

The context-specific proportion congruent Stroop effect: Location as a contextual cue

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The Stroop effect has been shown to depend on the relative proportion of congruent and incongruent trials. This effect is commonly attributed to experiment-wide word-reading strategies that change as a function of proportion congruent. Recently, Jacoby, Lindsay, and Hessels (2003) reported an item-specific proportion congruent effect that cannot be due to these strategies and instead may reflect rapid, stimulus driven control over word-reading processes. However, an item-specific proportion congruent effect may also reflect learned associations between color word identities and responses. In two experiments, we demonstrate a context-specific proportion congruent effect that cannot be explained by such word-response associations. Our results suggest that processes other than learning of word-response associations can produce contextual control over Stroop interference.

The Stroop task (Stroop, 1935) requires participants to identify the ink colors of color words (for a review, see MacLeod, 1991). Responses are typically slower on incongruent trials (RED in blue ink) than on congruent trials (BLUE in blue ink). The difference in response latency between congruent and incongruent trials is often taken as a measure of the contribution of automatic word-reading processes to performance (Lindsay & Jacoby, 1994). When the Stroop item is congruent, the word-reading process facilitates compatible ink color responses. In contrast, for incongruent items, the word-reading process conflicts with the ink color response and slows performance.

A strong automaticity hypothesis would predict that Stroop effects are entirely insensitive to context. However, several researchers have demonstrated that the proportion of congruent items in a Stroop task can modulate the size of Stroop interference (e.g., Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; West & Baylis, 1998), with high proportions of congruent items producing large Stroop effects. The effect of proportion congruent on the size of the Stroop effect is commonly attributed to changes in experiment-wide word-reading strategies that depend on the likelihood of congruency. For example, participants in a high-proportion congruent context may adopt the strategy of allowing word reading to influence the selection of responses. A consequence of this strategy would be relatively large Stroop effects, because word reading makes performance faster on congruent trials, but slower on incongruent

trials. In contrast, participants in a low-proportion congruent context may adopt the strategy of preventing word reading. This strategy would slow responses on congruent trials, but reduce conflict on incongruent trials, thereby yielding a smaller Stroop effect.

The idea that proportion congruent effects on Stroop interference necessarily reflect changes in experiment-wide word-reading strategies was challenged recently by Jacoby, Lindsay, and Hessels (2003). In their study, the proportion of congruent items was manipulated between different sets of Stroop items. High-proportion congruent items were created from WHITE, RED, and YELLOW word/color combinations, and low-proportion congruent items were created from BLACK, BLUE, and GREEN word/color combinations. These mostly congruent and mostly incongruent item types were mixed at random across the experimental session, so that participants could not predict whether the upcoming trial was likely to be congruent or incongruent. Consequently, any experiment-wide word-reading strategy employed by participants could be regarded as identical for the two item types. Nevertheless, the high-proportion congruent items produced a larger Stroop effect than did the low-proportion congruent items. Jacoby et al. labeled this difference an item-specific proportion congruent (ISPC) effect.

Because the ISPC effect cannot be explained via experiment-wide strategies implemented by a central task-demand mechanism (Cohen, Dunbar, & McClelland, 1990), Jacoby et al. (2003) concluded that the contribution of word-reading processes for the high- and low-proportion congruent sets may have been "controlled automatically." In other words, the contribution of word-reading processes to performance may have been modulated rapidly after stimulus onset in response to the item set of the target. This evidence for rapid, online control of the influence of word reading in a Stroop task has broad implications, because it challenges the conventional view that control processes are implemented in a slow, effortful

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manner (Posner & Snyder, 1975; Shiffrin & Schneider, 1977).

At the same time, Jacoby et al. (2003) acknowledged an alternative account of the ISPC effect that would not require any inferences about rapid control over word reading. Specifically, in their experiments, each color word was predictive of both proportion congruency and a particular ink color response. For example, participants could have learned that the word RED was usually presented in the ink color RED, as was the case for mostly congruent items. If so, then associations between words and responses could have speeded performance for congruent trials and increased the overall Stroop effect. Note that this influence of the association between a word and a response could well be independent of attention processes that control the contribution of word reading to performance, yet this influence would indeed produce an ISPC effect.

