Putting Attentional Control on the Map: An Investigation of Meaningful Boundaries and Context-Specific Control

Jackson Stuart Colvett

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Putting Attentional Control on the Map:
An Investigation of Meaningful Boundaries and Context-Specific Control
by
Jackson Stuart Colvett

A dissertation presented to
Washington University in St. Louis
in partial fulfillment of the
requirements for the degree
of Doctor of Philosophy

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# Table of Contents

List of Figures ................................................................. vi
List of Tables ................................................................. viii
Acknowledgments .............................................................. ix
Abstract of the Dissertation ................................................ xiii

## Chapter 1: Introduction .................................................. 1
1.1 Attentional control and CSPC effects ........................................ 1
1.2 Transfer of CSPC effects to novel locations ............................... 6
1.3 CSPC and meaningful boundaries ........................................... 10
1.4 Current study ............................................................... 15
1.5 Overview of experiments .................................................... 17

## Chapter 2: Experiment 1 .................................................... 20
2.1 Method ........................................................................ 23
   2.1.1 Participants .......................................................... 23
   2.1.2 Design and stimuli .................................................. 24
   2.1.3 Procedure .......................................................... 25
2.2 Results ........................................................................ 27
   2.2.1 Reaction time ......................................................... 28
   2.2.2 Error rate ............................................................. 30
2.3 Discussion ..................................................................... 34

## Chapter 3: Experiment 2 .................................................... 36
3.1 Method ........................................................................ 38
   3.1.1 Participants .......................................................... 38
   3.1.2 Design and stimuli .................................................. 38
   3.1.3 Procedure .......................................................... 38
3.2 Results ........................................................................ 38
   3.2.1 Reaction time ......................................................... 38
   3.2.2 Error rate ............................................................. 40
   3.2.3 Between-experiment analysis ..................................... 44
Chapter 4: Experiment 3 ................................................................. 47
   4.1 Method ................................................................. 48
      4.1.1 Participants ......................................................... 49
      4.1.2 Design and stimuli ............................................... 49
      4.1.3 Procedure ......................................................... 49
   4.2 Results ................................................................. 49
      4.2.1 Reaction time ..................................................... 49
      4.2.2 Error rate ......................................................... 51
      4.2.3 Between-experiment analysis ................................. 55
   4.3 Discussion ............................................................. 56
Chapter 5: Experiment 4 ............................................................ 58
   5.1 Method ................................................................. 59
      5.1.1 Participants ......................................................... 59
      5.1.2 Design and stimuli ............................................... 60
      5.1.3 Procedure ......................................................... 60
   5.2 Results ................................................................. 60
      5.2.1 Reaction time ..................................................... 60
      5.2.2 Error rate ......................................................... 62
      5.2.3 Between-experiment analysis ................................. 66
   5.3 Discussion ............................................................. 67
Chapter 6: Experiment 5 ............................................................ 69
   6.1 Method ................................................................. 71
      6.1.1 Participants ......................................................... 71
      6.1.2 Design and stimuli ............................................... 71
      6.1.3 Procedure ......................................................... 71
   6.2 Results ................................................................. 71
      6.2.1 Reaction time ..................................................... 71
      6.2.2 Error rate ......................................................... 73
   6.3 Discussion ............................................................. 77
Chapter 7: General Discussion........................................................................................................... 80

7.1 Evidence for meaningful and non-meaningful hypotheses ..................................................... 83
7.2 Competing predictors in CSPC designs .................................................................................. 86
7.3 Importance of diagonal display ............................................................................................. 88
7.4 Limitations and future directions .......................................................................................... 92
7.5 Conclusion .............................................................................................................................. 94

References ...................................................................................................................................... 96

Appendix A: Map survey ................................................................................................................. 104

8.1 Map survey: Experiments 1 and 2 ......................................................................................... 104
8.2 Map survey: Experiments 3, 4, and 5 ..................................................................................... 104
8.3 Map survey results ................................................................................................................ 105

Appendix B: Pilot experiment ....................................................................................................... 107

9.1 Method ..................................................................................................................................... 108
9.1.1 Participants .......................................................................................................................... 108
9.1.2 Design and stimuli .............................................................................................................. 109
9.1.3 Procedure .......................................................................................................................... 110
9.2 Results ..................................................................................................................................... 111
9.2.1 Reaction time ..................................................................................................................... 112
9.2.2 Error rate .......................................................................................................................... 113
9.3 Discussion ............................................................................................................................... 117

Appendix C: Analysis of effects in each background condition ................................................. 118

10.1 Pilot study .............................................................................................................................. 118
10.2 Experiment 1 ......................................................................................................................... 122
10.3 Experiment 2 ......................................................................................................................... 126
10.4 Experiment 3 ......................................................................................................................... 130
10.5 Experiment 4 ......................................................................................................................... 134
10.6 Experiment 5 ......................................................................................................................... 137

Appendix D: Linear mixed-effects models ................................................................................... 142

11.1 Experiment 1 ......................................................................................................................... 143
11.2 Experiment 2 ......................................................................................................................... 145
List of Figures

Figure 1.1: *Illustration Depicting the Design Used in Weidler and Bugg (2016, Experiment 1)* ................................................................. 8
Figure 1.2: *Illustration Depicting the Design Used in Weidler and Colleagues (2020, Experiments 1 and 2)* ......................................................... 10
Figure 1.3: *Illustration Depicting the Design Used in Colvett and Bugg (2022, Experiment 1)* ................................................................. 13
Figure 1.4: *Illustration Depicting the Design Used in Colvett and Bugg (2022, Experiments 3a and 3b)* ................................................................. 15
Figure 2.1: *Illustration Depicting the Design Used in the Map Background Condition of Experiment 1 and Predicted Results* ............................................. 22
Figure 2.2: *Mean Compatibility Effects at Inducer Locations in RT and Error Rate in Experiment 1* ................................................................. 32
Figure 2.3: *Mean Compatibility Effects at Diagnostic Locations in RT and Error Rate in Experiment 1* ................................................................. 33
Figure 3.1: *Illustration Depicting the Design Used in the Map Background Condition of Experiment 2 and Predicted Results* ............................................. 37
Figure 3.2: *Mean Compatibility Effects at Inducer Locations in RT and Error Rate in Experiment 2* ................................................................. 42
Figure 3.3: *Mean Compatibility Effects at Diagnostic Locations in RT and Error Rate in Experiment 2* ................................................................. 43
Figure 4.1: *Illustration Depicting the Design Used in the Map Background Condition of Experiment 3 and Predicted Results* ............................................. 48
Figure 4.2: *Mean Compatibility Effects at Inducer Locations in RT and Error Rate in Experiment 3* ................................................................. 53
Figure 4.3: *Mean Compatibility Effects at Diagnostic Locations in RT and Error Rate in Experiment 3* ................................................................. 54
Figure 5.1: *Illustration Depicting the Design Used in the Map Background Condition of Experiment 4 and Predicted Results* ............................................. 59
Figure 5.2: *Mean Compatibility Effects at Inducer Locations in RT and Error Rate in Experiment 4* ................................................................. 64
Figure 5.3: *Mean Compatibility Effects at Diagnostic Locations in RT and Error Rate in Experiment 4* ................................................................. 64
Figure 6.1: *Illustration Depicting the Design Used in the Map Background Condition of Experiment 5 and Predicted Results* ............................................. 70
Figure 6.2: *Mean Compatibility Effects at Inducer Locations in RT and Error Rate in Experiment 5* ................................................................. 75
Figure 6.3: *Mean Compatibility Effects at Diagnostic Locations in RT and Error Rate in Experiment 5* ................................................................. 76
Figure 7.1: *Illustration of the Background Image in the Map Background Condition in All Experiments of the Current Study* ............................................. 83
Figure 9.1: *Illustration Depicting the Design Used in the Pilot Study* ................................................................. 108
Figure 9.2: *Mean Compatibility Effects at Inducer Locations in RT and Error Rate in Pilot Study* ................................................................. 115
Figure 9.3: *Mean Compatibility Effects at Diagnostic Locations in RT and Error Rate in Pilot Study* ................................................................. 115
List of Tables

Table 2.1: Experiment 1 Reaction Time (ms) and Error Rate at Inducer and Diagnostic Locations with Standard Errors in Parentheses .................................. 33
Table 3.1: Experiment 2 Reaction Time (ms) and Error Rate at Inducer and Diagnostic Locations with Standard Errors in Parentheses ......................... 43
Table 4.1: Experiment 3 Reaction Time (ms) and Error Rate at Inducer and Diagnostic Locations with Standard Errors in Parentheses ......................... 54
Table 5.1: Experiment 4 Reaction Time (ms) and Error Rate at Inducer and Diagnostic Locations with Standard Errors in Parentheses ......................... 65
Table 6.1: Experiment 5 Reaction Time (ms) and Error Rate at Inducer and Diagnostic Locations with Standard Errors in Parentheses ......................... 76
Table 7.1: Summary of Results Across All Experiments .................................................. 80
Table 8.1: Responses to Map Survey in Experiments 1 and 2 with Standard Deviations in Parentheses .................................................................................. 105
Table 8.2: Responses to Map Survey in Experiments 3, 4, and 5 with Standard Deviations in Parentheses .................................................................................. 106
Table 9.1: Pilot Experiment Reaction Time (ms) and Error Rate at Inducer and Diagnostic Locations with Standard Errors in Parentheses ..................... 116
Table 11.1: Linear Mixed-Effects Model Output for Trials at Inducer Locations in Experiment 1 .............................................................................................. 144
Table 11.2: Linear Mixed-Effects Model Output for Trials at Diagnostic Locations in Experiment 1 .............................................................................................. 145
Table 11.3: Linear Mixed-Effects Model Output for Trials at Inducer Locations in Experiment 2 .............................................................................................. 146
Table 11.4: Linear Mixed-Effects Model Output for Trials at Diagnostic Locations in Experiment 2 .............................................................................................. 147
Table 11.5: Linear Mixed-Effects Model Output for Trials at Inducer Locations in Experiment 3 .............................................................................................. 149
Table 11.6: Linear Mixed-Effects Model Output for Trials at Diagnostic Locations in Experiment 3 .............................................................................................. 150
Table 11.7: Linear Mixed-Effects Model Output for Trials at Inducer Locations in Experiment 4 .............................................................................................. 151
Table 11.8: Linear Mixed-Effects Model Output for Trials at Diagnostic Locations in Experiment 4 .............................................................................................. 152
Table 11.9: Linear Mixed Model Output for Trials at Inducer Locations in Experiment 5 .............................................................................................. 154
Table 11.10: Linear Mixed Model Output for Trials at Diagnostic Locations in Experiment 5 .............................................................................................. 155
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Jackson Stuart Colvett

Washington University in St. Louis

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ABSTRACT OF THE DISSERTATION

Putting Attentional Control on the Map:
An Investigation of Meaningful Boundaries and Context-Specific Control

by

Jackson Stuart Colvett

Doctor of Philosophy in Psychological and Brain Sciences

Washington University in St. Louis, 2023

Professor Julie Bugg, Chair

People can learn and adopt relaxed or focused control settings based on the likelihood of conflict at specific inducer locations, then flexibly retrieve those control settings at nearby unbiased diagnostic locations. Importantly, people can learn that multiple distinct contexts predict conflict, such as specific locations or regions of space (e.g., all locations in the upper left). In realistic visual scenes, meaningful boundaries that demarcate objects or areas of space serve as an important signal that the area inside the boundary is distinct from the area outside the boundary. Recent research (Colvett & Bugg, 2022) indicated a role for meaningful boundaries in the learning and retrieval of control settings. The current study tested two questions regarding meaningful boundaries. First, will people learn about the area within a meaningful boundary and adopt a control setting associated with likelihood of conflict at all locations in that meaningful area? Second, will a meaningful boundary separating an inducer location from a diagnostic location disrupt retrieval of a control setting? Experiments 1 and 2 used simple black and white maps where familiar state borders grouped locations within boundaries. However, those meaningful boundaries did not impact the learning and retrieval of control settings. Experiments 3, 4, and 5 used realistic satellite images to make the difference between meaningful areas more
salient. Some evidence emerged that meaningful boundaries affected the learning of control settings at inducer locations, but no evidence emerged that transfer was enhanced by presenting diagnostic locations in the same meaningful area as inducer locations. Taken together, these findings have important implications for the flexibility of learned control settings, the role of meaningful boundaries, and the relative dominance of various contexts when participants can learn from multiple sources of information.
Chapter 1: Introduction
Imagine trying to find some important information for a project while you are working on your computer. You have two windows open on your screen: one window is a website where you are trying to find sources for the project, and the other window is a word processor where you are taking notes on what you find. As with many websites, the window with the website has some notifications and flashing advertisements; you need to ignore those irrelevant distractors to find the project-relevant information. If some new distracting notification appeared suddenly within the window with the website, would you effectively filter it out? If a similarly distracting notification appeared suddenly in the window with the word processor, would it be more likely to draw your attention? If you were more effective at dealing with distractions appearing in the more distracting window, it would suggest that you learned different scopes of attention for the parts of the computer screen that correspond to each of the two meaningfully distinct windows. The current study is broadly concerned with how people learn what scope of attention is needed within a meaningful boundary and whether what is learned within a meaningful boundary extends across the boundary into a new area of space.

1.1 Attentional control and CSPC effects
How individuals use previous experiences to prepare for and respond to attentional challenges in the current moment is a question that is important within the study of cognitive control. Broadly speaking, cognitive control refers to the processes that prioritize goal-relevant information over distracting, goal-irrelevant information. One way that the goal-directed nature of cognitive control can be tested is through tasks that present both goal-relevant and goal-irrelevant information, such as the flanker task. In the flanker task, participants respond to the identity of a central target stimulus (e.g., the direction of a central arrow) that is surrounded by other
competing stimuli (e.g., other arrows; Eriksen & Eriksen, 1974). This task indexes cognitive control, as there is goal-relevant information (i.e., central arrow) that needs to be attended to over and above the goal-irrelevant information (i.e., flanking arrows). The flanking arrows affect performance when responding to the central arrow, such that responses are faster and more accurate when the flanking arrows signal the same response as the central arrow (i.e., compatible; > > > > >) than when the flanking arrows signal a different response than the central arrow (i.e., incompatible; > > < > >). Incompatible trials are more difficult than compatible trials due to the increased conflict from the competing information signaling an inappropriate response.

Cognitive control takes many forms, and it is important to distinguish when a control adjustment is made in relation to stimulus onset. The Dual Mechanisms of Control account (Braver et al., 2007; see Braver et al., 2021) delineates two modes by which adjustments to control are made: proactive and reactive. Proactive control refers to preparing and sustaining an appropriate control setting (i.e., one’s scope of attention; the relative degree to which the target and distractor information are processed) before stimulus onset. Alternatively, reactive control refers to adjustments made after stimulus onset once the need for control is detected. A key distinction between the two is the predicted level of activity between trials: there is sustained maintenance of goal-relevant processing between trials when engaging proactive control, but not when engaging reactive control (e.g., Braver et al., 2007). In many situations, proactive or reactive control can be used to overcome cognitive challenges (e.g., conflict).
One element of the task environment that determines how control is deployed is the likelihood of conflict, often assessed through manipulations of proportion compatibility\(^1\) (PC), the percentage of trials that are compatible or incompatible (see Bugg & Crump, 2012 for a review). Indeed, one should adopt a different control setting based on whether trials are mostly incompatible (MI) or mostly compatible (MC). That is, it is more optimal to have a focused control setting\(^2\) (i.e., enhancing processing of goal-relevant information or filtering out goal-irrelevant information) when trials are likely to be incompatible, as it makes one less susceptible to conflict from the goal-irrelevant information. Conversely, one should adopt a more relaxed control setting (i.e., allowing processing of goal-irrelevant information) when trials are more likely to be compatible, as the distracting information often signals the correct response.

Statistically, these differences in control settings manifest as a difference in compatibility effects (i.e., difference in performance in reaction time or error rate between compatible and incompatible trials) between MC and MI conditions. Evidence exists that participants are capable of learning about a variety of features of the task environment that are predictive of PC. The feature that predicts PC may encourage either proactive or reactive control adjustments (e.g., Gonthier et al., 2016). For example, consider people learning that the list-wide PC (i.e., the PC of all the trials in an experiment or a block of trials; e.g., Bugg & Chanani, 2011; Logan & Zbrodoff, 1979) is either MC or MI. Because learning about the list can allow someone to probabilistically predict a likelihood of conflict on the next trial, one can use proactive control to

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\(^1\) This term is interchangeably referred to as proportion congruence. I will hereafter refer to these effects as proportion compatibility effects because the experiments of the current study used a flanker task (where the term compatibility is commonly used) as opposed to a task like color-word Stroop (where the term congruence is commonly used).

\(^2\) The term control setting is interchangeably referred to as a control state. I will refer to them as control settings throughout the current study. The term control setting is typically preferred when interpreting results from the perspective of the episodic retrieval account (Crump & Milliken, 2009) and the term control state is typically preferred when interpreting results from the perspective of the event files account (e.g., Hommel 1998; 2004).
prepare and maintain a relatively relaxed (MC list) or focused (MI list) control setting before stimulus onset.

In contrast to learning about list-wide PC, there are learned associations between PC and other features that lead to reactive control adjustments. Context-specific proportion compatibility (CSPC) designs (e.g., Corballis & Gratton, 2003; Crump et al., 2006) manipulate the proportion of compatible trials that co-occur with nominally task-irrelevant features in the environment. Many different task-irrelevant features have been used as contexts, but the literature most relevant to the current study uses spatial location as the context. For example, consider an experiment where trials could appear at one of two locations on screen (e.g., 12 cm above and below a central fixation). In a location-based CSPC design, the lower location could be MC, and the upper location could be MI. The CSPC effect refers to a larger compatibility effect for trials that are presented in the MC context compared to the MI context. Critical to these designs, the order of trials is randomly intermixed, such that the list-wide PC is unbiased (i.e., 50% compatible) and it is equally likely for the next trial to occur in the MC context or the MI context. In contrast to list-wide PC designs, participants cannot predict the likelihood of conflict before stimulus onset, so control adjustments in CSPC designs are therefore reactive. More specifically, CSPC effects index “learning-based reactive control”, because while the adjustments are reactive, the differences in control across contexts (locations) are based on learning the association between each context and the probability of conflict in that context.

For a CSPC effect to emerge, one must learn through experience that the dimensions of each context (e.g., the upper and lower locations) predict the PC of the trials. It is therefore important to understand how learning processes form that association via experiences throughout an experiment. The event files account (Hommel, 1998; 2004) provides a theoretical perspective
to understand how experiences with previous trials can affect current performance. This account posits that on each trial, a store is created in episodic memory with not just the task-relevant features of the trial (e.g., stimulus features like identity of the target and distractor, the response) but also the task-irrelevant features (e.g., co-occurrent context). When one of the features appears on a later trial, the task-relevant and task-irrelevant features alike are retrieved from episodic memory.

Building on that theoretical perspective, the episodic retrieval account of CSPC effects (Crump & Milliken, 2009) also claims that the stimulus features, responses, and contextual features from a trial are bound together and stored in episodic memory. Critically, it additionally posits that the control setting engaged on each trial is also encoded with the other features into the episodic representation. The episodic retrieval account was tested in a design that presented two types of items at MC and MI locations. The first set of items (e.g., red and blue items in a color-word Stroop task) was referred to as the “inducer set”. Inducer set items carried the PC bias consistent with the context, such that the items were MC in the MC context and MI in the MI context. A second set of items (e.g., green and yellow items in a color-word Stroop task) was referred to as the “diagnostic set”. Diagnostic set items were unbiased (i.e., 50% congruent) in both the MC and MI contexts, and shared no features (words, colors) with the inducer set. A CSPC effect was observed for inducer items. Critically, that effect transferred to the unbiased diagnostic set items, as evidenced by the significant CSPC effect for diagnostic set items (Crump & Milliken, 2009). From the perspective of the episodic retrieval account, a diagnostic set trial appearing in the MC or MI location would retrieve the relaxed or focused control setting.

3 More recent conceptions of event files that include a control setting as part of the file (e.g., Dignath et al., 2019; Jiang et al., 2015) are consistent with the episodic retrieval account.

4 The terms inducer and diagnostic have not been used uniformly across the relevant literature. Crump and Milliken (2009) instead used the terms training and transfer, I will use inducer and diagnostic in keeping with the recommendation of Braem and colleagues (2019).
associated with that location. While CSPC transfer effects have not always been observed reliably in using this design (see Bugg et al., 2020; Bugg et al., 2022; Crump et al., 2017; Hutcheon & Spieler, 2016), the CSPC effect for diagnostic set trials is the strongest evidence for episodic retrieval of a control setting.

1.2 Transfer of CSPC effects to novel locations
Building on the designs that included distinct inducer and diagnostic items, a new kind of context-specific design was developed to ask a distinct question: could the control setting learned at one location transfer to another location? Rather than using two sets of items at the same location, this design used the same set of items at two locations. Inducer locations were either MC or MI to create a difference in PC between locations (and thus a difference in the control setting at each location). Unbiased (50% compatible) diagnostic locations were near inducer locations and used identical stimuli. These diagnostic locations were used to assess whether the control setting learned at the inducer location was retrieved and implemented at a novel location (i.e., transfer). One possibility is that participants could learn each location independently from each other, such that the control setting learned at the inducer location has no impact on the diagnostic locations. Alternatively, participants could learn a context that flexibly includes multiple locations, such that the control setting learned at the inducer location would be retrieved when a trial appears at a nearby diagnostic location.

