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How Is Location Defined? Implications for Learning and Transfer of Location-Specific Control

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Much research has explored location-specific proportion compatibility (LSPC) effects (i.e., how the appearance of a stimulus in certain locations can reactively trigger different attentional control settings) to elucidate mechanisms underlying reactive control. Recently, however, failures to reproduce key evidence showing transfer of LSPC effects (originally reported in Crump & Milliken, 2009) have called into question whether control per se supports these effects. Notably, Crump and Milliken (2009), and all studies attempting to reproduce their findings, presented stimuli in two locations, one above and one below fixation. Inspired by research on differences between horizontal and vertical meridians, we examined the consequences of defining location in this way compared with alternatives. Experiments 1 and 2 demonstrated that LSPC effects are robust when location is defined as left versus right and larger than when location is defined as upper versus lower, and additionally demonstrated LSPC effects for two locations within the same coarse spatial category (e.g., left vs. farther left). In Experiment 3, we aimed to reproduce Crump and Milliken's key findings using left and right locations for the first time. Critically, we found transfer of the LSPC effect to diagnostic items across two designs and the first evidence for a robust experiment wide LSPC effect for inducer items. Our findings support theories positing that LSPC effects reflect location-specific attentional *control* and more generally suggest that choosing a definition of location is not a minor methodological decision but critically impacts learning and transfer of location-specific attentional control.

Public Significance Statement
Successfully accomplishing daily tasks requires focusing on relevant, while ignoring irrelevant, stimuli, by employing *attentional control*. Prior research has shown that attentional control can be allocated differentially across different areas of space depending on where it is most needed (i.e., locations where there are more often irrelevant stimuli that must be ignored). Here we examine how relationships between the locations needing differential control (e.g., are they in different vertical categorical locations—upper vs. lower, different horizontal categorical locations—left vs. right, or within the same category—both within left) influence the allocation of attentional control and demonstrate that some spatial layouts naturally lend to more efficient flexible attentional control. In other words, the degree to which humans can vary the amount of attentional control they exert to accomplish certain tasks is dependent on where stimuli for these tasks appear.

Keywords: attentional control, context-specific proportion congruence, location-specific proportion compatibility, reactive control

Countless times each day, we require the quick and flexible allocation of attentional control—focusing on goal-relevant stimuli while ignoring irrelevant ones—to simply get things done. There is considerable research demonstrating that attentional control can be allocated rapidly after the presentation of a stimulus in response to environmental cues, thereby producing moment-to-moment changes in behavior (cf. Bugg & Crump, 2012 for a review). An excellent example of this is cuing of the appropriate allocation of control by location. In a seminal study, Corballis and Gratton (2003) had participants indicate the central letter in a string of letters with a keypress (i.e., perform a classic *Flanker* task, see, e.g., Eriksen & Eriksen, 1974). That central letter could be *compatible*

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with the so-called flanking letters (i.e., embedded within other letters that would elicit the same response, e.g., SSSSS) or *incompatible* with the flanking letters (i.e., embedded within other letters that would elicit a different response, e.g., SSHSS). Unpredictably, the string of letters appeared on the left or right side of fixation, but when it appeared in one location of space (e.g., left) it was more likely to be a compatible trial whereas when it appeared in the other location (e.g., right) it was more likely to be an incompatible trial. The compatibility effect (slowing of response time on incompatible relative to compatible trials) was reduced in the mostly incompatible (MI) location that had a higher probability of incompatible trials (i.e., conflict) relative to the mostly compatible (MC) location that had a lower probability of those conflicting trials.

Much research has since replicated and expanded our knowledge about what has come to be known as *context-specific proportion compatibility* (CSPC) *effects*. For example, CSPC effects are not limited to the flanker task; they occur in Stroop[1] (e.g., Crump et al., 2006) and Simon (Hübner & Mishra, 2016) tasks, as well as in dual tasking (e.g., Fischer et al., 2014) and visual search (Crump et al., 2018) paradigms. Furthermore, other contextual features in addition to location, such as color (e.g., Lehle & Hübner, 2008), font (e.g., Bugg et al., 2008), shape (e.g., Crump et al., 2008), and higher-level concepts like gender (e.g., Cañadas et al., 2013), cue appropriate control settings (i.e., more or less stringent allocation of control). CSPC effects are important as they help us learn about the properties of *reactive control* (e.g., Braver et al., 2007). That is, in all CSPC paradigms, because it is impossible to predict the contextual feature (e.g., location in which a stimulus appears) prior to its onset, control must necessarily be allocated reactively and rapidly upon appearance of a stimulus

In the present studies, we exclusively examined the contextual cue of location and therefore, for increased precision, we henceforth refer to the empirical pattern—larger compatibility effects in MC versus MI locations—as the *location specific proportion compatibility* (LSPC) effect. As described above, Corballis and Gratton (2003) first demonstrated the LSPC effect. Crump and colleagues soon provided another demonstration (Crump et al., 2006) and established many other properties of the effect. For example, the LSPC effect occurs in the absence of awareness of the differential probabilities of conflict across locations (Crump et al., 2008). In addition, the LSPC effect seems more robust than other context-specific effects given that LSPC effects are observed in the absence of other design features that appear necessary to observe other CSPC effects (cf. e.g., Lehle & Hübner, 2008, for color-based CSPC effects; Crump et al., 2006, 2008, for shape-based CSPC effects).

The prevailing theoretical account of the LSPC effect is the *episodic retrieval account* (e.g., Crump & Milliken, 2009). This account posits that the LSPC effect reflects the learning of associations between each location, its proportion compatibility (i.e., likelihood of conflict), and the attentional control setting (i.e., more or less stringent) that has been frequently used when interacting with stimuli in a given location (Crump et al., 2006, 2008; Crump & Milliken, 2009). Thus, when later encountering a stimulus in a location, the associated attentional control setting is retrieved. Recruitment of a relatively more stringent setting in the MI locations produces a smaller compatibility effect than the less stringent setting that is recruited in the MC location.

There are competing accounts that argue LSPC effects are not attributable to shifts in attentional control but instead to learning about contingencies between stimuli (the irrelevant dimension) and associated responses in each location (see e.g., Schmidt & Besner, 2008; Schmidt & Lemercier, 2019). The strongest piece of evidence against such accounts stems from designs that afford the examination of transfer of location-specific attentional control settings to a novel set of stimuli. However, to date, the evidence for such transfer is mixed. We'll next review these designs and that evidence. Then we will introduce the primary variable we examined that we thought might critically influence a researcher's ability to observe LSPC effects and transfer of LSPC effects to novel stimuli, and accordingly, provide evidence for control-based accounts of LSPC effects (e.g., the episodic retrieval account).

Transfer of Location-Specific Attentional Control Settings: A Theoretically Important but Instable Pattern

The initial studies reporting LSPC effects (e.g., Corballis & Gratton, 2003; Crump et al., 2006, 2008) used only *inducer* items—a single set of stimuli that was MC when appearing in one location (e.g., upper location) and MI when appearing in the other location (e.g., lower location). Crump and Milliken (2009) were the first to use an inducer/diagnostic design that combined inducer items with *diagnostic* items in a LSPC paradigm. Diagnostic items are distinct from inducer items in that they are PC-unbiased (i.e., 50% compatible) in both locations and taken from a separate set of stimuli that shares no features with the inducer item set (e.g., the colors and words blue and yellow in a Stroop task might be used to create the inducer items, whereas the colors and words red and green would be used to create the diagnostic items). An LSPC effect for diagnostic items (i.e., a smaller compatibility effect for diagnostic items that appeared in the MI location compared with the MC location) demonstrates *transfer* of location-specific attentional control settings and represents the strongest evidence for location-specific control independent of known confounds (e.g., contingency learning, Schmidt & Besner, 2008; Schmidt & Lemercier, 2019; feature-based priming of associated control settings based on stimulus features like color, see Braem et al., 2019).

Using this inducer/diagnostic design, Crump and Milliken were the first to demonstrate that attentional control settings did indeed transfer beyond inducer items that were MC or MI (referred to as the "92/8" design where the MC condition is 92% compatible and the MI condition is 8% compatible) and beyond inducer items that were all compatible or all incompatible (referred to as the "100/0" design) to diagnostic items. However, recent studies have called into question the stability of these theoretically significant effects and accordingly whether control is at the heart of the LSPC effect. As is apparent from Table 1, since Crump and Milliken's (2009) demonstration, only one

[1] The Stroop and Simon are two commonly used tasks that also have compatible and incompatible trials (as described for the Flanker task referenced in Corballis & Gratton, 2003 earlier) and produce a *compatibility* effect that is modulated across locations to result in a CSPC effect. In the Stroop task, participants name the ink color and conflict arises when the word meaning conflicts (see e.g., MacLeod, 1992). In the Simon task, participants indicate the color of a shape, and conflict arises when the necessary response is on the opposite side of space in which that shape appears (e.g., a shape that needs a left response appears on the right, see e.g., Simon, 1990).

Table 1
Size of Inducer and Diagnostic Effects in Prior Research That Has Investigated Transfer From Biased Inducer Items to Novel Unbiased Diagnostic Items (All Using Upper and Lower Locations)

Study	Experiment	Task	PC of Inductor Items (%)	Inducer Effect (ms, η_p^2)	Diagnostic Effect (ms, η_p^2)
Crump and Milliken (2009)	1	Color Word Stroop (Prime Probe)	100/0	NA	8[ah], X
	2	“”	92/8	18[h], X	*14[a], .21
Hutcheon and Spieler (2017)	1	“”	92/8	−13, .05	16, .05
	2	“”	83/17	−9, .04	7, .04
Crump et al. (2017)	1	“”	100/0	NA	*20, .10
	2	“”	92/8	−20[a], X	0[a], X
	3	Letter flanker	100/0	NA	*11, .03
	4	Letter flanker	92/8	8[a], X	*22[a], .16
Bugg et al. (2020)	1	Picture word Stroop	75/25	6, .02	−4, .01

Note. * = Location-specific proportion compatibility effect was statistically significant overall. [h] = effect was only statistically significant in the second half of the experiment. [a] = overall effect was not reported and the presented number was derived by averaging across the reported numbers for each half (and response modality in Crump et al., 2017, Experiment 2). X = those data are not available in the publications.

study has reproduced transfer to diagnostic items in the 92/8 design (Crump et al., 2017; Experiment 4) whereas several studies from different labs have failed to reproduce the finding (Bugg et al., 2020 Experiment 1; Crump et al., 2017; Experiment 2; Hutcheon & Spieler, 2017; Experiments 1 and 2). Notably, in these studies not only was transfer (i.e., a LSPC effect for diagnostic items) not observed, but additionally no LSPC effect was found for the inducer items, in contrast to what Crump and Milliken observed. This suggests participants did not learn the association between location, PC, and the corresponding attentional control settings based on experience with the inducer items. Fewer labs have tried to reproduce the findings from the 100/0 design but thus far, the transfer effect in the diagnostic items has been stable (see Crump et al., Experiments 1 and 3; note that the inducer LSPC effect cannot be calculated in the 100/0 design).