The purpose of the present experiments was to determine whether the ISPC effect (Jacoby et al., 2003) is an idiosyncratic consequence of an experimental design that allows associations to build between a salient contextual cue (i.e., the word in a Stroop task) and a response. The alternative hypothesis that we forward is that the ISPC effect belongs to a larger class of effects that we call *context-specific proportion congruent* (CSPC) effects—that is, effects that are driven by associations between context and likelihood of congruency. To address this issue, we demonstrate a CSPC effect using a nominally irrelevant cue dimension that does not predict color responses, but does predict likelihood of congruency.

EXPERIMENT 1

Redundant Location and Shape Cues

In this experiment, a briefly presented color word prime appeared at fixation, followed by a colored shape that appeared above or below fixation. The task was to name aloud the color of the shape as quickly and accurately as possible. We followed the general logic of Jacoby et al.'s (2003) study, with the exception that the likelihood of congruency was not associated with particular color words. Instead, the nominally irrelevant shape/location contexts were associated with likelihood of congruency. Importantly, the contextual cues appeared in each color with equal frequency and therefore did not predict particular responses. The aim was to determine whether a context-specific proportion effect could be observed in the absence of biased word-color associations.

Method

Participants. The participants were 16 undergraduate students enrolled in psychology courses at McMaster University who volunteered for course credit. All participants spoke English as a first language, had normal color vision, and had normal or corrected-to-normal visual acuity.

Materials and Procedure. We followed a simple priming procedure involving the presentation of a color word prime, followed by a colored shape probe display. There were four equally frequent color word primes (RED, GREEN, BLUE, YELLOW). The colored shape was either a circle (2.6° in diameter) or a square (2.6° in width)

that appeared above or below the fixation point (5.7°), in one of the four colors (red, green, blue, yellow). The shape was redundant with its location (i.e., the circle always appeared above fixation and the square always appeared below fixation, or vice versa). One of these two shape/location contexts was associated with a high likelihood of congruency between the prime word and colored shape; the other shape/location context was associated with a low likelihood of congruency between the prime word and colored shape. Both shape/location contexts were combined with both proportions of congruency (high or low), and the resulting four conditions were counterbalanced across participants. Participants completed 10 practice trials, followed by four blocks of 96 experimental trials. Each block of 96 trials consisted of 48 trials in each of the two shape/location contexts, mixed randomly across the block. One of the shape/location contexts was defined as the high proportion congruent condition while the other was defined as the low proportion congruent condition. The 48 trials in the high proportion congruent condition consisted of nine presentations of each of the 4 possible congruent items (36 trials) and one presentation of each of the 12 possible incongruent items (12 trials). Similarly, the 48 trials in the low proportion congruent condition consisted of three presentations of each congruent item (12 trials) and three presentations of each incongruent item (36 trials).

The experiment was conducted on a PC with a 15-in. SVGA monitor using MEL experimental software (Schneider, 1988). Participants were seated approximately 57 cm from the computer monitor. At the beginning of each trial, participants were presented with a fixation cross displayed in white against a black background for 1,000 msec, followed by a blank interval of 250 msec. Next, a color word prime was centrally displayed in white against a black background for 100 msec. Following the prime display, a colored shape probe display appeared. Participants were instructed to name the color of the probe as quickly and accurately as possible. The probe was presented on the screen until the participant made a vocal response. Vocal response latencies were recorded with a microphone, and a voice-activated relay timed the response from the onset of the probe display. An experimenter coded each response as correct, incorrect, or spoil. A spoil was defined as a trial in which noise unrelated to the onset of the intended response triggered the voice key. After the completion of the experiment, participants were shown pictures of congruent and incongruent trial types in both the high and low proportion congruent conditions. The participants were then asked to estimate the percentages of congruent and incongruent trial types that occurred in both the high and low proportion congruent conditions. The participants were asked to give estimates that summed to 100 for each of the proportion congruent conditions.