The first study that assessed whether control settings learned at an inducer location would transfer to a diagnostic location presented trials at one of five locations along an invisible diagonal array (Weidler & Bugg, 2016). Two inducer locations, one MC and one MI, were the farthest from the center (see Figure 1.1). Participants first completed inducer only blocks where they responded to trials at the MC and MI locations (as well as an unbiased location in the
middle of the invisible diagonal array) to learn the PC of each inducer location. In a subsequent phase of the experiment, trials appeared at two diagnostic locations: a “near-MC location” and a “near-MI location”, which were presented along an invisible diagonal array between the central unbiased inducer location and one of the outer inducer locations. A significant CSPC effect was observed at the inducer locations, indicating that the context-PC associations were learned effectively. Critically, a significant CSPC effect was also observed at the diagnostic locations, indicating that the control setting learned at the inducer locations transferred to the diagnostic locations.
Figure 1.1. This experiment investigated transfer of the CSPC effect to novel locations. Diagnostic locations were presented between each inducer location and the central, unbiased inducer location. The control setting learned at the MC and MI inducer locations transferred to the closest diagnostic location (i.e., near-MC location for the MC inducer location; near-MI location for the MI inducer location) as evidenced by a CSPC effect at diagnostic locations (i.e., larger compatibility effect at the near-MC location compared to the near-MI location).

Two novel hypotheses were created to explain the finding that control settings learned at the inducer locations transferred to the diagnostic locations. First, the spatial proximity hypothesis predicts that people learn a control setting at inducer locations, then retrieve that control setting at nearby locations. In the context of Weidler and Bugg (2016) the near-MC location was closest to the MC location (and the near-MI location was closest to the MI location). The control setting learned at the inducer location transferred to the spatially proximal diagnostic location. Second, the categorical coding hypothesis predicts that people learn about the probability of conflict in a region of space (e.g., the upper right, the lower left) rather than a location (i.e., a particular set of coordinates). In the context of the design used in Weidler and
Bugg (2016), it is possible that participants learned that the MC location was in the upper right category of space and the MI location was in the lower left category of space. Trials at the diagnostic locations were presented in the same category of space as an inducer location, and thus retrieved the control setting associated with that category of space. To foreshadow, the current study will contrast the spatial proximity and categorical coding hypotheses with hypotheses that predict a role for meaningful boundaries in the learning and retrieval of control settings. As neither the spatial proximity hypothesis nor the categorical coding hypothesis predicts a role for meaningful boundaries, these hypotheses will hereafter be grouped under the label “non-meaningful boundary hypotheses”.

One of the first studies to examine the role of boundaries used the same five locations on an invisible diagonal array as Weidler and Bugg (2016). However, the position of the inducer and diagnostic locations were flipped to assess whether a control setting learned at an inducer location would transfer outward (i.e., further from the central fixation) to a novel diagnostic location (Weidler et al., 2020). In an experiment with no boundaries, participants responded to flanker stimuli that were superimposed over a white background (Weidler et al., 2020, Experiment 1; see Figure 1.2, Panel A). As in Weidler and Bugg (2016), a significant CSPC effect was observed at inducer and diagnostic locations. The authors asked whether separating the inducer location from the diagnostic location by a visual boundary (i.e., a non-meaningful boundary that separates two areas that are not semantically distinct) would disrupt the retrieval of the control setting at the diagnostic location. The visual boundary was created by a black rectangle separating the inducer locations from the diagnostic locations (Weidler et al., 2020, Experiment 2; see Figure 1.2, Panel B). However, a significant CSPC effect was still observed at diagnostic locations. The visual boundary did not disrupt retrieval of the control setting that was
learned at an inducer location when trials appeared at a diagnostic location. Again, all of these results are consistent with either the spatial proximity hypothesis or the categorical coding hypothesis.

Figure 1.2. Panel A (Weidler et al, 2020, Experiment 1) depicts a design with no boundary separating inducer locations from diagnostic locations. The control setting learned at the MC and MI inducer locations transferred to the closest diagnostic location (e.g., near-MI location for the MI inducer location), as evidenced by a CSPC effect at diagnostic locations. Panel B (Weidler et al, 2020, Experiment 2) is identical to Panel A except a visual boundary (i.e., a black rectangle) separated the inducer and diagnostic locations. Paralleling the previous experiment, transfer was observed at the diagnostic locations.

1.3 CSPC and meaningful boundaries
A simple visual boundary separating the inducer and diagnostic locations was not enough to disrupt the retrieval of a control setting at a diagnostic location. However, Weidler and colleagues (2020) hypothesized that using a meaningful boundary might be more salient and discourage treating diagnostic locations with the same control setting learned at inducer locations. In keeping with a previous study investigating the role of meaningful boundaries (Colvett & Bugg, 2022), I will operationalize a meaningful boundary as a visual boundary that

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5 Pickel and colleagues (2019) also assessed whether a control setting learned at an inducer location will be retrieved at a diagnostic location but questioned whether the specific task matters. They found that transfer occurred in tasks where conflict was spatial in nature (e.g., arrow flanker, spatial Stroop task) but not in tasks where conflict was informational in nature (e.g., color-word Stroop task).
separates two semantically distinct categories of space, and not just two categories of space (e.g., left and right, inside and outside). Colvett and Bugg (2022) proposed two hypotheses regarding how meaningful boundaries might affect the learning and retrieval of control settings. First, the “boundaries for retrieval” hypothesis addresses what happens when a meaningful boundary separates inducer from diagnostic locations. Specifically, this hypothesis predicts that a control setting should be learned at the inducer locations. However, separating the inducer location from a diagnostic location with a meaningful boundary should disrupt the retrieval of the control setting at the diagnostic location and thus disrupt transfer. To put it another way, the boundary serves as a signal that the diagnostic location is in a distinct meaningful area, and the control setting that was learned at the inducer location may not be relevant in the new area. To borrow from the example at the beginning of the introduction, the focused scope of attention adopted on the window with the distracting website should not transfer across the boundary to filter out potential distractions on the other window.

The second hypothesis, the “learning within boundaries” hypothesis concerns how control settings are learned. Specifically, participants may learn the overall PC of all locations within a shared meaningful area rather than learning location-specific PCs. An instructive idea here is “binning”, an interpretation of how participants encode and organize their experiences on each trial (Bugg et al., 2020). Take for example an experiment where MC and MI inducer locations appear in the same meaningful area of space, surrounded by a meaningful boundary. If participants bin their experiences by location, they should organize their experiences at the MC location separately from the MI location and retrieve a relatively relaxed and focused control setting at each location, respectively. However, if participants bin all experiences within a meaningful boundary together, participants will learn that the area within the boundary is 50%
compatible on average, and participants will retrieve an unbiased control setting when a trial appears at any location within the boundary. Indeed, the shared meaningful area within a boundary may serve as a competing organizational structure by which participants bin their experiences.

An earlier conception of the learning within boundaries hypothesis was referred to as the “attenuated learning hypothesis” (Colvett & Bugg, 2022). The results of that study indicated that participants learned about the PC of a meaningful area of space that contained MC and MI inducer locations, leading to an attenuated CSPC effect. However, that is not the only way that presenting locations in the same meaningful area could affect the learning of control settings. Consider a near-MC diagnostic location that is presented within the same meaningful area of space as an MC inducer location (and a near-MI diagnostic location that is presented within the same meaningful area of space as an MI inducer location). It is possible that the CSPC effect at the diagnostic location is not attenuated, but rather enhanced. To again borrow from the example at the beginning of the introduction, a distracting notification at a novel location within the website window should be filtered effectively, because participants associated the focused control setting with the area within the meaningful boundary (i.e., the whole website window).

The initial examination that proposed a potential role for meaningful boundaries in the learning and retrieval of control settings used a simple black outline on a white background that represented the border of an island (Weidler et al., 2020, Experiment 3). This experiment yielded mixed and thus inconclusive evidence using a design that was limited in several ways. Recently, Colvett and Bugg (2022) revisited this question by using a design that incorporated a background image that was realistic, meaningful, and familiar to participants. Colvett and Bugg (2022; Experiment 1) used the same layout of locations along the invisible diagonal array from Weidler
and colleagues (2020) but the background image was an aerial photograph of Washington University’s quad (Google et al., 2021). The inducer locations were superimposed over the quad, while the diagnostic locations were superimposed over buildings (see Figure 1.3). A significant CSPC effect was observed at the inducer locations. However, that control setting did not transfer across a meaningful boundary to diagnostic locations, as indicated by a non-significant CSPC effect.

Figure 1.3. This experiment investigated whether meaningful boundaries affected transfer of the CSPC effect to novel locations. MC and MI inducer locations were located within the meaningful boundary on a university quad, and the diagnostic locations were presented outside the meaningful boundary on university buildings. The control setting learned at the MC and MI inducer locations did not transfer to diagnostic locations, as evidenced by a non-significant CSPC effect at diagnostic locations (i.e., equivalent compatibility effects at near-MC and near-MI locations).

The finding of a non-significant CSPC effect at diagnostic locations is consistent with the boundaries for retrieval hypothesis (i.e., the control setting was learned at the inducer locations, but not retrieved at the diagnostic locations). However, it should be noted that the observed CSPC effect at inducer locations was smaller than comparable studies without a meaningful
boundary (e.g., Weidler et al., 2020, Experiments 1 & 2). Therefore, it is possible that the non-significant CSPC effect at diagnostic locations may also be attributable to learning within the boundary. That is, if a weaker CSPC effect was learned at inducer locations, a weaker signal would be available to transfer to diagnostic locations.

Colvett and Bugg (2022, Experiment 3) more directly investigated the learning within boundaries hypothesis by using a design with no diagnostic locations. Participants responded to locations on two invisible diagonal arrays, both of which presented one biased location (e.g., MC) at the upper right location of each diagonal array, and the other biased location (e.g., MI) at the lower left location of each diagonal array. The background image was either a white background (see Figure 1.4, Panel A) or a track and field where all locations were contained within a meaningful boundary on a field (see Figure 1.4, Panel B). There was a significant CSPC effect in the experiment with the white background but a non-significant CSPC effect in the experiment with the track and field background. The non-significant CSPC effect in the latter experiment is consistent with the learning within boundaries hypothesis, such that participants learned the PC of the entire meaningful area within the boundary (rather than learning the PC of each location and thus learning distinct control settings at MC and MI locations).
Figure 1.4. Panel A (Colvett & Bugg 2022, Experiment 3a) depicts a display where flanker stimuli were superimposed over a white background. Panel B (Colvett & Bugg 2022, Experiment 3b) depicts a display where flanker stimuli were superimposed over an image of a field within the meaningful boundary of a track. There were no diagnostic locations in these designs. A significant CSPC effect (i.e., larger compatibility effect at the MC locations compared to the MI locations) in the experiment depicted in Panel A, but not in the experiment depicted in Panel B, indicating learning within the meaningful boundary attenuated the CSPC effect.

1.4 Current study
While some evidence supports the idea that meaningful boundaries affect the learning and retrieval of control settings, many questions about the role of those boundaries remain. There were two primary goals of the current study. First, the experiments of the current study tested potential roles of meaningful boundaries in the learning (i.e., learning within boundaries hypothesis) and retrieval (i.e., boundaries for retrieval hypothesis) of control settings in a way that previous studies could not. The experiments of the current study compared each participant’s performance on a blank background (i.e., with no boundaries) to performance on a background image that grouped locations within meaningful boundaries. These boundaries were created using outlines of US States (i.e., Experiments 1 & 2) or satellite images of Earth (i.e., Experiments 3, 4, & 5). Flanker stimuli were superimposed on those backgrounds, such that
inducer and diagnostic locations were either separated from each other across a meaningful boundary (as in some prior studies; Weidler et al., 2020; Colvett & Bugg, 2022) or grouped together within a meaningful boundary (as in no prior studies). In addition, I will assess evidence for two hypotheses of CSPC transfer that do not include a role for meaningful boundaries (i.e., categorical coding hypothesis, spatial proximity hypothesis).

As a second goal, the experiments of the current study assessed which sources of information people used to predict likelihood of conflict when multiple different sources were available. While participants could learn the likelihood of conflict within a meaningful boundary, they could alternatively learn about the likelihood of conflict at individual locations, categories of space, or many other potential predictors. The results of these experiments help address the question of which of these predictors dominate when more than one is available, and whether certain situations make people more inclined to use a particular source of information to predict conflict likelihood.

Before adding additional design features in the current study (i.e., displays with meaningful boundaries), I conducted a pilot experiment to assess whether reliable CSPC effects would be learned at inducer locations and transfer to diagnostic locations using the layout of locations I intended to use in Experiments 1, 2, 3, and 4, and the PC I intended to use for inducer locations in all five experiments of the current study. The primary goal of the pilot experiment was to conceptually replicate the previous effects observed in two relevant studies, one without any boundary and one with a visual (but non-meaningful) boundary separating inducer from diagnostic locations (i.e., Weidler et al., 2020, Experiments 1 & 2). The key findings of the pilot study were as follows (see Appendix B for a full report of the pilot experiment). I found that participants learned location-based control settings for inducer locations that transferred to
diagnostic locations. Critically, there was no difference in performance at inducer and diagnostic locations for participants in a condition with a blank background and a condition where the black outline of a parallelogram separated inducer and diagnostic locations, replicating the prior studies. In other words, there was no difference for the learning and retrieval of control settings between a condition with no boundary and a condition with a non-meaningful boundary. Given the results of the pilot experiment, I can comfortably assume that any differences observed for inducer and diagnostic locations between the blank background condition and the map background condition in the experiments that follow indicate that the meaningful boundaries modulated performance.

1.5 Overview of experiments
Previous studies assessing meaningful boundaries (Colvett & Bugg, 2022; Weidler et al., 2020) relied on between-subjects comparisons to other experiments to make assumptions about the role of meaningful boundaries. In contrast, the experiments of the current study used within-subjects comparisons contrasting performance for flanker trials superimposed over a blank background to flanker trials superimposed over a map background with meaningful boundaries. Experiment 1 and Experiment 2 created these meaningful boundaries using white map backgrounds with simple black lines representing the borders of states. Experiment 1 asked whether learning about the PC of the meaningful space within a boundary disrupted learning the control settings for individual MC and MI locations within the boundary. If the learning within boundaries hypothesis is supported, then the CSPC effect at inducer locations would be attenuated at inducer locations in the map background condition compared with the blank background condition. If the boundaries for retrieval hypothesis is supported, the transfer would be attenuated in the map background condition compared with the blank background condition. Experiment 2 asked
whether transfer to the diagnostic locations would be enhanced by presenting MC and near-MC locations within one meaningful area of space and MI and near-MI locations within a distinct meaningful area of space. If the learning within boundaries hypothesis is supported, the CSPC effect at diagnostic locations would be larger in the map background condition. However, the presence of a map background that distinguished meaningful areas of space did not impact performance in Experiments 1 and 2. That is, a CSPC effect was learned at inducer locations that transferred to diagnostic locations regardless of background condition. This pattern of results is consistent with either the spatial proximity or categorical coding hypotheses, as control settings transferred to diagnostic locations that were both close to the inducer locations and in the same category of space as the inducer locations.

A reformed design was needed after the lack of modulation from the map backgrounds in Experiments 1 and 2. Experiments 3, 4, and 5 aimed to make the difference between meaningful areas (and thus the meaningful boundary) more salient by using a realistic satellite image depicting ocean and land. Experiment 3 replicated and extended the design from Experiment 1. An attenuated CSPC effect at inducer locations in the map background condition indicated evidence for the learning within boundaries hypothesis. However, the evidence for this hypothesis was mixed as the effect did not hold at inducer locations after including blocks where trials also appeared at diagnostic locations. Experiment 4 replicated and extended the design from Experiment 2. A significant CSPC effect again appeared at inducer and diagnostic locations regardless of background condition. Even with the realistic background image, Experiment 4 did not find that learning within the boundary enhanced the CSPC effect at diagnostic locations. This replication of the pattern from Experiment 2 is consistent with either the categorical coding hypothesis or the spatial proximity hypotheses.
Experiment 5 presented inducer locations spatially proximal to a diagnostic location but in a meaningful area of space that was shared with the more distal diagnostic location in the map background condition. Puzzlingly and not predicted by any of the hypotheses, no CSPC effect emerged at inducer locations in the map background condition. In the blank background condition, there was a significant CSPC effect at inducer locations, but no transfer to diagnostic locations. The observed pattern of results in Experiment 5 was remarkable, as it was not predicted by the spatial proximity or categorical coding hypotheses. That is, the diagnostic locations were proximal to an inducer location and in the same category of space (i.e., upper and lower half of the screen), and those hypotheses would have predicted transfer.
Chapter 2: Experiment 1

Experiment 1 used a meaningful boundary to group the inducer locations in one meaningful area of space, separated from diagnostic locations across the meaningful boundary. The goal was to use an improved design to test key predictions from both meaningful boundaries hypotheses that were not fully explored in Colvett and Bugg (2022). In the map background condition, the background image depicted a map centered on Arkansas with surrounding states visible in the image (see Figure 2.1). The MC and MI inducer locations were located within a shared meaningful boundary (i.e., within the border of Arkansas) that was 50% compatible overall.

The learning within boundaries hypothesis predicts an attenuated CSPC effect at inducer locations in the map background condition compared to the blank background condition. Someone learning about the probability of conflict in that meaningful area would learn that trials were 50% compatible overall and retrieve an unbiased control setting for any trial appearing at a location superimposed over Arkansas. The boundaries for retrieval hypothesis predicts an equivalent CSPC effect at inducer locations for map and blank background conditions, but an attenuated CSPC effect at diagnostic locations in the map background condition as the boundary would disrupt retrieval of the control setting. Finally, the categorical coding and spatial proximity hypotheses both predict significant CSPC effects at inducer and diagnostic locations that do not differ by background condition.

Note that Experiment 1 bears similarity to Experiment 1 of Colvett and Bugg (2022). In Colvett and Bugg, a significant CSPC effect was observed at inducer locations and a non-significant CSPC effect was observed at diagnostic locations. Two key differences⁶ exist between

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⁶ Other differences exist between Experiment 1 of the current study and Experiment 1 of Colvett & Bugg (2022). In the current study, there was no centrally presented unbiased inducer location. It is unlikely that this difference
the previous design and Experiment 1 of the current study. First, Experiment 1 of the current study addresses a potential confound that was present in the previous experiment. To create the meaningfully distinct areas in the display, the background image in Colvett and Bugg (2022, Experiment 1) displayed flanker images superimposed over the grass of a quad for the inducer locations and superimposed over the roof of a building at the diagnostic locations (see Figure 1.3). The quad and roof differ not only in their identity, but also in terms of the perceptual features of these locations. One interpretation of the previous data is that perceptual features such as color and texture were learned as the context rather than the boundary itself. Indeed, the result observed by Colvett and Bugg (i.e., a significant CSPC effect at the inducer locations and a non-significant CSPC effect at the diagnostic locations) is also predicted in the current experiment, unless the perceptual difference in the previous study drove the effect. Second, Experiment 1 of Colvett and Bugg (2022) did not benefit from a within-subjects comparison to performance without a meaningful background image. Comparison to a blank background condition allows for the learning within boundaries, boundaries for retrieval, and non-meaningful boundary hypotheses to be distinguished.

affected the ability for participants to learn control settings at the inducer locations and then transfer them to diagnostic locations, as the pilot experiment also did not use a central unbiased inducer location.
Figure 2.1. Whether an inducer location was MC or MI was counterbalanced between subjects. The MC and MI inducer locations were superimposed over the state of Arkansas, while the near-MC and near-MI diagnostic locations were superimposed over the states of Texas and Missouri. The learning within boundaries hypothesis predicts attenuated CSPC effects at both the inducer locations and diagnostic locations for the map background condition. The boundaries for retrieval hypothesis predicts equivalent CSPC effects at inducer locations for the map background condition and the blank background condition, but an attenuated CSPC effect at diagnostic locations for the map background condition. The non-meaningful boundary hypotheses predict CSPC effects at inducer and diagnostic locations with no difference between background conditions.
2.1 Method
2.1.1 Participants
To determine sample size, I ran a power analysis based on the results of a cross-experiment analysis comparing the results at diagnostic locations in two relevant experiments. These experiments were generally equivalent in their design, but they differed in their background image (i.e., blank background in Weidler et al., 2020; quad and surrounding buildings in Colvett & Bugg, 2022). That is, this analysis compared performance when there was no meaningful boundary to when a meaningful boundary separated inducer from diagnostic locations. I ran a 2x2x2 mixed-effects ANOVA for trials at the diagnostic location with a between-subjects factor of experiment (Weidler et al., 2020 or Colvett & Bugg, 2022) and within-subjects factors of near-PC (near-MC or near-MI) and trial type (compatible or incompatible). There was a marginally significant three-way interaction between experiment, near-PC, and trial type, ($F(1,115) = 3.51, p = .064, \eta_p^2 = .03$). Using G*Power 3.1.9.7 (Faul et al., 2009), a sample size of 59 subjects was suggested to observe a within-subjects effect, assuming an $\alpha$ of .05, a (1- $\beta$) of .9. In this and in following experiments, I collected data from 60 participants that met the inclusion criteria. It was counterbalanced between-subjects which inducer location was MC (lower left or upper right) and which background condition came first (map first or map second).

Sixty-seven Washington University undergraduates (54 female, 12 male, one preferred not to answer; Age $M = 19.38, SD = 1.15$) participated for course credit. I excluded participants with an excessively high error rate to ensure that only participants who followed the instructions were included. Three participants were removed for having an error rate above 33% on incompatible trials (cf. Colvett & Bugg, 2022; Colvett et al., 2023; Weidler et al., 2020). Three participants were excluded due to an error with the computer running the program. One participant was excluded for being under 18 years old at the time of the experiment. The data
from the remaining 60 participants (50 female, 10 male, Age $M = 19.45$, $SD = 1.13$) were included in the analysis.

