Acta Psychologica 178 (2017) 107–113

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Properties of context-driven control revealed through the analysis of sequential congruency effects

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ARTICLE INFO

Keywords:
Cognitive control
Selective attention

ABSTRACT

The context specific proportion congruent (CSPC) effect refers to the reduction in the size of the congruency effect at locations with a high proportion of incongruent trials compared to locations with a high proportion of congruent trials. The CSPC effect is commonly taken as evidence for context-driven modulation of cognitive control. Current models of context-driven control suggest that variations in the efficiency of control across locations are due to variations in the occurrence of conflict across locations (context). Moreover, these models predict that control settings are updated on a trial-to-trial basis. In Experiment 1, we investigated this prediction. If variations in conflict drive variations in the efficiency of control, and these location-based control settings are updated on each trial, then the occurrence of conflict at one location should lead to more efficient processing when the location repeats, but not when the location switches. Consistent with this prediction, we observed a sequential congruency effect when the location repeats, but not when the location switches. In Experiment 2, we looked for evidence of sequential congruency effects within and between locations in a manipulation in which an equal proportion of congruent and incongruent trials appear at each location. In contrast to the results of Experiment 1, we observed sequential congruency effects both when location repeated and when location switched. Thus, location appears to be a salient dimension on which to implement control settings when it is used in conjunction with variations in the proportion of congruent and incongruent trials.

Cognitive control in selective attention is commonly studied using interference tasks, of which the paradigmatic example is the Stroop task (MacLeod, 1991). 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 used as a measure of the efficiency of cognitive control. Specifically, large congruency effects are associated with less efficient control and small congruency effects are associated with more efficient control (Cohen, Dunbar, & McClelland, 1990; Verguts & Notebaert, 2009). In an effort to better understand the mechanisms that support the implementation and maintenance of cognitive control, recent work has sought to identify aspects of stimulus experience that lead to changes in the efficiency of control.

The conflict monitoring framework provides one such mechanism for how stimulus experience influences the implementation and maintenance of cognitive control (Botvinick et al., 2001). According to this framework, the occurrence of conflict in processing serves as information that can be used to monitor and adjust cognitive control processes in order to avoid conflict in the future. 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 Stroop, conflict is typically greatest on incongruent trials. Consistent with conflict monitoring, the size of the congruency effect is reduced following incongruent relative to congruent trials (Kerns et al., 2004) and this *sequential congruency*[1] effect occurs in the absence of specific stimulus overlap from trial N to

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[1] This effect is alternatively referred to as the conflict adaptation (Botvinick, Braver, Barch, Carter, & Cohen, 2001), Gratton (Desender, Van Opstal, & Van den Bussche, 2014), or congruency sequence effect (Weissman, Hawks, & Egner, 2016).

http://dx.doi.org/10.1016/j.actpsy.2017.06.005
Received 14 December 2016; Received in revised form 20 June 2017; Accepted 22 June 2017

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

Item type	Word	Color			
		Blue	Green	Red	Yellow
Mostly congruent	BLUE	36	12		
	GREEN	12	36		
Mostly incongruent	RED			12	36
	YELLOW			36	12

trial N + 1 (Desender et al., 2014; Kerns et al., 2004; Notebaert, Gevers, Verbruggen, & Liefooghe, 2006; but see: Weissman et al., 2016). In this way, the occurrence of conflict in processing appears to lead to an adjustment in the relative contribution of the color and word dimensions in producing a response.

A challenge to the conflict monitoring account comes from the results of *item level* manipulations. 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) (Jacoby, Lindsay, & Hessels, 2003). There are two important outcomes of item level manipulations. First, mostly incongruent items are associated with smaller congruency effects compared to mostly congruent items, a finding referred to as the item specific proportion congruence (ISPC) effect. Second, sequential congruency effects are absent between item type but can be observed within individual words. That is, the occurrence of an incongruent trial of a particular word is associated with a reduced congruency effect when that same word is encountered several trials later (Hutcheon & Spieler, 2014). These results contrast with the original instantiation of conflict monitoring and imply that under certain conditions, the occurrence of conflict in processing may serve to bias performance at the level of stimulus features (e.g. specific words) not the level of stimulus dimensions.