Results

For each participant, response times (RTs) for each condition were submitted to an outlier elimination procedure (Van Selst & Jolicœur, 1994). Mean RTs were then computed from those which remained. These means were submitted to a repeated measures ANOVA that included proportion congruent (high vs. low), and congruency (congruent vs. incongruent) as within-participants factors. The mean RTs in each condition, collapsed across participants, are displayed in Table 1.¹

The main effect of congruency was significant [$F(1,15) = 95.79, MS_e = 1,393.96, p < .0001$]. Responses on congruent trials (486 msec) were faster than responses on incongruent trials (577 msec). More important, the proportion congruent \times congruency interaction was significant [$F(1,15) = 7.87, MS_e = 133.11, p < .05$]. The Stroop effect for the high-proportion condition was larger (99 msec) than the Stroop effect for the low-proportion

Table 1
Mean Color-Naming Response Latencies (RTs, in Milliseconds,
With Standard Errors) for Experiment 1

Proportion Congruent	Item Type				I – C		CSPC Effect	
	Congruent (C)		Incongruent (I)		RT	SE	RT	SE
	RT	SE	RT	SE				
High	484	16.2	583	16.8	99	10.5		
Low	487	15.2	571	16.5	83	9.0	16	5.8

Note—CSPC, context-specific proportion congruent.

condition (83 msec). Participants' estimates of proportion congruent for the two proportion congruent conditions are reported in Table 2. The estimates of proportion congruent in the high and low conditions did not differ significantly. Thus, there was no evidence that participants were explicitly aware of the proportion congruent manipulation.

Discussion

The results of Experiment 1 demonstrate a CSPC effect in which the critical shape/location contextual cue was associated equally with each of the four color responses. Neither biased associations between the shape/location cue and response, nor biased associations between word and color can explain this effect. Alternatively, learning of associations between the shape/location contextual cue and likelihood of congruency can explain our effect. Furthermore, it is noteworthy that contextual control over the Stroop effect can involve associations between nominally irrelevant, incidental properties of the target, such as its shape or location, and likelihood of congruency.

EXPERIMENTS 2A AND 2B Separating Location/Shape Cues

In Experiment 1, the response-irrelevant shape and location cues were redundant. Consequently, it was not clear whether location information, shape information, or both were important to the learning that underlay the observed CSPC effect. We addressed this issue in Experiments 2A and 2B.

Method

Participants. The participants were 34 undergraduate students enrolled in psychology courses at McMaster University who volunteered for course credit. All participants spoke English as a first

language, had normal color vision, and had normal or corrected-to-normal visual acuity.

Materials and Procedure. Experiment 2A followed the same procedure as did Experiment 1, with the exception that shape differences were removed from the probe display. Colored rectangles 1.56° in height and 5.19° in width appeared above or below fixation. Experiment 2B followed the same procedure as did Experiment 1, with the exception that location differences were removed from the probe display. Probes consisted of one of two shapes, either a circle or a square, presented at fixation. The dimensions of these shapes were the same as in Experiment 1.

Results

Two participants in Experiment 2A whose error rates on incongruent trials exceeded 20% were excluded from all analyses. For the remaining 16 participants in each experiment, the RTs from correct trials for each condition were submitted to an outlier elimination procedure (Van Selst & Jolicœur, 1994). Mean RTs were then computed from those which remained. The results from both experiments were submitted to a 2 (proportion congruent: high vs. low) × 2 (congruency: congruent vs. incongruent) repeated measures ANOVA. RTs and error rates for each condition, collapsed across participants in each experiment, are displayed in Table 3.

Experiment 2A. There was a significant main effect of congruency [$F(1,15) = 96.22, MS_e = 855.26, p < .0001$]. Responses on congruent trials were faster (507 msec) than responses on incongruent trials (579 msec). More germane to the question at hand, the proportion congruent × congruency interaction was significant [$F(1,15) = 7.19, MS_e = 146.25, p < .05$]. The Stroop effect for the high proportion location condition was larger (80 msec) than the Stroop effect for the low proportion location condition (64 msec). A corresponding analysis of error rates revealed a main effect only of congruency [$F(1,15) = 6.63, MS_e = 5.25 \times 10^{-5}, p < .05$]; error rates were higher for incongruent trials (.003) than for congruent trials (.001).