### 2.1.2 Design and stimuli
Flanker stimuli were five black arrows in a horizontal row 2.4 cm wide and 1.6 cm tall superimposed over a white rectangle. Arrows could point either up, down, left, or right. On compatible trials, all arrows pointed in the same direction (e.g., `>`>`>`>) whereas on incompatible trials, the four flanking arrows pointed in a different direction than the central arrow (e.g., `<<<<<`). On incompatible trials, the direction of the flanking arrows was equally likely to be any of the three other directions (e.g., for an incompatible stimulus with a left pointing center arrow, the direction of the flanking arrows was equally likely to be up, down, or right). There were four unique compatible stimuli and 12 unique incompatible stimuli.

There were four locations at which a trial could appear (see Figure 2.1). These locations were superimposed on an invisible diagonal array that was 19.76 cm long. Each location was 6.58 cm apart from each other. Two distinct kinds of locations were used in the current study: inducer locations and diagnostic locations. The diagnostic location closer to the MC location was called the near-MC location, and the diagnostic location closer to the MI location was called the near-MI location.

The aforementioned pilot study used a between-subjects manipulation where participants either saw stimuli superimposed over a blank background or a background with a black parallelogram (see Appendix B for a full description of the pilot experiment). Experiment 1 (and the following experiments) instead used a within-subjects manipulation where participants completed four blocks in a map background condition, and four blocks in a blank background condition. It was counterbalanced between subjects whether the map background condition was first or second. In the blank background condition, the background image was entirely white. In
the map background condition, the background image depicted a map centered on Arkansas but more of the surrounding states were visible in the image. This image was white with black border lines. The background image used in Experiments 1 and 2 was modified from a public domain map of the United States (publicdomainvectors.org, accessed 2021). This image was presented in a rectangle 33.85 cm wide and 19.05 cm tall. The remainder of the screen was gray.

2.1.3 Procedure
Participants performed this experiment in individual cubicles within a group testing space. Experiments were coded and run using PsychoPy (Pierce et al., 2019). The experiment took approximately 50 minutes to complete. After consenting to participate, a brief demographic survey and a brief survey about maps was administered. The goal of the map survey was to assess what US states the participant had lived in, a participant’s knowledge of the US map, and a participant’s self-assessed confidence using maps. The survey and its results for each experiment are included in Appendix A.

Next, participants began the flanker task. Each trial began with a centrally presented fixation cross for 1000 ms. Next, a flanker stimulus appeared on screen until the participant responded. Participants were instructed to indicate the direction of the central arrow by pressing the 2 (down), 4 (left), 6 (right), or 8 (up) key with just their index finger on the number pad of a keyboard, and to return their finger centrally on the keypad between each trial such that their finger was over the 5 key and could press any key on the next trial. Participants were instructed to respond as quickly as possible while maintaining a high level of accuracy. Participants were instructed to return their attention to the central fixation cross in between each trial. Participants were positioned approximately 60 cm away from the computer screen.

Participants then completed a 20-trial practice block of the flanker task with 10 trials at each of the two inducer locations. The PC of each location was consistent with the PC of the
location during the experimental blocks. During this practice block, participants were given feedback as to whether their response was correct or incorrect.

Next, participants completed the map background condition and the blank background condition. For each background condition, there were two inducer blocks and two diagnostic blocks. In each of two 120-trial inducer blocks, 60 stimuli appeared at each of the two inducer locations. At the 80% compatible MC location, there were 12 repetitions of each of the four compatible stimuli and one repetition of each the 12 incompatible stimuli. At the 20% compatible MI location, there were three repetitions of each of the four compatible stimuli and four repetitions of each of the 12 incompatible stimuli. It was counterbalanced between subjects which inducer location was MC and which inducer location was MI, but those inducer location maintained the same PC throughout all blocks of the experiment. The order of the 120 trials was randomized without replacement in each block.

In each of the two 216-trial diagnostic blocks, in addition to the 120 trials that appeared at the inducer locations, identical sets of 48 PC-unbiased (i.e., 50% compatible) stimuli appeared at two novel locations along the invisible diagonal array. In each 50% compatible location, there were six repetitions of each of the four compatible stimuli, and two repetitions of each of the 12 incompatible stimuli. The order of the 216 trials was randomized without replacement in each block.

To separate the experiences between the map background condition and the blank background condition, participants took a timed break. During this time, participants saw a series of “Where’s Waldo” images, where they search for a particular man in a complex illustrated scene. This search task was intended to be a filler task that did not impact performance in the
primary flanker task. Each image remained on screen for 40 seconds, then a solution appeared on
screen for 10 seconds. There were 5 total images, so that the break lasted 250 seconds in total.

Before the map background condition, participants completed an orientation task to
acquaint them with the map used in the experiment and to encourage participants to think of each
state as a distinct area of space. This orientation task appeared before the map background
condition regardless of whether the map background condition came first or second. If
participants completed the map background condition first, the orientation task came after the
practice block. If the participants completed the map background condition second, the
orientation task came after the timed break. First, participants saw a map of the entire United
States. Next, the map zoomed toward the region of the United States that was seen during the
map background condition of the experiment (i.e., centered on Arkansas with more surrounding
states visible in Experiment 1). Participants then saw a version of that map with the name of each
visible state labelled. Participants were instructed to study the map in preparation for a task
where they will need to name prompted states. Participants then completed a five-trial state
labelling task, where one of the states on the map was highlighted, and participants typed the
name of the highlighted state into a textbox. The five states that were prompted in Experiment 1
were Missouri, Tennessee, Texas, Arkansas, and Oklahoma.

2.2 Results
For this and all subsequent experiments, an alpha of .05 was used. In addition, only trials with
RTs greater than 200 and less than 2000 ms were included (cf. Colvett & Bugg, 2022; Weidler &
Bugg, 2016; Weidler et al., 2020). Error trials were excluded from the analysis of RT. Error rates
were expressed as probabilities. A participant’s data were excluded from analysis if their error
rate was higher than 33% for incompatible trials. Analyses were completed using JASP version
0.16.3 (JASP Team, 2022) and R (R Core team, 2022). I ran separate analyses for reaction time and error rate. For both reaction time and error rate, I analyzed trials at inducer and diagnostic locations separately (cf. Colvett & Bugg, 2022; Weidler & Bugg, 2016; Weidler et al, 2020).

For null effects, I additionally presented Bayes Factors. I reported Bayesian evidence for the null hypothesis compared to evidence of the alternative hypothesis (BF$_{01}$). A value between 1 and 3 indicates anecdotal evidence for the null hypothesis and a value between 3 and 10 indicates substantial evidence for the null hypothesis (Wagenmakers, et al., 2011). I calculated Bayes Factors using the default settings of JASP (see Van Doorn et al., 2020).

For trials at inducer locations, I conducted 2x2x2 repeated-measures ANOVAs with factors of background (map or blank), PC (MC or MI), and trial type (compatible or incompatible). I analyzed effects for trials at inducer locations in the first two blocks (i.e., inducer only blocks before trials appeared at the diagnostic location) and throughout all four blocks. For trials at diagnostic locations, I conducted 2x2x2 repeated-measures ANOVAs with factors of background (map or blank), near-PC (near-MC or near-MI), and trial type (compatible or incompatible).

For Experiment 1 and the following experiments, several exploratory analyses were conducted. See the Appendix for a decomposition of map and background conditions, linear mixed-effects models for all analyses, an assessment of whether condition order (i.e., whether the blank or map background condition came first) affected performance, and an assessment of whether location repetitions or category repetitions (i.e., within the same meaningful area of space) affected performance.

### 2.2.1 Reaction time

**Inducer locations.** In the inducer only blocks, there was no interaction between background, PC, and trial type, $F(1, 59) = 0.87, p = .356, \eta_{p}^2 = .01, BF_{01} = 4.58$, such that there
was no difference in CSPC effects between background conditions (see Figure 2.2 & Table 2.1). There was an interaction between PC and trial type, $F(1, 59) = 34.89, p < .001, \eta_p^2 = .37$, indicating a CSPC effect, such that the compatibility effect was larger at the MC location ($M = 172, SE = 8$) than the MI location ($M = 138, SE = 7$). The interactions between background and trial type ($F(1, 59) < 0.01, p = .959, \eta_p^2 < .01, BF_{01} = 8.07$) and background and PC ($F(1, 59) = 0.98, p = .326, \eta_p^2 = .02, BF_{01} = 10.24$) were not significant. There was no effect of background, $F(1, 59) = 0.03, p = .959, \eta_p^2 < .01, BF_{01} = 10.15$. There was an effect of PC, such that responses were slower at MC locations ($M = 723, SE = 16$) than MI locations ($M = 717, SE = 15$), $F(1, 59) = 4.10, p = .048, \eta_p^2 = .07$. There was an effect of trial type, such that responses to compatible trials ($M = 643, SE = 11$) were faster than responses to incompatible trials ($M = 798, SE = 12$), $F(1, 59) = 883.45, p < .001, \eta_p^2 = .94$.

Across all four blocks, there was no interaction between background, PC, and trial type, $F(1, 59) = 1.23, p = .273, \eta_p^2 = .02, BF_{01} = 4.40$, such that there was no difference in CSPC effects between background conditions. There was an interaction between PC and trial type, $F(1, 59) = 34.59, p < .001, \eta_p^2 = .37$, indicating a CSPC effect, such that the compatibility effect was larger at the MC location ($M = 165, SE = 7$) than the MI location ($M = 141, SE = 6$). The interactions between background and trial type ($F(1, 59) = 0.02, p = .879, \eta_p^2 < .01, BF_{01} = 7.64$) and background and PC ($F(1, 59) = 0.42, p = .518, \eta_p^2 = .01, BF_{01} = 6.97$) were not significant. There were not effects of background ($F(1, 59) = 0.79, p = .378, \eta_p^2 = .01, BF_{01} = 7.22$) or PC ($F(1, 59) = 1.01, p = .318, \eta_p^2 = .02, BF_{01} = 9.71$). There was an effect of trial type, such that responses to compatible trials ($M = 644, SE = 9$) were faster than responses to incompatible trials ($M = 797, SE = 11$), $F(1, 59) = 999.57, p < .001, \eta_p^2 = .94$. 
Diagnostic locations. There was no interaction between background, near-PC, and trial type, $F(1, 59) = 1.68, p = .201, \eta^2_p = .03, BF_{01} = 3.77$, such that there was no difference in the CSPC effect between background conditions (see Figure 2.3). There was an interaction between near-PC and trial type, $F(1, 59) = 16.76, p < .001, \eta^2_p = .22$, such that the compatibility effect was larger at the near-MC location ($M = 175, SE = 6$) than the near-MI location ($M = 156, SE = 7$), indicating transfer of the CSPC effect. There was an interaction between background and trial type ($F(1, 59) = 8.37, p = .005, \eta^2_p = .12$), such that the compatibility effect was larger in the map background condition ($M = 173, SE = 6$) than in the blank background condition ($M = 157, SE = 7$). The interaction between background and near-PC ($F(1, 59) = 0.04, p = .848, \eta^2_p < .01, BF_{01} = 7.42$) was not significant. There were no effects of background ($F(1, 59) = 0.55, p = .462, \eta^2_p = .01, BF_{01} = 9.61$) or near-PC ($F(1, 59) = 0.55, p = .461, \eta^2_p = .01, BF_{01} = 9.61$). There was an effect of trial type, such that responses to compatible trials ($M = 702, SE = 10$) were faster than responses to incompatible trials ($M = 867, SE = 11$), $F(1, 59) = 1184.83, p < .001, \eta^2_p = .95$.

2.2.2 Error rate

Inducer locations. In the inducer only blocks, there was no interaction between background, PC, and trial type, $F(1, 59) = 0.19, p = .668, \eta^2_p < .01, BF_{01} = 4.90$, such that there was no difference in CSPC effects between background conditions (see Figure 2.2). There was an interaction between PC and trial type, $F(1, 59) = 21.19, p < .001, \eta^2_p = .26$, such that the compatibility effect was larger at the MC location ($M = 5.31\%, SE = 0.84\%$) than the MI location ($M = 2.69\%, SE = 0.38\%$), indicating the CSPC effect. The interactions between background and trial type ($F(1, 59) = 1.55, p = .219, \eta^2_p = .03, BF_{01} = 4.42$) and background and PC ($F(1, 59) = 0.09, p = .762, \eta^2_p < .01, BF_{01} = 7.06$) were not significant. There was no effect of background, $F(1, 59) = 2.31, p = .134, \eta^2_p = .04, BF_{01} = 3.82$. The was an effect of PC, such that responses were less accurate at MC locations ($M = 3.03\%, SE = 0.73\%$) than MI locations ($M = 1.70\%, SE = \ldots$
= 0.38%), $F(1, 59) = 18.79, p < .001, \eta^2_p = .24$. There was an effect of trial type, such that responses to compatible trials ($M = 0.36\%, SE = 0.21\%$) were more accurate than responses to incompatible trials ($M = 4.36\%, SE = 0.72\%$), $F(1, 59) = 76.36, p < .001, \eta^2_p = .56$.

Across all four blocks, there was no interaction between background, PC, and trial type, $F(1, 59) = 0.15, p = .699, \eta^2_p < .01, BF_{01} = 4.78$, such that the CSPC effect did not differ by background condition. There was an interaction between PC and trial type, $F(1, 59) = 23.17, p < .001, \eta^2_p = .28$, such that the compatibility effect was larger at the MC location ($M = 4.69\%, SE = 0.63\%$) than the MI location ($M = 2.92\%, SE = 0.38\%$), indicating the CSPC effect. The interactions between background and trial type ($F(1, 59) < 0.01, p = .996, \eta^2_p < .01, BF_{01} = 7.21$) and background and PC ($F(1, 59) = 1.83, p = .182, \eta^2_p = .03, BF_{01} = 6.01$) were not significant.

There was no effect of background, $F(1, 59) = 0.05, p = .827, \eta^2_p < .01, BF_{01} = 9.84$. There was an effect of PC, such that responses were less accurate at MC locations ($M = 2.86\%, SE = 0.59\%$) than MI locations ($M = 2.05\%, SE = 0.46\%$), $F(1, 59) = 13.52, p < .001, \eta^2_p = .19$. There was an effect of trial type, such that responses to compatible trials ($M = 0.55\%, SE = 0.28\%$) were more accurate than responses to incompatible trials ($M = 4.36\%, SE = 0.60\%$), $F(1, 59) = 93.25, p < .001, \eta^2_p = .61$.

**Diagnostic locations.** There was no interaction between background, near-PC, and trial type, $F(1, 59) = 1.06, p = .309, \eta^2_p = .02, BF_{01} = 4.48$, such that there was no difference in CSPC effects between background conditions (see Figure 2.3). There was an interaction between near-PC and trial type, $F(1, 59) = 7.28, p = .009, \eta^2_p = .11$, such that the compatibility effect was larger at the near-MC location ($M = 5.73\%, SE = 0.76\%$) than the near-MI location ($M = 4.52\%, SE = 0.64\%$), indicating transfer of the CSPC effect. The interactions between background and trial type ($F(1, 59) = 0.49, p = .826, \eta^2_p < .01, BF_{01} = 6.45$) and background and near-PC ($F(1,
There was no effect of background, $F(1, 59) = 0.01, p = .970, \eta_p^2 < .01, BF_{01} = 9.59$. The was an effect of near-PC, such that responses were less accurate at near-MC locations ($M = 3.40\%, SE = 0.74\%$) than at near-MI locations ($M = 2.77\%, SE = 0.65\%$), $F(1, 59) = 7.74, p = .007, \eta_p^2 = .12$. There was an effect of trial type, such that responses to compatible trials ($M = 0.52\%, SE = 0.29\%$) were more accurate than responses to incompatible trials ($M = 5.64\%, SE = 0.83\%$), $F(1, 59) = 84.11, p < .001, \eta_p^2 = .59$.

Figure 2.2. Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and location PC (MC or MI) at inducer locations in the inducer only blocks of Experiment 1. Error bars represent standard error of the mean. A significant CSPC effect was observed in reaction time and error rate for both map and blank background conditions. No statistical difference emerged between background conditions in either reaction time or error rate.
Figure 2.3. Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and nearby inducer PC (near-MC or near-MI) at diagnostic locations in Experiment 1. Error bars represent standard error of the mean. A significant CSPC effect was observed in both the map background and blank background condition for reaction time. In error rate, a CSPC effect only emerged in the blank background condition, but no statistical difference emerged between background conditions and patterns were consistent with reaction time.

Table 2.1

<table>
<thead>
<tr>
<th>BG</th>
<th>Location Type</th>
<th>PC</th>
<th>Trial Type</th>
<th>RT</th>
<th>CE (RT)</th>
<th>Error Rate</th>
<th>CE (Error Rate)</th>
</tr>
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<tr>
<td>Map</td>
<td>Inducer</td>
<td>MC</td>
<td>Compatible</td>
<td>638 (10)</td>
<td>174 (8)</td>
<td>0.48% (0.29%)</td>
<td>5.56% (0.88%)</td>
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<td>(Inducer Blocks Only)</td>
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<td>Incompatible</td>
<td>812 (12)</td>
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<td>6.03% (0.97%)</td>
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<tr>
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<td></td>
<td>MI</td>
<td>Compatible</td>
<td>648 (11)</td>
<td>136 (7)</td>
<td>0.43% (0.25%)</td>
<td>3.13% (0.42%)</td>
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<td></td>
<td></td>
<td>Incompatible</td>
<td>784 (12)</td>
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<td>3.56% (0.49%)</td>
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<tr>
<td>Inducer</td>
<td>MC</td>
<td>Compatible</td>
<td>635 (9)</td>
<td>167 (7)</td>
<td>0.48% (0.25%)</td>
<td>4.62% (0.59%)</td>
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<tr>
<td></td>
<td>(All Blocks)</td>
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<td>803 (10)</td>
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<td>5.11% (0.69%)</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>646 (9)</td>
<td>138 (6)</td>
<td>0.69% (0.45%)</td>
<td>2.99% (0.38%)</td>
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<td></td>
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<td>Diagnostic</td>
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<td>696 (9)</td>
<td>179 (6)</td>
<td>0.66% (0.22%)</td>
<td>5.83% (0.80%)</td>
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<td></td>
<td>Incompatible</td>
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<tr>
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<td></td>
<td>Near-MI</td>
<td>Compatible</td>
<td>705 (10)</td>
<td>166 (6)</td>
<td>0.46% (0.24%)</td>
<td>4.28% (0.69%)</td>
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<td></td>
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<td>Incompatible</td>
<td>872 (11)</td>
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<td>4.74% (0.81%)</td>
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<td>Blank</td>
<td>Inducer</td>
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<td>Compatible</td>
<td>636 (10)</td>
<td>171 (7)</td>
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<td>807 (13)</td>
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<td>BG Location Type</td>
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<td>Trial Type</td>
<td>RT</td>
<td>CE (RT)</td>
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<tr>
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<td>Compatible</td>
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<td>163 (6)</td>
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<td>4.75% (0.67%)</td>
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<td>(All Blocks)</td>
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<td>Incompatible</td>
<td>806 (11)</td>
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<td>5.29% (0.69%)</td>
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<tr>
<td>MI</td>
<td>Compatible</td>
<td>651 (10)</td>
<td>144 (5)</td>
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<td>2.86% (0.38%)</td>
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<tr>
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<td>3.35% (0.44%)</td>
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<td>Diagnostic</td>
<td>Near-MC</td>
<td>Compatible</td>
<td>695 (10)</td>
<td>170 (6)</td>
<td>0.40% (0.37%)</td>
<td>5.63% (0.73%)</td>
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<td>6.03% (0.81%)</td>
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<tr>
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<td>Near-MI</td>
<td>Compatible</td>
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<td>145 (7)</td>
<td>0.55% (0.29%)</td>
<td>4.76% (0.60%)</td>
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<tr>
<td></td>
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<td>855 (11)</td>
<td></td>
<td>5.31% (0.77%)</td>
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</tbody>
</table>

*Note:* BG = background condition; CE = compatibility effect; MC = mostly compatible inducer location; MI = mostly incompatible inducer location. Inducer = locations where trials were 80% PC when the MC object was superimposed and 20% PC when the MI object was superimposed over the location; Diagnostic = locations that were 50% PC regardless of which object was superimposed over the location.