Theoretically, there has been some effort to explain the instability of the LSPC effect. For example, Bugg et al. (2020, Experiment 3; see also Bugg et al., 2021) provided evidence in support of the item-PC learning hypothesis which suggests that in the LSPC paradigm, participants may be more inclined to attend to and learn associations between individual items (which are response relevant) and their associated attentional control settings than between locations (which are nominally irrelevant) and attentional control settings (see also Hutcheon & Spieler, 2017). Although this hypothesis can account for why prior attempts to reproduce the inducer and diagnostic LSPC effects from the 92/8 design of Crump and Milliken (2009) have yielded null effects, it has yet to provide an answer to the key question—how do you produce a LSPC effect for inducer and diagnostic items?

One notable observation in this respect is that *no* study to date using the inducer/diagnostic design has demonstrated a reliable LSPC effect for the inducer items across the whole experiment. In other words, no study has evidenced significant learning of the association between locations and attentional control settings (i.e., location-PC learning resulting in a more stringent setting for the MI than MC location). In Crump and Milliken (2009), the effect was observed only in the second half of trials, and all subsequent studies failed to produce a LSPC effect at all for inducer items (this includes Experiment 4 of Crump et al., 2017, where a LSPC effect was found for the diagnostic items). This raises the logical possibility that one might be more likely to observe transfer of the LSPC effect to diagnostic items if it can be determined how to increase learning of the association between locations and PC (i.e., strengthen the LSPC effect for inducer items). Here, we examined the potential role of a simple design element—where on screen stimuli are presented to create MC and MI locations (i.e., how location is defined)—in LSPC paradigms seeking critical evidence for learning and/or transfer of location-specific attentional control. In all prior investigations of transfer to novel diagnostic items (and more generally the majority of LSPC research), stimuli were presented on screen along the vertical axis (i.e., researchers defined location as upper vs. lower).[2] We reasoned that presenting stimuli along the horizontal axis (i.e., defining location as left vs. right) might strengthen the magnitude of the inducer LSPC effect that has been weak/instable in the past (see Table 1) and, further, facilitate transfer of location-specific control to the diagnostic items.

Although differences in attentional control modulation based on PC (i.e., the LSPC effect) across the axes have not been directly examined to date, there are several pieces of evidence that converge in raising the possibility that LSPC effects may be larger along the horizontal axis (i.e., left and right locations). Early work on the distribution of visual attention established that there are vertical and horizontal meridians that divide the visual field into left/right and upper/lower hemifields, respectively (e.g., Rizzolatti et al., 1987). There is evidence that these meridians act as permeable boundaries that inhibit the spread of attention from one hemifield to another (e.g., Tassinari et al., 1987). Importantly to the present investigation, it has been found that the vertical meridian (separating left and right hemifields) is less permeable than the horizontal meridian

[2] Indeed, most LSPC research has oriented the stimuli vertically, presumably based on Crump and colleagues' early work (Crump et al., 2006, 2008; Crump & Milliken, 2009) that defined their two location contexts as above and below fixation. Crump et al. (2006) did not specify why they chose this design, but what is clear is that the majority of subsequent LSPC research has also defined locations as above and below fixation (e.g., Bugg et al., 2020; Crump et al., 2008, 2017; Crump & Milliken, 2009; Diede & Bugg, 2016; Gottschalk & Fischer, 2017; Hübner & Mishra, 2016; Hutcheon & Spieler, 2017; Surrey et al., 2017, 2019; vel Grajewska et al., 2011; Vietze & Wendt, 2009; Weidler et al., 2021; but see, e.g., King et al., 2012, for a left-right example).

(separating upper and lower hemifields; Hughes & Zimba, 1987). This finding is consistent with the cortical representation of these fields; the left/right hemifields have interhemispheric segregation (i.e., the left represented in the right hemisphere and vice versa) whereas the upper/lower hemifields have intrahemispheric segregation (both upper and lower are in both the right and left hemispheres; cf., Sereno & Kosslyn, 1991). Together, these findings suggest that left and right locations could be represented more distinctively from each other than upper and lower locations. There is other converging evidence that attention may operate differentially along the vertical and horizontal axes—for example, there is better target discrimination in cuing tasks for stimuli presented along the horizontal as compared with vertical axis (Mackeben, 1999). Additionally, research has shown that automatic spatial codes may be activated more readily and that there may be more spatial codes—both across hemifield and within hemifield—available for recruitment along the horizontal than vertical axis (e.g., Nicoletti & Umiltà, 1984; Rubichi et al., 2005). Related to the speed of activation of spatial codes, when participants are cued about which response keys to use to respond to a subsequently appearing target with either a horizontal or vertical arrow cue, response times are faster following the horizontal cue (Proctor et al., 2006).

Taken together these findings point to two possible mechanisms —distinctiveness or speed of activation—that could potentially increase the LSPC effect along the horizontal. According to the distinctiveness hypothesis, the less permeable vertical meridian (Hughes & Zimba, 1987) could result in the more stringent attentional control setting associated with, for example, the left side of space being represented *more* distinctly from the less stringent setting associated with the right side of space relative to the case in which these settings are associated with upper versus lower space. Theoretically, more distinct representations for MC and MI locations could facilitate learning of location-specific attentional control settings that are central to the episodic retrieval account of LSPC effects (Crump & Milliken, 2009). These representations could also potentially facilitate targeted retrieval of associated attentional control settings (e.g., presentation of a stimulus in the left side of space uniquely retrieves the more stringent attentional control setting), resulting in stronger LSPC effects along the horizontal. Alternatively, the speed of activation hypothesis proposes that the increased speed of activation of spatial codes when stimuli are presented along the horizontal could help boost the LSPC effect. Considering that LSPC effects represent a reactive (poststimulus onset) adjustment in control, more automatic or rapid activation of spatial codes along the horizontal axis compared with the vertical axis (cf. e.g., Nicoletti & Umiltà, 1984; Proctor et al., 2006) may provide a head start for such adjustments and thereby produce earlier learning and ultimately larger LSPC effects. Of course, it is possible that both distinctiveness and speed could be in operation at the same time.

The Current Study

In the present investigation we conducted three experiments. The first two experiments aimed to gather evidence to determine whether there was merit to our idea that how locations are defined (where on a computer screen stimuli are presented to create MC and MI locations) may influence the magnitude of LSPC effects (and ultimately the critical transfer of these effects). Our primary goal was examining LSPC effects in the standard upper versus lower location (vertical) layout and the alternative left versus right (horizontal) layout and comparing these two layouts for the reasons we noted just above. To address a secondary goal, we additionally included conditions in which both locations were in the same broad location category (e.g., both in "left" or both in "upper"), conditions which have not been examined in previous studies. Doing so afforded another way to gain insight into the distinctiveness hypothesis in addition to a test of the *categorical coding* hypothesis (see Introduction to Experiment 1 for further rationale).

To briefly preview our results, the key findings from Experiments 1 and 2 were that LSPC effects were robust for the horizontal layout and larger than the vertical layout. This reinforced our assumption that how MC and MI locations are defined does have implications for the size of the LSPC effect. With this information in hand, in Experiment 3 we attempted to reproduce the key findings of Crump and Milliken (2009), with an eye toward the critical question of whether we would observe LSPC effects for diagnostic items if we used a horizontal rather than a vertical layout as in all prior reproduction attempts. Such a finding would have significant implications for the LSPC literature, including expanding our understanding of the most optimal confound-minimized designs to reveal flexible attentional control (see, e.g., Braem et al., 2019).

Experiment 1

The goal of Experiment 1 was to examine how the definition of location (i.e., where on screen MC and MI locations appeared) influences LSPC effects. To that end, participants performed an arrow flanker task and stimuli appeared unpredictably in one of two locations—one location was MC and one was MI (note, we did not use diagnostic items in this experiment because the initial focus was on the size of the LSPC effect from "inducer items" in MC and MI locations). For some participants (Experiment 1A) these stimuli were on the vertical axis and for some participants (Experiment 1B) they were along the horizontal. Furthermore, for some participants both MC and MI locations appeared within the same hemifield. We included these *same category* conditions for two reasons. First, following the logic above that the LSPC effect might be reduced on the vertical axis when the meridian between the two locations makes them less distinctive than along the horizontal, it is certainly an open question about the magnitude of the LSPC effect when *no* meridian separates the MC and MI locations. Including this condition allows an additional test of how the distinctiveness between the high and low conflict locations might lead to learning and manifestation of an LSPC effect *a la* the episodic retrieval account (cf., e.g., Crump & Milliken, 2009). If a comparable LSPC effect were to emerge in these same category conditions, that might suggest that distinctiveness of locations is not a critical factor for the emergence/magnitude of the LSPC effect.

Second, this condition allows for a test of the *categorical coding hypothesis.* Specifically, prior research has suggested that location is coded categorically in LSPC experiments (rather than in a coordinate-based fashion [i.e., each precise location on its own], Weidler & Bugg, 2016). Thus, on a strong version of a categorical coding hypothesis, which posits that the LSPC effect depends critically on the ability to code the locations in categorically distinct ways, an LSPC effect would not be expected when the MC and

MI locations are presented in the same category condition because the locations appear in the same coarse spatial category (i.e., both in upper space on one side of a horizontal meridian, or in the left space on one side of a vertical meridian). Instead, participants may group the two locations together into a single 50% upper (or left) category of space, resulting in no LSPC effect (because both would be treated with an intermediate attentional control setting associated with a 50% likelihood of conflict; see Diede & Bugg, 2016, 2019, for an example of such grouping).

In summary, for some participants the MC and MI locations fell in *different categories,* or coarse areas of space (e.g., above or below fixation in Experiment 1A, left or right of fixation in Experiment 1B) as in previous studies. However, for other participants the two locations fell within the *same* coarse *category* (e.g., both above fixation in Experiment 1A, both left of fixation in Experiment 1B). These two experiments allowed us to ascertain: (a) whether the LSPC effect differs across vertical and horizontal spatial layouts and (b) whether the LSPC effect can occur (or differs in magnitude) when the two locations are within the same coarse categorical location compared with when they are not.

Method

Participants

Sixty-four undergraduates from University of Toronto ($N = 24$) and Washington University in St. Louis[3] ($N = 40$) participated in Experiment 1A, and an additional 64 undergraduates at University of Toronto participated in Experiment 1B. We determined the sample size for this and subsequent experiments based on power analyses from Crump et al. (2017) and Hutcheon and Spieler (2017). Specifically, Crump et al. (2017) determined that $N = 16$ or $N = 32$ was sufficient to detect an LSPC effect (2×2 interaction between PC and compatibility) in diagnostic items (size depending on the PC of the inducer items; smaller N for higher PC). Hutcheon and Spieler (2017) also estimated $N = 32$ being sufficient for .80 power to detect a LSPC effect (2×2 interaction between PC and compatibility). Thus, we applied the more conservative estimate of $N = 32$ in each of our between subjects conditions (that had the potential for the two-way interaction, which was of primary interest). All participants were 18–25 years old, had normal or corrected-to-normal vision. The experiment was approved by the Human Subjects IRB at both institutions.