Experiment 2B. There was a significant main effect of congruency [$F(1,15) = 25.646, MS_e = 748.54, p < .0001$]. Responses on congruent trials were faster (485 msec) than responses on incongruent trials (562 msec). Interestingly, there was no significant proportion congruent × congruency interaction.

Combined analysis. To determine whether location cues produced a significantly larger proportion congruent effect than that produced by shape cues, a mixed design ANOVA with experiment (location vs. shape) as a between-participants factor was conducted. The three-way

Table 2
Mean Proportion Congruent Estimates, With
Standard Errors, for Experiments 1, 2A, and 2B

Experiment	Proportion Congruent	Congruent		Incongruent	
		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
1	High	.45	.16	.56	.16
	Low	.49	.17	.51	.18
2A	High	.52	.16	.48	.16
	Low	.47	.18	.53	.18
2B	High	.53	.13	.47	.13
	Low	.54	.15	.46	.15

Table 3
Mean Correct Color-Naming Response Latencies (RTs, in Milliseconds,
With Standard Errors) and Error Rates (ERs) for Experiments 2A and 2B

Experiment	Proportion Congruent	Item Type									
		Congruent (C)			Incongruent (I)			I – C		CSPC Effect	
		RT	SE	ER	RT	SE	ER	RT	SE	RT	SE
2A	High	501	12.6	.001	580	13.3	.001	80	8.5	16	6.0
	Low	513	13.0	.000	577	12.9	.004	64	7.2		
2B	High	486	13.5	.000	561	15.2	.001	75	7.4	-2	4.3
	Low	485	15.1	.000	563	14.6	.001	78	6.9		

Note—CSPC, context-specific proportion congruent.

interaction of experiment \times proportion congruent \times congruency was significant [$F(1,30) = 6.32$, $MS_e = 697.16$, $p < .05$]. In addition, it is noteworthy that the main effect of experiment was not significant; that is, responses were as fast in the experiment in which a CSPC effect occurred (Experiment 2A: location) as in the experiment in which this effect did not occur (Experiment 2B: shape).

Finally, participants' mean estimates of proportion congruent for both experiments are reported in Table 2. Again, these estimates of proportion congruent did not differ for the high and low proportion congruent conditions in either experiment.

Discussion

The results of Experiments 2A and 2B demonstrate that the CSPC effect reported in Experiment 1 depended on the nature of the contextual cue that was contingent upon likelihood of congruency. Specifically, Experiment 2A demonstrated a location-based CSPC effect, whereas Experiment 2B failed to demonstrate a shape-based CSPC effect.

The lack of a shape-based CSPC effect is potentially informative. Although both location and shape were nominally irrelevant to the color-naming task, participants may have attended to location when identifying colors in the periphery, whereas they may not have attended to the shape dimension when identifying colors presented centrally. This possibility fits well with the notion that location information receives priority during encoding (Logan, 1998; Mayr, 1996) and could therefore act as an effective proportion congruent cue. Alternatively, location cues may have been easier to discriminate than shape cues. If the absence of a shape-based CSPC effect was due to the relative difficulty with which these shapes could be discriminated from each other, then extended practice with these shape cues could make the discrimination easier and could potentially allow the shape dimension to act as an effective proportion congruent cue. This issue is an interesting one for further research.

Another possibility that cannot yet be ruled out is that spatial uncertainty of the probe is critical to the CSPC effects reported here. Given this view, a shape-based CSPC effect might be observable if the shapes were presented unpredictably above or below fixation. If so, this result would suggest that spatial uncertainty increases learning about covariation, again an interesting issue to pursue.