### 2.3 Discussion

In both the blank background and map background conditions in Experiment 1, a CSPC effect emerged at inducer and diagnostic locations. Moreover, there was no statistical difference in CSPC effects between background conditions. The only hint that meaningful boundaries affected the retrieval of control settings was the non-significant CSPC effect at diagnostic locations in error rate selectively in the map background condition. Though the strongest evidence for the hypotheses would come from differences in reaction time, there are reasons to believe that meaningful boundaries may have distinct effects on participant accuracy. Indeed, the pattern in Experiment 1 mirrors an effect in error rate in Experiment 3 of Weidler et al. (2020), such that CSPC effects in error rate transferred to diagnostic locations within a line drawing of an island but not across a meaningful boundary into water. I will return to the possibility that meaningful boundaries (and not simply visual boundaries) were a boundary for retrieval selectively in error rate in the General Discussion.
Overall, a comparison of the results of Experiment 1 to the attenuated CSPC effect at inducer locations and lack of transfer to diagnostic locations in the previous study in which meaningful areas also differed perceptually (i.e., campus map study; Colvett & Bugg, 2022, Experiment 1) calls into question whether those perceptual differences were important in encouraging participants to use meaningful boundaries to guide control. Before exploring this question further, it will be important to consider whether learning within a meaningful area can enhance transfer in another experiment that used simple black outlines as meaningful boundaries.
Chapter 3: Experiment 2

The primary goal of Experiment 2 was to test whether learning about the areas of space within a boundary can enhance the transfer of control settings. Previously, evidence for the influence of meaningful boundaries on the learning of control settings has only come from attenuated CSPC effects at inducer locations when the MC and MI inducer locations both resided within a meaningful boundary (e.g., Colvett & Bugg, 2022), though it should be noted that CSPC effects were not attenuated at inducer locations in Experiment 1 of the current study. In the map background condition of Experiment 2, the MC and MI inducer locations were presented across a meaningful boundary from each other and within separate meaningful areas. Participants saw an image depicting a map centered on Oklahoma, Arkansas, Louisiana, and Texas (see Figure 3.1). One inducer location and one diagnostic location resided within the same state (e.g., Texas) and the other inducer and diagnostic location resided within the other state (e.g., Arkansas).
Figure 3.1. Whether an inducer location was MC or MI was counterbalanced between subjects. One inducer location and one diagnostic location were superimposed over the state of Arkansas, while the other inducer and diagnostic location were superimposed over the state of Texas. The learning within boundaries hypothesis predicts that CSPC effects should be enhanced at diagnostic locations in the map background condition. The boundaries for retrieval hypothesis and the non-meaningful boundary hypotheses predict CSPC effects at inducer and diagnostic locations with no difference between background conditions.

The learning within boundaries hypothesis predicts that CSPC effects at inducer locations should be equivalent between map and blank background conditions. As an inducer location and diagnostic location resided within the same meaningful area of space (i.e., within each state), the learning within boundaries hypothesis also predicts that the CSPC effect should be larger at
diagnostic locations in the map background condition. The boundaries for retrieval hypothesis does not make a prediction distinguishing performance between the map and blank background conditions, as no boundaries separated inducer and diagnostic locations in the map background condition. As in Experiment 1, the categorical coding and spatial proximity hypotheses predict a significant CSPC effect at inducer and diagnostic locations in both the map and blank background conditions.

3.1 Method
3.1.1 Participants
Sixty-one Washington University undergraduates (41 female, 20 male; Age $M = 19.39$, $SD = 1.26$) participated for course credit. One participant was removed for having an error rate above 33% on incompatible trials. The data from the remaining 60 participants (41 female, 19 male, Age $M = 19.35$, $SD = 1.22$) were included in the analysis.

3.1.2 Design and stimuli
The design and stimuli were equivalent to Experiment 1, except for the following differences. In the map background condition, stimuli were now presented over a map centered on Arkansas and Texas, with more of the surrounding states visible in the image. In the five-state labelling task before the map background condition, the prompted states were Missouri, Texas, Illinois, Arkansas, and Oklahoma.

3.1.3 Procedure
The procedure was identical to Experiment 1.

3.2 Results
3.2.1 Reaction time

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7 A strong version of the learning within boundaries hypothesis would also predict that CSPC effects at inducer locations should be attenuated in blocks where diagnostic trials are introduced, as the overall PC of the meaningful area is closer to 50% compatible after including the unbiased diagnostic locations.
Inducer locations. In the inducer only blocks, there was no interaction between background, PC, and trial type, $F(1, 59) < 0.01, p = .975, \eta^2_p < .01, BF_{01} = 6.57$, such that the CSPC effect did not differ by background condition (see Figure 3.2 & Table 3.1). There was an interaction between PC and trial type, $F(1, 59) = 47.63, p < .001, \eta^2_p = .44$, indicating the CSPC effect, such that the compatibility effect was larger at the MC location ($M = 157, SE = 6$) than the MI location ($M = 130, SE = 6$). There was no interaction between background and trial type, $F(1, 59) = 2.77, p = .101, \eta^2_p = .05, BF_{01} = 4.58$. There was an interaction between background and PC, such that the difference in response time between MC and MI locations were larger in the map background condition ($M = 149, SE = 6$) than in the blank background condition ($M = 138, SE = 6$), $F(1, 59) = 5.76, p = .020, \eta^2_p = .09$. There was no effect of background ($F(1, 59) = 0.57, p = .811, \eta^2_p < .01, BF_{01} = 9.69$) or PC ($F(1, 59) = 1.16, p = .286, \eta^2_p = .02, BF_{01} = 9.23$). There was an effect of trial type, such that responses to compatible trials ($M = 635, SE = 14$) were faster than responses to incompatible trials ($M = 778, SE = 15$), $F(1, 59) = 1345.67, p < .001, \eta^2_p = .96$.

Across all four blocks, there was no interaction between background, PC, and trial type, $F(1, 59) = 0.43, p = .516, \eta^2_p = .01, BF_{01} = 5.13$, such that the CSPC effect did not differ between background conditions. There was an interaction between PC and trial type, $F(1, 59) = 47.40, p < .001, \eta^2_p = .45$, indicating the CSPC effect, such that the compatibility effect was larger at the MC location ($M = 157, SE = 5$) than the MI location ($M = 133, SE = 5$). The interactions between background and trial type ($F(1, 59) = 1.99, p = .163, \eta^2_p = .03, BF_{01} = 5.29$) and background and PC ($F(1, 59) = 0.26, p = .614, \eta^2_p < .01, BF_{01} = 7.39$) were not significant. There were no effects of background ($F(1, 59) = 0.06, p = .807, \eta^2_p < .01, BF_{01} = 9.84$) or PC ($F(1, 59) = 1.20, p = .277, \eta^2_p = .02, BF_{01} = 9.55$). There was an effect of trial type, such that responses to compatible
trials ($M = 636, SE = 13$) were faster than responses to incompatible trials ($M = 778, SE = 14$), $F(1, 59) = 1393.90, p < .001, \eta^2_p = .96$.

**Diagnostic locations.** There was no interaction between background, near-PC, and trial type, $F(1, 59) = 0.56, p = .458, \eta^2_p = .01, BF_{01} = 5.35$, such that the CSPC effect did not differ between background conditions (see Figure 3.3). There was an interaction between near-PC and trial type, $F(1, 59) = 37.06, p < .001, \eta^2_p = .39$, such that the compatibility effect was larger at the near-MC location ($M = 164, SE = 6$) than the near-MI location ($M = 138, SE = 6$), indicating transfer of the CSPC effect. The interactions between background and trial type ($F(1, 59) = 3.49, p = .069, \eta^2_p = .06, BF_{01} = 3.80$) and background and near-PC ($F(1, 59) = 0.01, p = .942, \eta^2_p < .01, BF_{01} = 7.47$) were not significant. The effects of background ($F(1, 59) = 0.50, p = .482, \eta^2_p = .01, BF_{01} = 8.29$) and near-PC ($F(1, 59) = 0.78, p = .382, \eta^2_p = .01, BF_{01} = 9.48$) were not significant. There was no effect of trial type, such that responses to compatible trials ($M = 691, SE = 14$) were faster than responses to incompatible trials ($M = 837, SE = 14$), $F(1, 59) = 1255.80, p < .001, \eta^2_p = .96$.

**3.2.2 Error rate**

**Inducer locations.** In the inducer only blocks, there was no interaction between background, PC, and trial type, $F(1, 59) = 1.29, p = .260, \eta^2_p = .02, BF_{01} = 4.28$, such that there was no difference in CSPC effects between the background conditions (see Figure 3.2). There was an interaction between PC and trial type, $F(1, 59) = 11.28, p = .001, \eta^2_p = .16$, such that the compatibility effect was larger at the MC location ($M = 4.38\%, SE = 0.76\%$) than the MI location ($M = 2.67\%, SE = 0.48\%$), indicating the CSPC effect. The interactions between background and trial type ($F(1, 59) = 0.57, p = .455, \eta^2_p = .01, BF_{01} = 5.85$) and background and PC ($F(1, 59) = 0.61, p = .437, \eta^2_p = .01, BF_{01} = 6.57$) were not significant. There was no effect of background, $F(1, 59) = 0.18, p = .674, \eta^2_p < .01, BF_{01} = 9.33$. There was an effect of PC, such that responses
were less accurate at MC locations ($M = 2.47\%, \ SE = 0.63\%$) than MI locations ($M = 1.55\%, \ SE = 0.42\%$), $F(1, 59) = 16.10, p < .001, \eta_p^2 = .21$. There was an effect of trial type, such that responses to compatible trials ($M = 0.25\%, \ SE = 0.11\%$) were more accurate than responses to incompatible trials ($M = 3.77\%, \ SE = 0.68\%$), $F(1, 59) = 58.04, p < .001, \eta_p^2 = .50$.

Across all four blocks, there was no interaction between background, PC, and trial type, $F(1, 59) < 0.01, p = .996, \eta_p^2 < .01, BF_{01} = 1.20$, such that the CSPC effect did not differ by background condition. There was an interaction between PC and trial type, $F(1, 59) = 13.03, p < .001, \eta_p^2 = .18$, such that the compatibility effect was larger at the MC location ($M = 4.23\%, \ SE = 0.58\%$) than the MI location ($M = 3.01\%, \ SE = 0.46\%$), indicating the CSPC effect. The interactions between background and trial type ($F(1, 59) = 2.07, p = .156, \eta_p^2 = .03, BF_{01} = 3.86$) and background and PC ($F(1, 59) = 0.07, p = .799, \eta_p^2 < .01, BF_{01} = 7.05$) were not significant. There was no effect of background, $F(1, 59) = 1.10, p = .299, \eta_p^2 = .02, BF_{01} = 6.22$. The was an effect of PC, such that responses were less accurate at MC locations ($M = 2.47\%, \ SE = 0.52\%$) than MI locations ($M = 1.84\%, \ SE = 0.43\%$), $F(1, 59) = 17.48, p < .001, \eta_p^2 = .23$. There was an effect of trial type, such that responses to compatible trials ($M = 0.34\%, \ SE = 0.13\%$) were more accurate than responses to incompatible trials ($M = 3.97\%, \ SE = 0.58\%$), $F(1, 59) = 73.83, p < .001, \eta_p^2 = .56$.

**Diagnostic locations.** There was no interaction between background, near-PC, and trial type, $F(1, 59) = 1.94, p = .169, \eta_p^2 = .03, BF_{01} = 3.74$, such that there was no difference in CSPC effects between background conditions (see Figure 3.3). There was an interaction between near-PC and trial type, $F(1, 59) = 31.17, p < .001, \eta_p^2 = .35$, such that the compatibility effect was larger at the near-MC location ($M = 5.56\%, \ SE = 0.84\%$) than the near-MI location ($M = 3.43\%, \ SE = 0.73\%$), indicating transfer of the CSPC effect. The interactions between background and
trial type ($F(1, 59) = 1.31, p = .257, \eta^2 = .02, BF_{01} = 4.13$) and background and near-PC ($F(1, 59) = 0.57, p = .455, \eta^2 = .01, BF_{01} = 4.77$) were not significant. There was no effect of background, $F(1, 59) = 1.08, p = .304, \eta^2 = .02, BF_{01} = 6.05$. The was an effect of near-PC, such that responses were less accurate at near-MC locations ($M = 3.21\%, \ SE = 0.75\%$) than at near-MI locations ($M = 2.25\%, \ SE = 0.59\%), F(1, 59) = 23.36, p < .001, \eta^2 = .28$. There was an effect of trial type, such that responses to compatible trials ($M = 0.48\%, \ SE = 0.17\%)$ were more accurate than responses to incompatible trials ($M = 4.98\%, \ SE = 0.84\%), F(1, 59) = 49.90, p < .001, \eta^2 = .46$.

Figure 3.2. Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and location PC (MC or MI) at inducer locations in the inducer only blocks of Experiment 2. Error bars represent standard error of the mean. A significant CSPC effect was observed in reaction time and error rate for both map and blank background conditions. No statistical difference emerged between the CSPC effects in each background condition.
Figure 3.3. Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and nearby inducer PC (near-MC or near-MI) at diagnostic locations in Experiment 2. Error bars represent standard error of the mean. A significant CSPC effect was observed in reaction time and error rate for both map and blank background conditions. No statistical difference emerged between the CSPC effects in each background condition.

Table 3.1

Experiment 2 Reaction Time (ms) and Error Rate at Inducer and Diagnostic Locations with

Standard Errors in Parentheses

<table>
<thead>
<tr>
<th>BG Location Type</th>
<th>PC Type</th>
<th>Trial Type</th>
<th>RT (ms)</th>
<th>CE (RT)</th>
<th>Error Rate</th>
<th>CE (Error Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map Inducer (Inducer Blocks Only)</td>
<td>MC</td>
<td>Compatible</td>
<td>631 (13)</td>
<td>162 (6)</td>
<td>0.28% (0.14%)</td>
<td>4.37% (0.61%)</td>
</tr>
<tr>
<td></td>
<td>Incompatible</td>
<td>794 (15)</td>
<td>4.66% (0.67%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>635 (14)</td>
<td>136 (6)</td>
<td>0.15% (0.10%)</td>
<td>3.10% (0.55%)</td>
</tr>
<tr>
<td></td>
<td>Incompatible</td>
<td>771 (15)</td>
<td>3.25% (0.62%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inducer (All Blocks)</td>
<td>MC</td>
<td>Compatible</td>
<td>630 (12)</td>
<td>161 (5)</td>
<td>0.34% (0.13%)</td>
<td>4.52% (0.52%)</td>
</tr>
<tr>
<td></td>
<td>Incompatible</td>
<td>792 (14)</td>
<td>4.86% (0.59%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>640 (13)</td>
<td>135 (5)</td>
<td>0.36% (0.17%)</td>
<td>3.30% (0.50%)</td>
</tr>
<tr>
<td></td>
<td>Incompatible</td>
<td>775 (14)</td>
<td>3.66% (0.60%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostic Near-MC</td>
<td>Compatible</td>
<td>684 (12)</td>
<td>167 (5)</td>
<td>0.54% (0.20%)</td>
<td>5.61% (0.83%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incompatible</td>
<td>851 (13)</td>
<td>6.14% (0.94%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Near-MI</td>
<td>Compatible</td>
<td>699 (14)</td>
<td>144 (6)</td>
<td>0.47% (0.19%)</td>
<td>4.16% (0.88%)</td>
</tr>
<tr>
<td></td>
<td>Incompatible</td>
<td>843 (14)</td>
<td>4.63% (0.91%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blank Inducer</td>
<td>MC</td>
<td>Compatible</td>
<td>628 (14)</td>
<td>152 (6)</td>
<td>0.28% (0.07%)</td>
<td>4.39% (0.89%)</td>
</tr>
<tr>
<td>BG Location Type</td>
<td>PC</td>
<td>Trial Type</td>
<td>RT</td>
<td>CE (RT)</td>
<td>Error Rate</td>
<td>CE (Error Rate)</td>
</tr>
<tr>
<td>------------------</td>
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<td>-------------</td>
<td>------</td>
<td>---------</td>
<td>------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>(Inducer Blocks Only)</td>
<td>MI</td>
<td>Compatible</td>
<td>644 (14)</td>
<td>125 (6)</td>
<td>0.28% (0.14%)</td>
<td>2.24% (0.38%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>776 (14)</td>
<td></td>
<td>2.51% (0.40%)</td>
<td></td>
</tr>
<tr>
<td>MI Compatible</td>
<td></td>
<td>Compatible</td>
<td>631 (13)</td>
<td>153 (5)</td>
<td>0.37% (0.08%)</td>
<td>3.94% (0.63%)</td>
</tr>
<tr>
<td>Incompatible</td>
<td></td>
<td>Incompatible</td>
<td>641 (13)</td>
<td>130 (5)</td>
<td>0.31% (0.13%)</td>
<td>2.72% (0.41%)</td>
</tr>
<tr>
<td>MI</td>
<td></td>
<td>Compatible</td>
<td>682 (13)</td>
<td>161 (6)</td>
<td>0.32% (0.13%)</td>
<td>5.52% (0.86%)</td>
</tr>
<tr>
<td>Incompatible</td>
<td></td>
<td>Incompatible</td>
<td>843 (14)</td>
<td></td>
<td>5.85% (0.89%)</td>
<td></td>
</tr>
<tr>
<td>Near-MC Compatible</td>
<td></td>
<td>Compatible</td>
<td>700 (15)</td>
<td>131 (6)</td>
<td>0.60% (0.16%)</td>
<td>2.70% (0.55%)</td>
</tr>
<tr>
<td>Incompatible</td>
<td></td>
<td>Incompatible</td>
<td>831 (15)</td>
<td></td>
<td>3.30% (0.54%)</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** BG = background condition; CE = compatibility effect; MC = mostly compatible inducer location; MI = mostly incompatible inducer location. Inducer = locations where trials were 80% PC when the MC object was superimposed and 20% PC when the MI object was superimposed over the location; Diagnostic = locations that were 50% PC regardless of which object was superimposed over the location.

### 3.2.3 Between-experiment analysis

Performance for trials at the inducer locations may have differed for Experiments 1 & 2, as both inducer locations resided inside the same meaningful area in Experiment 1 and the inducer locations resided on opposite sides of a meaningful boundary in Experiment 2. Performance for trials at diagnostic locations also may have differed between Experiments 1 & 2, as inducer and diagnostic locations were separated by a meaningful boundary in Experiment 1 and inducer and diagnostic locations were presented within the same meaningful area in Experiment 2. As performance at diagnostic locations relies on a control setting to first be learned at inducer locations, performance at diagnostic locations may have also differed between experiments at diagnostic locations if the signal learned at inducer locations was modulated. As the blank background conditions were identical in Experiments 1 and 2, between-experiment analysis was limited to the map background conditions. As in the primary analyses, separate analyses were
performed for trials at inducer locations in the inducer only blocks, trials at inducer locations across all blocks, and trials at diagnostic locations in the diagnostic blocks. A difference between experiments in the map background conditions would manifest statistically as a three-way interaction between experiment, PC, and trial type.

At inducer locations in inducer only blocks, there was no interaction between experiment, PC, and trial type in either reaction time \( (F(1, 118) = 1.61, p = .206, \eta_p^2 = .01, BF_{01} = 3.36) \) or error rate \( (F(1, 118) = 1.38, p = .242, \eta_p^2 = .01, BF_{01} = 4.38) \). At inducer locations across all blocks, there was no interaction between experiment, PC, and trial type in either reaction time \( (F(1, 118) = 0.18, p = .669, \eta_p^2 < .01, BF_{01} = 4.72) \) or error rate \( (F(1, 118) = 0.47, p = .496, \eta_p^2 < .01, BF_{01} = 4.11) \). At diagnostic locations, there was no interaction between experiment, near-PC, and trial type in either reaction time \( (F(1, 118) = 1.15, p = .286, \eta_p^2 = .01, BF_{01} = 3.42) \) or error rate \( (F(1, 118) = 0.48, p = .489, \eta_p^2 < .01, BF_{01} = 4.41) \).

3.3 Discussion

As in Experiment 1, there was a significant CSPC effect at both inducer locations and diagnostic locations in both background conditions in Experiment 2. Moreover, there was no difference between the map conditions in a between-experiment analysis, further indicating that the meaningful boundaries in the map background condition did not affect the learning or retrieval of control settings. Overall, the results of both Experiments 1 and 2 were consistent with either the categorical coding hypothesis or the spatial proximity hypothesis.

Like many potential contexts in CSPC designs, the information from the meaningful boundaries and meaningful areas is nominally irrelevant to task performance. That is, participants were not obliged to attend to that dimension to perform the task effectively. In comparison, location (e.g., Logan 1998; cf. Woodman, 2021) and stimulus features (i.e., item-
specific PC effects; e.g., Bugg et al., 2011; Jacoby et al., 2003) need to be attended to for participants to perform the task. Indeed, it is possible that participants only use meaningful boundaries to modulate control when the difference between meaningful areas is more salient. For example, the meaningful boundaries in the design where a campus map was used to create meaningful boundaries (Colvett & Bugg, 2022, Experiment 1; see Figure 1.3) modulated the learning and retrieval of control settings, whereas CSPC effects emerged at inducer and diagnostic locations in a similar design that did not have these perceptual differences inside and outside the meaningful boundary (Weidler et al., 2020, Experiment 3). The subsequent experiments used background images that attempted to make the meaningful boundaries more salient in the map background condition.
Chapter 4: Experiment 3
The goal of Experiment 3 was to assess the goals laid out in Experiment 1, but with a stronger meaningful boundary manipulation in the map background condition. Indeed, the evidence from Experiments 1 and 2 was consistent with the idea that participants did not use meaningful boundaries to inform the learning or retrieval of control settings. Experiment 3 (as well as Experiments 4 and 5) used realistic, colorful satellite images to make meaningful areas of space perceptually distinct from each other and the boundaries that separate those meaningful areas more salient. Specifically, the background image in the map background condition of Experiment 3 depicted an image of the Gulf of Mexico and the surrounding areas of land in North America. Trials at the inducer locations were superimposed over the water, and trials at the diagnostic locations were superimposed over the land (see Figure 4.1). As in Experiment 1, the MC and MI inducer locations resided within the same meaningful boundary, such that the PC of that shared meaningful space was 50% compatible overall.

The learning within boundaries hypothesis predicts that participants should learn the PC of all experiences within a meaningful area of space (e.g., in water), and subsequently retrieve an unbiased control setting for all trials in that meaningful area. If participants use the meaningful area to predict conflict, the CSPC effect at the inducer locations should be attenuated in the map background condition compared to the blank background condition. Separately, the boundaries for retrieval hypothesis predicts equivalent performance between the map background condition and blank background condition at inducer locations, but no or reduced transfer to diagnostic locations in the map background condition. As in previous experiments, the categorical coding hypothesis and spatial proximity hypothesis predict that meaningful boundaries would not affect the learning and retrieval of control settings. If these hypotheses are supported, the results should
mirror Experiment 1, such that a CSPC effect should be observed at inducer and diagnostic locations irrespective of background condition.

