RUNNING HEAD: Limits on the generalizability

Limits on the generalizability of context-driven control

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ABSTRACT

Context-driven control refers to the fast and flexible weighting of stimulus dimensions that may be applied at the onset of a stimulus. Evidence for context-driven control comes from interference tasks in which participants encounter a high proportion of incongruent trials at one location and a high proportion of congruent trials at another location. Since the size of the congruency effect varies as a function of location this suggests that stimulus dimensions are weighted differently based on the context in which they appear. However, manipulations of condition proportion are often confounded by variations in the frequency with which particular stimuli are encountered. To date, there is limited evidence for the context-driven control in the absence of stimulus frequency confounds. In the current paper, we attempt to replicate and extend one such finding (Crump & Milliken, 2009). Across three experiments we fail to find evidence for context-driven control in the absence of stimulus frequency confounds. Based on these results, we argue that consistency in the informativeness of the irrelevant dimension may be required for context-driven control to emerge.

Limits on the generalizability of context-driven control

A common assumption in the study of cognitive control is that task instructions provided by the experimenter map onto how participants process information within a task (Miller & Cohen, 2001; Cohen, Dunbar, & McClelland, 1990). If participants are instructed to ignore the word and name the color of a stimulus, then participants inhibit processing of the word dimension and select information from the color dimension (Cohen et al., 1990; MacLeod, 1991). However, accumulating evidence suggests that the weighting of stimulus dimensions is impacted not only by task instructions but also as a function of stimulus experience (Bugg, Jacoby, & Toth. 2008; Jacoby, Lindsay, & Hessels, 2003; Logan & Zbrodoff, 1979).

In context-level manipulations, a color word (prime) is presented at fixation immediately followed by a to-be-named color patch (probe) that appears randomly above or below fixation. Overall, trials are equally likely to be congruent or incongruent but probes presented at one location are associated with incongruent trials 75% of the time (mostly incongruent location) and probes presented at the other location are associated with congruent trials 75% of the time (mostly congruent location). Despite task instructions to ignore the word prime and name the color probe, the influence of the word dimension is different at each location. Specifically, the size of the congruency effect is reduced at the mostly incongruent location compared to the mostly congruent location (Bugg, 2014; Crump, Gong, & Milliken, 2006; Crump, Vaquero, & Milliken, 2008). This context specific proportion congruence (CSPC) effect has been taken as evidence that contextual cues such as location may be used to trigger different weightings on color and word dimensions within a single task (Bugg & Crump, 2012; Crump et al., 2006; Egner, 2014). This context-driven control represents a flexible view of cognitive control that highlights the interaction between task instructions and stimulus experience (Bugg, 2012; Bugg & Crump, 2012; Verguts & Notebaert, 2008).

The CSPC effect has been found across a variety of nominally irrelevant stimulus features including location (King, Korb, & Egner, 2012), font (Bugg et al., 2008), and color (Vietze & Wendt, 2009). However, as others have noted (Bugg & Crump, 2012; Crump & Milliken, 2009; Egner, 2014), the results of context-level manipulations are often confounded by variations in the frequency with which certain stimuli occur (see: Table 1). For example, participants encounter each congruent stimulus three times as often at the mostly congruent location compared to the mostly incongruent location. Similarly, participants encounter each incongruent stimulus three times as often at the mostly incongruent location compared to the mostly congruent location. In this way, stimuli in a typical context level manipulation are frequency biased. This is problematic for the context-driven control interpretation of the CSPC effect because an increase in stimulus frequency is associated with a corresponding decrease in response time (RT) (Logan, 1988; Medin & Schaffer, 1978; Nosofsky & Palmeri, 1997). Congruent trials may be faster when appearing at the mostly congruent location compared to mostly incongruent location, and incongruent trials may be faster when appearing at the mostly incongruent compared to the mostly congruent location because of variations in stimulus frequency and not variations in the weighting of stimulus dimensions (Crump & Milliken, 2009; Schmidt, 2014).

To address this confound, Crump and Milliken (2009) implemented a context-level manipulation containing two sets of stimuli: a context set and a transfer set. In the context set, stimuli were frequency biased. Color patches at the mostly congruent location were congruent on 92% of trials and incongruent on 8% of trials. Color patches at the mostly incongruent location were incongruent on 92% of trials and congruent on 8% of trials. The transfer set stimuli were frequency unbiased. Color patches at the mostly congruent location were congruent on 50% of trials and incongruent on 50% of trials. Color patches at the mostly incongruent location were incongruent on 50% of trials and congruent on 50% of trials (see Table 2). If participants implemented context-driven control then this should generalize to the unbiased transfer set. In the second half of the experiment, Crump and Milliken (2009) observed a CSPC effect for the frequency biased context set and the frequency unbiased transfer set. The finding of a CSPC effect in the context and transfer sets demonstrates that context-driven control can be observed in the absence of stimulus frequency biases and provides clear evidence that stimulus experience (variations in the proportion of congruent and incongruent trials at each location) leads participants to weight stimulus dimensions differently within a single task (Bugg & Crump, 2012; Crump & Milliken, 2009; Egner, 2014).