Two competing accounts have been put forth to explain the ISPC effect: item level control and contingency learning. Item level control accounts argue that in item level manipulations control is implemented at the feature level (e.g. if the word is RED, inhibit processing of the word dimension) rather than the dimension level (e.g. inhibit processing of the word dimension).[2] These accounts borrow the basic structure of conflict monitoring but move the level at which control is implemented. The occurrence of conflict for a particular feature (e.g. the word RED) leads to a tightening of control for that feature but not for other features (e.g. the word BLUE) (Blais, Robidoux, Risko, & Besner, 2007; Blais & Verguts, 2012; Verguts & Notebaert, 2008, 2009). The ISPC effect emerges because the frequent occurrence of conflict leads to the frequent tightening of control for mostly incongruent items and the infrequent occurrence of conflict leads to the infrequent tightening of control for mostly congruent items (Blais et al., 2007; Bugg & Crump, 2012; Verguts & Notebaert, 2008).

Jacoby et al. (2003) were the first to acknowledge 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". When presented with a stimulus containing the word BLUE, the use of word information to predict the likely response would 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". When presented with a stimulus containing the word RED, the use of word information to predict the likely response would lead to relatively fast incongruent trials and relatively slow congruent trials (Schmidt & Besner, 2008). Therefore, variations in the size of the congruency effect observed in item level manipulations may be driven not by variations in the occurrence of conflict across locations but by the predictive relationships between specific words and specific responses (Schmidt, 2013). Bugg and colleagues have recently proposed the dual item-specific mechanisms account which predicts contingency learning under certain conditions and control under others in item-level manipulations (Bugg, 2015; Bugg & Hutchison, 2013).

Fortunately, it is possible to remove the predictive relationship between specific words and responses endemic to item level manipulations. In *context level* manipulations, the proportion of congruent and incongruent trials varies along an additional irrelevant dimension such as spatial location. Participants are presented with a word at fixation immediately followed by a color patch either above or below fixation and 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, but the probability of encountering a congruent or incongruent color patch differs by location. At one location, the majority of color patches are associated with incongruent trials, and at the other location the majority of color patches are associated with congruent trials (Bugg, 2014; Crump et al., 2006). The irrelevant location dimension is uninformative about the likely response, but the probability of conflict is different at the two locations (see Table 2). Consistent with a control account, a context specific proportion congruent (CSPC) effect is observed in which the size of the congruency effect is reduced at mostly incongruent relative to mostly congruent locations (Bugg, 2014; Crump et al., 2006; King, Korb, & Egner, 2012). The CSPC effect has been extended to other irrelevant contextual features including color (Vietze & Wendt, 2009), font type (Bugg, Jacoby, & Toth, 2008), gender (Cañadas, Rodríguez-Bailón, Milliken, & Lupiáñez, 2013) and primes (Heinemann, Kunde, & Kiesel, 2009; Reuss, Desender, Kiesel, & Kunde, 2014), and together these findings appear to reflect a more general *context-driven* control (Crump, 2016).

Although the use of a context-level manipulation removes the predictive relationship between words and responses seen in a typical ISPC manipulation, it is still the case that participants could be using information about the combination of a specific location and a specific word to predict the likely response (Schmidt, 2013). This more complex contingency learning would similarly predict a reduction in the size of the congruency effect at mostly incongruent compared to mostly congruent locations in a context-level manipulation. However, the CSPC effect has also been found in context-manipulations that control for location-word contingencies (Crump & Milliken, 2009). In context-level transfer manipulations, two sets of items are used. One set, referred to as the context set, contains stimuli that frequently appear as incongruent at one location and frequently appear as congruent at the other location. The other set, referred to as the transfer set, contains stimuli that are equally likely to appear as congruent and incongruent trials at each location. In this way, the overall proportion of congruent and incongruent trials varies as a function of location but specific words and color patches are equally likely to occur as congruent and incongruent trials at each location. Consistent with a control account, a CSPC effect is observed for the unbiased transfer set (Crump, Brosowsky, & Milliken, 2017; Crump & Milliken, 2009, but see Hutcheon & Spieler, 2017).

In order for contingency learning to account for evidence of context-driven control such as the CSPC and CSPC transfer effect, it has been argued that individuals use the combination of the irrelevant location dimension, the irrelevant word dimension, and the pace of previous responding to increase or decrease the response threshold on the current trial. At mostly congruent locations this threshold is low and at

[2] In item level manipulations stimulus features are colors and words. However, since word information is available early in processing (MacLeod, 1991), it is generally assumed that word is the feature on which control operates (Bugg & Crump, 2012; Crump, Gong, & Milliken, 2006).