Stimuli, Procedure, and Design

All stimuli were black and presented against a white background. Each trial began with a fixation cross (1 cm in height) presented centrally for 1,000 ms. Next, a flanker stimulus (a central arrow facing one of four directions flanked by six arrows, facing one of four directions, 1.5 cm in height) appeared until response. Participants indicated the direction of the central arrow as quickly as possible with one of four keys on the number pad (2 = down, 4 = left, 6 = right, 8 = up) with the index finger of their right hand.

Participants completed three test blocks of 96 trials with a break between each block. Test blocks were preceded by a practice block of 12 trials (chosen randomly from the test block). During each test block 48 stimuli appeared in each of the two locations. In the MC location, 36 (75%) stimuli were compatible; in the MI location, 12 (25%) were compatible.[4]

In the *different category* condition, the center of one stimulus location was positioned 4 cm above fixation and other was 4 cm below fixation in 1A (to the left or right of fixation in 1B; see Figure 1). In the *same category* condition both locations were still 8 cm apart but were presented on the same side of fixation (e.g., 4 cm below and 12 cm below in 1A, 4 cm to the left and 12 cm to the left in 1B). The location of the MC and MI bias (between the two possible locations in all conditions) and the categorical location (upper vs. lower in 1A, left vs. right in 1B, selectively in same condition) were counterbalanced across participants.

The design of each experiment was a 2 category (different or same) $\times$ PC (MC or MI) $\times$ 2 compatibility (compatible or incompatible) mixed design (with category as the between-subjects variable).

Results

A participant was removed from analysis if they made errors on more than 33.3% of incompatible trials (cf. Weidler & Bugg, 2016; Weidler et al., 2021). This resulted in removal of two participants in Experiment 1A for errors on 59.0 and 96.5% of incompatible trials and two participants in Experiment 1B (47.2% and 50.7% incompatible trial errors). Only trials with response times (RTs) between 200 and 2,000 ms (cf., e.g., Weidler & Bugg, 2016; 2018) were included in the analyses (trim removed .6% and .5% of trials in Experiments 1A and 1B respectively), and only RTs from correct trials were included in the RT analysis. In addition to the ANOVA results, we also present BF $10_{\text{inclusion}}$ factors for all null interactions with Fs > 1 (or for theoretically meaningful nulls regardless of the statistics) from JASP (e.g., Marsman & Wagenmakers, 2017; cf. Weidler et al., 2021). Bayes factors can be interpreted along a continuum with values less than 1 providing support for the null and larger than 1 providing support for the alternative, with increasing support provided as numbers get farther away from 1. Typically, BFs below 1/3 are considered to provide substantial evidence for the null (Wagenmakers et al., 2011).

Experiment 1A (Vertical)

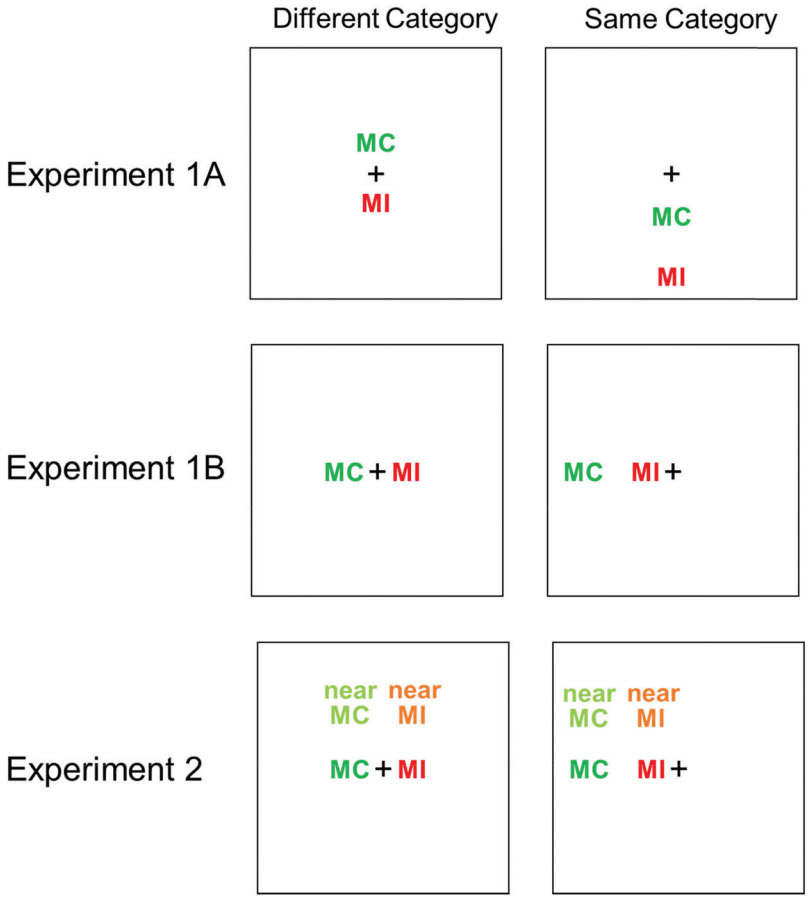
First, we present the theoretically important results from the 2 category (different or same) $\times$ 2 PC (MC or MI) $\times$ 2 compatibility (compatible or incompatible) mixed ANOVA on average RT (see Figure 2 and Table 2) Overall, there was a PC $\times$ compatibility interaction, $F(1, 60) = 11.76$, $p = .001$, $\eta_p^2 = .16$, revealing the LSPC effect: the compatibility effect was larger in the MC (132 ms[5]) than MI (111) location, and this effect was not modulated by category, $F < 1$, $\text{BF}_{\text{inclusion}} = .01$.

[3] We thank Jackson Colvett for help with data collection.

[4] A reader may wonder why we chose to use 75/25 PC instead of the 92/8 mentioned in related prior research (e.g., Crump & Milliken, 2009). In that 92/8 design, when collapsed across inducer and diagnostic items, the locations were 71% vs. 29% compatible. Therefore, our design more closely approximates the overall location PC of past studies, including those that included only inducer items (including the first demonstrations of LSPC effects which used 75/25; e.g., Corballis & Gratton, 2003; Crump et al., 2006). Relative to the 92/8 design, our design also increases observations of the infrequent cell in each PC (e.g., compatible in MI) for inducer items.

[5] All RT analyses units are milliseconds (ms), error rate analysis are percentages (%), and BFs are BF_{10} inclusion, although we drop the notation subsequently.

Figure 1
Schematic Example of the Two Locations in Each Category for Experiments 1 and 2



Note. In the different category condition, location of MC versus MI was counterbalanced across participants. In the same category condition, both the category in which stimuli appeared (e.g., left versus right in Experiment 1) and the location of MC versus MI within the category was counterbalanced across participants. See the online article for the color version of this figure.

Additional reliable effects were the main effect of compatibility, $F(1, 60) = 305.84$, $p < .001$, $\eta_p^2 = .84$, with compatible trials (595) faster than incompatible trials (717). There were no other main effects or interactions (Fs < 1).

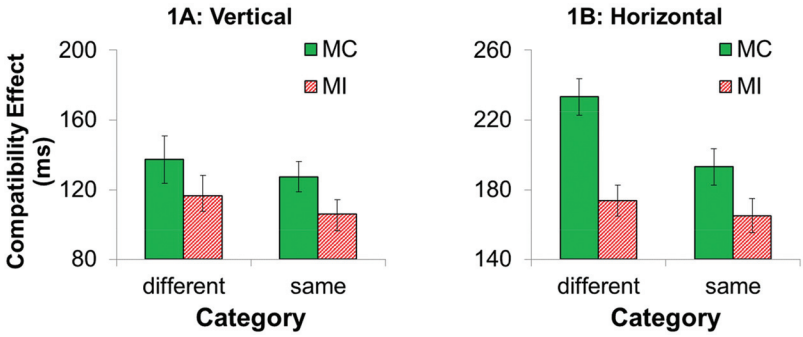
In the same analysis on error rate there were reliable main effects of compatibility and PC: with more errors in incompatible trials, $F(1, 60) = 48.23$, $p < .001$, $\eta_p^2 = .45$ (compatible = .54, incompatible = 4.09), and in the MC location, $F(1, 60) = 4.71$, $p = .034$, $\eta_p^2 = .07$, $M_{MC} = 2.59$, $M_{MI} = 2.05$). There was no main effect of category, $F(1, 60) = 3.41$, $p = .070$. PC and compatibility did not interact, $F(1, 60) = 2.32$, $p = .133$, BF = .26, nor did category and compatibility, $F(1, 60) = 2.90$, $p = .094$, BF = 2.51. Finally, PC and category did not interact and there was not a 3-way interaction, Fs < 1.

Experiment 1B (Horizontal)

Again discussing the theoretically important results first, the 2 category × 2 PC × 2 compatibility mixed ANOVA revealed a PC by compatibility interaction (i.e., there was an LSPC effect), $F(1, 60) = 49.53$, $p < .001$, $\eta_p^2 = .45$. The compatibility effect was larger in the MC (213) than MI (169) location. Interestingly, category modulated this effect, $F(1, 60) = 6.36$, $p = .014$, $\eta_p^2 = .10$. To further decompose the three-way interaction, we ran a 2 PC × 2 compatibility ANOVA within each category. The factors interacted both when the two locations were in different categories, $F(1, 31) = 49.40$, $p < .001$, $\eta_p^2 = .61$, and the same category, $F(1, 29) = 9.43$, $p = .005$, $\eta_p^2 = .25$, but the LSPC effect was larger in the different condition (59) than the same condition (28, see Figure 2 for critical pattern and Table 2 for all cell means).

In addition, there was a main effect of compatibility, $F(1, 60) = 926.30$, $p < .001$, $\eta_p^2 = .94$, with compatible trials (622) faster than incompatible trials (813). There was also a main effect of PC, $F(1, 60) = 5.60$, $p = .021$, $\eta_p^2 = .09$, with faster RTs in the MI (712) than the MC (722) location. There was not a main effect of category, $F(1, 60) = 1.09$, $p = .301$. However, category interacted with PC, $F(1, 60) = 5.66$, $p = .021$, $\eta_p^2 = .09$. The slowing in MC compared with MI trials was driven by the different category (20) not the

Figure 2
Compatibility Effects as a Function of Whether the Two Locations Were in a Different Category or the Same Category and PC in Experiment 1A (Left Panel; When the Stimuli Were Along the Vertical Axis) and 1B (Right Panel; When the Stimuli Were Along the Horizontal Axis)



Note. There was a reliable LSPC effect in both category conditions in both experiments. However, selectively in Experiment 1B, the LSPC effect was larger when the two locations were in different categories than the same category. Error bars are standard errors of the mean. See the online article for the color version of this figure.

same category (0) condition. The compatibility by category interaction, $F(1, 60) = 3.76$, $p = .057$, BF = 7.74, did not reach significance.