![Diagram showing learning within boundaries, boundaries for retrieval, and spatial proximity or categorical coding.]

**Figure 4.1.** Whether an inducer location was MC or MI was counterbalanced between subjects. The MC and MI inducer locations were superimposed over water (specifically, the Gulf of Mexico), while the near-MC and near-MI diagnostic locations were superimposed over land (specifically, North America). The learning within boundaries hypothesis predicts attenuated CSPC effects at both the inducer locations and diagnostic locations for the map background condition. The boundaries for retrieval hypothesis predicts equivalent CSPC effects at inducer locations for the map background condition and the blank background condition, but an attenuated CSPC effect at diagnostic locations for the map background condition. The non-meaningful boundary hypotheses predict CSPC effects at inducer and diagnostic locations with no difference between background conditions.

### 4.1 Method

#### 4.1.1 Participants

Sixty-six Washington University undergraduates (47 female, 19 male; Age $M = 19.80$, $SD = 1.82$) participated for course credit. Five participants were removed for having an error rate
above 33% on incompatible trials. One participant was excluded for being under 18 years old at the time of the experiment. The data from the remaining 60 participants (41 female, 19 male, Age \(M = 19.87, SD = 1.89\)) were included in the analysis.

### 4.1.2 Design and stimuli
The design and stimuli were equivalent to Experiments 1 and 2, except for the following differences. The map survey no longer included general knowledge about US states, and now asked whether the participant had been to the oceans that appeared in the map background condition (see Appendix A). As the background image was no longer white in the map background condition, the stimuli now appeared to be surrounded by a white rectangle.

The image in the map background condition depicted the Gulf of Mexico and the surrounding areas of land in North America (see Figure 4.1). The background image was modified from a Google Maps satellite aerial image (Google et al., 2022). In the orientation task, participants no longer studied a map then labelled highlighted states. Each of the four locations where a stimulus could appear were highlighted one at a time. Participants were told to type in an activity that a person could do at each of the four locations on a map.

### 4.1.3 Procedure
The procedure was identical to Experiments 1 and 2.

### 4.2 Results
#### 4.2.1 Reaction time
**Inducer locations.** In the inducer only blocks, there was an interaction between background, PC, and trial type, \(F(1, 59) = 5.48, p = .023, \eta_p^2 = .09\), such that CSPC effects were smaller in the map background condition (\(M = 17, SE = 7\)) than the blank background condition (\(M = 41, SE = 7\); see Figure 4.2 and Table 4.1). There was an interaction between PC and trial type, \(F(1, 59) = 43.19, p < .001, \eta_p^2 = .42\), indicating the CSPC effect such that the compatibility
effect was larger at the MC location \( (M = 156, SE = 7) \) than the MI location \( (M = 127, SE = 6) \).
The interaction between background and trial type was significant, such that compatibility effects were smaller in the map background condition \( (M = 131, SE = 7) \) than the blank background condition \( (M = 152, SE = 7) \), \( F(1, 59) = 14.58, p < .001, \eta^2_p = .20 \). There was no interaction between background and PC, \( F(1, 59) = 0.02, p = .895, \eta^2_p < .01, BF_{01} = 7.06 \). There were no effects of background \( (F(1, 59) = 0.10, p = .759, \eta^2_p < .01, BF_{01} = 9.60) \) or PC, \( (F(1, 59) = 2.21, p = .143, \eta^2_p = .04, BF_{01} = 8.71) \). There was an effect of trial type, such that responses to compatible trials \( (M = 649, SE = 14) \) were faster than responses to incompatible trials \( (M = 790, SE = 15) \), \( F(1, 59) = 877.44, p < .001, \eta^2_p = .94 \).

Across all four blocks, there was no interaction between background, PC, and trial type, \( F(1, 59) = 1.34, p = .252, \eta^2_p = .02, BF_{01} = 4.22 \), such that the CSPC effect did not differ by background condition. There was an interaction between PC and trial type, \( F(1, 59) = 36.38, p < .001, \eta^2_p = .38 \), indicating the CSPC effect such that the compatibility effect was larger at MC locations \( (M = 156, SE = 6) \) than at MI locations \( (M = 135, SE = 5) \). There was an interaction between background and trial type, such that compatibility effects were smaller in the map background condition \( (M = 135, SE = 6) \) than in the blank background condition \( (M = 156, SE = 5) \), \( F(1, 59) = 24.73, p < .001, \eta^2_p = .30 \). There was no interaction between background and PC, \( F(1, 59) = 0.33, p = .571, \eta^2_p = .01, BF_{01} = 7.45 \). There were no effects of background \( (F(1, 59) = 0.93, p = .340, \eta^2_p = .02, BF_{01} = 6.26) \) or PC \( (F(1, 59) = 3.02, p = .088, \eta^2_p = .05, BF_{01} = 8.60) \). There was an effect of trial type, such that responses to compatible trials \( (M = 648, SE = 14) \) were faster than responses to incompatible trials \( (M = 794, SE = 14) \), \( F(1, 59) = 1121.94, p < .001, \eta^2_p = .95 \).
Diagnostic locations. There was no interaction between background, near-PC, and trial type, $F(1, 59) = 0.37, p = .543, \eta^2_p = .01, BF_{01} = 4.52$, such that there was no difference in CSPC effects between background conditions (see Figure 4.3). There was an interaction between near-PC and trial type, $F(1, 59) = 5.15, p = .027, \eta^2_p = .08$, such that the compatibility effect was larger at the near-MC location ($M = 151, SE = 7$) than the near-MI location ($M = 139, SE = 7$) indicating transfer of the CSPC effect. There was an interaction between background and trial type, such that the compatibility effect was larger in the blank background condition ($M = 157, SE = 7$) than the map background condition ($M = 133, SE = 6$), $F(1, 59) = 15.48, p < .001, \eta^2_p = .21$. There was no interaction between background and near-PC, $F(1, 59) = 0.68, p = .414, \eta^2_p = .01, BF_{01} = 6.25$. There was an effect of background, such that responses were faster in the blank background condition ($M = 767, SE = 17$) than the map background condition ($M = 792, SE = 17$), $F(1, 59) = 8.21, p = .006, \eta^2_p = .12$. The was no effect of near-PC, $F(1, 59) = 0.51, p = .478, \eta^2_p = .01, BF_{01} = 9.45$. There was an effect of trial type, such that responses to compatible trials ($M = 707, SE = 14$) were faster than responses to incompatible trials ($M = 852, SE = 15$), $F(1, 59) = 1035.22, p < .001, \eta^2_p = .95$.

4.2.2 Error rate

Inducer locations. In the inducer only blocks, there was no interaction between background, PC, and trial type, $F(1, 59) = 0.76, p = .387, \eta^2_p = .01, BF_{01} = 4.31$, such that there was no difference in CSPC effects between background conditions (see Figure 4.2). There was an interaction between PC and trial type ($F(1, 59) = 8.87, p = .004, \eta^2_p = .13$), such that the compatibility effect was larger at the MC location ($M = 3.80\%, SE = 0.69\%$) than the MI location ($M = 2.59\%, SE = 0.46\%$), indicating the CSPC effect. The interactions between background and trial type ($F(1, 59) = 1.51, p = .224, \eta^2_p = .03, BF_{01} = 4.02$ and background and PC ($F(1, 59) = 1.10, p = .299, \eta^2_p = .02, BF_{01} = 6.48$) were not significant. There was no effect of background,
\( F(1, 59) = 0.50, p = .487, \eta^2 = .01, \text{BF}_{01} = 7.90 \). There was an effect of PC, such that responses were less accurate at MC locations (\( M = 2.41\%, SE = 0.58\% \)) than MI locations (\( M = 1.54\%, SE = 0.39\% \)), \( F(1, 59) = 17.28, p < .001, \eta^2 = .23 \). There was an effect of trial type, such that responses to compatible trials (\( M = 0.38\%, SE = 0.18\% \)) were more accurate than responses to incompatible trials (\( M = 3.57\%, SE = 0.61\% \)), \( F(1, 59) = 51.57, p < .001, \eta^2 = .47 \).

Across all four blocks, there was no interaction between background, PC, and trial type, \( F(1, 59) = 0.79, p = .377, \eta^2 = .01, \text{BF}_{01} = 4.83 \), such that the CSPC effect did not differ between background conditions. There was an interaction between PC and trial type, \( F(1, 59) = 8.56, p = .005, \eta^2 = .13 \), such that the compatibility effect was larger at the MC location (\( M = 3.89\%, SE = 0.61\% \)) than the MI location (\( M = 3.07\%, SE = 0.47\% \)), indicating the CSPC effect. There was an interaction between background and trial type, such that the compatibility effect was larger in the blank background condition (\( M = 3.93\%, SE = 0.63\% \)) than the map background condition (\( M = 3.04\%, SE = 0.44\% \)), \( F(1, 59) = 4.41, p = .040, \eta^2 = .07 \). There was no interaction between background and PC, \( F(1, 59) = 0.24, p = .627, \eta^2 < .01, \text{BF}_{01} = 6.94 \). There was no effect of background, \( F(1, 59) = 3.95, p = .052, \eta^2 = .06, \text{BF}_{01} = 2.69 \). The was an effect of PC, such that responses were less accurate at MC locations (\( M = 2.38\%, SE = 0.52\% \)) than MI locations (\( M = 1.71\%, SE = 0.40\% \)), \( F(1, 59) = 23.24, p < .001, \eta^2 = .28 \). There was an effect of trial type, such that responses to compatible trials (\( M = 0.30\%, SE = 0.11\% \)) were more accurate than responses to incompatible trials (\( M = 3.78\%, SE = 0.57\% \)), \( F(1, 59) = 57.58, p < .001, \eta^2 = .49 \).

**Diagnostic locations.** There was no interaction between background, near-PC, and trial type, \( F(1, 59) = 3.22, p = .078, \eta^2 = .05, \text{BF}_{01} = 2.06 \), such that the CSPC effect was only nominally smaller in the map background condition (\( M = -0.05\%, SE = 0.55\% \)) than the blank background condition (\( M = 1.55\%, SE = 0.72\% \); see Figure 4.3). The interaction between near-
PC and trial type was non-significant \((F(1, 59) = 2.76, p = .102, \eta^2_p = .05, BF_{01} = 3.02)\), indicating no transfer of the CSPC effect. There was no interaction between background and near-PC, \(F(1, 59) = 0.16, p = .691, \eta^2_p < .01, BF_{01} = 7.02\). There was an interaction between background and trial type, such that compatibility effects were larger in the blank background condition \((M = 4.51\%, SE = 0.66\%)\) compared to the map background condition \((M = 3.13\%, SE = 0.53\%)\), \(F(1, 59) = 9.52, p = .003, \eta^2_p = .14\). There was an effect of background, such that responses were less accurate in the blank background condition \((M = 2.71\%, SE = 0.59\%)\) than in the map background condition \((M = 2.06\%, SE = 0.47\%)\), \(F(1, 59) = 6.86, p = .011, \eta^2_p = .10\). There was no effect of near-PC, \(F(1, 59) = 0.42, p = .521, \eta^2_p = .01, BF_{01} = 9.25\). There was an effect of trial type, such that responses to compatible trials \((M = 0.47\%, SE = 0.16\%)\) were more accurate than responses to incompatible trials \((M = 4.29\% SE = 0.65\%)\), \(F(1, 59) = 70.98, p < .001, \eta^2_p = .55\).

![Figure 4.2](image)

*Figure 4.2.* Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and location PC (MC or MI) at inducer locations in the inducer only blocks of Experiment 3. Error bars represent standard error of the mean. A significant CSPC effect was observed in reaction time for both map and blank background conditions, and the CSPC effect was larger in the blank background condition. In error rate, a CSPC effect was only observed in the map background condition, but no statistical difference emerged between background conditions and overall patterns followed reaction time.
Figure 4.3. Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and nearby inducer PC (near-MC or near-MI) at diagnostic locations in Experiment 3. Error bars represent standard error of the mean. In reaction time, there was a CSPC effect overall, but the effect was not significant in each background condition alone. In error rate, a CSPC effect only emerged in the blank background condition.

Table 4.1

<table>
<thead>
<tr>
<th>BG</th>
<th>Location Type</th>
<th>PC</th>
<th>Trial Type</th>
<th>RT</th>
<th>CE (RT)</th>
<th>Error Rate</th>
<th>CE (Error Rate)</th>
</tr>
</thead>
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<tr>
<td>Map</td>
<td>Inducer</td>
<td>MC</td>
<td>Compatible</td>
<td>654</td>
<td>139</td>
<td>0.56%</td>
<td>3.65%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Compatible</td>
<td>793</td>
<td></td>
<td>4.22%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>657</td>
<td>122</td>
<td>0.28%</td>
<td>2.11%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Compatible</td>
<td>780</td>
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<td>2.39%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inducer</td>
<td>MC</td>
<td>Compatible</td>
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<td>0.44%</td>
<td>3.34%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Compatible</td>
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<td>3.78%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>660</td>
<td>127</td>
<td>0.14%</td>
<td>2.73%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Compatible</td>
<td>786</td>
<td></td>
<td>2.87%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diagnostic</td>
<td>Near-MC</td>
<td>Compatible</td>
<td>725</td>
<td>137</td>
<td>0.53%</td>
<td>3.10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Compatible</td>
<td>863</td>
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<td>3.63%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Near-MI</td>
<td>Compatible</td>
<td>726</td>
<td>128</td>
<td>0.46%</td>
<td>3.15%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Compatible</td>
<td>854</td>
<td></td>
<td>3.61%</td>
<td></td>
</tr>
<tr>
<td>Blank</td>
<td>Inducer</td>
<td>MC</td>
<td>Compatible</td>
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<td>3.95%</td>
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<tr>
<td></td>
<td></td>
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<td>Compatible</td>
<td>807</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>650</td>
<td>132</td>
<td>0.21%</td>
<td>3.07%</td>
</tr>
</tbody>
</table>
BG Location Type | PC | Trial Type | RT | CE (RT) | Error Rate | CE (Error Rate)
---|---|---|---|---|---|---
Only) | Incompatible | 782 (14) | 3.28% (0.54%)
Inducer (All Blocks) | MC | Compatible | 635 (13) | 169 (5) | 0.41% (0.09%) | 4.45% (0.72%)
 | Incompatible | 804 (13) | 4.87% (0.74%)
 | MI | Compatible | 642 (13) | 144 (5) | 0.21% (0.08%) | 3.41% (0.53%)
 | Incompatible | 786 (13) | 3.62% (0.52%)
Diagnostic | Near-MC | Compatible | 684 (14) | 150 (7) | 0.18% (0.08%) | 5.29% (0.75%)
 | Incompatible | 849 (14) | 5.47% (0.79%)
 | Near-MI | Compatible | 692 (14) | 137 (6) | 0.73% (0.20%) | 3.74% (0.56%)
 | Incompatible | 841 (13) | 4.47% (0.61%)

Note: BG = background condition; CE = compatibility effect; MC = mostly compatible inducer location; MI = mostly incompatible inducer location. Inducer = locations where trials were 80% PC when the MC object was superimposed and 20% PC when the MI object was superimposed over the location; Diagnostic = locations that were 50% PC regardless of which object was superimposed over the location.

### 4.2.3. Between-experiment analysis

Experiment 1 and Experiment 3 both presented inducer locations that resided within a meaningful boundary, but they used different background images in the map background condition. A difference between experiments would indicate a difference in the degree to which participants used the map background in Experiment 1 (i.e., a white background with black lines separating meaningfully but not visually distinct areas) compared with Experiment 3 (i.e., a realistic, colored satellite image with a meaningful boundary separating two meaningfully and visually distinct areas) to guide control. As in the previous between-experiment analysis, only performance in the map background condition was analyzed and a three-way interaction between experiment, PC, and trial type would reveal a difference between experiments.

At inducer locations in inducer only blocks, there was an interaction between experiment, PC, and trial type in reaction time \(F(1, 118) = 4.39, p = .038, \eta^2_p = .04\) such that the CSPC...
effect was larger in Experiment 1 \((M = 38)\) than in Experiment 3 \((M = 17)\). This result is consistent with the idea that CSPC effects were attenuated when participants learned about the PC of the area within a meaningful area of space but only when the meaningful areas also differed perceptually. In error rate, there was no interaction between experiment, PC, and trial type, \(F(1, 118) = 0.92, p = .339, \eta^2_p = .01, BF_{01} = 5.16\). At inducer locations across all blocks, there was no interaction between experiment, PC, and trial type in either reaction time \((F(1, 118) = 2.60, p = .109, \eta^2_p = .02, BF_{01} = 2.89)\) or error rate \((F(1, 118) = 3.67, p = .058, \eta^2_p = .03, BF_{01} = 2.61)\). At diagnostic locations, there was no interaction between experiment, near-PC, and trial type in either reaction time \((F(1, 118) = 0.19, p = .667, \eta^2_p < .01, BF_{01} = 4.49)\) or error rate \((F(1, 118) = 1.26, p = .264, \eta^2_p = .01, BF_{01} = 3.28)\).

4.3 Discussion

For the first time in the current study, there was evidence that a meaningful boundary affected the learning or retrieval of control settings. Consistent with the learning within boundaries hypothesis, presenting MC and MI locations within a shared meaningful area of space led to an attenuated CSPC effect in the map background condition compared to the blank background condition in the inducer only blocks. Moreover, the CSPC effect in inducer only blocks of the map background condition was attenuated in Experiment 3 compared to Experiment 1. This result is consistent with the idea that participants learned that the PC of a meaningful area of space (i.e., water in the map background condition of Experiment 3) was 50% compatible on average. There was evidence that the image used in the map background condition in Experiment 3 affected performance in a way that it did not in the first two experiments. It should be noted that this effect did not remain significant when looking at inducer locations across all four blocks.
In terms of the boundaries for retrieval hypothesis, the CSPC effect did not transfer to diagnostic locations in the map background condition. However, this effect is qualified by the nonsignificant transfer to diagnostic locations in the blank background condition. Indeed, if no transfer emerged without a meaningful boundary, it cannot be assumed that boundaries for retrieval explained the non-significant transfer to diagnostic locations in reaction time in the map background condition. However, the effects in error rate were once again consistent with the boundaries for retrieval hypothesis. That is, the CSPC effect was significant at inducer locations in both map and blank background conditions, but transfer to diagnostic locations only occurred in the blank background condition.

There are two key implications from the finding that a difference emerged between blank and map background conditions in Experiment 3 but not in Experiment 1. First, the realistic and colorful satellite image provided not only differences in meaning between inducer and diagnostic locations, but also a perceptual difference for the areas on which the flanker stimuli were superimposed. This result potentially suggests that the visual difference between meaningful areas of space is needed for people to use meaningful boundaries (see Colvett & Bugg, 2022) or even serve as a signal for learning-based reactive control in the absence of meaningful boundaries. This possibility will be discussed further in the General Discussion. Second, there is evidence that participants used meaningful boundaries to guide control in the design using a colorful and realistic background image. As such, it makes sense to continue to use similar images in the subsequent experiments.

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8 Patterns were consistent with a CSPC effect in the inducer only blocks and at inducer locations across all blocks in both background conditions. The interaction of PC and trial type was significant for both those analyses when background conditions were combined. However, when background conditions were analyzed separately, a statistically significant CSPC effect only emerged in the inducer only blocks for the map background condition and across all blocks in the blank background condition.
Chapter 5: Experiment 4
Mirroring the relationship of Experiments 1 and 3, the goal of Experiment 4 was to test the research questions laid out in Experiment 2 with a more salient meaningful boundary in the map background condition. Specifically, the background image in the map background condition depicted a satellite image of the eastern half of North America as well as the Atlantic Ocean. One set of inducer and diagnostic locations (e.g., MC and near-MC) was superimposed over the land, and the other set (e.g., MI and near-MI) was superimposed over the water (see Figure 5.1).

If the learning within boundaries hypothesis is supported, the CSPC effect should be enhanced at diagnostic locations in the map background condition compared to the blank background condition. That hypothesis predicts that participants learn the probability of conflict within a meaningful boundary (i.e., on the Atlantic Ocean; on North America) and they would be more likely to learn that the meaningful area of space with the MC location predicts low conflict and the meaningful area of space with the MI location predicts high conflict, enhancing the CSPC effect at diagnostic locations. The boundaries for retrieval hypothesis does not make a prediction distinguishing performance between the map and blank background conditions. As in Experiments 1, 2, and 3, the categorical coding hypothesis and spatial proximity hypothesis both predict significant CSPC effects at inducer and diagnostic locations that do not differ by background condition.
Figure 5.1. Whether an inducer location was MC or MI was counterbalanced between subjects. One inducer location and one diagnostic location were superimposed over land (specifically North America), while the other inducer and diagnostic location were superimposed water (specifically the Atlantic Ocean). The learning within boundaries hypothesis predicts that CSPC effects should be enhanced at diagnostic locations in the map background condition. The boundaries for retrieval hypothesis and the non-meaningful boundary hypotheses predict CSPC effects at inducer and diagnostic locations with no difference between background conditions.

5.1 Method
5.1.1 Participants
Sixty-five Washington University undergraduates (43 female, 21 male, one non-binary; Age $M = 19.75$, $SD = 1.37$) participated for course credit. Three participants were removed for having an error rate above 33% on incompatible trials. Two participants withdrew from the
experiment before finishing after reporting boredom and asking to leave the study. The data from
the remaining 60 participants (41 female, 18 male, one non-binary; Age $M = 19.70$, $SD = 1.36$)
were included in the analysis.