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

Location type	Word	Color			
		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

mostly incongruent locations this threshold is high (Schmidt, 2016). From a control perspective, the frequent occurrence of conflict at mostly incongruent locations leads to the frequent tightening of control whereas the infrequent occurrence of conflict at mostly congruent locations leads to the infrequent tightening of control (King, Donkin, Korb, & Egner, 2012; Verguts & Notebaert, 2009). Therefore, the CSPC effect is simply the outcome of participant's implementing control differently based on location specific differences in proportion congruency.

In a context-level manipulation using faces as stimuli, King, Korb, et al. (2012) found that the CSPC effect was present when the location repeated from trial N to trial N + 1 and absent when location switched from trial N to trial N + 1. Therefore, control settings appear to be flexibly implemented based on stimulus features (i.e. locations) but take some time to initiate. However, to date, there is no evidence that directly links the presence of a CSPC effect to the operation of a control mechanism operating at the level of stimulus features that is adjusted on a trial-to-trial basis. In fact, in a context-level manipulation, Crump et al. (2006) observed a sequential congruency effect regardless of whether location switched from trial-to-trial. However, assessing sequential congruency effects was not the primary focus of that study, and it has become standard in the analysis of sequential congruency effects to exclude trials with overlap between the color and/or word dimension on consecutive trials to prevent stimulus specific repetition effects (Mayr, Awh, & Laurey, 2003) or feature integration effects (Hommel, Proctor, & Vu, 2004) from biasing the analysis (Kerns et al., 2004; Notebaert et al., 2006).

In Experiment 1, we adjusted a typical context level manipulation (Crump et al., 2006) in order to investigate sequential congruency effects within and between locations. Specifically, we expanded the size of the stimulus set and doubled the number of trials participants encountered over the length of the experiment. This allows us to retain a sufficient number of trials for the analysis of sequential congruency effects. The removal of trials with overlap on the color and/or word dimension from the analysis is important for two reasons. First, this allows us to rule out many of the low-level stimulus-response confounds identified elsewhere as biasing the estimation of sequential congruency effects (Mayr et al., 2003; Schmidt & Houwer, 2011). Second, item level control models can readily account for trial-to-trial fluctuations in control in the absence of overlap on the color or word dimension (Verguts & Notebaert, 2009). In contrast, existing contingency accounts (Schmidt, 2013; Schmidt & Besner, 2008) would require an additional assumption to account for sequential congruency effects within but not across locations. Specifically, that information learned about a particular location generalizes to all stimuli at that location (Schmidt, 2016). Therefore, while the current experiment does not constitute a direct test of the control versus contingency accounts, the finding of sequential congruency effects within but not between locations would suggest that the implementation of control settings is impacted by location-specific differences in proportion congruency.

In the current experiment, we analyzed sequential congruency effects in a context-level manipulation. If context-driven control is implemented and updated by the occurrence of conflict at the feature level, sequential congruency effects should be present when the location repeats from trial N to trial N + 1, but not when the location switches from trial N to trial N + 1.

1. Experiment 1: assessing sequential congruency effects in a CSPC manipulation

1.1. Method

1.1.1. 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 participation.

1.1.2. 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.

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 each 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 five trials and in the remaining five words on three trials each. Thus, stimuli at the mostly congruent location were congruent on 75% of trials while stimuli at the mostly incongruent location were incongruent on 75% of trials (see Table 3 for a representative stimulus list).

Participants completed 18 practice trials. A fully counterbalanced

Table 3
Representative block from context level manipulation with the six colors and words used in the experiment.

Location type	Word	Color					
		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

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.

1.1.3. Procedure

On every trial, a color-word (prime) was briefly presented, followed by a to-be-named color patch (probe). 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. 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 h.

1.2. Results

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

1.2.1. CSPC effect

All remaining correct trials were analyzed in a 2 Location Type (mostly congruent, mostly incongruent) × 2 Congruency (congruent, incongruent) repeated measures Analysis of Variance (ANOVA). As seen in Table 4, congruent trials were faster than incongruent trials, $F(1, 31) = 133.22$, $\eta^2 = 0.811$, $p < 0.001$, and the size of the congruency effect was reduced at mostly incongruent relative to mostly congruent locations, $F(1, 31) = 4.41$, $\eta^2 = 0.124$, $p = 0.044$. Thus, we were able to replicate the CSPC effect using a larger stimulus set.