The same analysis on error rate also revealed the PC by compatibility interaction, $F(1, 60) = 4.13$, $p = .047$, $\eta_p^2 = .06$, because the compatibility effect was larger in the MC (5.44) than MI (4.28) location. There was also an effect of compatibility, $F(1, 60) = 52.59$, $p < .001$, $\eta_p^2 = .47$ (compatible = .61, incompatible = 5.47) and an effect of category, $F(1, 60) = 4.13$, $p = .046$, $\eta_p^2 = .06$ (different = 3.90, same = 2.18). There was no effect of PC, $F(1, 60) = 3.51$, $p = .066$, no compatibility by category interaction, $F(1, 60) = 2.15$, $p = .148$, BF = 1.96, no PC by category interaction, $F < 1$, and no three-way interaction, $F(1, 60) = 1.92$, $p = .171$, BF = .05.

Across-Experiment Comparisons

We directly compared performance across the vertical and horizontal conditions with a 2 experiment × 2 category × 2 PC × 2 compatibility mixed ANOVA on RT data. Focusing on the experiment factor, the analysis revealed that experiment modified the PC by compatibility interaction (i.e., the LSPC effect), $F(1, 120) = 6.76$, $p = .010$, $\eta_p^2 = .05$, because the LSPC effect overall was larger along the horizontal axis in Experiment 1B (44) than along the vertical axis in Experiment 1A (21). There was also a main effect of experiment, $F(1, 120) = 13.39$, $p < .001$, $\eta_p^2 = .10$, and an interaction between experiment and compatibility, $F(1, 120) = 54.81$, $p < .001$, $\eta_p^2 = .31$, because RTs were slower and compatibility effects were bigger along the horizontal (717 and 191, respectively) than the vertical axis (656 and 122, respectively). The four-way interaction failed to reach significance, $F(1, 120) = 3.34$, $p = .070$, BF = .05, and neither the three-way interaction between experiment, PC, and category, $F(1, 120) = 1.75$, $p = .188$, BF = .13, nor the two-way experiment × PC interaction, $F(1, 120) = 1.69$, $p = .196$, BF = .55, was significant. Finally, there was no three-way interaction between experiment, category, and compatibility, $F < 1$.

Discussion

Three main findings emerged from Experiment 1. First, and most importantly, the definition of location did influence the LSPC effect: The LSPC effect was robust in the horizontal context and larger than in the vertical context. This finding is meaningful because it suggests there is value in investigating the theoretically important question of whether transfer to diagnostic items may be more easily facilitated when stimuli are along the horizontal, where larger LSPC effects are found for inducer items.

Second, we found that the LSPC effect was observed even when the two locations were presented within the same coarse category of space. This was true regardless of whether the locations were arranged vertically (1A) or horizontally (1B). This suggests that a strong form of the *categorical coding* hypothesis is not tenable. When Weidler and Bugg (2016) found that novel, 50% compatible locations took on the control settings of nearby MC or MI locations, they hypothesized that experiences with conflict may be encoded categorically instead of in terms of specific coordinate locations (cf. e.g., Jager & Postma, 2003). Under a strong form of this hypothesis, there should have been no LSPC effect in the same category conditions of Experiment 1, because both locations were within the same coarse category. Of course, it is possible that a weaker form of this hypothesis is tenable—that is, LSPC effects in the same category conditions may have been supported by associating the attentional control settings with more narrowly defined categories (e.g., left = stringent; further left = more stringent), and this possibility will be investigated in Experiment 2.

Third, when the stimuli were presented horizontally, the LSPC effect was reliably larger when the two locations were in different categories of space than when the two locations were in the same category. This may not be surprising given that prior research has found that both hemifield and relative (i.e., in relation to each other) coding can be employed along the horizontal but not along the vertical axis (e.g., Rubichi et al., 2005). Selectively then the

Table 2
Mean Average RT (ms) and Error Rate (%) in Each Condition for Experiment 1 (SEs in Parentheses)

Experiment	Category	PC	Compatibility	RT (*SE*) in ms	Error (*SE*) in %
1A: Vertical	Different	MC	Compatible	592 (18)	.42 (.14)
			Incompatible	729 (19)	3.52 (.81)
			Interference	137	3.10
		MI	Compatible	598 (16)	.27 (.15)
			Incompatible	714 (22)	2.53 (.41)
			Interference	116	2.26
			LSPC	21	.84
	Same	MC	Compatible	591 (13)	.75 (.27)
			Incompatible	718 (18)	5.66 (1.23)
			Interference	127	4.91
		MI	Compatible	601 (13)	.73 (.29)
			Incompatible	707 (16)	4.66 (.98)
			Interference	106	3.93
			LSPC	21	.98
1B: Horizontal	Different	MC	Compatible	624 (14)	0.81 (.43)
			Incompatible	857 (21)	7.63 (1.50)
			Interference	233	6.82
		MI	Compatible	633 (15)	1.14 (.45)
			Incompatible	807 (18)	6.00 (.99)
			Interference	174	4.86
			LSPC	59	1.96
	Same	MC	Compatible	608 (15)	0.40 (.12)
			Incompatible	801 (21)	4.46 (1.04)
			Interference	193	4.06
		MI	Compatible	622 (18)	0.09 (.09)
			Incompatible	787 (23)	3.78 (.69)
			Interference	165	3.69
			LSPC	28	0.37

Note. PC = proportion compatibility; RT = response time; MC = mostly compatible; MI = mostly incompatible; LSPC = location-specific proportion compatibility effect.

different category condition along the horizontal axis could incorporate multiple forms of spatial coding to differentiate between the biases (MC vs. MI) across locations, which could have boosted the LSPC effect. Among other novel elements, Experiment 2 provides a chance to replicate these findings. Therefore, we reserve consideration of the broader implications of these findings (e.g., for the distinctiveness and speed of activation hypotheses) for the discussion section of Experiment 2

Experiment 2

Experiment 2 had two broad goals—the first goal was to further probe the categorical coding hypothesis, and the second goal was to attempt to replicate findings from Experiment 1B that have implications for the distinctiveness and speed of activation hypotheses. Turning to the novel elements of Experiment 2 first, in Experiment 1 the assumption was that locations on the left/right (or above/below) constitute different categories of space whereas locations, for example, entirely on the left (or above) constitute the same category. On this assumption, the results of Experiment 1 (namely, the presence of LSPC effects for the same category condition, in addition to the different category condition) challenged a strong categorical coding hypothesis which argues that the LSPC effect depends critically on the ability to code the locations in categorically distinct ways. However, an alternative interpretation is that our definition was too restrictive, and it is equally plausible that participants could encode two locations on the left, for example, in categorically distinct ways (e.g., left and farther left). Experiment 2 directly tested this possibility.

The design for this experiment mirrored Experiment 1B (horizontal) with two additional blocks of trials. These two final blocks included the identical trials as in Blocks 1–3 and, critically, an equal number of trials occurring in two novel, PC-unbiased (50% compatible) *transfer* locations presented directly above the two training locations (see Figure 1) and thereby representing the same category of space as the two training locations (e.g., left and farther left in one of the same category conditions). Thus, Experiment 2 afforded a test of transfer of the LSPC effect to novel locations both in the same category condition and the different category condition. This test of transfer[6] allows us to determine whether there is categorical coding of space selectively when the two locations are in different coarse spatial categories, or additionally when the locations are in the same broad location.

[6] For clarity we note that these *transfer* items are similar in purpose to *diagnostic* items discussed in the introduction (cf. Crump & Milliken, 2009) and employed in the subsequent experiments in this article (Experiments 3a/3b) in that they assess the flexibility of attentional control to extend beyond learning from biased trials. There is an important difference however—the transfer items discussed here and employed in Experiment 2 are drawn from the same set of stimuli as MC and MI items but are presented at different locations. Diagnostic items are presented in the same locations as MC and MI items but are drawn from a different set of items.

Transfer of the LSPC effect to new locations occurs when there is evidence for differing compatibility effects between the two novel locations based on whether they are nearer to an MC or MI location (larger compatibility effects emerge for novel locations near MC locations than novel locations near MI locations even though the novel locations are both 50% compatible). Importantly, this transfer is attributed to the categorical coding of space (i.e., if location-conflict relationships were coded based on specific coordinates, there would not be evidence for transfer; Weidler & Bugg, 2016; Weidler et al., 2018). We expect to see transfer in the different category condition, given prior findings (e.g., Pickel et al., 2019; Weidler & Bugg, 2016; Weidler et al., 2018). The critical test is in the same category condition—if categorical coding of space is not occurring in this condition, then we should expect to see no transfer to novel locations. However, if categorical encoding (e.g., left vs. further left) is still indeed being employed then we should expect transfer to the novel locations in these categories of space.

Given that the first three blocks of the experiment were identical to Experiment 1B, Experiment 2 also afforded the opportunity to potentially replicate the findings of Experiment 1B: (a) that the LSPC effect emerged in the same category condition, (b) that it was smaller than in the different category condition, and (c) the generally robust LSPC effect along the horizontal, the latter of which would reinforce the goal of seeking further evidence that this particular definition of location might be useful for informing the theoretical debate about mechanisms underlying the LSPC effect (i.e., if it is control-based or not; cf. e.g., Crump et al., 2017).

Method

Participants

Sixty-four undergraduates at Towson University participated for course credit. All were 18–25 years old and had normal or corrected-to-normal vision. The study was approved by Towson University's Human Subjects IRB.

Stimuli, Procedure, and Design

The method was as in Experiment 1B except there were two additional blocks of 192 trials each. Within these blocks, 96 trials were exactly as the first three blocks, and 96 trials were presented as the Same × Coordinates as the other trials but 4 cm above the *x* axis (see Figure 1). These items were 50% compatible regardless of their location (i.e., each of the four compatible trials was repeated six times and each of the 12 incompatible trials was repeated two times in each location). In this experiment we refer to two "location types"—either training (for inducer locations with a PC bias [MC or MI]) or transfer (for locations without a PC bias that are either nearer to the MC or MI location, hence the *near MC* or *near MI* terminology)

Results

Three participants that made errors on 98.2, 53.0, and 95.5% of incompatible trials were excluded. The RT trim removed 1.4% of trials in remaining participants.

We first replicated the Experiment 1 analysis on RT from the MC and MI locations (now across all five test blocks). The 2 category × 2 PC × 2 compatibility mixed ANOVA revealed a PC by compatibility interaction, $F(1, 59) = 36.39$, $p < .001$, $\eta_p^2 = .38$ (i.e., LSPC effect). The compatibility effect was larger in the MC (230) than the MI location (187). Unlike in Experiment 1, category did not modulate the LSPC effect ($F < 1$; BF = .56, LSPC effect was 39 in different and 47 in same[7]; see Figure 3 and Table 3).

