbalanced across participants so that each prime/probe combination appeared in the context set and transfer set for an equivalent number of participants. In the context set, color patches were equally likely to appear above or below fixation, however at one location (mostly congruent) color patches were likely be congruent and at the other location (mostly incongruent) they were likely be incongruent. In the transfer set, color patches were equally likely to appear at either location and were equally likely to be congruent or incongruent. Mostly congruent and mostly incongruent locations were counterbalanced across participants.

Participants performed six blocks consisting of 96 trials each. The first four blocks of trials were considered training blocks and consisted only of stimuli from the context set. Stimuli presented at the mostly congruent location consisted of color patches with their corresponding word on nine trials and with the remaining three members of the set on one trial each. Stimuli presented at the mostly incongruent location consisted of color patches with their corresponding word on three trials and with the remaining three members of the set on three trials each.

The final two blocks were considered test blocks and consisted of stimuli from both the context and transfer set. During the training blocks, stimuli from the context set at the mostly incongruent location consisted of color patches presented in the three other members of the set on five trials each. In contrast, stimuli from the context set at the mostly congruent location consisted of color patches presented with their corresponding words on 15 trials each. Stimuli from the transfer set consisted of color patches presented with their corresponding words on nine trials and with the remaining member of the set on nine trials. During the test blocks, stimuli from the context and transfer sets were randomly mixed across trials. See Table 7 for a representative stimulus list.

Participants completed 12 practice trials consisting of one congruent trial and one incongruent trial for each of the six color patches. Participants performed six blocks of 96 trials for a total of 576 trials.

*Procedure*

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

Table 7. Representative stimulus list for the context level introduction manipulation in Experiment 1C.

| Blocks 1-4 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Color** | | | | | |
| **Location Type** | **Probe Type** | **Word** | RED | YELLOW | ORANGE | PINK | BLUE | GREEN |
| **Mostly Congruent** | Context | red | 36 | 4 | 4 | 4 | | |
| | | yellow | 4 | 36 | 4 | 4 | | |
| | | orange | 4 | 4 | 36 | 4 | | |
| | | pink | 4 | 4 | 4 | 36 | | |
| | Transfer | blue | | | | | | |
| | | green | | | | | | |
| **Mostly Incongruent** | Context | red | 12 | 12 | 12 | 12 | | |
| | | yellow | 12 | 12 | 12 | 12 | | |
| | | orange | 12 | 12 | 12 | 12 | | |
| | | pink | 12 | 12 | 12 | 12 | | |
| | Transfer | blue | | | | | | |
| | | green | | | | | | |

| Blocks 5-6 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Color** | | | | | |
| **Location Type** | **ProbeType** | **Word** | RED | YELLOW | ORANGE | PINK | BLUE | GREEN |
| **Mostly Congruent** | Context | red | 15 | | | | | |
| | | yellow | | 15 | | | | |
| | | orange | | | 15 | | | |
| | | pink | | | | 15 | | |
| | Transfer | blue | | | | | 9 | 9 |
| | | green | | | | | 9 | 9 |
| **Mostly Incongruent** | Context | red | | 5 | 5 | 5 | | |
| | | yellow | 5 | | 5 | 5 | | |
| | | orange | 5 | 5 | | 5 | | |
| | | pink | 5 | 5 | 5 | | | |
| | Transfer | blue | | | | | 9 | 9 |
| | | green | | | | | 9 | 9 |

## Results

An alpha level of 0.05 was used for all reported results. Prior to all analyses, RTs less than 200 ms and RTs greater than 1500 ms were excluded. This lead to the exclusion of less than 1.9% of all trials.

*Response Time*

Stimuli from the training blocks (blocks 1 through 4) were analyzed in a 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA. As seen in Figure 5, congruent trials were faster than incongruent trials, $F(1, 15) = 93.51$, $\eta^2 = 0.861$, and the size of the congruency effect was reduced at mostly incongruent relative to mostly congruent trials, $F(1,15) = 6.07$, $\eta^2 = 0.289$. Thus, within four training blocks, participants were demonstrating a significant CSPC effect in the absence of transfer stimuli.

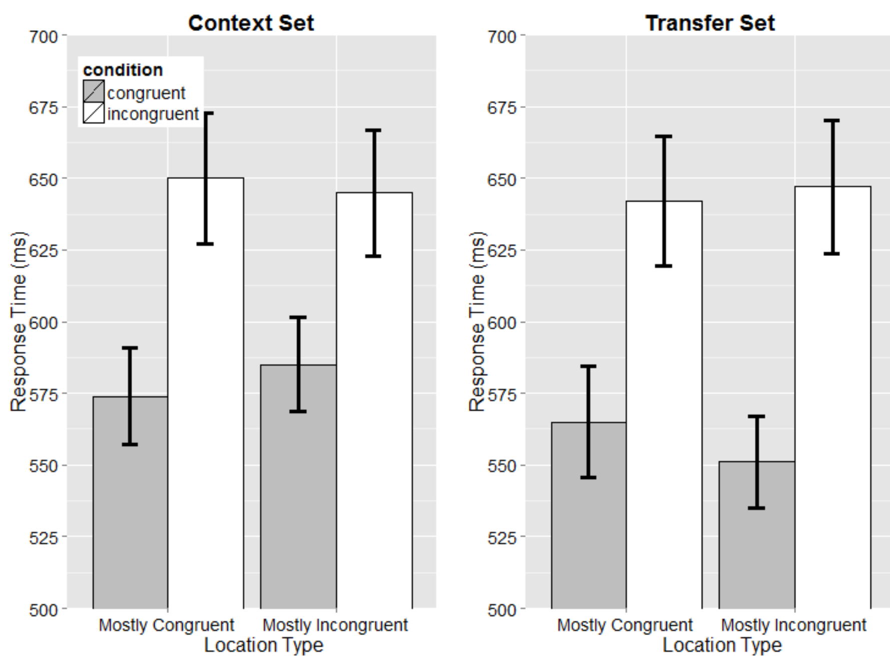


Figure 5. Mean color-naming response latencies with 95% confidence intervals from the context level introduction manipulation in Experiment 1C. On the left, the CSPC effect during training blocks. On the right, the CSPC effect for the transfer set during blocks test blocks.

To assess whether the CSPC transfer effect was present during test blocks, data from the transfer set (blocks five and six) were analyzed in a 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA. As expected, congruent trials were faster than incongruent trials, F(1,15) = 62.611, $\eta^2$= 0.807, however, unlike the results from training, the size of the congruency effect did not vary as a function of location. In fact, though not statistically significant, the CSPC effect was in the wrong numerical direction (-19 ms). Despite evidence for a CSPC effect during training, no CSPC transfer effect was observed in test blocks.

To confirm that the CSPC transfer effect was not present early in the test blocks, the data were analyzed in two separate 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVAs for blocks five and six. Note, both blocks five and six were necessary for a counterbalance. Therefore, there was some variability in the proportion of congruent and incongruent trials at each location type across participants. However, the size of the congruency effect did not differ across locations for either the first or second blocks of trials. The results of this analysis reveals that the CSPC effect goes away within the first 96 trials in which transfer stimuli were introduced.