EXPERIMENT 1

The CSPC transfer effect is a critical finding in the cognitive control literature. Whereas the weighting of stimulus dimensions is classically thought to reflect relatively stable processes implemented based on task instructions (Miller & Cohen, 2001; Cohen et al., 1990), the CSPC transfer effect demonstrates that dimension weighting varies as a function of stimulus experience. While other studies have demonstrated a CSPC effect for frequency unbiased stimuli (King, Donkin, Korb, & Egner, 2012; King et al., 2012; Reuss, Desender, Kiesel, & Kunde, 2014; Weidler & Bugg, in press), we know of no other report of a location-based CSPC transfer effect where in the literature where the contribution of context and transfer sets can be independently estimated. In Experiment 1 we perform a direction replication of the context-level transfer manipulation used by Crump & Milliken (2009) and look for evidence that context-driven control generalizes to frequency unbiased stimuli.

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. We used 32 participants in order to achieve a power of 0.80 given the F value reported for the context by condition interaction in Crump and Milliken (2009) (Keppel & Wickens, 2004).

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 millisecond. 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 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/Green and Red/Yellow). 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 pair appeared in the 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 preceded by 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 preceded by 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 preceded by their corresponding words on six trials and preceded by 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.

Participants completed ten practice trials. A fully counterbalanced block required 96 trials. Participants performed four blocks for a total of 384 trials. A representative stimulus list is presented in Table 2.

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 start of the next 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 one hour.

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 times

To test for the presence of a CSPC effect, 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 analysis of variance (ANOVA). Congruent trials were faster than incongruent trials, $F(1,31)=130.37$, $\eta_P^2 = 0.808$, but the size of the congruency effect did not differ by location $F < 0.2$. No other effects were significant.

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. As seen in Table 3, congruent trials were faster than incongruent trials for both the context, $F(1, 31) = 109.84$, $\eta_P^2 = 0.779$ and transfer set, $F(1, 31) = 99.18$, $\eta_P^2 = 0.761$. However, the size of the congruency effect did not depend on location for either the context, $F(1, 31) = 1.55$, $\eta_P^2 = 0.047$ (in the unexpected direction) or transfer sets, $F(1, 31) = 1.768$, $\eta_P^2 = 0.053$.

In contrast with Crump and Milliken (2009), in the current experiment we find no evidence for a CSPC effect in either the context or transfer set. One explanation for the current results is that these effects might take time to build. In fact, in the initial report (Crump & Milliken, 2009), the CSPC effect emerged for both the context and transfer set only during the second half of the experiment. Combining performance at the beginning and end of the experiment as we did here may have served to dilute the effect. To assess whether the CSPC effect emerged over the course of the experiment for the context and transfer sets, 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, η_P^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, η_P^2 = 0.162, and the size of the congruency effect was larger for the first half compared to the second half of the experiment, F(1,31) = 5.63, η_P^2 = 0.153. For the transfer set, congruent trials were faster than incongruent trials, F(1,31) = 98.42, η_P^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, η_P^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. Finally, two separate 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVAs for the context and transfer sets were conducted on only the second half of trials. The Location Type X Condition was not significant for either set, F's < 1. Taken together, there is no evidence that a CSPC effect emerged over the course of the experiment in either the context or the transfer set.

One difference between the results of the current experiment and the results reported in Crump and Milliken (2009) 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). It is unclear why RTs would be higher in the current experiment, 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 (see Table 3).

Elsewhere it has been suggested that individual difference variables, such as working memory capacity, may influence the expression of CSPC effects (Hutchison, 2011). It is possible that participants in the current sample were simply less sensitive to context level manipulations compared to the original Crump and Milliken (2009) sample. If a difference in the sample compositions accounts for the current results, it should still be possible to show that individuals who demonstrate a CSPC effect in the context set also demonstrate a CSPC effect in the transfer set. 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 a CSPC effect in the transfer set. To assess the relationship between the presence of a CSPC effect in context and transfer sets within individuals, a Pearson's correlation was calculated. As seen in Figure 1, across participants there was no relationship between the presence of a CSPC effect and the presence of a CSPC transfer effect, $r = -0.067$, $p > 0.7$. While admittedly this correlation is between two difference scores, this analysis does not provide any suggestion that a CPSC effect is present in these data.