5.1.2 Design and stimuli
The design and stimuli were equivalent to Experiment 3 except the image in the map background
condition now depicted an image of the eastern half of North America as well as the Atlantic
Ocean (see Figure 5.1). The background image was modified from a Google Maps satellite aerial
image (Google et al., 2022).

5.1.3 Procedure
The procedure was identical to Experiments 1, 2, and 3.

5.2 Results
5.2.1 Reaction time
Inducer locations. In the inducer only blocks, there was no interaction between
background, PC, and trial type, $F(1, 59) = 0.57, p = .453, \eta_p^2 = .01, BF_{01} = 4.52$, such that the
CSPC effect did not differ between background conditions (see Figure 5.2 and Table 5.1). There
was an interaction between PC and trial type, $F(1, 59) = 21.33, p < .001, \eta_p^2 = .27$, indicating the
CSPC effect such that the compatibility effect was larger at the MC location ($M = 149, SE = 7$)
than the MI location ($M = 125, SE = 7$). There was an interaction between background and trial
type, such that the compatibility effect was larger in the blank background condition ($M = 150, 
SE = 8$) than the map background condition ($M = 124, SE = 6$), $F(1, 59) = 14.26, p < .001, \eta_p^2 = 
.20$. There was no interaction between background and PC, $F(1, 59) = 0.46, p = .499, \eta_p^2 = .01, 
BF_{01} = 7.15$. There were no effects of background ($F(1, 59) = 0.33, p = .569, \eta_p^2 = .01, BF_{01} = 
7.83$) or PC ($F(1, 59) = 0.12, p = .730, \eta_p^2 < .01, BF_{01} = 9.79$). There was an effect of trial type,
such that responses to compatible trials ($M = 655, SE = 14$) were faster than responses to incompatible trials ($M = 792, SE = 16$), $F(1, 59) = 944.60, p < .001, \eta^2_p = .94$.

Across all four blocks, there was no interaction between background, PC, and trial type, $F(1, 59) < 0.01, p = .980, \eta^2_p < .01, BF_{01} = 4.27$, such that there was no difference in CSPC effects between background conditions. There was an interaction between PC and trial type, $F(1, 59) = 17.91, p < .001, \eta^2_p = .23$, indicating the CSPC effect such that the compatibility effect was larger at the MC location ($M = 147, SE = 5$) than the MI location ($M = 131, SE = 6$). There was an interaction between background and trial type, such that the compatibility effect was larger in the blank background condition ($M = 148, SE = 5$) than the map background condition ($M = 130, SE = 5$), $F(1, 59) = 18.75, p < .001, \eta^2_p = .24$. Background and PC did not interact, $F(1, 59) = 2.98, p = .090, \eta^2_p = .05, BF_{01} = 6.61$. There was an effect of background, such that responses were faster in the blank background condition ($M = 716, SE = 17$), than the map background condition ($M = 733, SE = 17$), $F(1, 59) = 5.20, p = .026, \eta^2_p = .08$. The was no effect of PC, $F(1, 59) = 0.41, p = .524, \eta^2_p = .01, BF_{01} = 9.17$. There was an effect of trial type, such that responses to compatible trials ($M = 655, SE = 13$) were faster than responses to incompatible trials ($M = 794, SE = 15$), $F(1, 59) = 1275.25, p < .001, \eta^2_p = .96$.

**Diagnostic locations.** There was no interaction between background, near-PC, and trial type, $F(1, 59) = 0.06, p = .804, \eta^2_p < .01, BF_{01} = 12.12$, such that CSPC effects did not differ between background conditions (see Figure 5.3). There was an interaction between near-PC and trial type, $F(1, 59) = 21.97, p < .001, \eta^2_p = .27$, such that the compatibility effect was larger at the near-MC location ($M = 156, SE = 6$) than the near-MI location ($M = 134, SE = 6$) indicating transfer of the CSPC effect. There was an interaction between background and trial type, such that the compatibility effect was larger in the blank background condition ($M = 152, SE = 7$) than
the map background condition \((M = 138, SE = 6)\), \(F(1, 59) = 9.43, p = .003, \eta^2_p = .14\). There was no interaction between background and near-PC, \(F(1, 59) = 0.57, p = .454, \eta^2_p = .01, \text{BF}_{01} = 6.82\). There was an effect of background, \(F(1, 59) = 28.51, p < .001, \eta^2_p = .33\), such that responses were faster in the blank background condition \((M = 767, SE = 17)\) than the map background condition \((M = 800, SE = 18)\). There was no effect of near-PC, \(F(1, 59) = 1.54, p = .219, \eta^2_p = .03, \text{BF}_{01} = 8.86\). There was an effect of trial type, such that responses to compatible trials \((M = 711, SE = 14)\) were faster than responses to incompatible trials \((M = 856, SE = 16)\), \(F(1, 59) = 1229.18, p < .001, \eta^2_p = .95\).

### 5.2.2 Error rate

**Inducer locations.** In the inducer only blocks, there was no interaction between background, PC, and trial type, \(F(1, 59) = 0.01, p = .921, \eta^2_p < .01, \text{BF}_{01} = 4.80\), such that there was no difference in CSPC effects between background conditions (see Figure 5.2). There was an interaction between PC and trial type, \(F(1, 59) = 4.13, p = .047, \eta^2_p = .07\), such that the compatibility effect was larger at the MC location \((M = 3.02\%, SE = 0.63\%)\) than the MI location \((M = 2.03\%, SE = 0.38\%)\), indicating the CSPC effect. The interactions between background and trial type \((F(1, 59) = 1.46, p = .232, \eta^2_p = .02, \text{BF}_{01} = 3.72\) and background and PC \((F(1, 59) = 1.36, p = .249, \eta^2_p = .02, \text{BF}_{01} = 5.06\) were not significant. There were no effects of background \((F(1, 59) = 0.08, p = .785, \eta^2_p < .01, \text{BF}_{01} = 9.20\) or PC \((F(1, 59) = 3.19, p = .079, \eta^2_p = .05, \text{BF}_{01} = 3.59\). There was an effect of trial type, such that responses to compatible trials \((M = 0.66\%, SE = 0.32\%)\) were more accurate than responses to incompatible trials \((M = 3.18\%, SE = 0.55\%)\), \(F(1, 59) = 65.04, p < .001, \eta^2_p = .52\).

Across all four blocks, there was no interaction between background, PC, and trial type, \(F(1, 59) = 0.09, p = .769, \eta^2_p < .01, \text{BF}_{01} = 5.61\), such that CSPC effects did not differ between background conditions. There was an interaction between PC and trial type \((F(1, 59) = 8.73, p =\)
.004, $\eta_p^2 = .13$) such that the compatibility effect was larger at the MC location ($M = 3.10\%, \ SE = 0.48\%$) than the MI location ($M = 2.27\%, \ SE = 0.34\%$), indicating the CSPC effect. The interactions between background and trial type ($F(1, 59) = 2.66, \ p = .108, \ \eta_p^2 = .04, \ BF_{01} = 2.05$) and background and PC ($F(1, 59) = 1.83, \ p = .182, \ \eta_p^2 = .03, \ BF_{01} = 5.57$) were not significant. There was no effect of background, $F(1, 59) = 0.17, \ p = .682, \ \eta_p^2 < .01, \ BF_{01} = 8.81$. There was an effect of PC, such that responses were less accurate at MC locations ($M = 2.18\%, \ SE = 0.45\%$) than MI locations ($M = 1.79\%, \ SE = 0.39\%$), $F(1, 59) = 7.07, \ p = .010, \ \eta_p^2 = .11$. There was an effect of trial type, such that responses to compatible trials ($M = 0.65\%, \ SE = 0.28\%$) were more accurate than responses to incompatible trials ($M = 3.33\%, \ SE = 0.46\%$), $F(1, 59) = 88.96, \ p < .001, \ \eta_p^2 = .60$.

**Diagnostic locations.** There was no interaction between background, near-PC, and trial type, $F(1, 59) = 2.41, \ p = .126, \ \eta_p^2 = .04, \ BF_{01} = 3.07$, such that CSPC effects did not differ between background conditions (see Figure 5.3). There was no interaction between near-PC and trial type ($F(1, 59) = 2.23, \ p = .140, \ \eta_p^2 = .04, \ BF_{01} = 4.10$), indicating no transfer of the CSPC effect. There were no interactions between background and trial type ($F(1, 59) = 2.85, \ p = .097, \ \eta_p^2 = .05, \ BF_{01} = 1.43$) or background and near-PC ($F(1, 59) = 0.73, \ p = .397, \ \eta_p^2 = .01, \ BF_{01} = 6.30$). There was no effect of background, $F(1, 59) = 1.14, \ p = .290, \ \eta_p^2 = .02, \ BF_{01} = 5.05$. There was an effect of near-PC, such that responses were less accurate at near-MC locations ($M = 2.38\%, \ SE = 0.51\%$) than near-MI locations ($M = 2.12\%, \ SE = 0.43\%$), $F(1, 59) = 5.23, \ p = .025, \ \eta_p^2 = .08$. There was an effect of trial type, such that responses to compatible trials ($M = 0.73\%, \ SE = 0.34\%$) were less accurate than responses to incompatible trials ($M = 3.78\%, \ SE = 0.50\%$), $F(1, 59) = 115.40, \ p < .001, \ \eta_p^2 = .66$. 

63
Figure 5.2. Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and location PC (MC or MI) at inducer locations in the inducer only blocks of Experiment 4. Error bars represent standard error of the mean. In reaction time, there was a significant CSPC effect in both the map background and blank background condition, and there was no statistical difference between background conditions. In error rate, the CSPC effect was not significant in either the map background or blank background condition. However, the CSPC effect was significant overall, and patterns were consistent with reaction time.

Figure 5.3. Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and nearby inducer PC (near-MC or near-MI) at diagnostic locations in Experiment 4. Error bars represent standard error of the mean. In reaction time, there was a significant CSPC effect in both the map background and blank background condition, and there was no statistical difference between background conditions. In error rate, the CSPC effect was not significant in either background condition.
Table 5.1

*Experiment 4 Reaction Time (ms) and Error Rate at Inducer and Diagnostic Locations with Standard Errors in Parentheses*

<table>
<thead>
<tr>
<th>BG Location Type</th>
<th>PC Type</th>
<th>Trial Type</th>
<th>RT</th>
<th>CE (RT)</th>
<th>Error Rate</th>
<th>CE (Error Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map Inducer (Inducer Blocks Only)</td>
<td>MC</td>
<td>Compatible</td>
<td>660 (15)</td>
<td>135 (6)</td>
<td>0.69% (0.32%)</td>
<td>2.73% (0.62%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>795 (17)</td>
<td></td>
<td>3.42% (0.61%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>669 (14)</td>
<td>114 (6)</td>
<td>1.04% (0.49%)</td>
<td>1.70% (0.37%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>783 (15)</td>
<td></td>
<td>2.74% (0.47%)</td>
<td></td>
</tr>
<tr>
<td>Map Inducer (All Blocks)</td>
<td>MC</td>
<td>Compatible</td>
<td>665 (14)</td>
<td>138 (5)</td>
<td>0.67% (0.28%)</td>
<td>2.72% (0.42%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>803 (16)</td>
<td></td>
<td>3.39% (0.45%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>672 (13)</td>
<td>122 (5)</td>
<td>0.83% (0.40%)</td>
<td>1.99% (0.36%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>793 (15)</td>
<td></td>
<td>2.82% (0.40%)</td>
<td></td>
</tr>
<tr>
<td>Diagnostic Near-MC Compatible</td>
<td>MC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>873 (17)</td>
<td></td>
<td>3.92% (0.52%)</td>
<td></td>
</tr>
<tr>
<td>Diagnostic Near-MI Compatible</td>
<td>MC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>737 (15)</td>
<td>128 (6)</td>
<td>0.61% (0.25%)</td>
<td>3.02% (0.46%)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blank Inducer (Inducer Blocks Only)</td>
<td>MC</td>
<td>Compatible</td>
<td>637 (15)</td>
<td>164 (8)</td>
<td>0.56% (0.21%)</td>
<td>3.31% (0.64%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>801 (16)</td>
<td></td>
<td>3.86% (0.64%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>654 (14)</td>
<td>136 (7)</td>
<td>0.35% (0.19%)</td>
<td>2.36% (0.39%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>790 (17)</td>
<td></td>
<td>2.72% (0.47%)</td>
<td></td>
</tr>
<tr>
<td>Blank Inducer (All Blocks)</td>
<td>MC</td>
<td>Compatible</td>
<td>635 (13)</td>
<td>156 (5)</td>
<td>0.59% (0.19%)</td>
<td>3.48% (0.53%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>791 (14)</td>
<td></td>
<td>4.07% (0.57%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>648 (13)</td>
<td>140 (6)</td>
<td>0.49% (0.17%)</td>
<td>2.55% (0.32%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>788 (16)</td>
<td></td>
<td>3.04% (2.55%)</td>
<td></td>
</tr>
<tr>
<td>Diagnostic Near-MC Compatible</td>
<td>MC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>846 (15)</td>
<td></td>
<td>5.24% (0.65%)</td>
<td></td>
</tr>
<tr>
<td>Diagnostic Near-MI Compatible</td>
<td>MC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incompatible</td>
<td>699 (14)</td>
<td>141 (6)</td>
<td>0.63% (0.20%)</td>
<td>3.39% (0.58%)</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Note: BG = background condition; CE = compatibility effect; MC = mostly compatible inducer location; MI = mostly incompatible inducer location. Inducer = locations where trials were 80% PC when the MC object was superimposed and 20% PC when the MI object was superimposed.
over the location; Diagnostic = locations that were 50% PC regardless of which object was superimposed over the location.

5.2.3 Between-experiment analysis
Experiment 2 and Experiment 4 both used displays where one inducer and diagnostic location resided within one meaningful area and the other inducer and diagnostic location resided within a different meaningful area. Importantly, the two experiments used different background images in the map background condition. A difference between experiments would indicate a difference in the degree to which participants used the map background in Experiment 2 (i.e., a white background with black lines separating meaningfully but not visually distinct areas) compared with Experiment 4 (i.e., a realistic, colored satellite image with a meaningful boundary separating meaningfully and visually distinct areas) to guide control. As in the previous between-experiment analyses, only performance in the map background condition was analyzed and a three-way interaction between experiment, PC, and trial type would reveal a difference between experiments.

At inducer locations in inducer blocks, there was no interaction between experiment, PC, and trial type in either reaction time ($F(1, 118) = 0.58, p = .446, \eta_p^2 = .01, BF_{01} = 6.70$) or error rate ($F(1, 118) = 0.08, p = .779, \eta_p^2 < .01, BF_{01} = 3.56$). At inducer locations across all blocks, there was no interaction between experiment, PC, and trial type in reaction time ($F(1, 118) = 3.30, p = .072, \eta_p^2 = .03, BF_{01} = 3.24$), though the CSPC effect was nominally larger in Experiment 2 ($M = 26$) than Experiment 4 ($M = 16$). At inducer locations across all blocks, there was no interaction between experiment, PC, and trial type for error rate ($F(1, 118) = 0.70, p = .406, \eta_p^2 = .01, BF_{01} = 4.95$). At diagnostic locations, there was no interaction between experiment, PC, and trial type in reaction time ($F(1, 118) = 0.04, p = .838, \eta_p^2 < .01, BF_{01} = ...
3.65). There was also no interaction between experiment, near-PC, and trial type for error rate 
\(F(1, 118) = 3.84, p = .052, \eta^2_p = .03, BF_{01} = 2.66\), though the CSPC effect was nominally larger 
in Experiment 2 \((M = 1.45\%\) than Experiment 4 \((M = 0.05\%\).

Performance for trials at the inducer locations also may have differed between 
Experiments 3 and 4. Both inducer locations resided within the same meaningful area in 
Experiment 3, and the inducer locations resided on opposite sides of a meaningful boundary in 
Experiment 4. Performance for trials at diagnostic locations also may have differed between 
Experiments 3 and 4, as inducer locations and diagnostic locations were separated by a 
meaningful boundary in Experiment 3 and inducer and diagnostic locations were presented 
within the same meaningful area in Experiment 4.

At inducer locations in inducer blocks, there was no interaction between experiment, PC, 
and trial type in either reaction time \(F(1, 118) = 0.14, p = .709, \eta^2_p < .01, BF_{01} = 8.27\) or error 
rate \(F(1, 118) = 0.41, p = .524, \eta^2_p < .01, BF_{01} = 5.32\). At inducer locations across all blocks, 
there was no interaction between experiment, PC, and trial type in either reaction time \(F(1, 118) 
= 0.07, p = .798, \eta^2_p < .01, BF_{01} = 4.15\) or error rate \(F(1, 118) = 0.07, p = .799, \eta^2_p < .01, BF_{01} = 
5.67\). At diagnostic locations, there was no interaction between experiment, near-PC, and trial 
type in either reaction time \(F(1, 118) = 1.24, p = .261, \eta^2_p = .01, BF_{01} = 3.13\) or error rate \(F(1, 
118) = 0.02, p = .881, \eta^2_p < .01, BF_{01} = 4.83\).

5.3 Discussion
The results of Experiment 4 were consistent with the effects observed in Experiment 2 and thus 
consistent with either the categorical coding hypothesis or the spatial proximity hypothesis. In 
Experiment 4, a CSPC effect emerged at both inducer and diagnostic locations in reaction time, 
and that relationship was not modulated by the background condition. Inconsistent with the
learning within boundaries hypothesis, no difference emerged between CSPC effects at diagnostic locations between background conditions when inducer and diagnostic locations resided within the same meaningful boundary. Moreover, CSPC effects in Experiment 4 were statistically equivalent to Experiment 2 (and nominally smaller than Experiment 2).

Control settings again transferred to diagnostic locations as evidenced by CSPC effects in the near MC and near MI locations in a design in which inducer and diagnostic locations were presented along an invisible diagonal array. Indeed, transfer has emerged reliably using this design when not disrupted by opportunities to learn about environmental factors other than location (e.g., Experiment 3; Colvett & Bugg, 2022). It is possible an invisible diagonal array is important for observing transfer to diagnostic locations, as the simple and easily representable structure allows for the grouping of inducer and diagnostic locations as part of the same linear slope. This idea will be explored in Experiment 5 and in the General Discussion.
Chapter 6: Experiment 5

The goal of Experiment 5 was to test whether people use meaningful or spatial contexts to predict conflict when the two contexts compete. Previous experiments (Experiments 1, 2, 3, & 4, as well as the pilot experiment of the current study; Colvett & Bugg, 2022; Pickel et al., 2019; Weidler & Bugg, 2016; Weidler et al., 2020) presented inducer and diagnostic locations along an invisible diagonal array. Experiment 5 presented trials at two inducer locations along an invisible diagonal array, such that one location was above and to the left of the central fixation, and the other was below and to the right of the central fixation. The diagnostic locations were presented proximally to those inducer locations, above and below the central fixation along the vertical axis (see Figure 6.1). In the map background condition, the background image was a satellite image of South America and the Pacific Ocean. Critically, each inducer location shared a meaningful category of space with the more distal diagnostic location: the upper inducer location and lower diagnostic location were both on South America. The lower inducer location and the upper diagnostic location were both on the Pacific Ocean.

All hypotheses predict a CSPC effect at inducer locations in both the map and blank background conditions. If the boundaries for retrieval hypothesis is supported, then a CSPC effect should emerge at inducer locations that would not transfer across the boundary to the nearby diagnostic location in the map background condition. If the learning within boundaries hypothesis is supported, there should be a CSPC effect at diagnostic locations consistent with the PC of the more distal inducer location in the map background condition. Participants would learn the PC of the area within a meaningful boundary (i.e., on South America; on the Pacific Ocean), then they would retrieve the control setting associated with the inducer location in the shared meaningful boundary. Alternatively, participants might organize their experiences using a spatial
category (e.g., the upper half of the screen; experiences at proximal inducer locations). Both the categorical coding and spatial proximity hypotheses predict a significant CSPC effect at diagnostic locations consistent with the PC of the more proximal inducer location. While previous studies have found transfer of control settings from inducer locations to nearby diagnostic locations, it is not necessarily apparent that transfer will occur using a layout where there is no easily representable structure guiding transfer from inducer locations to diagnostic locations (e.g., where both inducer and diagnostic locations do not fall along an invisible diagonal array).

Figure 6.1. Whether an inducer location was MC or MI was counterbalanced between subjects. One inducer location and one diagnostic location were superimposed over land (specifically South America), while the other inducer and diagnostic location were superimposed over water (specifically the Pacific Ocean). All hypotheses predict equivalent performance at inducer locations for the map background condition and the blank background condition. The learning
within boundaries hypothesis predicts a CSPC effect at diagnostic locations consistent with the PC of the more distal inducer location for the map background condition, but a CSPC effect consistent with the more proximal inducer location for the blank background condition. The boundaries for retrieval hypothesis predicts no CSPC effect at diagnostic locations for the map background condition, but a CSPC effect consistent with the more proximal inducer location for the blank background condition. The non-meaningful boundary hypotheses predict CSPC effects at diagnostic locations consistent with the PC of the more proximal inducer location in both background conditions.

6.1 Method
6.1.1 Participants
Sixty-three Washington University undergraduates (39 female, 24 male; Age \( M = 19.66, SD = 0.93 \)) participated for course credit. Two participants were removed for having an error rate above 33% on incompatible trials. One participant was excluded due to an error with the computer running the program. The data from the remaining 60 participants (37 female, 23 male, Age \( M = 19.68, SD = 0.95 \)) were included in the analysis.

6.1.2 Design and stimuli
The design and stimuli were equivalent to Experiments 3 and 4 except for the following difference. The background image in the map background condition depicted a map centered on South America and the Pacific Ocean (see Figure 6.1). The background image was modified from a Google Maps satellite aerial image (Google et al., 2022).