Out of 16 participants, 13 participants showed the CSPC effect during training blocks. Out of these 13 participants, six showed a positive CSPC transfer effect during test. A Pearson's correlation for context and transfer effects yielded a significant effect, r = 0.656. However, as can be seen in Figure 3, a single outlier with large negative CSPC effect for the transfer set is driving this correlation. When excluding this participant, the correlation changes to non-significant, 0.334. Again, there was no observable relationship between the occurrence of context and transfer effects in this sample of participants.

## Discussion

In the current experiment, participants were given an opportunity to instantiate different control settings. There was evidence that stimuli at each location were being treated differently because a CSPC effect was observed during training. However, within one block of introducing the transfer set, this effect disappears. This result is difficult to reconcile with the existing literature. Variations in the proportion of congruent and incongruent trials should have been sufficient to observe variations in the size of the congruency effect in the presence of transfer stimuli.

## SUMMARY OF CONTEXT LEVEL TRANSFER MANIPULATION RESULTS

In Experiment 1A, I attempted a conceptual replication of the context level transfer manipulation that increased the overall number of stimuli in the response set. I found that performance was similar at a location containing a high proportion of congruent trials relative to a location containing a low proportion of congruent trials. In Experiment 1B, I attempted a direct replication of the context level transfer manipulation. Again, performance was similar at each location type. Finally, in Experiment 1C, I induced a CSPC effect using only a context set during the first part of the experiment. However, this effect vanished once a transfer set was introduced. In sum, across three experiments there is no evidence supporting the results of previous context level transfer manipulations (Crump & Milliken, 2009). In contrast, I have shown that when transfer stimuli are included, participants do not treat stimuli at each location differently.

From a theoretical perspective, the absence of a CSPC effect in a context level transfer manipulation suggests these effects are delicate and sensitive to subtle variations in stimulus experience. Though these results were unexpected given the prior demonstration of a CSPC transfer effect, they are entirely consistent with the notion that participants are sensitive to the consistency in the informativeness of stimulus dimensions (Hutcheon & Spieler, 2014). For example, in a typical CSPC manipulation, all color patches appearing at the mostly incongruent location are incongruent with the same probability. Similarly, all color patches appearing at the mostly congruent location are incongruent with the same probability. Though these probabilities are different across locations, they are consistent within locations. When transfer stimuli are added, this consistency is disrupted. Now, all color patches appearing at the mostly incongruent location are no longer incongruent with the same probability and color patches appearing at the mostly congruent location are no longer incongruent with the same probability. In this case, a control setting at each location is not instantiated because participants are not treating stimuli at that location as similar.

After finding no evidence for the CSPC transfer effect across three separate experiments, I turn to a standard CSPC manipulation. The inclusion of a transfer set was one way to assess whether different control settings were operational. An alternative method is to look for conflict adaptation within and between locations. Previous studies have not included stimulus sets that were sufficiently large to estimate conflict adaptation within a CSPC manipulation. Therefore, the current experiment represents a conceptual replication of the CSPC effect with an increased stimulus-set.

# CHAPTER 3

# EXPERIMENT 2

In this experiment, I expand the number of stimuli in the context level manipulation from four to six, which allows for the estimation of conflict adaptation effects across and within locations in the absence of stimulus-response repetitions.

## Method

### *Participants*

Thirty-two participants (16 female, M=20.43 years, SD=3.27) were recruited from the Georgia Institute of Technology undergraduate population and received course credit for their participation.

### *Materials and Stimuli*

The presentation was identical to that reported in Experiment 1A. On every trial, a color-word (prime) was briefly presented, followed by a to-be-named color patch (probe). There were six color-word primes (BLUE, GREEN, ORANGE, PINK, RED, and YELLOW) along with their corresponding color-patch probes (blue, green, orange, pink, red, and yellow). Primes were approximately 1.6° in height and 4.9° in width presented at fixation in Times New Roman font in white against a black background. Color patches consisted of colored rectangles 1.6° in height and 5.2° in width appearing either 5.68° above or below fixation.

In this experiment there was no transfer set. In each experimental block, stimuli were equally likely to appear at either location but one of the two locations was associated with a high proportion of congruent trials (mostly congruent location) and the other location was associated with a high proportion of incongruent trials (mostly incongruent location). Location was counterbalanced across participants so that the mostly congruent location occurred at the top of the screen for half of the participants and at the bottom of the screen for half of the participants. Color patches presented at the mostly congruent location appeared with their corresponding word on 15 trials and in the remaining three words on one trial each. Color patches presented at the mostly incongruent location appeared in their corresponding word on three trials and in the remaining three words on three trials each. See Table 8 for a representative experimental block.

Table 8. Representative block of trials for the context level manipulation in Experiments 2 and 3.

| | | Color | | | | | |
|---|---|---|---|---|---|---|---|
| Location Type | Word | blue | green | orange | pink | red | yellow |
| **Mostly Congruent** | | | | | | | |
| | BLUE | 15 | 1 | 1 | 1 | 1 | 1 |
| | GREEN | 1 | 15 | 1 | 1 | 1 | 1 |
| | ORANGE | 1 | 1 | 15 | 1 | 1 | 1 |
| | PINK | 1 | 1 | 1 | 15 | 1 | 1 |
| | RED | 1 | 1 | 1 | 1 | 15 | 1 |
| | YELLOW | 1 | 1 | 1 | 1 | 1 | 15 |
| **Mostly Incongruent** | | | | | | | |
| | BLUE | 5 | 3 | 3 | 3 | 3 | 3 |
| | GREEN | 3 | 5 | 3 | 3 | 3 | 3 |
| | ORANGE | 3 | 3 | 5 | 3 | 3 | 3 |
| | PINK | 3 | 3 | 3 | 5 | 3 | 3 |
| | RED | 3 | 3 | 3 | 3 | 5 | 3 |
| | YELLOW | 3 | 3 | 3 | 3 | 3 | 5 |

Participants completed 18 practice trials. A fully counterbalanced block required 240 trials. Participants performed three blocks for a total of 720 trials. To make the task more manageable for participants, a rest was given after every 120 trials.

*Procedure*

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

**Results**

An alpha level of 0.05 was used for all results. Prior to all analyses, voice key errors, RTs less than 200 ms and RTs greater than 2500 ms were excluded. This procedure resulted in the exclusion of less than 1.2% of all trials.

*CSPC Effect*

All remaining correct trials were analyzed in a 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA. As seen in Figure 6, congruent trials were faster than incongruent trials, $F(1, 31) = 133.22$, $\eta^2 = 0.811$, and the size of the congruency effect and was reduced at mostly incongruent relative to mostly congruent locations, $F(1, 31) = 4.41$, $\eta^2 = 0.124$. The finding of a CSPC effect is consistent with the results of the training blocks in Experiment 1C as well as previous reports in the literature (Crump et al., 2006; King et al., 2012). This finding suggests that participants use control settings tied to each location.