Accuracy

Due to the relatively low error rate (< 3% of all trials) we do not report statistical analyses of accuracy. However, error rates are presented in Table 3.

Discussion

In a direct replication of the context level transfer manipulation we find no evidence for a CSPC effect in either the context or transfer set. Specifically, the size of the congruency effect was not reduced at a location at which there were a high proportion of incongruent trials compared to a location at which there were a high proportion of congruent trials. Moreover, we find no evidence that these effects emerge over time. These results contrast with an earlier report of a CSPC effect for both the context and transfer sets using an identical experimental manipulation (Crump & Milliken, 2009) and cast doubt on the reliability the effect.

EXPERIMENT 2

In Experiment 2, we extend the context level transfer manipulation to a larger stimulus set. We ask whether context-driven control generalizes to frequency unbiased stimuli when the stimulus set size is relatively large. The primary reason for this extension is that a larger set size (4 items vs. 2 items) has been shown to encourage the use of context-driven control (Bugg & Hutchison, 2013).

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

The stimulus presentation was identical to that described in Experiment 1. However, in the current experiment eight color-word primes (BLUE, BROWN, GREEN, ORANGE, PINK, PURPLE, RED, and YELLOW) were used along with their corresponding color-patch probes (blue, brown, green, orange, pink, purple, red, and yellow).

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 preceded by their corresponding words on 15 trials and preceded by 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 preceded by their corresponding word on three trials and preceded by the remaining three members of the set on five trials each. Stimuli from the transfer set consisted of color patches preceded by their corresponding words on nine trials and preceded 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.

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. A representative stimulus list is presented in Table 4.

Procedure

The procedure was identical to that reported in Experiment 1.

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.

Response times

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 ANOVA. Again, congruent trials were faster than incongruent trials, $F(1,31) = 142.13$, $\eta_P^2 = 0.821$, and stimuli from the context set were responded to faster than stimuli from the transfer set, $F(1, 31) = 5.36$, $\eta_P^2 = 0.147$. However, the size of the congruency effect was not different across locations. Consistent with the results of Experiment 1, there was no evidence for a CSPC effect in the current experiment. No additional effects were significant.

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. As seen in Table 3, congruent trials were faster than incongruent trials for both the context, F(1, 31) = 107.95, η_P^2 = 0.776 and transfer sets, F(1, 31) = 155.43, η_P^2 = 0.833. However, the size of the congruency effect did not depend on location for either the context, F(1, 31) = 1.29, η_P^2 = 0.040 (again in the unexpected direction) or transfer sets, F(1, 31) = 1.308, η_P^2 = 0.041.

To test whether the CSPC effect emerged over the course of an experiment, we analyzed 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 the context and transfer sets. Congruent trials were again faster than incongruent trials for both context, F(1, 31) = 106.324, η_P^2 = 0.774, and transfer sets, F(1, 31) = 154.26, η_P^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, η_P^2 = 0.178. No other results were significant. Finally, two separate 2 Location Type (mostly congruent, mostly incongruent) X 2 Congruency (congruent, incongruent) repeated measures ANOVAs for the context and transfer sets were conducted on only the second half of trials. Again, the Location Type X Condition was not significant for either set, Fs < 0.5. Therefore, there was no evidence that the CSPC effect emerged over the course of the experiment.

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

If individual differences are driving the absence of the CSPC effect in context and transfer sets (Hutchison, 2011), participants in our sample who demonstrate a CSPC effect in the context set should also show a CSPC effect in the transfer set. Of the 32 participants in the current experiment, 15 demonstrated a numerical CSPC effect in the context set. Of the 15 participants who showed a numerical CSPC effect in context items, 11 showed a numerical 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 1, a Pearson's correlation shows that this relationship is not significant across participants, $r = 0.04$, $p>0.8$.

Accuracy

Due to the relatively low error rate (< 3% of all trials) we do not report statistical analyses of accuracy. However, error rates are presented in Table 3.

Discussion

In a second experiment we find no evidence of a CSPC effect in either the transfer or context set. Specifically, there was no reduction in the size of the congruency effect at locations associated with a high proportion of incongruent trials compared to a location associated with a high proportion of congruent trials. Again, this effect did not emerge over time. These results were obtained despite using a large stimulus set previously shown to induce context-driven control (Bugg & Hutchison, 2013). Taken with the results of Experiment 1, the current results suggest that the previously reported CSPC transfer effect represents a Type I error. The inclusion of a transfer set appears to prevent the implementation of context-driven control.