The results of Experiments 2A and 2B may also be relevant to the study of task switching. Researchers of task switching (Allport & Wylie, 2000) have demonstrated both list-wide and item-specific costs associated with the switching of task sets. One might wonder whether similar switch costs are associated with rapidly switching between high and low proportion congruent item types. If so, it would be reasonable to expect that the mean RT for Experiment 2A (542 msec), in which a CSPC effect was observed, should be slower than the mean RT for Experiment 2B (523 msec). Although the direction of this difference is consistent with this interpretation, the effect was not statistically significant. Nevertheless, the putative relation between contextually-driven control processes and task-switching costs is yet another interesting issue for future research.

In summary, that a CSPC effect was observed with location cues, but not with shape cues, is an interesting finding. Nevertheless, the absence of an effect for shape cues does nothing to undermine the main conclusion here. That location cues did produce a CSPC effect is the critical result, because it demonstrates contextual control over the Stroop effect in the absence of biased associations between the critical contextual cue (i.e., location) and response.

EXAMINATION OF SEQUENCE EFFECTS

Gratton, Coles, and Donchin (1992) demonstrated that trial-to-trial perseveration of strategies could explain proportion congruent modulations of Stroop-like interference. They found that congruency effects were larger for trials that were preceded by a congruent stimulus. When the majority of trials in a session are congruent, the preceding trial is always more likely to be congruent than incongruent, which would in turn lead to larger interference effects in a high proportion congruent block of trials, than would be the case for a low-proportion block of trials.

To examine the role of sequence effects of this nature here, we conducted a sequence analysis to determine whether or not our CSPC effects depended on the trial type of the immediately preceding trial. RTs from each condition in Experiments 1 and 2A were submitted to an outlier elimination procedure (Van Selst & Jolicœur, 1994), and then submitted to a 2 (trial $n-1$ proportion congruent: high vs. low) \times 2 (trial $n-1$ congruency: congruent vs.

incongruent) \times 2 (trial n proportion congruent: high vs. low) \times 2 (trial n congruency: congruent vs. incongruent) \times 2 (Experiment: 1 vs. 2A) mixed design ANOVA with experiment treated as the lone between-participants variable. No effects involving the between-participants factor were significant, and therefore the sequence analysis reported here was collapsed across experiments. Mean RTs in each condition, collapsed across participants in Experiments 1 and 2A, are displayed in Table 4.

The trial $n-1$ congruency \times trial n congruency interaction was significant [$F(1,31) = 14.54$, $MS_e = 1,151.86$, $p < .001$]. The congruency effect on the current trial was larger when the previous trial was congruent (92 msec) than when the previous trial was incongruent (69 msec). This result demonstrates that sequential effects of the type reported by Gratton et al. (1992) influence the congruency effect measured by our procedure.

More important, the trial n proportion congruent \times trial n congruency interaction was significant [$F(1,31) = 14.68$, $MS_e = 718.63$, $p < .001$], and these factors did not interact with trial $n-1$ congruency or trial $n-1$ proportion congruency. In other words, the CSPC effect was not affected by the preceding trial type; the Stroop effect was larger in the high proportion congruent condition (90 msec) than in the low proportion congruent condition (72 msec), and this effect was consistent across the four trial sequence types.²

In summary, the sequence analysis demonstrates that the nature of the preceding trial can influence the size of the Stroop effect (Gratton et al., 1992). However, the sequence analysis also demonstrates that the CSPC effect reported here does not depend on the nature of the preceding trial.³

GENERAL DISCUSSION

One explanation for the ISPC effect reported by Jacoby et al. (2003) is that it reflects differences in word-color associations between items that accrue as a consequence of the item-specific proportion congruent manipulation. An alternative view is that the ISPC effect is one of a larger family of CSPC effects that reflect the learning of an association between salient contextual cues and the likelihood of congruency. Given the latter view, such context-

tual cues might then cue the retrieval of control processes that are most appropriate for the current item type, be it "likely congruent" or "unlikely congruent." The location-based CSPC effect appears to be explained best by the latter view, because the location contextual cue was associated equally with each of the four color responses. To our knowledge, this is the first demonstration that learning of nominally irrelevant cues to proportion congruent can provide a basis for contextual control over the Stroop effect.