*Conflict Adaptation*

Having demonstrated the CSPC effect in a large stimulus set, I now turn to the analysis of conflict adaptation effects. For this analysis, I also excluded trials in which the previous prime overlapped with the current prime and trials in which the previous probe overlapped with the current probe. This was done to exclude simple stimulus-response learning effects that can artificially produce conflict adaptation effects (Kerns et al., 2004; Mayr & Awh, 2009; Mayr et al., 2003). This additional trimming procedure resulted in the removal of 31% of the remaining trials.

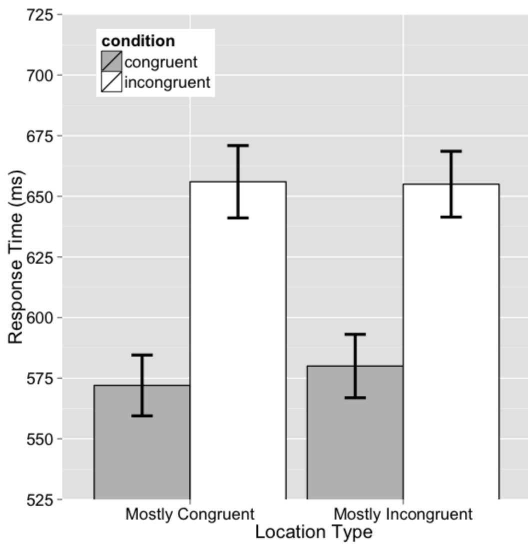


Figure 6. Mean color-naming response latencies with 95% confidence intervals from the context level manipulation in Experiment 2.

Following the trimming, all trials were entered into a 2 Location Transition (location repeat, location switch) X 2 Previous Condition (congruent, incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA. Congruent trials were faster than incongruent trials, F(1,31) = 133.65, $\eta^2$= 0.811, and trials following congruent trials were faster than trials following incongruent trials, F(1,31) = 8.67, $\eta^2$= 0.218. In addition, the size of the congruency effect was smaller following incongruent relative to congruent trials, F(1, 31) = 7.22, $\eta^2$= 0.188. Importantly, as seen in Figure 7, the reduction in the size of the congruency effect was present when the location repeated but absent when the location switched, F(1, 31) = 5.481, $\eta^2$= 0.150. Consistent with the maintenance of multiple control settings tied to each location, individuals appear to treat stimuli at each location as different. Information learned at one location generalized to stimuli at that location but not to stimuli at the other location.

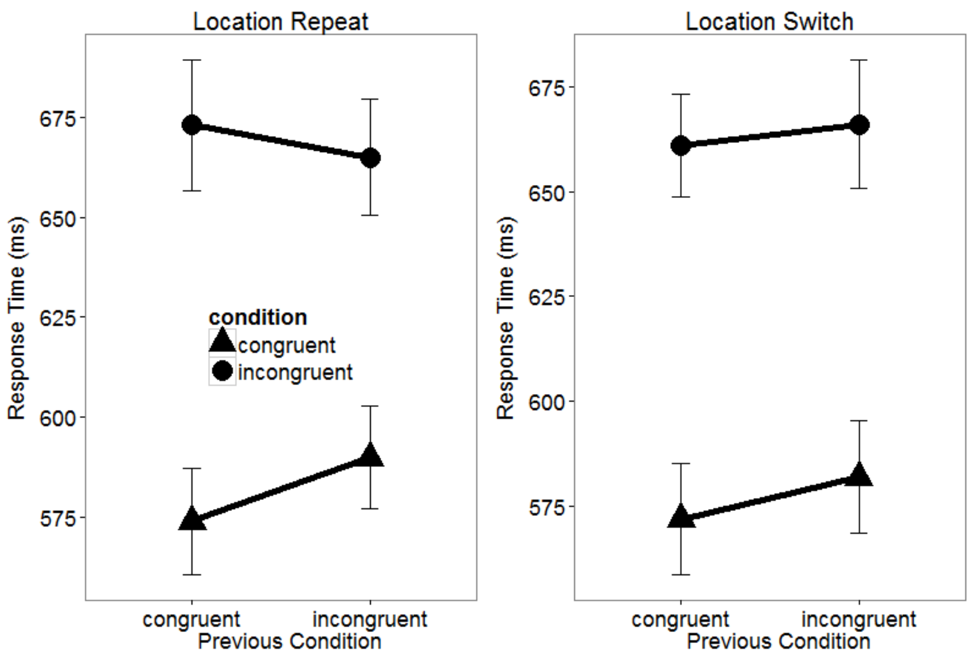


Figure 7. Conflict Adaptation effect with 95% confidence intervals when the location repeats (left) and switches (right) from the context level manipulation in Experiment 2.

*Accuracy*

Overall, accuracy rate was over 97.5%. Due to the low error rate, statistical analyses on error rates are not reported. However, the results are presented in Table 9.

Table 9. Accuracy rate in Experiment 2.

| | Condition | |
|---|---|---|
| Location Type | congruent | incongruent |
| mostly congruent | 0.99 | 0.97 |
| mostly incongruent | 0.99 | 0.97 |

## Discussion

In the current experiment, a CSPC effect was observed. Further, prior trial condition influenced performance when the location repeated but not when the location switched. Specifically, when location repeated from trial N to trial N+1, the size of the congruency effect was smaller on trials following an incongruent relative to a congruent trial. This finding of a conflict adaptation effect sensitive to stimulus location suggests that participants treat the two locations as separate sources of information and is consistent with the predictions of both stimulus-driven control and item level control accounts. Having found evidence for multiple control settings, I now investigate whether these control settings are transient or durable.

Models of item level control include a conflict monitoring module that serves to strengthen or weaken control along the various stimulus dimensions (Blais et al., 2007). In contrast, the stimulus-driven control account explains ISPC and CSPC effects in terms of an episodic learning process (Bugg, 2012; Bugg & Crump, 2012; Crump et al., 2006; Crump et al., 2008). Information about a trial is encoded into a single memory representation (Logan, 1988; Hommel, 2004) and when a similar stimulus is encountered in the future, previously stored representations are retrieved and influence performance. In addition to information about stimulus dimensions and responses (Hutcheon & Spieler, submitted), these stored representations include all generalizable aspects of processing (Kolers & Roediger, 1984; Jacoby & Brooks, 1984), including control settings active at the time of encoding (Crump & Milliken, 2009; Crump et al., 2008).

# CHAPTER 4

# EXPERIMENT 3

To differentiate between these two competing explanations, in the current experiment I implemented the same experimental design as in Experiment 2, however I varied the time between trials from relatively short (550 ms) to relatively long (4250 ms). The influence of conflict on processing has been shown to be relatively transient (Egner et al., 2010). When the time between the occurrence of conflict and the current stimulus is relatively short (<2,000 ms) conflict adaptation is present, but when the time is relatively long (>2,000 ms) conflict adaptation is absent. If the CSPC effect and conflict adaptation effects found in Experiment 2 are supported by a conflict monitoring mechanism, then within location conflict adaptation effects should be absent at relatively long intervals. In contrast, if the CSPC effect is supported by a process of episodic learning, the manipulation of time between trials should have no effect.

## Method

### *Participants*

Thirty-two participants (17 females, M=20.19 years, SD= 2.88) were recruited from the Georgia Institute of Technology undergraduate population and received course credit for their participation.