1.2.2. Sequential congruency effects

Having demonstrated the presence of a CSPC effect, we turn to the analysis of sequential congruency effects. For this analysis, we 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-repetitions that can artificially produce sequential congruency effects (Hommel et al., 2004; Mayr et al., 2003). This trimming procedure resulted in the removal of 36% of the remaining trials.

All remaining trials were entered into a 2 Location Transition (location repeat, location switch) × 2 Previous Congruency (congruent, incongruent) × 2 Congruency (congruent, incongruent) repeated measures ANOVA. Congruent trials were faster than incongruent trials, $F(1,31) = 133.650$, $\eta^2 = 0.812$, $p < 0.001$, and trials following congruent trials were faster than trials following incongruent trials, $F(1,31) = 8.679$, $\eta^2 = 0.219$, $p = 0.006$. In addition, the size of the congruency effect was smaller following incongruent relative to congruent trials, $F(1, 31) = 7.220$, $\eta^2 = 0.189$, $p = 0.011$, indicative of a sequential congruency effect. Importantly, as seen in Fig. 1, this sequential congruency effect was present when the location repeated, but was absent when the location switched, $F(1, 31) = 5.481$, $\eta^2 = 0.150$, $p = 0.026$.

To follow up on the previous analysis, we conducted two separate 2 Previous Congruency (congruent, incongruent) × 2 Congruency (congruent, incongruent) repeated measures ANOVAs for location repeat and location switch trials. As expected, the size of the congruency effect was smaller following incongruent relative to congruent trials for location repeat $F(1,31) = 13.705$, $\eta^2 = 0.307$, $p = 0.001$, but not location switch trials $F(1, 31) = 0.334$, $\eta^2 = 0.011$, $p = 0.568$.

1.2.3. Accuracy

Overall, the error rate was $< 2.5\%$. Due to the low error rate, statistical analyses are not reported, however, the results are presented in Table 4.

1.3. Discussion

In Experiment 1, in a context-level manipulation, we find evidence for a sequential congruency effect when location repeats but not when location switches. The current results suggest that when the proportion of congruent and incongruent trials varies as a function of location, location-based control settings are implemented and updated on a trial-to-trial basis (Blais et al., 2007; Verguts & Notebaert, 2009). However, in Experiment 1, location and proportion congruent are confounded. That is, the absence of sequential congruency effects when location switches could be attributed to either a change in location or the change in proportion congruency (Hutcheon & Spieler, 2014). In Experiment 2, we implement a CSPC manipulation with the proportion of congruency and incongruent trials equated at each location. This allows us to test whether location is the crucial variable or if it is variation in the proportion of congruent and incongruent at each location that leads to the implementation of location-based control settings.

Table 4
Mean color-naming response latencies with 95% confidence intervals (CI) and error rates (ER).

Experiment 1

Location type	Congruency						Stroop effect	CSPC effect
	Congruent			Incongruent				
	RT	CI	ER	RT	CI	ER	RT	RT
Mostly congruent	572	12	0.01	656	14	0.03	84	9*
Mostly incongruent	580	13	0.01	655	13	0.03	75	

Experiment 2

Location	Congruency						Stroop effect	CSPC effect
	Congruent			Incongruent				
	RT	CI	ER	RT	CI	ER	RT	RT
Top	614	17	0.01	704	21	0.04	90	6
Bottom	628	18	0.01	712	19	0.05	84	

2. Experiment 2: assessing sequential congruency effects in a balanced manipulation

2.1. Method

2.1.1. Participants

24 participants[3] (12 female, M = 20.33 years, SD = 3.01) were recruited from the Bard College undergraduate population and received course credit for their participation. Data from two participants were excluded due to a technical error in the recording of responses and data from one participant was excluded due to an error rate of over 15%.

[3] Prior to the start of data collection for Experiment 2, we determined that a sample size of 24 participants was required to achieve power of at least 0.8 to detect the Previous Condition × Current Condition interactions for switch and repeat trials. This calculation was based on the results of Experiment 1.