There was, as expected, also a main effect of compatibility, $F(1, 59) = 1051.69$, $p < .001$, $\eta_p^2 = .95$ (compatible = 737, incompatible = 946) as well as a main effect of PC, $F(1, 59) = 8.98$, $p = .004$, $\eta_p^2 = .13$, with responses faster in the MI (837) than MC (846) location. There was no main effect of category, $F(1, 59) = 1.33$, $p = .253$, nor did category interact with compatibility, $F(1, 59) = 3.68$, $p = .060$, BF = 5.10. Category also did not interact with PC, $F < 1$.

We then conducted a similar 2 category (different or same) × 2 location (near MC or near MI) × 2 compatibility mixed ANOVA on the novel transfer locations. There was a location by compatibility interaction, $F(1, 59) = 7.34$, $p = .009$, $\eta_p^2 = .11$, which is indicative of transfer: the compatibility effect was larger for unbiased items in locations near the MC location (197) than those near the MI location (175). Importantly, category did not modulate this effect ($F < 1$, BF = .07), indicating that the transfer effects were equivalent across the same and different category conditions (25 in different and 19 in same, see Table 2 and Figure 3). The only other reliable effect was that of compatibility, $F(1, 59) = 1192.70$, $p < .001$, $\eta_p^2 = .95$ (compatible = 718, incompatible = 904). There was no effect of category, $F(1, 59) = 2.95$, $p = .091$, or PC, $F(1, 59) = 2.58$, $p = .114$, nor did category interact with compatibility, $F(1, 59) = 1.54$, $p = .220$, BF = .61, or PC interact with category, $F < 1$.

The same analysis on error rates was conducted, first for MC and MI locations. There was the expected main effect of compatibility, $F(1, 59) = 38.76$, $p < .001$, $\eta_p^2 = .40$ (compatible = .57, incompatible = 4.29). Additionally, PC interacted with category, $F(1, 59) = 5.59$, $p = .021$, $\eta_p^2 = .09$. In the different category condition errors were .64 higher in MC than MI whereas in the same category condition errors were .06 lower in the MC location. There was no PC by compatibility interaction, $F(1, 59) = 3.12$, $p = .083$, BF =.09, nor was this interaction moderated by category, $F(1, 59) = 3.67$, $p = .060$, $BF < .01$. There was no main effect of PC, $F(1, 59) = 3.86$, $p = .054$, or category, $F < 1$, nor was there a compatibility by category interaction, $F < 1$.

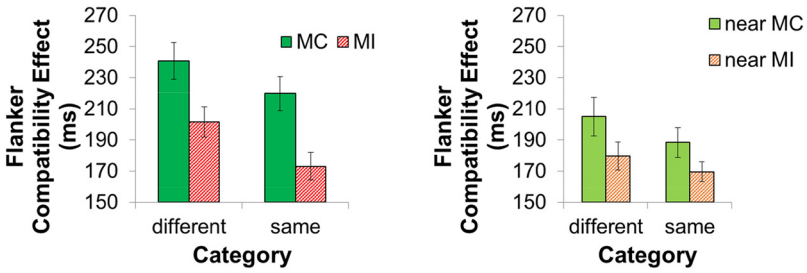
The same analysis was conducted for the novel transfer locations and revealed a Location × Compatibility interaction that mirrored that in RT, $F(1, 59) = 5.26$, $p = .025$, $\eta_p^2 = .08$: compatibility effects were larger in MC (4.55) than MI (3.16) locations. The only other effect was that of compatibility, $F(1, 59) = 32.20$, $p < .001$, $\eta_p^2 = .35$ (compatible = .66, incompatible = 4.52. There was no main effect of PC, $F(1, 59) = 1.64$, $p = .206$, nor a main effect of category, $F < 1$. There was also not a compatibility by category interaction, $F(1, 59) = 1.11$, $p = .296$, BF = .26, nor a PC by category interaction or three-way interaction, Fs < 1.

Discussion

We first discuss the results from the novel design elements of Experiment 2. Specifically, in terms of our test of transfer, there

[7] We additionally checked the LSPC effect in the first 3 blocks (i.e., the length of Experiment 1) and there was no difference between the size of the effect in the different (39) and same (45) conditions.

Figure 3
Results From Experiment 2



Note. There was an equivalently sized LSPC effect in both the same and different category conditions. There was also an equivalently sized transfer effect in both the same and different category conditions. See the online article for the color version of this figure.

was transfer of the LSPC effect from the MC and MI locations to the novel (50% compatible) locations in both the same and different category conditions. This suggests that participants are employing categorical encoding even when both locations appear in the same coarse category of space (for example, by coding the two locations as "left" and "further left"). However, we note that it is not mandatory that participants coded the space categorically in the present experiment. Given that the transfer locations were closer in space to their linked biased location than to each other, it could be possible that participants "grouped" the two categorically similar locations (e.g., grouped with MC locations and MC locations given their proximity; cf. Diede & Bugg, 2016). In either case, it is clear that coordinate coding (i.e., each location on its own; cf. Jager & Postma, 2003) is not being used because if participants had used coordinate coding, such transfer should not have been observed.

Turning to comparisons with Experiment 1B, we again saw an LSPC effect emerge when both MC and MI locations were in the same coarse category of space. However, we did not replicate the finding of a larger LSPC effect in the different (left vs. right) than

Table 3
Mean Average RT (ms) and Error Rate (%) in Each Condition for Experiment 2 (SEs in Parentheses)

Category	Location Type	PC	Compatibility	RT (*SE*) in ms	Error (*SE*) in %
Different	Training	MC	Compatible	741 (14)	0.65 (.18)
			Incompatible	982 (19)	4.82 (1.00)
			Interference	241	4.17
		MI	Compatible	749 (17)	0.67 (.27)
			Incompatible	951 (17)	3.51 (.74)
			Interference	202	2.84
			LSPC	39	1.33
	Transfer	near MC	Compatible	729 (14)	0.77 (.42)
			Incompatible	934 (18)	4.67 (1.33)
			Interference	205	3.90
		near MI	Compatible	736 (15)	0.99 (.38)
			Incompatible	916 (15)	3.37 (.98)
			Interference	180	2.38
			LSPC	25	1.52
Same	Training	MC	Compatible	720 (20)	0.46 (.16)
			Incompatible	940 (21)	4.37 (1.03)
			Interference	220	3.91
		MI	Compatible	736 (20)	0.49 (.18)
			Incompatible	909 (21)	4.46 (1.11)
			Interference	173	3.97
			LSPC	47	−0.06
	Transfer	near MC	Compatible	701 (16)	0.27 (.13)
			Incompatible	890 (15)	5.49 (1.23)
			Interference	188	5.22
		near MI	Compatible	705 (16)	0.61 (.22)
			Incompatible	875 (16)	4.55 (1.25)
			Interference	170	3.94
			LSPC	19	1.28

Note. PC = proportion compatibility; RT = response time; MC = mostly compatible; MI = mostly incompatible; LSPC = location-specific proportion compatibility effect.

the same category condition (e.g., left vs. farther left). Regarding the mechanism by which the LSPC effect may be boosted along the horizontal, these findings suggest that the distinctiveness of locations may not be the critical factor for the strength of an LSPC effect (because it appears the LSPC effect might not reliably differ in magnitude as a function of whether the locations are distributed across a meridian or not) but the speed of activation hypothesis remains viable (see the General Discussion for further discussion).

There was another consistency with Experiment 1, which is most important for our primary goal—LSPC effects in the different category conditions for MC and MI locations presented along the horizontal (59 ms and 39 ms for Experiments 1B and 2, respectively, resulting in effect sizes of η_p^2 = .61 and .29) were both larger than the different category condition in Experiment 1A where stimuli were presented along the vertical (21 ms difference and effect size of .16). As a reminder, this is potentially important because most LSPC research—including all experiments seeking transfer of LSPC attentional control settings to 50% compatible diagnostic *items* – have presented stimuli along the vertical axis (Bugg et al., 2020; Crump & Milliken, 2009; Crump et al., 2017; Hutcheon & Spieler, 2017). With the results of Experiments 1 and 2 in hand and lending support to our idea that how location is defined may matter for learning and transfer of LSPC effects, we proceeded to examine whether the failures to reproduce the theoretically important transfer from inducer to diagnostic items (Crump and Milliken's, 2009) as well as the LSPC effects for inducer items may in part be due to the vertical spatial configuration (i.e., upper and lower locations) used in prior research.

Experiment 3

All previous studies investigating the transfer of location-specific control from inducer to diagnostic *items* used stimuli that were presented along the vertical axis. Yet, our findings thus far suggest that LSPC effects are larger along the horizontal axis. Thus, in Experiments 3A and 3B we aimed to reproduce Crump and Milliken's (2009) pivotal findings using flanker stimuli presented along the horizontal axis. In Experiment 3A we attempted to reproduce their Experiment 1 finding using 100% or 0% compatible inducer items (and 50% compatible diagnostic items). Fewer labs have attempted to replicate or reproduce their finding of a LSPC effect for diagnostic items using this design (a LSPC effect cannot be calculated for the inducer items in this design), but the finding has thus far been stable (see Experiments 1 and 3, Crump et al., 2017) and therefore we expected to reproduce their findings with the flanker task. If our expectation is confirmed, Experiment 3A would also serve to reinforce that there is not something unique about our methodology that produces divergent findings from prior studies. This is important because in Experiment 3B we attempted to reproduce Crump and Milliken's Experiment 2 findings using MC or MI inducer items (and 50% compatible diagnostic items), and we predicted that we would find LSPC effects for inducer and diagnostic items unlike all reproduction attempts to date which have found a highly consistent pattern of findings that diverged from Crump and Milliken (i.e., no LSPC effect for inducer or diagnostic items; Bugg et al., 2020; Crump et al., 2017; Hutcheon & Spieler, 2017; for one exception showing an effect for diagnostic but not inducer items, see Crump et al., 2017; Experiment 4).

Method

Participants

Undergraduates at Towson University participated for course credit—68[8] in 3A and 64 in 3B. All were 18–25 years old, had normal or corrected-to-normal vision, and had not participated in Experiment 2.

Stimuli, Procedure, and Design

The stimuli were the same as in prior experiments. Participants completed 6 blocks of the same 96 trials in this experiment, half of which appeared left of fixation and half of which appeared to the right (in the same locations as the biased stimuli in the different category condition in Experiments 1B and 2). The blocks were designed as in Crump and Milliken (2009), and thus the flanker stimuli were divided into two sets: Left/Right and Up/Down. Counterbalanced across participants, one set of items served as the inducer items (100% compatible or 0% compatible in Experiment 3A; 92% compatible or 8% compatible in Experiment 3B), whereas the other set was diagnostic items. For the inducer items, when they appeared in the MC location they were all compatible (in 3A, 92% compatible in 3B) and when they appeared in the MI location they were all incompatible (in 3A, 8% compatible in 3B). See Figure 4 for a depiction of the method and trial counts in Experiment 3. The diagnostic items were 50% compatible regardless of the location in which they appeared.