6.1.3 Procedure
The procedure was identical to Experiments 1, 2, 3, and 4.

6.2 Results
6.2.1 Reaction time
   **Inducer locations.** In the inducer only blocks, there was an interaction between background, PC, and trial type, \( F(1, 59) = 6.88, p = .011, \eta_p^2 = .10 \), such that CSPC effects were smaller in the map background condition \( (M = 2, SE = 8) \) than the blank background condition \( (M = 29, SE = 6; \) see Figure 6.2 and Table 6.1). Importantly, the direction of this effect was not
anticipated by any of the hypotheses. There was an interaction between PC and trial type, $F(1, 59) = 10.67, p = .002, \eta^2_p = .15$, indicating the CSPC effect such that the compatibility effect was larger at the MC location ($M = 142, SE = 8$) than the MI location ($M = 127, SE = 6$). There was an interaction between background and trial type, such that compatibility effects were larger in the blank background condition ($M = 146, SE = 7$) than the map background condition ($M = 123, SE = 7$), $F(1, 59) = 11.36, p = .001, \eta^2_p = .16$. There was no interaction between background and PC, $F(1, 59) = 2.86, p = .096, \eta^2_p = .05$, BF$_{01} = 5.75$. There were no effects of background ($F(1, 59) = 2.21, p = .143, \eta^2_p = .04$, BF$_{01} = 2.81$) or PC ($F(1, 59) = 2.44, p = .124, \eta^2_p = .04$, BF$_{01} = 6.88$). There was an effect of trial type, such that responses to compatible trials ($M = 678, SE = 12$) were faster than responses to incompatible trials ($M = 813, SE = 13$), $F(1, 59) = 855.24, p < .001, \eta^2_p = .94$.

Across all four blocks, there was an interaction between background, PC, and trial type, $F(1, 59) = 4.28, p = .043, \eta^2_p = .07$, such that CSPC effects were smaller in the map background condition ($M = 9, SE = 5$) than in the blank background condition ($M = 24, SE = 6$). There was an interaction between PC and trial type, $F(1, 59) = 16.22, p < .001, \eta^2_p = .22$, indicating the CSPC effect such that the compatibility effect was larger at the MC location ($M = 146, SE = 7$) than the MI location ($M = 130, SE = 5$). There was an interaction between background and trial type, such that the compatibility effect was larger in the blank background condition ($M = 154, SE = 6$) than in the map background condition ($M = 123, SE = 6$), $F(1, 59) = 37.51, p < .001, \eta^2_p = .39$. There was no interaction between background and PC, $F(1, 59) = 2.11, p = .152, \eta^2_p = .04$, BF$_{01} = 6.91$. There was an effect of background, such that responses were faster in the blank background condition ($M = 735, SE = 15$) than the map background condition ($M = 753, SE = 14$), $F(1, 59) = 9.25, p = .004, \eta^2_p = .14$. The was no effect of PC, $F(1, 59) = 2.30, p = .135, \eta^2_p =
.04, BF\textsubscript{01} = 8.71. There was an effect of trial type, such that responses to compatible trials (\(M = 675, SE = 11\)) were faster than responses to incompatible trials (\(M = 813, SE = 12\)), \(F(1, 59) = 1083.80, p < .001, \eta^2_p = .95\).

**Diagnostic locations.** There was no interaction between background, near-PC, and trial type, \(F(1, 59) = 0.58, p = .448, \eta^2_p = .01, BF\textsubscript{01} = 4.09\), such that there was no difference in CSPC effects between background conditions (see Figure 6.3). There was no interaction between near-PC and trial type (\(F(1, 59) = 0.53, p = .471, \eta^2_p = .01, BF\textsubscript{01} = 6.39\)) or between background and near-PC (\(F(1, 59) = 0.75, p = .389, \eta^2_p = .01, BF\textsubscript{01} = 6.93\)) indicating no transfer of the CSPC effects. There was an interaction between background and trial type, such that the compatibility effect was larger in the blank background condition (\(M = 131, SE = 7\)) than the map background condition (\(M = 107, SE = 6\)), \(F(1, 59) = 24.15, p < .001, \eta^2_p = .29\). There was an effect of background, such that responses were faster in the blank background condition (\(M = 718, SE = 14\)) than in the map background condition (\(M = 748, SE = 13\)), \(F(1, 59) = 31.34, p < .001, \eta^2_p = .35\). The was no effect of near-PC, \(F(1, 59) = 0.23, p = .637, \eta^2_p < .01, BF\textsubscript{01} = 9.55\). There was an effect of trial type, such that responses to compatible trials (\(M = 673, SE = 11\)) were faster than responses to incompatible trials (\(M = 792, SE = 12\)), \(F(1, 59) = 693.17, p < .001, \eta^2_p = .92\).

**6.2.2 Error rate**

**Inducer locations.** In the inducer only blocks, there was an interaction between background, PC, and trial type, \(F(1, 59) = 8.87, p = .004, \eta^2_p = .13\), such that CSPC effects were smaller in the map background condition (\(M = -0.12\%, SE = 0.53\%)\) than in the blank background condition (\(M = 1.24\%, SE = 0.65\%\); see Figure 6.2). There was, however, no interaction between PC and trial type, \(F(1, 59) = 0.11, p = .745, \eta^2_p < .01, BF\textsubscript{01} = 7.05\), such that the compatibility effect was equivalent at the MC location (\(M = 4.15\%, SE = 0.77\%)\) and the MI location (\(M = 4.00\%, SE = 0.57\%)\), indicating the CSPC effect. There was an interaction between
background and trial type, such that compatibility effects were larger in the blank background condition ($M = 4.65\%, SE = 0.71\%$) than in the map background condition ($M = 3.51\%, SE = 0.63\%), $F(1, 59) = 4.79, p = .033, \eta_p^2 = .08$. There was an interaction between background and PC, such that the difference in error rate between MC and MI was larger in the map background condition ($M = 0.27\%, SE = 0.29\%$) than in the blank background condition ($M = -0.69\%, SE = 0.33\%), $F(1, 59) = 6.63, p = .013, \eta_p^2 = .10$. There were no effects of background ($F(1, 59) = 2.72, p = .104, \eta_p^2 = .04, BF_{01} = 2.98$) or PC ($F(1, 59) = 0.76, p = .388, \eta_p^2 = .01, BF_{01} = 8.61$). There was an effect of trial type, such that responses to compatible trials ($M = 0.53\%, SE = 0.19\%$) were more accurate than responses to incompatible trials ($M = 4.61\%, SE = 0.71\%), $F(1, 59) = 57.69, p < .001, \eta_p^2 = .49$.

Across all four blocks, there was no interaction between background, PC, and trial type, $F(1, 59) = 1.97, p = .166, \eta_p^2 = .03, BF_{01} = 2.12$, such that the CSPC effect did not differ by background condition. There was no interaction between PC and trial type ($F(1, 59) = 1.02, p = .318, \eta_p^2 = .02, BF_{01} = 5.79$), indicating no CSPC effect. There were no interactions between background and trial type ($F(1, 59) = 0.99, p = .324, \eta_p^2 = .02, BF_{01} = 5.61$) or background and PC ($F(1, 59) = 0.87, p = .356, \eta_p^2 = .01, BF_{01} = 7.14$). There was no effect of background, $F(1, 59) = 0.67, p = .415, \eta_p^2 = .01, BF_{01} = 7.90$. The was an effect of PC, such that responses were less accurate at MC locations ($M = 3.40\%, SE = 0.65\%$) than MI locations ($M = 2.98\%, SE = 0.57\%), $F(1, 59) = 4.32, p = .042, \eta_p^2 = .07$. There was an effect of trial type, such that responses to compatible trials ($M = 0.81\%, SE = 0.26\%$) were more accurate than responses to incompatible trials ($M = 5.83\%, SE = 0.79\%), $F(1, 59) = 88.86, p < .001, \eta_p^2 = .60$.

**Diagnostic locations.** There was no interaction between background, near-PC, and trial type, $F(1, 59) = 1.31, p = .257, \eta_p^2 = .02, BF_{01} = 3.78$, such that the CSPC effect was equivalent.
between background conditions (see Figure 6.3). There were no interactions between near-PC and trial type ($F(1, 59) = 0.63, p = .430, \eta^2_p = .01, BF_{01} = 6.54$), indicating no transfer of the CSPC effect. There was no interaction between background and near-PC ($F(1, 59) = 0.52, p = .476, \eta^2_p = .01, BF_{01} = 6.23$). There was an interaction between background and trial type, such that compatibility effects were larger in the blank background condition ($M = 4.48\%, SE = 0.68\%$) than the map background condition ($M = 2.99\%, SE = 0.50\%$), $F(1, 59) = 12.19, p < .001, \eta^2_p = .17$. There were no effects of background ($F(1, 59) = 2.08, p = .154, \eta^2_p = .03, BF_{01} = 1.21$) or near-PC ($F(1, 59) = 1.76, p = .189, \eta^2_p = .03, BF_{01} = 8.21$). There was an effect of trial type, such that responses to compatible trials ($M = 1.24\%, SE = 0.40\%$) were faster than responses to incompatible trials ($M = 4.97\%, SE = 0.77\%$), $F(1, 59) = 63.10, p < .001, \eta^2_p = .52$.

**Figure 6.2.** Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and location PC (MC or MI) at inducer locations in the inducer only blocks of Experiment 5. Error bars represent standard error of the mean. In reaction time, there was a significant CSPC effect in the blank background condition but not the map background condition. In error rate, there was no CSPC effect in either the map background or blank background condition.
Figure 6.3. Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and nearby inducer PC (near-MC or near-MI) at diagnostic locations in Experiment 5. Error bars represent standard error of the mean. In both reaction time and error rate, there was no CSPC effect in either the map background condition or the blank background condition.

Table 6.1

Experiment 5 Reaction Time (ms) and Error Rate at Inducer and Diagnostic Locations with Standard Errors in Parentheses

<table>
<thead>
<tr>
<th>BG Location Type</th>
<th>PC Type</th>
<th>Trial Type</th>
<th>RT (ms)</th>
<th>CE (RT)</th>
<th>Error Rate</th>
<th>CE (Error Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map Inducer (Inducer Blocks Only)</td>
<td>MC</td>
<td>Compatible</td>
<td>684 (12)</td>
<td>124 (8)</td>
<td>0.62% (0.14%)</td>
<td>3.04% (0.69%)</td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>Incompatible</td>
<td>808 (15)</td>
<td>122 (6)</td>
<td>0.42% (0.17%)</td>
<td>3.98% (0.57%)</td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>697 (13)</td>
<td>119 (5)</td>
<td>0.63% (0.21%)</td>
<td>4.60% (0.53%)</td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>Incompatible</td>
<td>816 (11)</td>
<td>107 (6)</td>
<td>1.47% (0.44%)</td>
<td>2.91% (0.54%)</td>
</tr>
<tr>
<td>Blank Inducer</td>
<td>MC</td>
<td>Compatible</td>
<td>658 (11)</td>
<td>160 (7)</td>
<td>0.56% (0.14%)</td>
<td>5.27% (0.82%)</td>
</tr>
</tbody>
</table>
BG Location Type | PC | Trial Type | RT | CE (RT) | Error Rate | CE (Error Rate)
--- | --- | --- | --- | --- | --- | ---
(Inducer Blocks Only) | MI | Incompatible | 818 (12) | 5.83% (0.85%)
| | Compatible | 674 (12) | 131 (6) | 0.50% (0.27%) | 4.03% (0.58%)
| | Incompatible | 806 (13) | 4.52% (0.65%)
Inducer (All Blocks) | MC | Compatible | 651 (10) | 165 (6) | 0.86% (0.26%) | 5.48% (0.75%)
| | Incompatible | 817 (12) | 6.34% (0.86%)
| MI | Compatible | 664 (11) | 142 (5) | 0.75% (0.26%) | 4.58% (0.56%)
| | Incompatible | 806 (12) | 5.33% (0.72%)
Diagnostic | Near-MC | Compatible | 651 (11) | 135 (7) | 1.43% (0.44%) | 4.09% (0.62%)
| | Incompatible | 786 (13) | 5.52% (0.85%)
| Near-MI | Compatible | 655 (11) | 127 (7) | 1.06% (0.36%) | 4.88% (0.74%)
| | Incompatible | 782 (12) | 5.95% (0.87%)

*Note:* BG = background condition; CE = compatibility effect; MC = mostly compatible inducer location; MI = mostly incompatible inducer location. Inducer = locations where trials were 80% PC when the MC object was superimposed and 20% PC when the MI object was superimposed over the location; Diagnostic = locations that were 50% PC regardless of which object was superimposed over the location.

### 6.3 Discussion

Results in Experiment 5 are not fully consistent with any of the existing hypotheses. First, a three-way interaction emerged at inducer locations, such that the CSPC effect was larger in the blank background condition than the map background condition. The boundaries for retrieval hypothesis and learning within boundaries hypotheses predicted no difference between background conditions at the inducer locations. The spatial layout was identical in map and blank background conditions, so both the categorical coding and spatial proximity hypotheses also predicted no difference between background conditions at inducer locations or diagnostic locations. Second, no CSPC effect emerged at inducer locations in the map background condition. The learning within boundaries hypothesis predicted no disruption to the CSPC effect.
at inducer locations, especially in the inducer only blocks where stimuli appeared at no other locations within the same meaningful area of space. One of the goals of Experiment 5 was to assess whether participants would learn about meaningful categories or spatial categories when the two compete. However, participants did not learn a difference between MC and MI locations in the map background condition. As no difference was learned at inducer locations, it is not possible to infer whether diagnostic locations were grouped with the spatially proximal inducer location or with the more distal inducer location within the same meaningful boundary.

Third, a CSPC effect was observed at inducer locations in the blank background condition, but transfer did not occur to nearby diagnostic locations. This pattern was not predicted by the spatial proximity or categorical coding hypotheses: diagnostic locations were both in the same region of space as inducer locations (e.g., upper half and lower half) and spatially proximal to inducer locations. A notable difference between Experiment 5 of the current study and most previous studies assessing transfer to diagnostic locations (e.g., Colvett & Bugg, 2022; Pickel et al., 2019; Weidler & Bugg, 2016; Weidler et al., 2020) is that inducer and diagnostic locations were not presented along an invisible diagonal array. It is possible that the categorical coding and spatial proximity hypotheses are limited, and designs like the invisible diagonal array are needed for transfer to occur. One possible reason is that displays like the invisible diagonal array provide an easily representable structure (i.e., a linear slope) that encourages grouping of inducer and diagnostic locations, while the display in Experiment 5 did not. A second reason may be that displays like the invisible diagonal array encourage participants to process conflict information (e.g., the flanking arrows). The processing of conflict plausibly leads to larger compatibility effects and thus stronger CSPC effects (Colvett et al., 2023; Weidler
et al., 2022). Both of these possibilities and their implications for theoretical accounts of CSPC transfer will be explored further in the General Discussion.
Chapter 7: General discussion

A growing literature has found that people are capable of learning control settings at inducer locations and flexibly transferring those control settings to nearby unbiased diagnostic locations. The five experiments of the current study compared performance without boundaries to performance using backgrounds with meaningful boundaries that separated or grouped locations (see Table 7.1 for a review of the results across all experiments; see Figure 7.1 for the image and layout of locations in the map background condition of each experiment). Multiple hypotheses exist regarding how control settings learned at inducer locations transfer to diagnostic locations. There were two primary questions addressed by the current study. First, what evidence emerged for hypotheses that included a role for meaningful boundaries (i.e., learning within boundaries hypothesis and boundaries for retrieval hypothesis) and for hypotheses that did not (categorical coding hypothesis and spatial proximity hypothesis)? Second, which sources of information did people use to predict likelihood of conflict when multiple different sources were available?

Table 7.1

Summary of Results Across All Experiments

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<tr>
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<th>Background Condition</th>
<th>Location Type</th>
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<th>RT (PC*TT)</th>
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**Note:** Three-way interaction refers to an interaction between background, PC, and trial type, such that CSPC effect differed between map and blank background conditions. PC*TT refers to an interaction between PC and trial type, indicating a CSPC effect. Yes = the interaction was significant. No = the interaction was non-significant.
Figure 7.1. Panels 1, 2, 3, 4, and 5 depict the trial locations and the background image from the map background condition of Experiments 1, 2, 3, 4, and 5 respectively.

7.1 Evidence for meaningful and non-meaningful hypotheses

Overall, evidence that meaningful boundaries affected the learning and retrieval of control settings was mixed. Regarding the learning within boundaries hypothesis, one prediction was that CSPC effects should be attenuated at inducer locations if MC and MI locations were grouped within a meaningful boundary. In Experiment 1, this effect did not emerge, though it is possible that people were less inclined to learn about the meaningful area within the boundary.
when it was not also perceptually distinct from the meaningful area outside the boundary. Supporting that possibility, the CSPC effect at inducer locations in Experiment 3 was attenuated in the map background condition compared to the blank background condition. However, that effect was specific to inducer only blocks and did not extend across all blocks. A second prediction of the learning with boundaries hypothesis was that transfer of control settings to diagnostic locations would be enhanced when inducer and diagnostic locations resided in a shared meaningful area of space within a meaningful boundary. This effect emerged neither when the meaningful areas were perceptually similar (i.e., Experiment 2) nor when the meaningful areas were perceptually distinct (i.e., Experiments 4 & 5).

The boundaries for retrieval hypothesis predicted that CSPC effects at inducer locations would not transfer to diagnostic locations if diagnostic locations were presented across a meaningful boundary. No evidence supporting this hypothesis emerged in reaction time. Evidence for these hypotheses is typically assessed using reaction time, due to the ceiling effects associated with error rate. The control settings learned at inducer locations transferred to diagnostic locations in Experiment 1. Learning within boundaries attenuated the CSPC effect in the map background condition of Experiment 3, providing no signal (or a weaker signal) to be transferred to diagnostic locations. No CSPC effect emerged at inducer locations in the map background condition of Experiment 5, so one cannot assume the boundary disrupted retrieval at diagnostic locations.

However, evidence for the boundaries for retrieval hypothesis was clearer in error rate. In the map background conditions of Experiments 1 & 3, there was a significant CSPC effect in error rate at inducer locations that was statistically equivalent to the effect in the blank background condition. Consistent with the boundaries for retrieval hypothesis, that effect did not
transfer to the diagnostic location in the map background condition. Importantly, the same pattern was also observed in error rate in previous studies that separated inducer and diagnostic locations with a meaningful boundary (Colvett & Bugg, 2022, Experiment 1; Weidler et al., 2020, Experiment 3). Moreover, it should be noted that a simple visual (i.e., non-meaningful) boundary did not disrupt retrieval (Weidler et al., 2020, Experiment 2). This pattern is especially remarkable in Experiment 1 of the current study, as it indicates that people used a meaningful boundary even when the areas inside and outside the boundary did not differ perceptually (i.e., white background separated by black lines).

So why might meaningful boundaries affect the retrieval of control settings in error rate but not reaction time? One possibility is that the presence of meaningful boundaries affected the retrieval of control settings but more selectively for mechanisms like response caution that affect error rate more sensitively than reaction time. Another potentially important factor is that diagnostic locations were farther from the central fixation than the inducer locations in these designs. Reaction time was therefore higher overall at diagnostic locations and may have allowed participants more time to prepare the correct response before responding. One could test whether the increased distance to diagnostic locations drove this effect by using a design like Weidler and Bugg (2016, Experiment 1) where diagnostic locations were more proximal to the center than inducer locations.

While the categorical coding hypothesis and spatial proximity hypothesis make distinguishable predictions for CSPC transfer, their predictions were identical for all experiments in the current study: CSPC effects should be learned at inducer locations, then transfer to nearby

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9 The error rate effects in Experiments 2 and 4 were not inconsistent with boundaries for retrieval hypothesis, as inducer and diagnostic locations were not separated by a boundary. Some evidence exists for learning within boundaries affecting error rate and not reaction time in a design that presented locations on either forest or water (Dey et al., 2018). The observed effects in Experiment 5 do not provide evidence for or against the boundaries for retrieval hypothesis, as no difference in control setting was learned at inducer locations.
diagnostic locations regardless of the background condition. Indeed, many of the results of the current study are consistent with these predictions. Experiments 1, 2, and 4 all found significant CSPC effects at inducer locations and diagnostic locations, with no modulation from background condition. The attenuation of CSPC effects at inducer locations in the map background condition of Experiment 3 was not consistent with the non-meaningful boundary hypotheses, but rather supported the learning within boundaries hypothesis. Most troubling for categorical coding and spatial proximity hypotheses, no transfer occurred from inducer locations to nearby diagnostic locations in the blank background condition of Experiment 5. The design of that experiment departed from the previous experiments by not presenting locations along an invisible diagonal array. The diagnostic locations were proximal to an inducer location and in the same category of space (i.e., upper and lower half of the screen), so the categorical coding and spatial proximity hypotheses predicted transfer would occur. The difference in design between Experiment 5 and the other experiments calls in to question the importance of the invisible diagonal array in observing transfer to nearby diagnostic locations.

7.2 Competing predictors in CSPC designs
There were multiple competing contexts that participants could learn about to predict conflict in the experiments of the current study. A key theoretical question concerns why certain predictors dominated over others. Among many other predictors, participants could have learned the probability of conflict at the four locations, categories of space (e.g., the lower left area of the screen, the upper right area of the screen), or within meaningful boundaries in the map background condition (e.g., on water, on land). Two relatively simple design choices may have encouraged participants to learn about spatial regions rather than the meaningful areas in the current study. First, the task used in the current study (i.e., arrow flanker task) had conflict that
was spatial in nature. Indeed, it has been demonstrated that CSPC effects are larger when there is synergy between the nature of the context and the nature of the conflict (Pickel et al., 2019). Location is inherently spatial, and location-based CSPC effects were larger using a task with spatial conflict (i.e., a spatial Stroop task) than using a task with informational conflict (i.e., a color-word Stroop task). In the case of the current study with competing contexts, location or spatial region may have had an advantage over meaningful categories due its synergy with the spatial conflict of the flanker task.