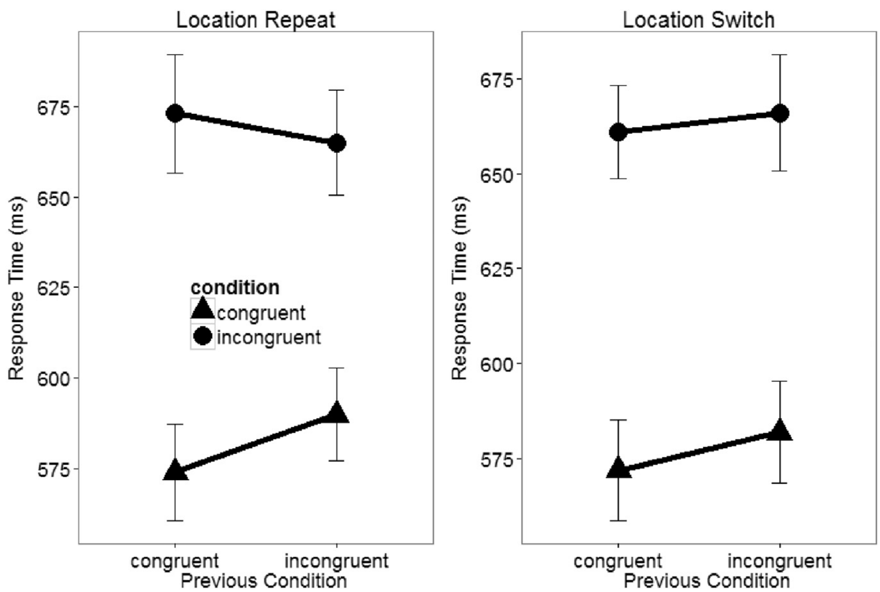

Fig. 1. Sequential congruency effect with 95% confidence intervals when the location repeats (left) and switches (right) for a context-level manipulation in Experiment 2.

2.1.2. Materials and stimuli

Materials and stimuli were the same as in Experiment 1 with the following exceptions. In each block, the proportion of congruent and incongruent trials was the same across locations. Specifically, color patches presented at each location appeared with their corresponding words on 10 trials and in the remaining five words on two trials each. Thus, stimuli at each location were congruent 50% of the time and incongruent 50% of the time.

Participants completed 18 practice trials followed by two blocks of 240 trials for a total of 480 trials. To make the task more manageable for participants, a rest was given after every 120 trials.

2.1.3. Procedure

The procedure was identical to that reported in Experiment 1.

2.2. Results

An alpha level of 0.05 was used for all results. Prior to all analyses, voice key errors, RTs < 200 ms, and RTs > 2500 ms were excluded. This procedure results in the exclusion of 2.9% of all trials.

2.2.1. Location effect

All remaining correct trials were analyzed in a 2 Location (top, bottom) × 2 Congruency (congruent, incongruent) ANOVA. As seen in Table 4, congruent trials were faster than incongruent trials, $F(1, 20) = 80.383$, $\eta^2 = 0.801$, $p < 0.001$. In addition, trials presented at the top of the screen were responded to faster than trials at the bottom of the screen, $F(1, 20) = 26.096$, $\eta^2 = 0.566$, $p < 0.001$. However, the size of the congruency effect did differ across location, $F(1, 20) = 0.588$, $\eta^2 = 0.028$, $p = 0.452$.

2.2.2. Sequential congruency effects

In a balanced CSPC manipulation, we observed no difference in the size of the congruency effect across location. We now turn to the analysis of sequential congruency effects. For this analysis, we again 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-repetitions that can artificially produce sequential congruency effects (Hommel et al., 2004; Mayr et al., 2003). This trimming procedure resulted in the removal of 29% of the remaining trials.

All remaining trials were entered into a 2 Location Transition (location repeat, location switch) × 2 Previous Congruency (congruent, incongruent) × 2 Congruency (congruent, incongruent) repeated measures ANOVA. Congruent trials were faster than incongruent trials, $F(1, 20) = 73.306$, $\eta^2 = 0.785$, $p < 0.001$, and the size of the congruency effect was smaller following incongruent relative to congruent trials, $F(1, 20) = 6.189$, $\eta^2 = 0.236$, $p = 0.022$, indicative of a sequential congruency effect. In contrast to Experiment 1, the sequential congruency effect did not vary as a function of location transition, $F(1,20) = 0.024$, $\eta^2 = 0.002$, $p = 0.879$.