Although we have compared our results to Jacoby et al. (2003), we acknowledge that caution should be taken in making such comparisons. For example, our Stroop task employed spatially and temporally segregated Stroop stimuli, whereas the task used by Jacoby et al. employed integrated word and color stimuli. Spieler, Balota, and Faust (2000) have noted that Stroop interference measured with integrated and spatially segregated color word stimuli may depend on different processes. The temporal segregation of word and color in our study is also a potential concern. The fact that our word stimuli were presented 100 msec prior to the onset of the color patch sets unique constraints on how our CSPC effect should be interpreted. Specifically, it is unlikely that our location-based CSPC effect reflects a process that modulates whether word reading occurs, because the cue to congruency occurs 100 msec after presentation of the word. Instead, we assume that word reading takes place in both proportion congruent conditions, that word reading can be integrated with color-naming processes to varying degrees, and that this integration process is sensitive to the location information afforded by probe onset. In contrast, the ISPC effect reported by Jacoby et al. could reflect control over whether word reading occurs. Whether the ISPC and CSPC effects actually do tap into different processes must be left as a question for further research.

The location-based CSPC effect reported here cannot be explained by the learning of associations between a single contextual dimension (e.g., location) and response. However, our results do not entirely rule out all associative accounts of CSPC effects. Note that, in our experiments, some word/location/color events appeared more frequently than others. Consequently, our location-based

Table 4
Sequence Analysis: Mean Color-Naming Response Latencies (RTs, in Milliseconds, With Standard Errors), Collapsed Across Experiments 1 and 2A

Trial $n-1$	Trial n												CSPC Effect	
	High Proportion Congruent						Low Proportion Congruent							
	Congruent		Incongruent		I - C		Congruent		Incongruent		I - C			
RT	SE	RT	SE	RT	SE	RT	SE	RT	SE	RT	SE	RT	SE	
High Proportion Congruent														
Congruent	487	10.6	586	10.7	99	8.7	495	10.5	582	10.8	87	7.6	11	7.3
Incongruent	504	10.4	578	11.3	74	8.5	519	10.9	570	11.3	51	9.7	23	12.0
Low Proportion Congruent														
Congruent	484	10.8	587	15.0	103	10.5	491	13.2	570	10.9	79	10.2	24	12.2
Incongruent	496	10.1	579	10.5	83	7.1	502	10.1	570	10.3	68	6.2	15	6.3

Note—I - C, incongruent minus congruent.

CSPC effect could be driven by learning of associations between word/location compounds and responses. Although it is unclear why the learning of these compounds would not contribute to performance when likelihood of congruency is tied to shape contexts, we acknowledge that further research on the viability of associative accounts is warranted.

We propose instead that the location-based CSPC effect may reflect the learning of associations between context and likelihood of congruency. In this case, two distinct mechanisms could contribute to contextual control over the Stroop effect reported here. First, the CSPC effect could reflect a contextually driven control process that rapidly modifies the selection of abstract task sets. Given this view, abstract task sets that control word-reading processes would be selected in response to some preliminary perceptual processing of the target item's context. A very different account of CSPC effects would make reference to episodic memory principles. Given this alternative view, perceptual processing of a target item's context may reinstantiate the procedures used to encode previously experienced items (Kolers & Roediger, 1984). Accordingly, adaptive control over the contribution of word reading to performance would be inherent in the memory procedures that are recapitulated in the service of responding to particular word/location/color combinations. Our current work on this issue is aimed at distinguishing between a strong episodic view of stimulus-driven control and the more abstract set-switching alternative.