### *Materials and Stimuli*

Stimulus presentation was identical to that reported in Experiment 1A. The stimuli were identical to those described in Experiment 2. However, RSIs varied randomly between 550, 2400, and 4250 ms. Each RSI occurred with equal frequency and preceded each trial condition on an equal proportion of trials.

*Procedure*

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

**Results**

An alpha level of 0.05 was used for all results. Prior to all analyses, voice key errors, RTs less than 200 ms and RTs greater than 2500 ms were excluded. This procedure resulted in the removal of less than 2.1% of all trials.

*CSPC Effect*

All remaining correct trials were entered into a 3 RSI (550, 2400, 4250) X 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA. Consistent with the results of Experiment 2, congruent trials were faster than incongruent trials, $F(1,31) = 163.68$, $\eta^2 = 0.841$, and the size of the congruency effect was smaller at mostly incongruent compared to mostly congruent locations, $F(1,31) = 8.06$, $\eta^2 = 0.206$. Thus, in a context level manipulation in which RSIs varied, a CSPC effect was observed. No other effects were significant.

To further assess the influence of RSIs, the data were broken into three separate 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVAs corresponding to each of the three RSIs. For RSIs of 550, congruent trials were faster than incongruent trials, $F(1,31) = 104.45$, $\eta^2 = 0.768$, and the size of the congruency effect was smaller at mostly incongruent relative to mostly congruent locations, $F(1,31) = 5.75$, $\eta^2 = 0.157$. For RSIs of 2400, congruent trials were faster than incongruent trials, $F(1,31) = 116.58$, $\eta^2 = 0.789$, and while the size of the congruency effect was numerically smaller at mostly incongruent relative to mostly congruent locations (92 ms vs. 84 ms), this effect did not reach significance, $F < 1$. For

RSIs of 4250, congruent trials were faster than incongruent trials, $F(1,31) = 154.64$, $\eta^2 = 0.833$, and the size of the congruency effect was smaller at mostly incongruent relative to mostly congruent locations, $F(1,31) = 4.63$, $\eta^2 = 0.129$. As seen in Figure 8, the CSPC effect was present at relatively short and relatively long RSIs, but not at medium RSIs.

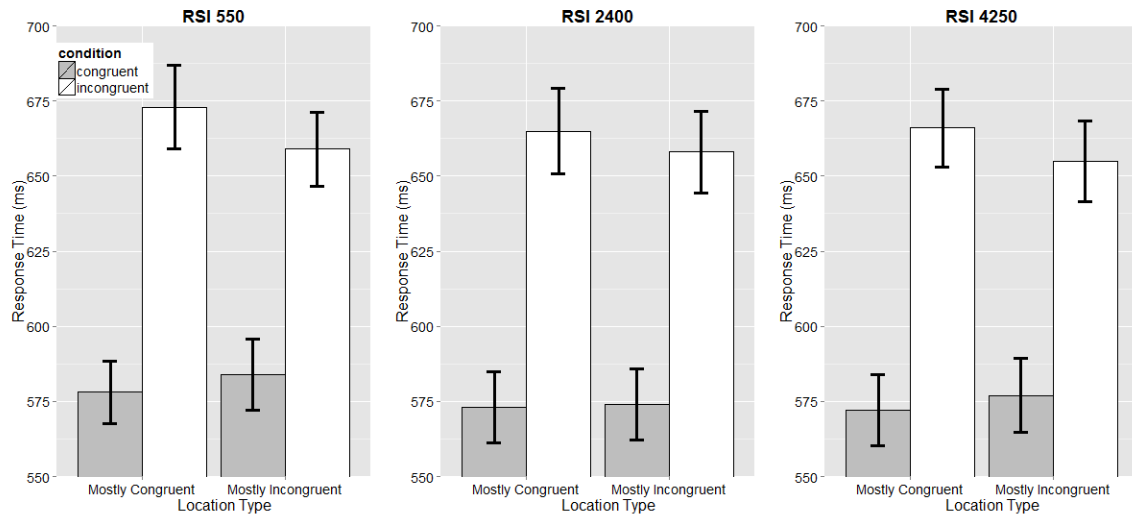


Figure 8. Mean color-naming response latencies with 95% confidence intervals across the three RSIs from the context level manipulation in Experiment 3.

*Conflict Adaptation*

For this analysis, I also excluded trials in which the previous prime overlapped with the current prime and when the previous probe overlapped with the current probe. Again, this was done to avoid observing simple stimulus-response learning effects that can artificially inflate conflict adaptation effects (Kerns et al., 2004; Mayr et al., 2003; Mayr & Awh, 2009). This procedure resulted in removal of 29% of the remaining trials. To assess conflict adaptation within and across locations, data were analyzed in a 3 RSI (550, 2400, 4250) X 2 Location Transition (location switch, location repeat) X 2 Previous Condition (congruent, incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA. Again, congruent trials were faster than incongruent trials, F(1,31) =

137.64, $\eta^2$= 0.816, and the previous condition influenced current trial performance (1, 31) = 7.33, $\eta^2$= 0.191. Additionally, the four-way interaction was observed indicating that conflict adaptation within and across locations depended on RSIs, F(1,32) = 3.63, $\eta^2$= 0.105. No other effects were significant.