To follow up on the previous analysis, we conducted two separate 2 Previous Congruency (congruent, incongruent) × 2 Congruency (congruent, incongruent) repeated measures ANOVAs for location repeat and location switch trials. As expected, the size of the congruency effect was smaller following incongruent relative to congruent trials for both location repeat $(1, 20) = 4.213$, $\eta^2 = 0.174$, $p = 0.050$, and location switch trials, $F(1,20) = 5.273$, $\eta^2 = 0.208$, $p = 0.033$ (see Fig. 2).

2.2.3. Accuracy

Overall, the error rate was 2.5%. Due to the relatively low error rate, statistical analyses are not reported, however, the results are presented in Table 4.

3. General discussion

The current results suggest that when the proportion of congruent and incongruent trials varies as a function of location, control appears to operate at the level of specific stimulus features (e.g. locations). Moreover, this form of control is updated on a trial-to-trial basis (Blais et al., 2007; Verguts & Notebaert, 2009). Specifically, in a context-level manipulation, sequential congruency effects were present when location repeated from trial N to trial N + 1, but not when location switched. However, when congruent and incongruent trials were equally likely to appear at each location, sequential congruency effects were present both when location repeated from trial N to trial N + 1, and when location switched. Together, these results are consistent with models of item level control that have suggested control can operate at the level of stimulus features in spite of task instructions at the dimension level (Blais & Verguts, 2012; Blais et al., 2007; Verguts & Notebaert, 2008).

These findings represent an extension of previous work that points to conflict-induced control operating at a local level not dimension level (Hutcheon & Spieler, 2014; Spapé & Hommel, 2008). Specifically, Spapé and Hommel (2008) asked participants to identify high and low pitched tones presented along with hearing either a male of female voice saying

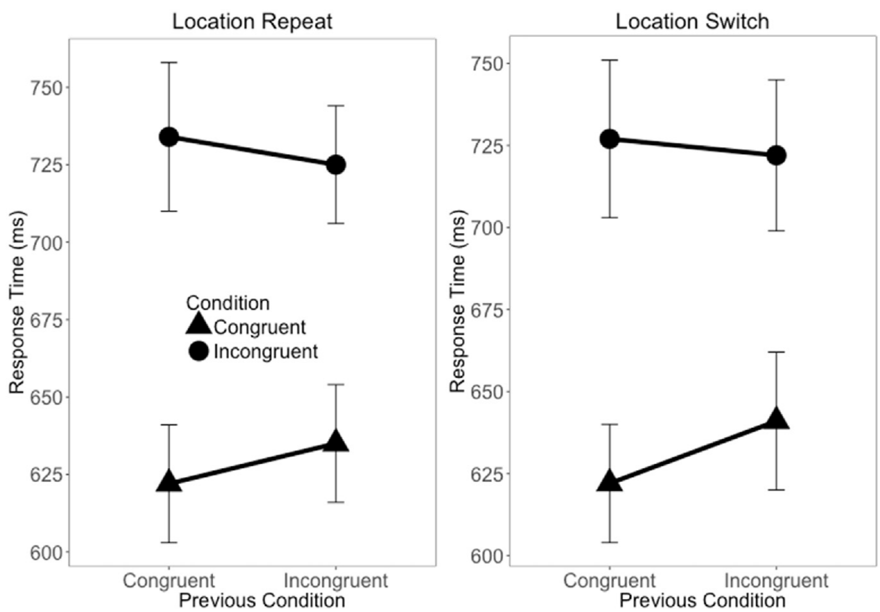

Fig. 2. Sequential congruency effect with 95% confidence intervals when the location repeats (left) and switches (right) in Experiment 2.

"high" or "low". A Stroop-like effect was observed in which participants were slower to identify a tone when the word was incongruent with the tone (e.g. low tone, "high") compared to when the word was congruent with the tone (e.g. low tone, "low"). A sequential congruency effect was observed for trials in which the gender of the voice repeated from trial N to trial N + 1 but not for trials in which the gender of the voice switched. In this way, conflict appears to tighten control for stimuli that overlap on the gender dimension. This is a similar pattern to the results reported in Experiment 1, in which sequential congruency effects were observed within but not across locations. However, in the current study, the informativeness of the location dimension must be learned through experience within the task (Hutcheon & Spieler, 2014).