EXPERIMENT 3

Across two experiments the inclusion of frequency unbiased transfer stimuli appear to have prevented participants from implementing context-driven control (i.e. weighting stimulus dimensions differently as a function of location). In Experiment 3 we ask what happens if participants are exposed to only a frequency biased context set shown across a number of studies to induce a CSPC effect (Bugg, 2014; Crump et al., 2006; Heinemann, Kunde, & Kiesel, 2009; King et al., 2012), prior to the inclusion of a transfer set. After participants were exposed to a frequency biased context set, a frequency unbiased transfer set was introduced. In this way, we tested whether participants who appear to weight stimulus dimensions differently during training will generalize these already established weightings to the frequency unbiased stimuli.

Method

Participants

Thirty-two participants (16 female, M = 20.33 years, SD = 3.30) 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 1. However, in the current experiment six color-word primes (BLUE, GREEN, ORANGE, PINK, RED, and YELLOW) were used along with their corresponding color-patch probes (blue, green, orange, pink, red, and yellow).

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 preceded by their corresponding word on nine trials and preceded by the remaining three members of the set on one trial each. Stimuli presented at the mostly incongruent location consisted of color patches precede by their corresponding word on three trials and preceded by 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 test blocks, stimuli from the context set at the mostly incongruent location consisted of color patches preceded by the words of 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 preceded by 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.

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. See Table 4 for a representative stimulus list.

Procedure

The procedure was identical to that reported in Experiment 1 with one exception. Due to the high accuracy observed in the first two experiments, voice onset time was recorded but errors and voice key errors were not collected.

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. We adopted a more conservative RT cut off in order to exclude unidentified voice key errors. The results reported here are consistent with the results from a more liberal cut off (2500 ms). In total, this lead to the exclusion of less than 1.9% of all trials**.**

Response times

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 Table 6, congruent trials were faster than incongruent trials, F(1, 31) = 93.51, $\eta_P^2 = 0.861$, and the size of the congruency effect was reduced at mostly incongruent relative to mostly congruent location, F(1,31) = 6.07, $\eta_P^2 = 0.289$. Thus, within four training blocks, participants were demonstrating a significant CSPC effect in the absence of transfer stimuli.

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 seen in

Table 6, congruent trials were faster than incongruent trials, $F(1,31) = 62.611$, $\eta_P^2 = 0.807$, 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). Thus, despite evidence for a CSPC effect during training, no CSPC transfer effect was observed in test blocks. We are unable to assess whether the CSPC transfer effect was present in blocks five and six separately. This is because both blocks were necessary for a complete counterbalance.

Out of 32 participants, 24 showed the CSPC effect during training blocks. Out of these 24 participants, 11 showed a positive CSPC transfer effect during test. As seen in Figure 1, the correlation between CSPC effect during training and CSPC effect during test was not significant, $r = 0.28$, $p > 0.1$. Again, there was no observable relationship between the presence of context and transfer effects in this sample of participants.

Discussion

In the current experiment, we observed a CSPC effect during training blocks that contained a frequency biased context stimuli. Following training, participants performed test blocks in which a frequency unbiased transfer set was introduced. Due to the design of the test blocks we were unable to test for the presence of a CSPC effect in the context set, however we were able to test for the presence of a CPSC effect in the transfer set. Consistent with the results of Experiment 1 and Experiment 2 we failed to observe a CSPC effect in the transfer set during test blocks. In contrast to the results of Experiment 1 and Experiment 2, this failure to generalize occurred despite evidence for the operation of context-driven control in the blocks prior to the introduction of a transfer set. 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 (Crump & Milliken, 2009). However, this result is entirely consistent with the results of Experiment 1 and Experiment 2. For the third experiment, we find no evidence for context-driven control when stimulus frequency biases were removed from context level manipulations.

GENERAL DISCUSSION

Across three experiments we find no evidence for context-driven control in the presence of frequency unbiased stimuli. In Experiment 1, in a direct replication of the Crump and Milliken (2009) context level transfer manipulation, the size of the congruency effect did not differ as a function of location for either the frequency biased context set or the frequency unbiased transfer set. This results contrasts with Crump and Milliken (2009) in which the size of the congruency effect was reduced for both the context and transfer set during the second half of the experiment. To follow up on our null result, in Experiment 2 we used a larger stimulus-set size previously shown to induce the use of context-driven control (Bugg & Hutchison, 2013). Just as in Experiment 1, we found no difference in the size of the congruency effect across locations for either the context or the transfer set. Finally, in Experiment 3, we trained participants on a frequency biased context level manipulation known to elicit variations in the size of the congruency effect across locations (Crump et al., 2006; King et al., 2014; King, et al., 2012, Bugg, 2014). Despite evidence that stimulus dimensions were weighted differently at each location during training, as demonstrated by a CSPC effect, this effect failed to generalize to frequency unbiased transfer stimuli. All three datasets can be made available via request of the first author.