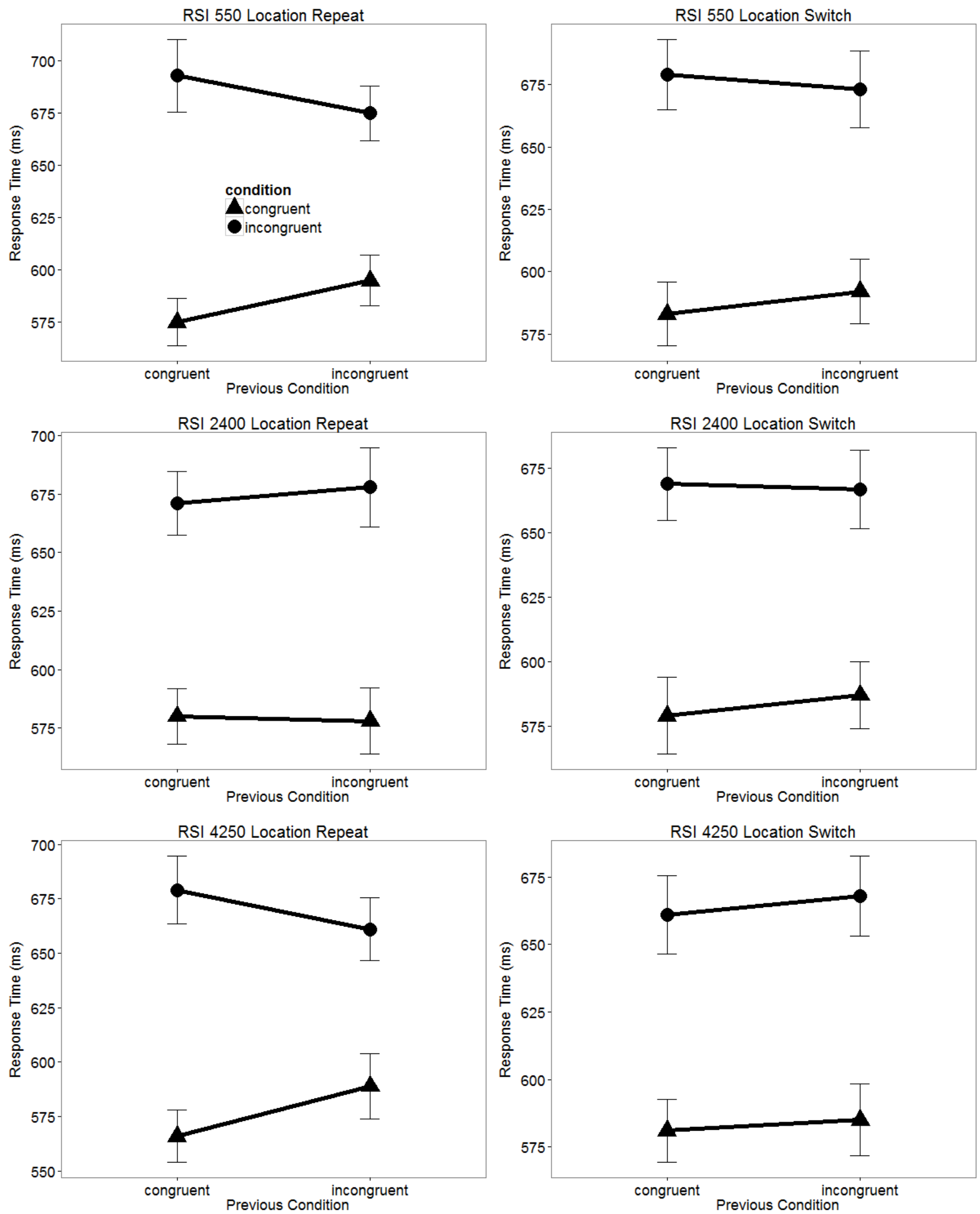


Figure 9. Conflict Adaptation effects with 95% confidence intervals when the location repeats (left) and switches (right) at each RSI in Experiment 2.

To explore this four-way interaction, three separate 2 Location Transition (location switch, location repeat) X 2 Previous Condition (congruent, incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVAs were performed for each RSI. Congruent trials were faster than incongruent trials at all three RSIs, F(1,31) = 109.55, $\eta^2$= 0.779 for RSIs of 550, F(1,31) = 83.82, $\eta^2$= 0.730 for RSIs of 2400, and F(1,31) = 120.83, $\eta^2$= 0.795 for RSIs of 4250. As seen in Figure 9, the size of the congruency effect was significantly reduced following incongruent trials at RSIs of 550, F(1,31) = 16.01, $\eta^2$= 0.341. However, the reduction in the size of the congruency effect following incongruent trials did not depend on location repetition. Therefore, at RSIs of 550, conflict adaptation was observed when locations switched and when locations repeated. In contrast, at RSIs of 4250, the reduction in the size of the congruency effect was present when location matched but absent when location switched, F(1,31) = 7.72, $\eta^2$= 0.199. No additional effects were significant for RSIs 2400.

**Discussion**

In the current experiment, I found that the CSPC effect is observed at both relatively long and relatively short RSIs. At medium RSIs, there was a numerical CSPC effect but this did not reach significance. This represents the first demonstration that stimulus experience influencing the CSPC effect is relatively long lasting. The durability of this effect over time is more consistent with an episodic learning account than an item level account based on the workings of conflict monitoring that must be continually updated by conflict. If the CSPC effect were driven by relatively transient conflict information, then we would expect to find no CSPC effect at RSIs that have previously been shown to be sufficient to remove this effect. In the current experiment, even at RSIs of 4250, which are sufficiently long for the influence of conflict to dissipate (Egner et al., 2010), a CSPC effect is observed.

The CSPC findings are consistent with the results of the conflict adaptation analysis. At short RSIs, conflict adaptation was general. An incongruent trial reduced the size of the congruency effect on the next trial regardless of whether the location switched or repeated. At medium RSIs, the size of the congruency effect was not influenced by the previous trial condition. At long RSIs, the size of the congruency effect was reduced only when the location repeated. As expected, for RSIs demonstrating a CSPC effect (long and short), conflict adaptation was observed when locations repeated. For RSIs that did not demonstrate a CSPC effect (medium), conflict adaptation was not observed when locations repeated. The lack of a CSPC effect at medium RSIs is somewhat unexpected given that an effect is observed at long RSIs. One explanation for this is that RSIs of 2400 ms are the only situation in which there is uncertainty as to when the upcoming trial will occur.

In summary, the results of the current experiment generally support theories of stimulus-driven control whereby durable changes to underlying episodic memory drive variations in control performance. In the final experiment, I investigate whether the condition in which features of the stimulus most recently appeared influenced current trial performance.

# CHAPTER 5

# EXPERIMENT 4

The results of Experiment 3 suggest that the learning that occurs within context level manipulations is relatively durable. When there is a long time between the occurrence of conflict and the next trial, both a CSPC effect and a within location conflict adaptation effect are observed. The following experiment tests whether control settings are maintained proactively in parallel over the course of an experiment that are void of specific stimulus information or they are reactively triggered by the occurrence of the specific stimulus. To test this, I used a stimulus list consisting of pictures and names of common objects. While this represents a departure from typical context level manipulations, a similar paradigm has been shown to produce an ISPC effect (Bugg & Hutchison, 2013).

If control settings are constantly maintained in parallel over the course of an experiment and are void of stimulus information, the condition in which a word most recently appeared should not influence performance. In contrast, if control settings are triggered by the occurrence of a specific stimulus, and carry stimulus-specific information, the condition in which the word most recently appeared should influence performance.

## Method

### *Participants*

Twenty-four participants (10 females, M=19.61 years, SD=1.32) were recruited from the Georgia Institute of Technology undergraduate population and received course credit for their participation. One participant was excluded due to an error rate of over 30%. In total, the data from 23 participants were analyzed.

*Materials and Stimuli*

The presentation of stimuli was identical to that of Experiment 1A. Stimuli consisted of line drawings with words embedded in the center used in studies by Waszak, Hommel, and Allport (2003) (see Figure 10 for stimulus examples). Waszak et al (2003) used a total of 108 pictures and names that were selected for their high imageability, high frequency, and high semantic overlap (La Heij, 1988; Lupker, 1979). Line drawings were obtained from Snodgrass and Vanderwart's (1980) picture-naming norming data. In total, 48 picture-word pairs from the set used in Waszak et al (2003) were selected for the current experiment[2]. A full list of the stimuli used is presented in appendix A.

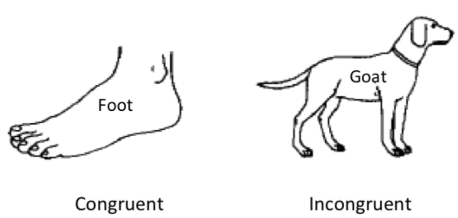


Figure 10. Example of a congruent and incongruent stimulus used in Experiment 4.