REFERENCES

- ALLPORT, A., & WYLIE, G. (2000). Task-switching, stimulus-response bindings, and negative priming. In S. Monsell & J. Driver (Eds.), *Control of cognitive processes: Attention and performance XVIII* (pp. 35-70). Cambridge, MA: MIT Press.
- COHEN, J. D., DUNBAR, K., & MCCLELLAND, J. L. (1990). On the control of automatic processes: A parallel distributed processing model of the Stroop effect. *Psychological Review*, *97*, 332-361.
- GRATTON, G., COLES, M. G. H., & DONCHIN, E. (1992). Optimizing the use of information: Strategic control of activation of responses. *Journal of Experimental Psychology: General*, *121*, 480-506.
- JACOBY, L. L., LINDSAY, D. S., & HESSELS, S. (2003). Item-specific control of automatic processes: Stroop process dissociations. *Psychonomic Bulletin & Review*, *10*, 638-344.
- KOLERS, P. A., & ROEDIGER, H. L., III (1984). Procedures of mind. *Journal of Verbal Learning & Verbal Behavior*, *23*, 289-314.
- LINDSAY, D. S., & JACOBY, L. L. (1994). Stroop process dissociations: The relationship between facilitation and interference. *Journal of Experimental Psychology: Human Perception & Performance*, *20*, 219-234.
- LOGAN, G. D. (1998). What is learned during automatization? II. Obligatory encoding of spatial location. *Journal of Experimental Psychology: Human Perception & Performance*, *24*, 1720-1736.
- LOGAN, G. D., & ZBRODOFF, N. J. (1979). When it helps to be misled: Facilitative effects of increasing the frequency of conflicting stimuli in a Stroop-like task. *Memory & Cognition*, *7*, 166-174.
- LOWE, D., & MITTERER, J. O. (1982). Selective and divided attention in a Stroop task. *Canadian Journal of Psychology*, *36*, 684-700.
- MACLEOD, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin*, *109*, 163-203.
- MAYR, U. (1996). Spatial attention and implicit sequence learning: Evidence for independent learning of spatial and nonspatial sequences. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *22*, 350-364.
- POSNER, M. I., & SNYDER, C. R. R. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola Symposium* (pp. 55-85). Hillsdale, NJ: Erlbaum.
- SCHNEIDER, W. (1988). Micro Experimental Laboratory: An integrated system for IBM PC compatibles. *Behavior Research Methods, Instruments, & Computers*, *20*, 206-217.
- SHIFFRIN, R. M., & SCHNEIDER, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, *84*, 127-190.
- SPIELER, D. H., BALOTA, D. A., & FAUST, M. E. (2000). Levels of selective attention revealed through analyses of response time distributions. *Journal of Experimental Psychology: Human Perception & Performance*, *26*, 506-526.
- STROOP, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*, 643-662.
- VAN SELST, M., & JOLICŒUR, P. (1994). A solution to the effect of sample size on outlier elimination. *Quarterly Journal of Experimental Psychology*, *47A*, 631-650.
- WEST, R., & BAYLIS, G. C. (1998). Effects of increased response dominance and contextual disintegration on the Stroop interference effect in older adults. *Psychology & Aging*, *13*, 206-217.

NOTES

1. Because of a technical difficulty, we were unable to analyze the error rates for each participant in this experiment. However, error rates in the subsequent experiments were extremely low, and it is assumed that participants in the present experiment were performing the task with few errors.
2. Of less importance are the main effects derived from the sequential analysis. The main effect of trial $n-1$ proportion congruent was significant [$F(1,31) = 8.25, MS_e = 454.90, p < .01$]. Performance on trial n was slower when trial $n-1$ was high proportion congruent (540 msec) than when it was low proportion congruent (534 msec). The main effect of trial $n-1$ congruency was significant [$F(1,31) = 4.3, MS_e = 578.25, p < .05$]. Performance on trial n was faster when trial $n-1$ was congruent (535 msec) than when it was incongruent (540 msec). Of course, the main effect of trial n congruency was also significant, with faster performance on congruent trials (497 msec) than on incongruent trials (578 msec).
3. In combining the data from Experiments 1 and 2A, we were also interested in whether the CSPC effect depended on the particular locations that were counterbalanced across participants. Thus, the analysis reported for Experiments 1 and 2A was repeated as a mixed design ANOVA with location (up or down) as a between-participants factor. The three-way interaction of location \times proportion congruent \times congruency was not significant. There was no evidence that the CSPC effects observed here depended on particular locations.

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