Results

Five participants were excluded from 3A (incompatible error %s: 84.4, 57.6, 37.8, 95.5, and 100.0) and four participants (incompatible error percentages of 60.8, 37.2, 100.0, and 49.7%) were excluded from 3B based on the same exclusion criteria as the preceding experiments. In 3A the RT trim removed 2.7% of trials in the remaining participants and 2.2% of the remaining trials were errors (these numbers were 1.9% and 1.3%, respectively, in Experiment 3B).

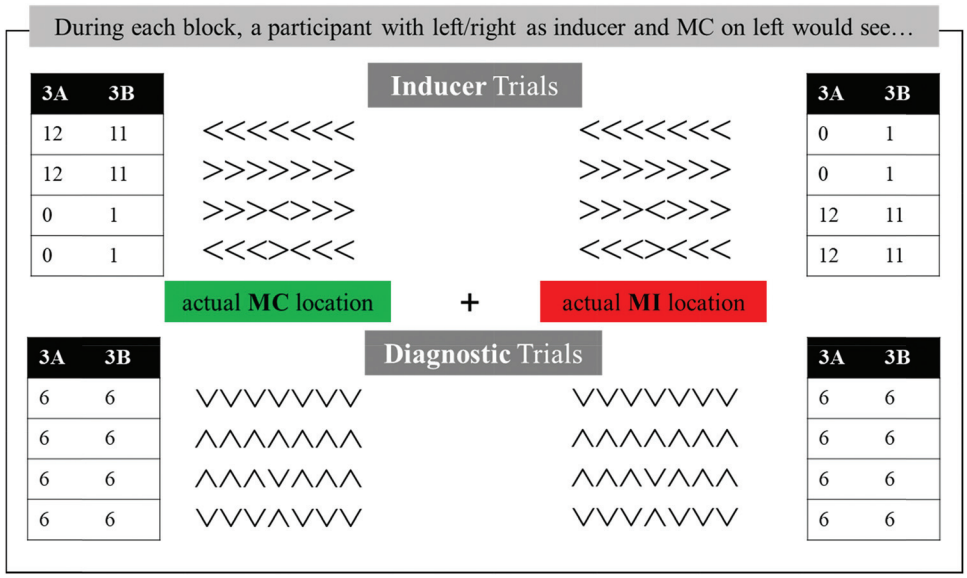
Experiment 3A: 100%0/0% Bias

As a reminder, LSPC effects cannot be calculated for inducer items in this design variant. We analyzed the diagnostic items with a 2 location (MC or MI) × 2 compatibility (compatible or incompatible) repeated-measures ANOVA. Importantly, there was a robust location by compatibility interaction indicating significant transfer, $F(1, 62) = 24.26$, $p < .001$, $\eta_p^2 = .28$. The compatibility effects were larger for diagnostic items that appeared in the MC location (301) than the same exact items that appeared in the MI location (261; see Figure 5 and Table 4 for all descriptive statistics from Experiment 3).[9]

[8] Although there was no between-subjects manipulation in Experiment 3 we maintained the sample size to be comparable with more recent reports seeking transfer to diagnostic items (cf. Bugg et al., 2020).

[9] Although the effects of half (first vs. second) on the LSPC effect have not proved to be stable (Bugg et al., 2020; Hutcheon & Spieler, 2017), we nonetheless (for completeness) reran this analysis including half of experiment as a factor. The 2 half × 2 location × 2 compatibility ANOVA revealed a main effect of half, $F(1, 62) = 70.719$, $p < .001$, $\eta_p^2 = .53$ (first = 942, second = 862) and a half by compatibility interaction (304 in first, 261 in second). There was no three-way interaction, $F(1, 62) = 2.34$, $p = .131$.

Figure 4
Method of Experiments 3A and 3B



Note. On each trial a single flanker stimulus would appear alone on screen in the location of either the green or red box depicted above. The numbers in the table indicate how many of each stimulus would appear in the left/right location per block for a participant assigned to left/right arrows as the inducer set and for MC bias to be on the left. See the online article for the color version of this figure.

There were also main effects of both variables. RTs were faster on compatible (761) than incompatible (1,042) trials, $F(1, 62) = 360.29$, $p < .001$, $\eta_p^2 = .85$, and in the MI (895) compared with the MC (908) location, $F(1, 62) = 8.87$, $p = .004$, $\eta_p^2 = .13$.

The same analysis on error rate produced converging results. The factors interacted, $F(1, 62) = 9.07$, $p = .004$, $\eta_p^2 = .13$, because the increased error rate in incompatible trials relative to compatible trials was larger in the MC (3.84) than the MI (2.78) location. There were more errors on incompatible trials (4.08) than compatible trials (.77), $F(1, 62) = 16.22$, $p < .001$, $\eta_p^2 = .21$, and in the MC (2.84) compared with MI (2.01) location, $F(1, 62) = 14.13$, $p < .001$, $\eta_p^2 = .19$.

For completeness we also compared RTs and error rates in the all (i.e., 100%) C versus all I inducer trials with paired samples t tests. Performance was better in compatible (756, .86 error rate) than incompatible trials (1,027; 3.41 error rate), $t(62) = 16.34$, $p < .001$ and $t(62) = 5.12$, $p < .001$, for RT and error rate, respectively.

Experiment 3B: 92%/8% Bias

The inducer items in this experiment were analyzed with a 2 PC (MC or MI) × 2 compatibility (compatible or incompatible) ANOVA. Most importantly, there was a PC by compatibility interaction, $F(1, 59) = 45.05$, $p < .001$, $\eta_p^2 = .43$, because the compatibility effect was larger for the MC (346) than the MI location (263; i.e., an 83-ms LSPC effect; see Figure 5). There were main effects of both variables. RTs were faster on compatible (728) than incompatible (1,032) trials, $F(1, 59) = 337.25$, $p < .001$, $\eta_p^2 = .85$, and in the MI (871) compared with the MC (889) location, $F(1, 59) = 12.19$, $p = .001$, $\eta_p^2 = .17$.

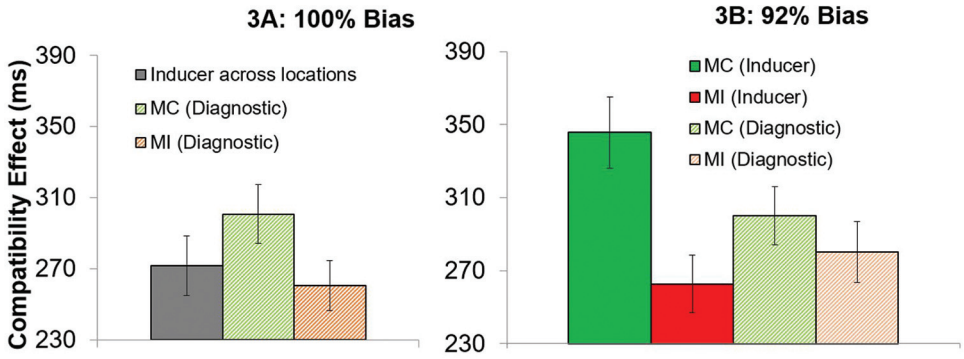
The error rate analysis on inducer items also mirrored the RT data. The interaction, $F(1, 59) = 8.06$, $p = .006$, $\eta_p^2 = .12$, occurred because compatibility effects were larger for the MC (5.10) than MI (1.67) location. There were more errors in incompatible trials (3.75, .36 for compatible), $F(1, 59) = 20.12$, $p < .001$, $\eta_p^2 = .25$, and in the MC location (2.86, 1.25 for MI), $F(1, 59) = 7.59$, $p = .008$, $\eta_p^2 = .11$.

The diagnostic items were analyzed with a 2 location (MC or MI) × 2 compatibility (compatible or incompatible) ANOVA. As in Experiment 3A, there was a location by compatibility interaction indicating significant transfer, $F(1, 59) = 5.81$, $p = .019$, $\eta_p^2 = .09$. The compatibility effects were larger for diagnostic items that appeared in the MC location (300) than the same exact items that appeared in the MI location (280 see Figure 5). RTs were faster on compatible (723) than incompatible (1,013) trials, $F(1, 59) = 339.21$, $p < .001$, $\eta_p^2 = .85$. There was no effect of location, $F < 1$.[10]

The same analysis on error rate revealed an interaction, $F(1, 59) = 6.99$, $p = .010$, $\eta_p^2 = .11$, as well as effects of compatibility, $F(1, 59) = 33.60$, $p < .001$, $\eta_p^2 = .36$ and location, $F(1, 59) = 7.03$ $p = .010$, $\eta_p^2 = .11$. The interaction mirrored the RT data with larger compatibility effects for diagnostic items in the MC

[10] Again, for completeness we also reran the inducer and diagnostic item RT analysis with half as factor. Focusing only on effects of half, for inducer items, the 2 half × 2 PC × 2 compatibility ANOVA revealed only a reliable main effect of half, $F(1, 59) = 80.16$, $p < .001$, $\eta_p^2 = .58$ (first = 924, second = 839). The half by compatibility interaction failed to reach significance, $F(1, 59) = 3.21$, $p = .078$, There was no three-way interaction ($F < 1$). The same analysis on diagnostic items produced the same pattern: a main effect of half, $F(1, 59) = 86.49$, $p < .001$, $\eta_p^2 = .59$ (first = 909, second = 828), a reliable half by compatibility interaction, $F(1, 59) = 19.86$, $p < .001$, $\eta_p^2 = .25$ (first half = 312, second half = 270) and no three-way interaction ($F < 1$).

Figure 5
Results From Experiment 3



Note. Importantly, in both experiments there was a transfer effect for the diagnostic items, in that those in the same locations as MC trials exhibited larger compatibility effects. Furthermore, a robust LSPC effect was observed in the inducer items of Experiment 3B (an inducer effect cannot be calculated for Experiment 3A). See the online article for the color version of this figure.

(2.70) than MI (1.66) location. Furthermore, there were more errors in incompatible (2.44) than compatible (.26) trials and in the MC (1.61) than MI (1.09) location (see Table 4).

Across-Experiment Comparisons

We conducted a 2 experiment × 2 location × 2 compatibility mixed ANOVA on RT data from diagnostic items in Experiments 3A and 3B. The only statistically significant effect of the experiment factor was a Location × Experiment interaction, $F(1, 121) = 5.18$, $p = .025$, $\eta_p^2 = .04$, because in 3A RTs were 13 ms faster in the MI than MC location whereas in 3B they were 1 ms slower overall in the MI location. There was not a main effect of experiment, $F(1, 121) = 2.24$, $p = .137$, an experiment by compatibility interaction, $F < 1$, or a three-way interaction, $F(1, 121) = 2.91$, $p = .090$, BF = .01.