Just as in a typical context level manipulation, stimuli were equally likely to occur either above or below fixation, but at one location these trials were likely to be congruent (mostly congruent) and at the other they were likely to be incongruent (mostly incongruent). Mostly congruent and mostly incongruent locations were counterbalanced across participants. In a single block of trials, context stimuli at the mostly congruent location consisted of each picture paired with the matching label on three trials with a non-matching label on one trial. In contrast, context stimuli at the mostly incongruent location consisted of each picture paired with the matching label on one trial and with a non-matching label on three trials.

*Procedure*

Participants were instructed to ignore the word and name the picture as quickly as possible while maintaining a high degree of accuracy. The following sequence of events occurred on each trial: a) a fixation cross was presented in the center of the screen for 1000 ms b) a blank screen appeared for 250 ms, c) the picture-word stimulus was presented above or below fixation and remained on the screen until a vocal response was detected. Participants were tested individually while seated next to an experimenter who coded incorrect responses and voice key errors.

A counterbalance required a total of 96 trials. Participants performed four blocks for a total of 384 trials. The entire experimental session lasted approximately one hour.

**Results**

An alpha level of 0.05 was be used for all reported results. Prior to all analyses, voice key errors, RTs less than 200 ms and RTs greater than 2500 ms were excluded. This procedure resulted in the removal of less than 2.0% of all trials.

*Response Time*

The remaining data were analyzed in a 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA. Congruent trials were faster than incongruent trials, $F(1, 22) = 124.06$, $\eta^2 =$

0.849, but the size of the congruency effect did not differ by location F(1,22) = 1.308, $\eta^2$= 0.056. No other effects were significant. Thus, in a novel picture-word context level manipulation, a congruency effect was observed but there was no evidence of a CSPC effect.

To test whether the CSPC effect emerged over the course of the experiment, two separate 2 Location Type (mostly congruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVAs were performed for the first half and the second half of the experiment. Congruent trials were faster than incongruent trials during both the first half, F(1, 22) = 88.93, $\eta^2$= 0.801, and the second half of the experiment, F(1, 22) = 117.393, $\eta^2$= 0.842. No other effects were significant. Although the picture-word stimuli were sufficient to induce interference, participants did not appear to treat stimuli differently at the different locations.

*Conflict Adaptation Effects*

For the analysis of conflict adaptation effects, trials where the current stimulus overlapped with the previous stimulus on either the picture or word dimension were excluded (Kerns et al., 2004). This trimming procedure resulted in removal of 2% of the remaining trials.

All remaining trials were entered into a 2 Location Transition (location repeat, location switch) X 2 Previous Condition (congruent, incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA. As seen in Figure 11, congruent trials were faster than incongruent trials, F(1,22) = 138.36, $\eta^2$= 0.862, and the size of the congruency effect was smaller following incongruent relative to congruent trials, F(1, 22) = 7.23, $\eta^2$= 0.247, indicating a conflict adaptation effect. However, unlike the results of

Experiment 3, there was no effect of Location Transition, F < 1.  In other words, conflict adaptation occurred regardless of whether the location switched or repeated from trial N to trial N+1.

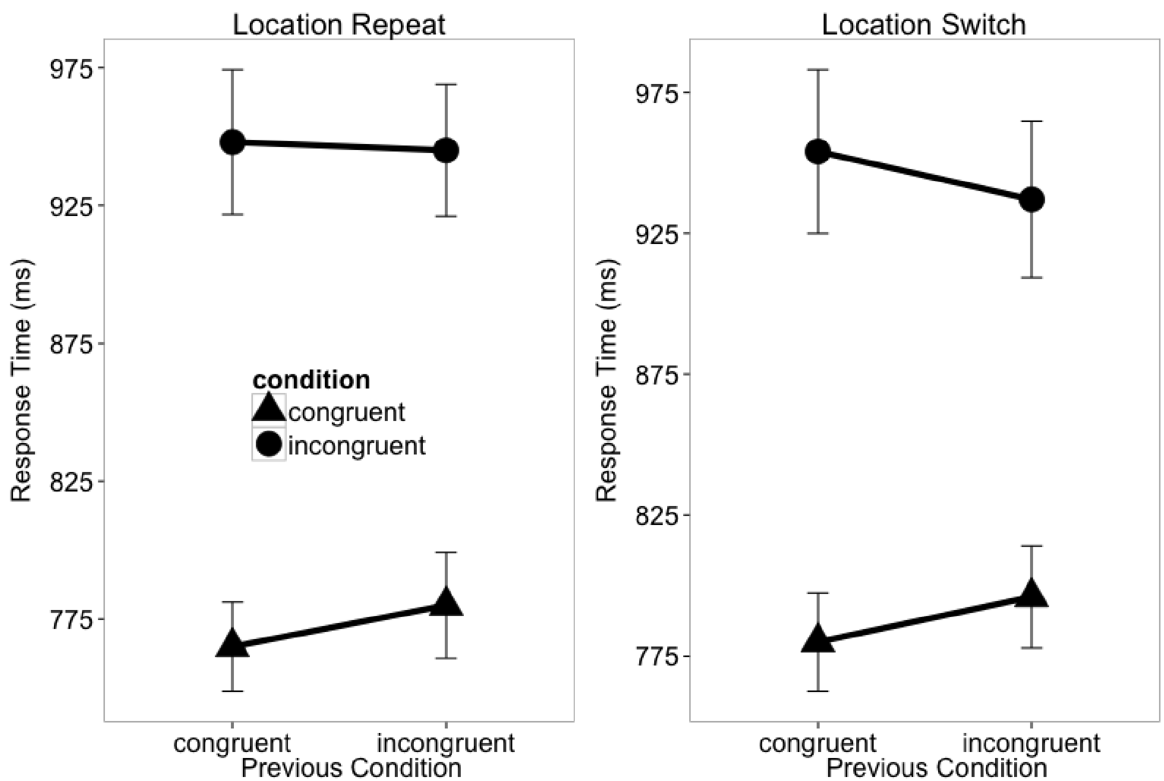


Figure 11.  Conflict Adaptation effects with 95% confidence intervals when the location repeats (left) and switches (right) in Experiment 4.

*Word-Specific Conflict Adaptation Effect*

In the conflict adaptation analysis, the location in which the previous trial occurred did not influence current trial performance.  Here, I assess the word-specific conflict adaptation effect.  That is, does the condition in which a word most recently appeared influence current trial performance even when there is a long interval between the current and previous occurrence of the word.  To test this, the same trials were analyzed as in the conflict adaptation analyses reported above.  These trials were submitted to a 2 Previous Word Match Condition (congruent, incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVA. As seen in Figure 12, congruent trials were faster than incongruent trials, F(1, 22) = 134.89, $\eta^2$= 0.859. Importantly, the size of the congruency effect was reduced for words in which the previous occurrence of that word was in an incongruent condition relative to if it was previously in a congruent condition, F(1,22) = 18.69, $\eta^2$= 0.459. Thus, in the current experiment, performance on the current trial is influenced by the condition in which the word last appeared. This is particularly interesting because it occurs over a long time course. The average lag between word repetitions was over 25 trials. This means that participants learn relatively detailed information about specific stimuli and apply this information when similar stimuli are encountered in the future.