Although the context-level manipulation used the studies reported here removes the predictive relationship between words and responses seen in a typical ISPC manipulation, it is still the case that participants could be using information about the combination of a specific location and a specific word to predict the likely response (Schmidt, 2013). While evidence for CSPC effects in frequency unbiased stimuli exist in the literature supporting our control interpretation (Bugg, 2014; Crump & Milliken, 2009; Crump et al., 2017), the current experimental design cannot fully account for all possible forms of contingency learning. Specifically, a relatively complicated form of contingency learning, that information learned about a particular location generalizes to all stimuli at that location could be an alternative account for the current results (Schmidt, 2016).

In the current experimental design, it is not possible to fully control for the impact of feature-integration. As shown elsewhere, when consecutive stimuli are complete matches on stimulus features or complete mismatches on stimulus features, response time will be relatively fast. In contrast, when consecutive stimuli are partial matches on stimulus features, response time will be relatively slow (Hommel et al., 2004). In our analyses, we looked separately for sequential congruency effects using trials that included only partial matches (location repeat) and trials that included only complete mismatch trials (location switch). Therefore, feature-integration cannot fully account for our findings of a sequential congruency effect when location repeats but not when location switches because trial-to-trial transitions involving cC, cI, iC, and iI trials do not differentially include partial repetitions. However, models of control that incorporate conflict and feature-integration can readily explain our findings (Egner, 2014; Verguts & Notebaert, 2008; Weissman et al., 2016). Future work could employ two distinct stimulus-sets at each location and present one stimulus-sets on odd-numbered trials and another stimulus set on even number trials (Jiménez & Méndez, 2013; Mayr et al., 2003). This would serve to avoid all stimulus and response repetitions (with the exception of location on location repetition trials).

The analysis of sequential congruency effects provides a method for understanding the structure and organization of information processing (Funes, Lupiáñez, & Humphreys, 2010a, 2010b). For example, in the task-switching literature, sequential congruency effects are typically observed when the task repeats from trial N to trial N + 1, but absent when the task switches (Akçay & Hazeltine, 2011; Notebaert & Verguts, 2008) suggesting that control settings corresponding to each task are active and are independently updated by the occurrence of conflict. While different tasks are a particularly salient way for participants to organize information, recent evidence points to more flexible task boundaries meaning that stimulus experience over the course of the task has an influence on how information processing is organized (Hazeltine, Lightman, Schwarb, & Schumacher, 2011; Schumacher, Schwarb, Lightman, & Hazeltine, 2011). In the current experiment, variations in the occurrence of congruent and incongruent trials at each location appear to be a particularly salient piece of information for how to organize information in the task.

Our results contrast with the results of a recent study that failed to find evidence for sequential congruency effects in the presence of a CSPC effect (Blais, Harris, Sinanian, & Bunge, 2015). In that study, context was defined by the semantic meaning of a distracting word. Participants encountered distracting words that were either professions or animals. When the distracting word was an animal, trials were likely to be incongruent and when the distracting word was a profession, trials were likely to be congruent. Although the authors note a reduction in the size of the congruency effect for animal compared to profession trials, suggesting control operating at the level semantic meaning, they found no evidence for trial-to-trial updating of control. In the current study, context is defined as location on the screen where represents relatively low-level perceptual feature (see also: Hutcheon & Spieler, 2014; Spapé & Hommel, 2008). It is an open question as to why trial-to-trial adjustments can be observed along perceptual but not semantic dimensions. Understanding this relationship represents an important extension to our understanding of context-driven control.

At the start of the experiment, participants are instructed to ignore the word and to name the color. Before encountering any stimuli participants are likely to use these instructions to implement control at the dimension level. What causes participants to adjust control within a single experimental setting? One possibility that we are currently investigating is that participants are sensitive to the consistency of occurrence of conflict (Melara & Algom, 2003). When a stimulus dimension is equally associated with the conflict across features (as is the case for word information in a typical Stroop manipulation), then control may generalize across those features. Thus, sequential congruency effects are present across words in a typical Stroop manipulation (Kerns et al., 2004). However, when a stimulus dimension is differentially predictive of conflict (as is the case for location information context-level manipulations), then control does not generalize across features (Hutcheon & Spieler, 2017).

The observation of context-driven control is particularly important because this form of control is in sharp contrast with previous instantiations of cognitive control. Whereas cognitive control has been thought of as rigid and unaffected by stimulus experience, context-driven control reflects a flexible form of control that emerges in response to specific stimulus experience.

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