Discussion

Experiments 1 and 2 suggested LSPC effects are larger along the horizontal than vertical axis. This is important because all prior investigations of transfer of location-specific attentional control settings from inducer items to diagnostic items have presented stimuli vertically (cf. Bugg et al., 2020; Crump & Milliken, 2009; Crump et al., 2017, Hutcheon & Spieler, 2017). In Experiments 3A and 3B, for the first time, we examined LSPC effects in inducer/diagnostic designs using left and right locations along the horizontal. The key finding was that we found transfer to diagnostic items in both experiments, in addition to a LSPC effect for inducer items. In so doing we reproduced Crump and Millike (2009)'s original findings for both the 100/0 (3A) and 92/8 (3B) designs, the latter of which represents a departure from prior replication/reproduction attempts in the literature.

Although the observation of an LSPC effect for diagnostic items is arguably of greatest theoretical significance because it provides evidence for location-specific control independent of known confounds (Braem et al., 2019), it is also noteworthy that the LSPC effect was found for inducer items in Experiment 3B. No prior experiment has revealed an LSPC effect for inducer items across the whole experiment in this critical 92/8 design variant where LSPC effects can be examined both for inducer and diagnostic items (see Table 1 for a study that has shown it selectively in the second half). In contrast, there was a robust ($\eta_p^2 = .43$) LSPC effect for the inducer items overall in Experiment 3B. Given the results of Experiments 1 and 2, we believe this difference is attributable to presenting the stimuli along the horizontal axis. Thus, the findings are consistent with the idea that presenting stimuli along the horizontal allows for strong learning of location-specific control settings for the inducer items that can then facilitate reliable transfer of these attentional control settings to the diagnostic items.

General Discussion

The goal of this research was to examine the potential empirical and theoretical consequences of a simple design decision—where on screen stimuli are presented to create MC and MI locations (i.e., how location is defined)—in the LSPC paradigm. Inspired by research on differences between the horizontal and vertical representations of space—including meridians and their permeability (e.g., Hughes & Zimba, 1987) and research demonstrating differential attentional performance for stimuli presented along the vertical versus horizontal axis (e.g., Mackeben, 1999), we posited that the definition of location may affect the learning of associations between locations and attentional control settings as evidenced by the magnitude of LSPC effects and have implications for observing transfer to diagnostic items (Crump & Milliken, 2009), arguably the most important theoretical pattern in the LSPC literature (Braem et al., 2019). Striking to us was the fact that all prior investigations of transfer in the LSPC paradigm (and most LSPC studies more generally) used the same definition of location by presenting stimuli along the vertical axis (i.e., in upper and lower locations), yet the prior research referred to just above raised the strong possibility that this might not be the optimal definition of location for learning and adjusting attention based on the relationship between conflict and location. To investigate this

Table 4
Mean Average RT (ms) and Error Rate (%) in Each Condition for Experiment 3 (SEs in Parentheses)

Experiment	Type	PC	Compatibility	RT (*SE*) in ms	Error (*SE*) in %
3A	Inducer	100	Compatible	756 (15)	.86 (.33)
			Incompatible	—	—
		0	Compatible	—	—
			Incompatible	1,027 (22)	3.40 (.58)
	Diagnostic	50	Compatible	757 (16)	0.92 (.29)
		(MC location)	Incompatible	1,058 (20)	4.76 (.95)
			Interference	301	3.84
		50	Compatible	764 (16)	0.62 (.21)
		(MI location)	Incompatible	1,025 (19)	3.40 (.88)
			Interference	261	2.78
			LSPC	40	1.05
3B	Inducer	92	Compatible	716 (14)	0.31 (.08)
			Incompatible	1,062 (26)	5.41 (1.27)
			Interference	346	5.10
		8	Compatible	739 (16)	0.42 (.24)
			Incompatible	1,002 (24)	2.08 (.49)
			Interference	263	1.67
			LSPC	83	3.44
	Diagnostic	50	Compatible	717 (15)	0.25 (.10)
		(MC location)	Incompatible	1,017 (19)	2.96 (.47)
			Interference	300	2.70
		50	Compatible	728 (15)	0.26 (.08)
		(MI location)	Incompatible	1,008 (20)	1.91 (.39)
			Interference	280	1.66
			LSPC	20	1.05

Note. PC = proportion compatibility; RT = response time; MC = mostly compatible; MI = mostly incompatible; LSPC = location-specific proportion compatibility effect.

possibility directly, we conducted three experiments. We'll first summarize the key findings corresponding to our primary aim of examining whether presenting stimuli along the horizontal axis (i.e., in left and right locations) would strengthen LSPC effects and facilitate transfer and the implications of these findings for theoretical accounts of LSPC and CSPC effects. Then we'll discuss the findings pertaining to our secondary question of whether another definition of location, namely one that involves presentation of stimuli in the same coarse spatial category (e.g., both in upper space), yields LSPC effects and the theoretical implications of these findings.

Regarding our primary aim, Experiments 1 and 2 demonstrated that the LSPC effect was robust along the horizontal axis (i.e., in left and right locations) and the effect was larger than that observed using the traditional definition (i.e., upper and lower locations). These experiments were important in establishing that there was merit to our idea that the definition of location does influence the magnitude of LSPC effects. With this information in hand, we conducted Experiment 3 with the goal of reproducing the theoretically important findings of Crump and Milliken (2009). The key findings were that we observed transfer of the LSPC effect to diagnostic items (in both the 100/0 and 92/8 design), in addition to an LSPC effect for inducer items in the 92/8 design (this effect cannot be calculated for the 100/0 design). These findings are significant from an empirical and theoretical perspective.

Empirically, our findings are significant because they represent the first successful reproduction of the transfer pattern to date using the 92/8 design. All other reproduction attempts failed to produce this pattern and these attempts also failed to find a LSPC effect for the inducer items (see Table 1). In the one other study where researchers simultaneously attempted to reproduce the findings from Crump and Milliken's (2009) design (the only attempted reproduction with that design) and their 92/8 design using otherwise the same methodology across the two designs, only the 100/0 design reproduced the original findings (Crump et al., 2017). In sum, this is the first study in which the findings from both designs were reproduced, and the first study that has reproduced the LSPC effect for both the inducer and diagnostic items in the 92/8 design.

Theoretically, our findings are significant because transfer of the LSPC effect to diagnostic items represents the strongest evidence in support of accounts of the LSPC effect that attribute the effect to variations in attentional control across locations (e.g., episodic retrieval account) and accordingly, the strongest evidence countering alternative accounts such as location-based contingency learning (e.g., Schmidt & Lemercier, 2019). Not surprisingly given the prior failures to reproduce the transfer effect, debates regarding the mechanisms underlying the LSPC effect remain prominent (Braem et al., 2019). The present evidence for transfer adds weight to the view that an abstract location-triggered control mechanism that is stimulus blind (Crump & Milliken, 2009) and thus activated by not only the presentation of an inducer item but additionally novel, diagnostic items, underlies the LSPC effect. More broadly speaking, this evidence adds to other evidence in the literature demonstrating reactive adjustments in control that are triggered by an external event. What is unique about this evidence as compared with the evidence for item-specific control, for example, is that the adjustments were triggered not by a response-relevant feature of the stimulus itself (e.g., the target dimension in a Stroop task, e.g., Bugg et al., 2011; Bugg & Hutchison, 2013; or target arrow's identity in a flanker task; Bugg, 2015), which is predictive of PC in an item-specific PC paradigm, but by a nominally irrelevant contextual

feature (location on screen, in this case). Thus, the present evidence reinforces the view that reactive control can be triggered by a range of external events.

The current findings are also theoretically important in providing new insights into understanding when transfer of the LSPC effect is most likely to be observed, that is, when LSPC effects can be confidently attributed to location-specific control. More specifically, our findings suggest that an important factor is the strength of location-PC learning with the presentation of stimuli along the horizontal axis enhancing such learning as evidenced by the robust LSPC effects in Experiments 1 and 2, and tellingly, the strong evidence for an LSPC effect for inducer items in Experiment 3B (recall again that the effect cannot be calculated for Experiment 3A). While Crump and Milliken (2009) also found an LSPC effect for inducer items in their 92/8 design, it was only significant in the second half of the experiment and, as noted above, none of the other reproduction attempts (all with upper and lower locations) successfully produced an LSPC effect for inducer items (overall or in one half). In contrast, the LSPC effect for inducer items in our 92/8 design (Experiment 3B) using left and right locations was highly robust (effect size of .43, whereas the largest reported in prior research is .05), and we believe that this was a key factor in our observing transfer of the LSPC effect to diagnostic items. Indeed, it's quite reasonable to assume that the transfer of learned associations between locations and attentional control settings to unbiased, 50% compatible diagnostic items is less probable if these associations are not robustly learned to begin with (via experience with the MC and MI inducer items). In sum, our findings provide much needed support for control-based accounts of the LSPC effect by demonstrating transfer to diagnostic items across two designs (100/0 and 92/8). The latter finding starkly contrasts with extant reproduction attempts, a contrast we attribute to our use of left and right (rather than upper and lower) locations that enhanced the learning of location-PC associations as evidenced by the large LSPC effects for inducer items across all experiments.

A key theoretical question to be tackled by future research is specifying the precise mechanism(s) by which the use of left and right locations enhances location-PC learning and can thereby facilitate transfer of location-specific control. We suggested that presenting stimuli in the left and right locations could facilitate a robust LSPC effect (relative to upper and lower locations) via two possible mechanisms. First, the distinctiveness hypothesis posits that the left/right advantage for LSPC effects is attributable to these locations being represented more distinctively (compared with each other) because they straddle the relatively impermeable vertical meridian (Hughes & Zimba, 1987). More distinctiveness between locations could allow participants to learn the appropriate control setting more readily for the left and right sides of space or may lead to more targeted retrieval of a control setting (uncontaminated by the other control setting) when a stimulus appears in a left or right location compared with upper and lower spaces. Second, the speed of activation hypothesis posits that because activation of spatial codes is speeded along the horizontal axis (e.g., Proctor et al., 2006), the faster speed of stimulus discrimination could influence how quickly the location-based, reactive modulation of control is triggered, which in turn may lead to larger LSPC effects. Notably, either or both of these mechanisms could theoretically affect both the magnitude of LSPC effects for inducer items and the transfer of LSPC effects to diagnostic items. As previewed in the Experiment 2 discussion and detailed further below, the data from the present experiments favor the speed of activation account.

Regardless of the precise mechanism enhancing the LSPC effect along the horizontal, it remains an open question whether the horizontal layout per se, or merely the enhancement of the inducer effect through any means, is the key factor for facilitating transfer. We note that other manipulations (e.g., counting instances of the relevant contextual feature) that have facilitated learning of other more stubborn CSPC effects (e.g., color; cf. e.g., Lehle & Hübner, 2008) have not produced location-PC learning (when stimuli are presented in upper and lower locations; Bugg et al., 2021). However, it is possible that other manipulations that could further boost the location-PC signal could also be successful at inducing location-PC learning and transfer to diagnostic items.