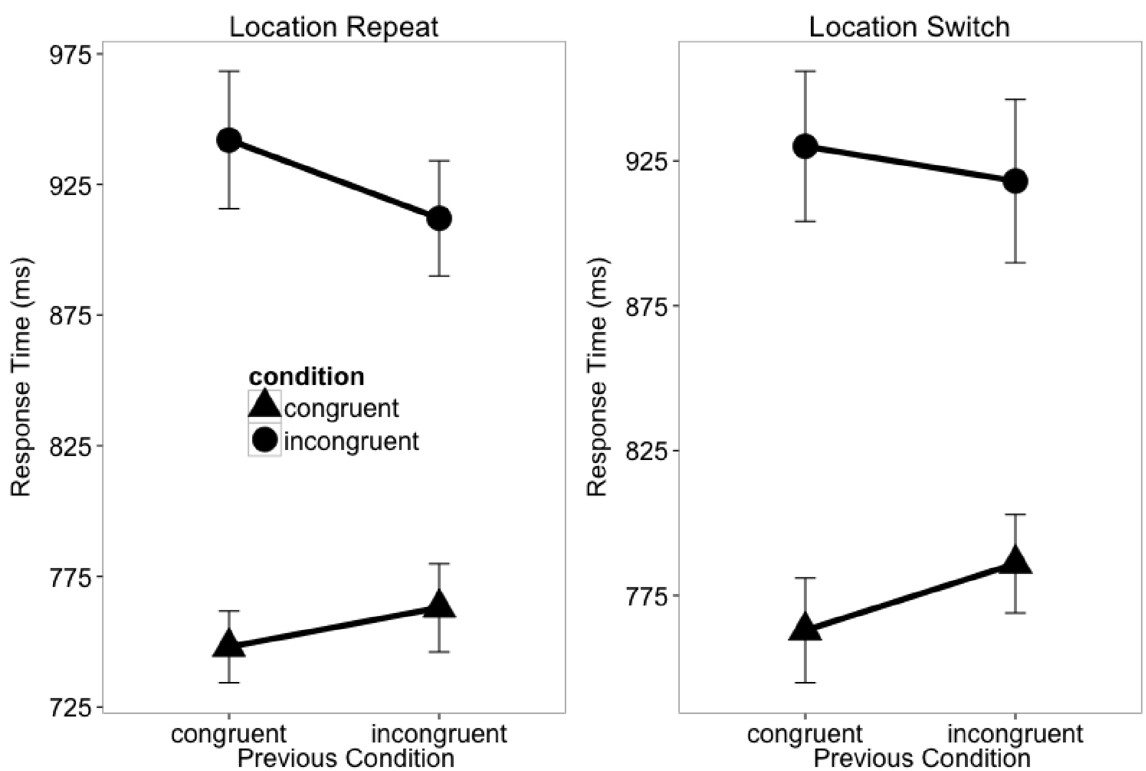


Figure 12. Word Adaptation effect as a function of Location Repetition (Experiment 4).

## Discussion

In a novel picture-word context level manipulation, I did not observe a CSPC effect. In this experiment, participants do not appear to use location as a relevant dimension by which to organize the task. Instead, participants use information about specific stimulus features to drive performance. In the word-specific conflict adaptation analysis, the size of the congruency effect is reduced as a function of the trial condition in which the word was most recently presented. When the picture previously occurred in an incongruent condition, the congruency effect is reduced relative to when the picture previously occurred in a congruent condition. This is taken as evidence that participants are encoding information about specific stimuli and that this information is relatively long lasting.

The absence of the CSPC effect hints at another way in which participants organize the task. In Experiments 1A through 1C, the use of stimuli that were differentially predictive of the upcoming condition at each location prevented the formation of control settings tied to each location. In the current experiment, the large number of different stimuli seems to prevent the formation of distinct control settings. It appears that increasing the variability in the stimuli encountered by participants across a number of dimensions may serve to block instantiation of multiple control settings.

# CHAPTER 6

# GENERAL DISCUSSION

The current set of experiments investigated the mechanisms underlying cognitive control in tasks of selective attention. It is now well established that varying the proportion of congruent and incongruent trials encountered over the course of an experiment influences performance in interference tasks (Jacoby et al., 2003; Logan & Zbrodoff, 1979; Schmidt & Besner, 2008). Here, I focused on one class of manipulations in which nominally irrelevant locations are differentially informative of the likelihood of congruent and incongruent trials. In context level manipulations, the size of the congruency effect is reduced for locations in which there are a high proportion of incongruent trials relative to a high proportion of congruent trials (Crump et al., 2006). This difference in the size of the congruency effect across locations is referred to as the CSPC effect and is commonly taken as evidence that participants implement multiple control settings within a single experiment (see: Bugg & Crump, 2012 for a review). Across six experiments, I find evidence for multiple control settings that are relatively long lasting but fragile. Multiple control settings can be maintained within a single experiment and can last over relatively long periods of time, however, without the proper contextual support these control settings fall apart.

## Context Level Transfer Manipulations

I began investigating the mechanisms supporting cognitive control with context level transfer manipulations as there is consensus that the CSPC transfer effect cannot be accounted for simply by contingency learning (see: Schmidt, 2013). In contrast to previous results (Crump & Milliken, 2009), in Experiments 1A and 1B, I did not observe the critical CSPC transfer effect. I take the absence of this effect as evidence that participants are sensitive to the consistency in the informativeness of stimulus dimensions (Hutcheon & Spieler, 2014). In a standard CSPC manipulation, there is consistency in the informativeness of colors within locations. For example, at the mostly incongruent location, each color patch is associated with incongruent trials 75% of the time. At the mostly congruent location, each color patch is associated with incongruent trials 25% of the time. Therefore, information learned about a specific color patch at one location should generalize to other color patches at that location. In contrast, in a context level transfer manipulation, there is variability in the informativeness of color patches within locations. At the mostly incongruent location, some color patches are associated with incongruent trials 85% of the time while other color patches are associated with incongruent trials 50% of the time. At the mostly congruent location, some color patches are associated with incongruent trials 15% of the time while other color patches are associated with incongruent trials 50% of the time. The inclusion of transfer items creates variability in the informativeness of stimulus dimensions at each location and prevents participants from instantiating multiple control settings.

Further evidence that participants are sensitive to consistency in the informativeness of stimulus dimensions, and that this consistency influences the expression of multiple control settings, is provided by the results of Experiment 1C. In this experiment, during the first four blocks of trials participants were presented with a standard context level manipulation. Then, for the final two blocks of trials participants were presented with a context level transfer manipulation. Despite the fact that participants appeared to maintain control settings tied to each location during the first four blocks of trials as evidence by a CSPC effect, the CSPC transfer effect were absent during the final two blocks of trials. Therefore, locations are only treated differently when stimuli at each location are equally informative of the correct response but as soon as variability is added in the form of transfer trials, this effect disappears.