Although our results largely constitute three null results, based on the effect size reported in Crump and Milliken (2009) we included a sufficient number of participants in experiment 1 to ensure power of 0.8. We used the same number of participants in Experiments 2 and 3. Thus, although we are not able to estimate the power of these novel experimental designs, the probability that we would obtain three null results given that the CPSC transfer effect was a true effect is approximately 0.008. Therefore, we take our results as evidence that the original report of the CSPC transfer effect (Crump & Milliken, 2009) is a Type I error. This is an important finding as CSPC transfer effect is commonly used as evidence against stimulus frequency accounts of context-driven control (Bugg & Crump, 2012; Egner, 2014).

In Experiments 1 and 2 the inclusion of a transfer set was associated not only with the absence of a CSPC effect for the transfer set but also an absence of a CSPC effect for the context set. This is somewhat surprising as stimuli in the context set still occurred with different frequencies at each location. This variation in stimulus frequency should have been sufficient to observe variations in the size of the congruency effect for context stimuli (Logan, 1988; Medin & Schaffer, 1978). That we do not find a CSPC effect under these conditions suggests that participants are not treating location as a meaningful dimension on which to organize the task. Context stimuli are frequency biased to the extent that a given color patch (e.g. RED) is treated as a different stimulus when it is presented above relative to below fixation. The absence of a CSPC effect in the context set in Experiments 1 and 2 suggests that participants treat a RED color patch above fixation the same as a RED color patch below fixation. The inclusion of variability in the informativeness of the word dimension (how often the word dimension carries the correct response) at each location through the presence of transfer stimuli, (see Figure 2) makes the location dimension less useful for organizing consistent properties of stimuli. In contrast, consistency in the informativeness of the word dimension allows participants to accurately bias processing in order to allow more or less word information into the system

(Logan & Zbrodoff, 1979; Hutcheon & Spieler, 2014; Melara & Algom, 2003). When this informativeness is consistent within a location participants generalize within location (training blocks in Experiment 3) and when this informativeness is not consistent within location we see no evidence for generalization within location (Experiments 1 and 2). Future work will attempt to incorporate consistency into models of context-driven control (Blais, Robidoux, Risko, & Besner, 2007; Verguts & Notebaert, 2008).

The context-level transfer manipulation employed in the current set of studies is only one method for addressing stimulus frequency biases endemic to studies of context-driven control. There are other paradigms that have demonstrated a similar CSPC effects. For example, in King et al. (2012), participants were asked to report the direction in which a central face was looking and ignore the direction of flanking faces. Because the use of facial stimuli allowed the experimenters to create unique stimuli for each trial, the finding of a reduced congruency effect at most incongruent compared to mostly congruent locations is evidence for context-driven control that cannot be accounted for by stimulus-frequency biases (in this case, the individual faces). However, the informativeness of the irrelevant flanking faces was consistent within locations. The probability of any one face being associated with an incongruent trial was 75% at the mostly incongruent location and 25% at the mostly congruent location. It is the breaking of this consistency through the inclusion of a transfer set that appears to prevent the implementation of context-driven control. The results of King et al. (2012) along with findings from several different experimental paradigms including task-switching (Leboe, Wong, Crump, & Stobbe, 2008; Crump & Logan, 2010), priming (Heinemann et al., 2009; Reuss, Desender, Kiesel, & Kunde, 2014), and N-back tasks (Crump, in press) suggest that the context-driven control can be observed under certain conditions. Our results indicate that the context-driven control is not present when both frequency biased and frequency unbiased stimuli are present and suggest that participants may use consistency in the informativeness of the irrelevant dimension as an important organizing principle.

In order for context-driven control to be implemented, the particular context must provide a meaningful way to organize information processing. In a standard context level manipulation, location serves this function because stimuli at one location are congruent with the same probability as all other stimuli at that location. Moreover, this probability is different across locations. In this way, weightings applied to color and word dimensions should be implemented within locations. In a context level transfer manipulation the probability of congruency differs for stimuli within a location. In this way, weighting applied to color and word dimensions are applied across locations. Together, the current results suggest a delicate but important interaction between cognitive control implemented by task instructions and the accumulation of stimulus experience.

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