Stated differently, considering recent theorizing about LSPC effects, another way to approach the question of what is unique about the present experimental design is to ask why participants learned location-PC associations as opposed to item-PC associations (cf., Bugg et al., 2020, 2021) when stimuli were presented in the horizontal layout. As noted earlier, in all prior attempts to reproduce Crump and Milliken (2009) using the 92/8 design (all of which used the vertical layout), neither a LSPC effect for inducer or diagnostic items was found, and this is consistent with the view that participants learned associations between items and their PC and not between locations and their PC (that is, in our paradigm, item-PC learning means encoding the PC separately for left, right, up, and down target arrows, each of which is 50% compatible on average across both locations; i.e., the item-PC learning hypothesis; Bugg et al., 2020; see also Hutcheon & Spieler, 2017). However, in the present study, we found a strong inducer effect and a transfer effect, both of which are inconsistent with item-PC learning but consistent with location-PC learning. Bugg et al. (2020) considered the role of relative salience in explaining the dominance of item-PC learning in prior studies—how salient are the items relative to the locations? An interesting possibility is that horizontal locations are simply preferentially attended relative to vertical locations. Indeed, for more than 35 years researchers have noted that there may be "something special about right and left locations that renders them more salient than other locations, such as above, below" (Nicoletti & Umiltà, 1984, p. 339; see, e.g., Jeffery et al., 2013, for more recent theorizing on why humans process vertical and horizontal dimensions differently). Uniquely or especially in the case of the horizontal layout, location may be more likely (than items) to be the dimension on which prior experiences during the task are organized and the dimension that becomes most strongly associated with PC. To summarize, we propose that presenting stimuli in the left and right sides of space pushes the cognitive system toward learning of location-PC associations rather than item-PC associations, and that this occurs despite the fact that design features were present that have tended to promote item-PC learning in past studies with stimuli presented in the upper and lower part of the screen (e.g., 92/8 design, varying PCs of items in each location; see Hutcheon & Spieler, 2017, consistency hypothesis).

Another open question regards the extent to which our findings may be specific to the flanker task we used in these experiments. Other types of transfer effects (i.e., to novel locations such as in Experiment 2) have been found to depend on the task used to elicit

control (e.g., Pickel et al., 2019) such that transfer is found selectively for tasks that evoke spatial conflict. Only one other study has used the 92/8 design with a flanker task. In that study a letter flanker task was used and an LSPC effect was evidenced for diagnostic items but not inducer items (Crump et al., 2017; see Table 1). To our knowledge Experiment 3B represents the first demonstration of an LSPC effect in inducer items and transfer to novel diagnostic items using an arrow flanker task. This raises the possibility that presenting stimuli in left and right locations encourages location-PC learning (as opposed to item-PC learning) particularly in tasks in which the stimuli naturally evoke *spatial* conflict in incompatible trials (versus, e.g., a Stroop task that evokes nonspatial conflict between semantic and color processing; cf. e.g., McLeod, 1991). In contrast to this speculation, however, Bugg et al. (2021) recently reproduced their finding showing the dominance of item-PC over location-PC learning in a LSPC paradigm (Bugg et al., 2020; Experiment 3) with upper and lower locations in the arrow flanker task (in addition to a color-word Stroop task). Thus, we do not believe that the task alone explains why we found that location-PC learning dominated in the present experiments.

Turning to our secondary aim, another novel finding in the present study was that LSPC effects were found when the MC and MI locations were presented in the same coarse category of space (e.g., in the same category conditions–both within, e.g., upper for 1A, both within, e.g., left for 1B or 2). This suggests participants were able to learn and retrieve separate control settings for two locations even when they were within the same coarse category of space. Theoretically under a strong version of the category coding hypothesis (e.g., Weidler & Bugg, 2016), the LSPC effect should not have emerged in the same category conditions (because, e.g., the whole upper or left location would be considered a 50% compatible location when averaged across the two locations in which stimuli appeared). It does however seem possible that a weaker form of the categorical coding hypothesis (i.e., attentional control settings become associated with more narrowly defined categories such as left and further left) is tenable given that transfer of the LSPC effect to nearby unbiased locations was found in the same category condition (as well as the different category condition, which replicates Weidler & Bugg, 2016; Weidler et al., 2018). Thus, we suggest that even when two locations are in the same coarse category, more precise, but still categorical, control can be utilized (e.g., "left" vs. "further left," or "inner" vs. "outer"; cf. Weidler & Bugg, 2016). Future research will be necessary to determine when this categorical coding of space breaks down (e.g., can it support even more locations such as "farthest left," "far left" and "close left"?). Furthermore, we note that the present research only demonstrated transfer of the LSPC effect to novel locations along the horizontal axis in the same category condition when transfer locations were presented in the upper hemifield—future research should explore whether the same pattern of transfer occurs along the vertical, or for different transfer locations, as well.

Finally, turning to the mechanism our data favor for explaining the general boost of the LSPC effect along the horizontal—looking across our experiments at the LSPC effect in the same versus different category conditions, the evidence does not seem to suggest that distinctiveness between locations is the critical mechanism for boosting the LSPC effect. If distinctiveness between locations were the critical mechanism, one would expect LSPC effects to consistently be larger in the different category condition when the locations are across a meridian (i.e., in the horizontal condition) than when they are both on the same side of a meridian, especially when they straddle the less permeable vertical meridian (Hughes & Zimba, 1987). However, we only saw larger LSPC effects in the same category condition of 1B, and not in Experiment 2 (also horizontal) or 1A (vertical).[11,12] It therefore appears that the speed hypothesis is most plausible based on the present data. That is, the LSPC effect was boosted along the horizontal because of more rapid activation of spatial codes along that axis (e.g., Proctor et al., 2006). A fruitful avenue for future research is to test this speed of activation hypothesis utilizing electrophysiology methodology. A prior event-related potential study found that the P1 component was sensitive to PC as early as 100 ms after stimulus onset in a reactive control paradigm (item-specific PC; Shedden et al., 2013). That is, that was the point in time at which the MC and MI conditions were processed differently according to differences in the P1 waveform. If in future research this component showed earlier sensitivity to PC for horizontally arranged stimuli than other location configurations in an LSPC paradigm, this would lend support to our suggestion that more rapid activation of spatial codes along the horizontal might have facilitated learning PC-location relationships.

Prior to concluding, we note a few additional limitations and suggestions for future research. First, in addition to larger LSPC effects along the horizontal, in Experiment 1 overall RTs were slower and compatibility effects were larger along that axis compared with along the vertical axis. We first note this is not the first demonstration of larger compatibility effects for horizontal than vertical stimuli (e.g., Rubichi et al., 2005). We do however acknowledge this overall RT slowing could potentially be attributable to the fact that we (and much classic, e.g., Eriksen & Eriksen, 1974, and relevant research, e.g., Corballis & Gratton, 2003; Crump et al., 2017) presented horizontally oriented flanker stimuli (e.g., the flanking arrows were on the sides of the target and not above and below). Perhaps the necessity to scan through the flanking arrows to "reach" the target slowed RTs overall, and especially on incompatible trials, when the stimuli appeared along the horizontal relative to fixation. In terms of the larger LSPC effects, from a theoretical perspective it is not surprising that larger compatibility effects are associated with larger LSPC effects. Larger compatibility effects correspond with more conflict and conflict is thought to be a signal that triggers reactive adjustments in control (e.g., Botvinick et al., 2001) including in models applicable to context-specific PC paradigms (Verguts & Notebaert, 2008). This is also consistent with patterns found in the I(tem)SPC literature (see, e.g., Bugg et al., 2011; Bugg & Dey, 2018; Suh & Bugg,

[11] We note that we cannot fully rule out that insufficient power may have played some role in the instable three-way interaction (Category × PC × Compatibility) across the first two experiments (e.g., the fact that category modulated the LSPC effect in Experiment 1B and not E2) given that power estimates were drawn from studies that did not focus on a between subjects factor (Crump et al., 2017; Hutcheon & Spieler, 2017).

[12] When pooling across Experiments 1A, 1B, and 2 to increase power, the LSPC effect was not modulated by category, $F(1, 183) = 1.05$, $p = .307$, BF = .75. Furthermore, when only considering Experiments 1B and 2 along the horizontal where one might expect a larger difference of category, the LSPC effect was not modulated by category, $F(1, 121) = 1.59$, $p = .209$. BF = 1.61.

2021). However, future research should investigate how the orientation of the flanker stimulus itself impacts findings surrounding LSPC effects and CSPC effects more broadly.

Finally, although we compared the horizontal and vertical conditions in Experiment 1, we did not directly compare horizontal and vertical conditions in Experiment 3. Rather, our conclusions are based on a comparison of the present findings using horizontally presented stimuli (left vs. right locations) to a large body of past findings using vertically presented stimuli (upper vs. lower locations; see Table 1 and Footnote 2). Specifically, in past research there was a highly consistent pattern of neither an LSPC effect for inducer items nor an LSPC effect for diagnostic items in the 92/8 design (except for one experiment that showed the latter but not the former, which is not easy to interpret; Crump et al., 2017, Experiment 4). Accordingly, we thought it reasonable to assume a strong prior probability of no effect for the inducer or diagnostic items in the vertical condition under conditions that matched those in Experiment 3 (i.e., when the Crump & Milliken, 2009, 92/8 inducer/diagnostic design is used). Future research might pit the two head-to-head in the inducer/diagnostic design or other design variants (see Bugg et al., 2020, Experiment 3; Bugg et al., 2021) to further examine the empirical and theoretical consequences of using left/right as compared with upper/lower location definitions on location-PC learning, as well as other types of learning (e.g., item-PC learning).

Conclusion

Overall, the present experiments expand our knowledge about how associations between locations and attentional control settings are learned and applied to appropriately adjust attentional control to environmental demands. Specifically, our work makes four novel contributions. First, we demonstrated LSPC effects are bigger along the horizontal than vertical axis. Second, with this knowledge in mind, when stimuli were presented along the horizontal axis, we demonstrated an LSPC effect for novel diagnostic items (transfer) in two distinct designs, a theoretically important finding that offers strong support that LSPC effects result from shifts in attentional control. Furthermore, the emergence of a strong inducer LSPC effect provided support for the theoretical possibility that strengthening learning (in our case through the horizontal layout) is important for demonstrating transfer. Third, we demonstrated that learning about location-PC associations can occur even when both locations are within the same coarse spatial category (e.g., "left" or "up"), which rules out a strong categorical coding hypothesis (cf. e.g., Weidler & Bugg, 2016). Finally, we demonstrated that a weaker version of the categorical coding hypothesis is viable, as transfer to novel locations occurred even when items were within the same broad spatial category. Overall, our findings demonstrate that the definition of location has important consequences for empirical patterns and theoretical accounts in the LSPC literature. Future research should further explore how spatial layout influences learning about control to better understand how our cognitive system can optimize performance in daily tasks.

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