## Context Level Manipulations and Conflict Adaptation

An alternative measure to assess the mechanisms underlying control performance in context level manipulations was used in Experiments 2, 3, and 4. The conflict adaptation effect is the finding in interference tasks that the size of the congruency effect is reduced following incongruent relative to congruent trials (Gratton et al., 1992; Kerns et al., 2004; Stürmer et al., 2002). In task-switching, conflict adaptation is viewed as evidence for the maintenance of multiple control settings (Egner, 2008; Funes et al., 2010; Notebaert & Verguts, 2008). Specifically, if control settings are tied to each task, then conflict originating from one task should lead to a tightening of control for that task but not the alternative task. Accordingly, conflict adaptation is consistently found when the task repeats from trial N to trial N+1 but is absent when the task switches from trial N to trial N+1 (Funes et al., 2010; Akçay and Hazeltine, 2011; Notebaert & Verguts, 2008). Similarly, in CSPC manipulations, if control settings represent the weights that are assigned to stimulus dimensions and distinct control settings are maintained at different locations, then two stimuli occurring at the same location should be processed under the same settings. In contrast, two stimuli occurring at different locations should be processed under different settings. Thus, the occurrence of conflict on a trial N should influence performance on trial N+1 only if location repeats.

To test whether participants maintain separate control settings for different locations, I looked for the presence of conflict adaptation when the location repeated from trial N to trial N+1 and when the location switched from trial N to trial N+1. The results of Experiment 2 suggest participants maintain multiple control settings that are tied to each location. Conflict adaptation effects were present when the location repeated from trial N to trial N+1, but were absent when the location switched from trial N to trial N+1.

There are two competing control explanations for the CSPC effect and both suggest that control settings are strengthened by the consistent occurrence of incongruent trials at the mostly incongruent location. According to the item level control account, control settings are maintained via a conflict monitoring mechanism. Elsewhere, the influence of conflict monitoring has been shown to be relatively transient. Specifically, conflict adaptation effects are present when the time between trials is short (< 2,000 ms) but absent when the time between trials is long (> 2,000 ms) (Egner et al., 2010). According to the stimulus-driven control account, control is maintained through episodic memory[3] and thus operates at a longer time scale. Experiment 3 represents an attempt to tease apart these two accounts. To do so, RSIs were varied from 550 to 4250 ms. At RSIs of over two seconds both the CSPC effect was present and there was evidence for conflict adaptation effects within but not across locations. Therefore, consistent with stimulus-driven control accounts, the control settings created within a CSPC manipulation appear to be relatively long lasting.

Finally, in Experiment 4, using a novel picture naming CSPC manipulation, I attempted to test whether the trial in which the current word was most recently presented influenced current trial performance. Although I found no evidence for a CSPC effect, the trial in which a word was most recently presented did influence performance. Despite an average of over 25 trials between the current trial and the previous trial in which a word was presented, the size of the congruency effect was reduced when the word was previously incongruent relative to when the word was previously congruent. This word specific conflict adaptation effect is similar to the word adaption effect found in typical Stroop manipulations (Hutcheon & Spieler, 2014). That is, information about the presentation of a specific stimulus in the past influences current trail performance. Although I did not find evidence for a CSPC effect in this experiment, one explanation might be that the relatively high number of stimuli (over 40) discouraged the generalization of information at each location (Hazeltine et al., 2011).

## CSPC Effects and Contingency Learning

The absence of evidence for a CSPC transfer effect across three experiments suggests there are alternative explanations for the CSPC effect. One possibility is that participants learn the contingent relationships between the word, location, and the upcoming response. In order for contingency learning to account for the CSPC effect, it must be assumed that individuals learn information about the relative informativeness of the irrelevant dimension. Instead of using the irrelevant word dimension to predict the specific response, they might use the irrelevant location dimension to predict the likelihood that the word dimension will provide the correct response (cf. Melara & Algom, 2003; Schmidt, 2013). Viewed in this way, contingency learning is difficult to differentiate from control. A related account for the CSPC effect is that variations in the size of the congruency effect at each location do not require a control explanation.

Instead, the frequency in which participants encounter certain stimuli differs as a function of location and a model that incorporates this stimulus structure has been shown to be able to account for CSPC-like effects in the absence of variations in control (Hutcheon & Spieler, submitted). However, neither contingency learning nor models incorporating stimulus frequency anticipate the results of Experiments 2 and 3. The finding of within location conflict adaptation in the absence of stimulus-response repetitions is strong evidence for the maintenance of multiple control settings.

## Future Directions

A number of open questions remain. First, the results of these experiments are consistent with the idea that participants organize tasks based on the consistency in the informativeness of dimensions. Exactly how the system knows to generalize remains unknown. Second, the CSPC effect is evidence that multiple control settings can operate within a single task. It has been shown elsewhere that multiple control settings can be operational at the task level. What is the relationship between these two? Can multiple control settings be operational within a single task in the presence of task-switching? Or, does the consistent reactivation of task-level information in task-switching prevent the formation of effects like CSPC? Third, how many control settings can participants maintain at any one time. It is common to look at two or three locations, but this seems to be limited by the current experimental paradigms. Fourth, the results of the current study could be applied to neuroimaging.

## Conclusions

The results of this series of experiments emphasize an important but often overlooked point. Participants are sensitive to manipulations between the irrelevant and relevant dimensions (c.f. Melara & Algom, 2003). When viewed in this way, many control processes in tasks of selective attention resemble a learning process. Rather than conflict reflecting a relatively dumb signal that strengthens active task representations, acknowledging that variations in control are closely tied to stimulus experience should allow for a more nuanced understanding of variations in cognitive control.

## APPENDIX A

List of incongruent words and picture pairs used in Experiment 4.

| Picture | Word |
|---|---|
| axe | spade |
| barn | castle |
| bed | locker |
| bread | soup |
| broom | shovel |
| brush | spatula |
| bus | tank |
| candle | torch |
| chain | rope |
| clock | balance |
| cow | elk |
| crown | scepter |
| dog | goat |
| door | wall |
| ear | mouth |
| flower | grass |
| foot | throat |
| fork | plate |
| glasses | loop |
| hammer | pliers |
| hand | heel |
| hat | umbrella |
| horse | llama |
| house | palace |

| Picture | Word |
|---|---|
| leg | thumb |
| lobster | crab |
| mountain | cliff |
| mouse | toad |
| mushroom | plum |
| nose | tongue |
| onion | bean |
| ostrich | blackbird |
| owl | raven |
| pencil | pen |
| pitcher | bucket |
| ring | bracelet |
| screw | drill |
| shoe | helmet |
| spoon | scoop |
| sun | moon |
| table | shelf |
| tiger | pig |
| toaster | mixer |
| train | tractor |
| vest | sock |
| well | pond |
| wheel | axle |
| window | balcony |

## FOOTNOTES

1. Prior to running Experiment 1C, errors and voice key errors were recorded for eight participants tested in a context level manipulation identical to the one that participants saw during the training trials. The behavioral results of those eight participants are identical to the context level manipulation portion of Experiment 1C.

2. Prior to running Experiment 4, eight participants were tested with the 108 stimuli obtained from Waszak et al. (2003). The 48 stimuli that were responded to above 90% and were associated with the largest congruency effect were selected for Experiment 4.

3. Typically, episodic memory implies conscious awareness. That is not implied in the current interpretation of CSPC effects. I use the term episodic memory here to be consistent with the existing control literature. It is used to refer to the fact that memory for an event influences future performance.

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