Second, there were just two locations where trials could appear during the inducer only blocks and just four locations where trials could appear during diagnostic blocks. When there are relatively few locations, it is plausibly easier to learn about and keep track of the probability of conflict at each location. In a design where participants learned about the conflict probability at multiple locations, participants grouped nearby MC and MI locations (i.e., adopted an unbiased control setting for trials at MC and MI locations) when there were six nearby locations, but participants learned the control settings associated with each distinct location when there were just two nearby locations (Diede & Bugg, 2016; 2019). This interpretation begs a question: why would control settings reliably transfer to diagnostic locations when participants can learn about specific locations? That is, if there were only four locations in the experiments of the current study, why would they not learn about the probability of conflict at each location (and thus learn that the diagnostic locations have a conflict probability of 50%)?

Consider again the concept of binning (see Bugg et al., 2020). One prediction from the binning account is that when multiple binning structures are possible to use, participants will use the most efficient binning structure to predict conflict. Learning about two categories of space (or two halves of a linear slope) requires two bins, while learning each individual location requires
four bins. While it was not more efficient for participants to use meaningful boundaries in the current study, future research should assess whether participants are more inclined to use meaningful areas to predict conflict when that binning structure is relatively more efficient than location or spatial region. In an experiment that found evidence for the learning within boundaries hypothesis (Colvett & Bugg, 2022, Experiments 2, 3a & 3b) there were six locations along two invisible diagonal arrays (rather than three locations along one invisible diagonal array) inside the meaningful boundary. Participants in the current study might have been more likely to use meaningful boundaries to predict conflict if there were relatively more locations that appeared within the same boundary.

7.3 Importance of diagonal display
While meaningful boundaries did not consistently modulate CSPC effects in the current study, there is remarkably consistent evidence that participants can learn control settings at inducer locations that can be retrieved and implemented at nearby diagnostic locations. In Experiments 1, 2, 4, and the pilot experiment, a significant CSPC effect was observed at both inducer and diagnostic locations.\(^\text{10}\) In all those studies, the inducer and diagnostic locations were presented along an invisible diagonal array to the lower left and upper right of the central fixation. Indeed, significant effects at inducer and diagnostic locations were also observed in previous studies that used this arrangement of locations (Pickel et al., 2019; Weidler & Bugg, 2016; Weidler et al., 2020; cf. Colvett & Bugg, 2022).\(^\text{11}\) The use of an invisible diagonal array may be particularly

\(^{10}\) The same overall pattern was observed in Experiment 3, but the effect was not significant at diagnostic locations.

\(^{11}\) The stability of this effect is remarkable, especially considering the difficulty observing reliable transfer in another CSPC designs with upper and lower locations along a central vertical axis (e.g., Bugg et al., 2020; Bugg et al., 2022; Crump et al., 2017; Hutcheon & Spieler 2016; cf. Weidler et al., 2022). Note that this is a different form of transfer than the designs used in the designs of the current study where a control setting learned at an inducer location is retrieved and implemented at a diagnostic location. In these experiments, there were distinct sets of items that were presented at an MC location or an MI location. The inducer set of items was MC at the MC location and MI at the MI location. A distinct diagnostic set of items were 50% congruent at both locations. Transfer was indicated by a larger congruency effect for diagnostic set items at the MC location than the MI location.
important here, as transfer to diagnostic locations was not observed in the blank background condition of Experiment 5,\(^1\) the only experiment of the current study that did not use the diagonal display.

So what design factors make presenting inducer and diagnostic locations along a diagonal linear slope conducive to the learning and transfer of control settings? One possible reason relates to the degree to which that design encourages processing of distractor information and thus conflict. A recent set of experiments (Colvett et al., 2023; Weidler et al., 2022) assessed whether location-based CSPC effects differed based on where the locations were presented on screen. These studies presented flanker stimuli either on the horizontal axis (i.e., to the left and right of the central fixation) or on the vertical axis (i.e., above and below the central fixation). While the initial evidence appeared to support the idea that CSPC effects were larger when trials appeared on the horizontal axis (Weidler et al., 2022), that effect was limited to when the flanker stimuli were horizontally oriented (i.e., flanking arrows to the left and right of the central arrow, as in the current study). When flanker stimuli were vertically oriented (i.e., flanking arrows above and below the central arrows), the CSPC effects were larger when trials were on the vertical axis (Colvett et al., 2023, Experiment 1). Moreover, effects were equivalent between the horizontal and vertical axis when flanker stimuli had flanking arrows surrounding the central arrow in the four cardinal directions (Colvett et al., 2023, Experiment 2). Across these studies, CSPC effects were larger in conditions where the flanking arrows of a flanker stimulus were placed in the gaze path between the central fixation and the target arrow. This pattern suggested that designs that encourage greater processing of conflict may produce larger CSPC effects.

Turning back to the current study (excluding Experiment 5), the use of locations along a diagonal

\(^{1}\) I am specifically highlighting the blank background condition as no CSPC effect emerged at inducer locations in the map background condition.
array placed the flanking arrows in a participant’s gaze path in all locations across experiments. Enhanced processing of the distractors potentially led to larger compatibility effects and correspondingly stronger learning and retrieval of control settings. Other CSPC designs, regardless of whether they use a location or spatial context, could plausibly also increase the strength of their manipulation by encouraging processing of conflict information and thus giving participants a greater chance to learn the association between context and conflict probability.

A second possible reason for the consistent CSPC effects at inducer and diagnostic locations using the invisible diagonal array is that a linear slope provides a simple and familiar representation for the participant to organize experiences with conflict at inducer and diagnostic locations that are presented one at a time across many trials. Indeed, presenting locations along this diagonal array may provide a structure that guides the learning and retrieval of attentional control settings. It is possible that rather than specific locations, people may be inclined to learn about parts of this structure (e.g., the upper right section of a linear slope). As such, this simple representation potentially encouraged transfer by providing an unambiguous guide that grouped the inducer locations with the diagnostic locations as part of the linear slope. Participants could have also potentially represented this information as a linear continuum, where one side of the continuum predicts low conflict and the other side of the continuum predicts high conflict. A simple and easily learnable representation was also available in another design where a control setting was learned at inducer locations and transferred to diagnostic locations without using a diagonal array (Weidler & Bugg, 2016, Experiment 2). In that design, flanker stimuli appeared at different locations in either the inner, middle, or outer rings of a bullseye. The control setting learned at inducer locations in either the inner ring or outer ring transferred to diagnostic
locations within the same ring. Here, the structure of the rings provided a familiar and easy to
learn representation for participants to distinguish an MC context from an MI context.

The role of easy to learn representations provides an important theoretical challenge to
the categorical coding hypothesis and the spatial proximity hypothesis. Consider the layout of
Experiment 5 of the current study where the inducer locations were presented to the upper left
and lower right of the central fixation and the diagnostic locations were presented along a
vertical axis above and below the central fixation. From the perspectives of the categorical
coding and spatial proximity hypotheses, transfer should have occurred to the nearby diagnostic
locations. However, there was a significant CSPC effect at inducer locations that did not transfer
to the nearby diagnostic locations in the blank background condition without the structure of a
representation like the diagonal array. Indeed, if an easily representable structure encourages
people to group inducer and diagnostic locations, the absence of such a structure may have
encouraged participants to learn about each location separately. Alternatively, it is also possible
that participants learned about one diagonal linear slope connecting the inducer items and a
second separate linear slope along the vertical axis connecting the diagnostic locations.

A future direction could distinguish the role of easily representable structures from
categorical coding and spatial proximity hypotheses by presenting diagnostic locations a set
distance away from an invisible diagonal array. The diagnostic locations would still be in the
same category of space as the inducer locations and at the same distance from the inducer
locations as previous studies that observed transfer. If presenting inducer and diagnostic
locations along an easily representable structure is important, transfer should be disrupted.
However, the categorical coding hypothesis and spatial proximity hypothesis would predict
transfer, as the diagnostic locations are still inside shared categories of space (e.g., the upper right and lower left areas of the screen) and proximal to the inducer locations.

7.4 Limitations and future directions
The strongest evidence for the learning within boundaries hypothesis came in Experiment 3, where the CSPC effect at inducer locations in the inducer only blocks was significantly smaller in the map background condition (i.e., an image of the Gulf of Mexico and North America, where the inducer locations were superimposed over the ocean) than the blank background condition. As in Colvett and Bugg (2022, Experiment 1), the two meaningful areas of space differed in terms of both their meaning and the perceptual elements of the background in those spaces. That is, the color and texture of the land section of the map were distinct from the color and texture of the water section of the map. Importantly, no difference between map and blank background conditions emerged in Experiment 1, where the areas differed in their meaning but did not differ perceptually. An intriguing possibility is that participants could have used one of these perceptual features, rather than the meaningful area, to predict conflict probability. Indeed, future research should test this possibility by presenting inducer and diagnostic locations on a background image with areas that differ perceptually but do not carry any meaningful information. Of course, meaningfully distinct areas in real-world visual scenes are typically also perceptually distinct from each other. Another possibility is that people will use meaningful boundaries to guide the learning and retrieval of control settings, but they need a combination of meaningful and perceptual differences between these areas to do so.

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These perceptual differences were also present in Experiments 4 and 5. There was no evidence that participants used a perceptual feature that differed between the land and water to guide the learning and retrieval of control settings. However, an account predicting that participants should learn about the conflict probability of a simple perceptual feature also assumes that whatever perceptual feature is being used to make the prediction is consistently present throughout the water or land area of the image.
The background images in the map background conditions of Experiments 3, 4, and 5 were chosen to make the meaningful boundaries more salient than the meaningful boundaries in Experiments 1 and 2. The images used in Experiments 3, 4, and 5 were in full color and different meaningful areas of space were visually distinct from each other. While these background images were meaningful, they lacked personal relevance (as in, for example, the campus map used in Experiment 1 of Colvett & Bugg [2022] was from the university that the participants attended) and potentially poorly mirrored what a participants might see in real life. A major factor motivating both meaningful boundary hypotheses was that people use meaningful boundaries to guide control in real-world settings. Future work may capture meaningful boundaries more effectively by using realistic visual scenes that represent something that participants would see from their own perspective. For example, several paradigms in the neuropsychology literature have been developed that integrate Stroop (and Stroop-like) tasks into realistic visual scenes in virtual reality environments such as the windshield of a car (Parsons et al., 2013), a classroom (Lalonde et al., 2016), or an apartment (Parsons & Bennett, 2018). Moreover, a stronger version of the task could even include meaningful cues that participants already associate with high or low control demands, such as a computer screen displaying task-relevant work in one window and a video playing in another window.

Even with the changes to the background image in Experiments 3, 4, and 5, there was not consistent evidence that participants learned about the probability of conflict within meaningful areas and used meaningful areas as contexts to guide the learning and retrieval of control settings. Like many contextual predictors, it was not necessary for participants to attend to the meaningful area of space or the boundaries that separate areas to perform the flanker task. It may be possible that it was too easy for participants to habituate to the information from the
background image in the map background conditions because it was present and static throughout each block. In a CSPC design where participants learned about the conflict probability of two objects, participants used the objects to guide the learning and retrieval of control settings when the objects moved between each trial but not when the objects were stationary between each trial (Colvett et al., under review). Participants may be more likely to use a meaningful area of space to predict conflict if those meaningful areas move or participant’s perspective on those areas move between trials. Additional design choices might also push participants to distinguish meaningful areas of space and learn about the probability of conflict in each area separately. For example, asking participants to keep a running count of how many trials appeared in one level of a context (e.g., an upper or lower location) encouraged participants to use that context to guide control (Brosowsky & Crump 2021; Colvett et al., under review; Crump et al., 2009; cf. Bugg et al., 2022). This manipulation enhanced CSPC effects by acting on the task relevance of a contextual feature, as participants must attend to the context to be able to report how many trials appeared there. Indeed, future work may find greater use of task-relevant meaningful boundaries by asking participants to keep a running count of how many trials appeared in a particular meaningful area.

7.5 Conclusion
People are capable of learning focused or relaxed control settings based on their experiences at specific locations that are subsequently retrieved and implemented at nearby unbiased locations. The current study assessed whether meaningful boundaries affected the learning of control settings within a meaningful boundary and the retrieval of control settings across a meaningful boundary. Additionally, the current study aimed to assess whether participants were more inclined to learn about meaningful areas of space over and above other contextual predictors like
spatial categories. Meaningful boundaries only affected learning at inducer locations when the distinct meaningful areas were also perceptually distinct from each other. However, there was neither evidence that learning within meaningful boundaries enhanced transfer to diagnostic locations in the same meaningful area as an inducer location, nor evidence for disruption of retrieval based on the presence of the meaningful boundary. Consistent with either the spatial proximity or categorical coding hypotheses, the control settings learned at inducer locations reliably transferred to nearby diagnostic locations. However, control settings did not transfer to diagnostic locations in Experiment 5, even though diagnostic locations were presented proximally and in the same categorical region of space as inducer locations. These results indicate that participants may use meaningful boundaries to guide the learning and retrieval of control settings, but there are also important roles for perceptual features and the layout of locations.
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Colvett, J. S., Weidler, B. J., Bugg, J. M., (Under Review) Revealing object-based attentional control in a moving object paradigm.


https://www.google.com/maps/@38.6486422,-90.3106649,399a,35y,276.49h/data=!3m1!1e3

https://earth.google.com/web/@25.01753188,-92.9910118,-2099.65843882a,2610738.082847d,35y,348.76855921h,0t,0r

https://earth.google.com/web/@37.03430057,-73.39505359,-2210.79053081a,2724998.96915317d,35y,7.6924791h,0t,0r

14.58310154,-76.52180955,-3296.28869818a,6709757 .14293838d,35y,4.74452595h,0t,0r


van Doorn, J., van den Bergh, D., Böhm, U., Dablander, F., Derks, K., Draws, T., Etz, A., Evans, N.J., Gronau, Q.F., Haaf, J.M., Hinne, M., Kucharský, Š., Ly, A., Marsman, M., Matzke,


Appendix A: Map survey

8.1 Experiments 1 and 2

1. Starting with the most recent (including now) and then going backwards chronologically, what US states have you lived in & approximately how long did you live there?

2. How many of the 50 US States do you believe you could label on a map?

3. There are 8 states that border Missouri. Name as many of them as you can.

On a scale of 1-7 (7 being the highest) –

4a. I am capable of learning and remembering the identities of locations by studying a map

4b. I have a lot of exposure to maps in my life

4c. I am capable of navigating to a new place using a physical map

The correct answers to question 3 are Iowa, Illinois, Kentucky, Tennessee, Arkansas, Oklahoma, Kansas, and Nebraska. Correct hits and false alarms were assessed for participants’ responses to question 3, and MapScore was calculated by subtracting false alarms from correct hits and dividing that total by 8.

The map knowledge score is derived from averaging ([Answer to question 2] / 50) and ([MapScore from question 3 / 8).

The map confidence and experience score is derived from averaging responses to question 4a, 4b, and 4c.

8.2 Experiments 3, 4, and 5

1. Starting with the most recent (including now) and then going backwards chronologically, what US states have you lived in & approximately how long did you live there?
2. What oceans have you been to, if any?

On a scale of 1-7 (7 being the highest) –

3a. I know more about geography than the average person

3b. I am capable of learning and remembering the identities of locations by studying a map

3c. I have a lot of exposure to maps in my life

3d. I am capable of navigating to a new place using a physical map

The map confidence and experience score is derived from averaging responses to question 3a, 3b, 3c, and 3d.

### 8.3 Map survey results

Table 8.1
*Responses to Map Survey in Experiments 1 and 2 with Standard Deviations in Parentheses*

<table>
<thead>
<tr>
<th>Question</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is state the participant lived in first on map?</td>
<td>17 yes, 42 no</td>
<td>14 yes, 46 no</td>
</tr>
<tr>
<td>Is state the participant lived in for the longest amount of time on map?</td>
<td>21 yes, 38 no</td>
<td>17 yes, 42 no</td>
</tr>
<tr>
<td>Was participant born in the United States?</td>
<td>50 yes, 10 no</td>
<td>51 yes, 9 no</td>
</tr>
<tr>
<td>How many of the 50 US States do you believe you could label on a map?</td>
<td>33.66 (12.19)</td>
<td>29.31 (14.86)</td>
</tr>
<tr>
<td>There are 8 states that border Missouri. Name as many of them as you can. (Correct hits)</td>
<td>4.2 (2.19)</td>
<td>4.28 (2.04)</td>
</tr>
<tr>
<td>There are 8 states that border Missouri. Name as many of them as you can. (False alarms)</td>
<td>0.6 (0.89)</td>
<td>0.38 (0.72)</td>
</tr>
<tr>
<td>I am capable of learning and remembering the identities of locations by studying a map</td>
<td>5.1 (1.07)</td>
<td>4.83 (1.24)</td>
</tr>
<tr>
<td>I have a lot of exposure to maps in my life</td>
<td>3.72 (1.26)</td>
<td>3.62 (1.55)</td>
</tr>
<tr>
<td>I am capable of navigating to a new place using a physical map</td>
<td>3.82 (1.53)</td>
<td>3.9 (1.54)</td>
</tr>
</tbody>
</table>

*Note:* Responses to the map survey in Experiments 1 and 2.
Table 8.2

*Responses to Map Survey in Experiments 3, 4, and 5 with Standard Deviations in Parentheses*

<table>
<thead>
<tr>
<th>Question</th>
<th>Experiment 3</th>
<th>Experiment 4</th>
<th>Experiment 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has participant been to ocean depicted on the map?</td>
<td>48 yes, 12 no</td>
<td>43 yes, 17 no</td>
<td>41 yes, 19 no</td>
</tr>
<tr>
<td>Is participant from United States originally?</td>
<td>52 yes, 8 no</td>
<td>48 yes, 12 no</td>
<td>47 yes, 13 no</td>
</tr>
<tr>
<td>I know more about geography than the average person</td>
<td>3.45 (1.36)</td>
<td>3.37 (1.52)</td>
<td>3.55 (1.56)</td>
</tr>
<tr>
<td>I am capable of learning and remembering the identities of locations by studying a map</td>
<td>4.8 (1.27)</td>
<td>4.58 (1.12)</td>
<td>4.73 (1.31)</td>
</tr>
<tr>
<td>I have a lot of exposure to maps in my life</td>
<td>3.82 (1.38)</td>
<td>3.27 (1.51)</td>
<td>3.45 (1.40)</td>
</tr>
<tr>
<td>I am capable of navigating to a new place using a physical map</td>
<td>4.57 (1.58)</td>
<td>4.02 (1.71)</td>
<td>4.28 (1.70)</td>
</tr>
</tbody>
</table>

*Note:* Responses to the map survey in Experiments 3, 4, and 5.
Appendix B: Pilot experiment

The primary goal of the pilot experiment was to conceptually replicate the previous effects observed in a previous study (Weidler et al., 2020) before moving forward with predictions about how these effects may differ in the presence of meaningful boundaries. Those previous experiments used no boundaries (Weidler et al., 2020, Experiment 1) or a visual, non-meaningful boundary separating inducer from diagnostic locations (Weidler et al., 2020, Experiment 2). The pilot study used the same location positions and location PCs as the experiments of the current study.

As in previous studies that presented stimuli on an invisible diagonal array (Colvett & Bugg, 2022; Pickel et al., 2019; Weidler & Bugg, 2016; Weidler et al., 2020), participants responded to stimuli that appeared at inducer locations and diagnostic locations. The inducer locations were more proximal to the central fixation and the diagnostic locations were more distal from the central fixation. Participants were in one of two background image conditions. In the blank background condition, participants responded to flanker stimuli that were superimposed over a white background (see Figure 9.1, Panel A). Given prior findings (e.g., Weidler & Bugg, 2016; Experiment 1; Weidler et al., 2020, Experiment 1), a significant CSPC effect was expected at inducer locations and diagnostic locations. The transfer of the control setting to the diagnostic location could be explained by either the spatial proximity or the categorical coding hypothesis. In the black parallelogram background condition, the stimuli were superimposed on a white background with a black parallelogram separating the inducer locations from the diagnostic locations (see Figure 9.1, Panel B). The black parallelogram background condition will serve as a conceptual replication of Weidler et al. (2020, Experiment 2). In keeping with the results of that study (i.e., a significant CSPC effect for inducer and diagnostic
locations), a visual boundary should not disrupt the retrieval of the control setting that was learned at the inducer location when stimuli are presented in a diagnostic location. If a non-significant CSPC effect is observed at the diagnostic location in the black parallelogram condition, it would be necessary to re-evaluate whether non-meaningful visual boundaries are capable of disrupting transfer.

![Figure 9.1](image)

*Figure 9.1.* Panel A depicts a condition where flanker stimuli were superimposed over a white background. Panel B depicts a condition where flanker stimuli were superimposed over a white background with the outline of a black parallelogram. The MC and MI inducer locations were presented inside the parallelogram, while the near-MC and near-MI diagnostic locations were located outside the parallelogram.

### 9.1 Method

#### 9.1.1 Participants

Sixty-two Washington University undergraduates (44 female, Age $M = 19.47$, SD = 1.33) participated for cash or course credit. Two participant’s data were removed for error rate 2.5 SD higher than average. The data from the remaining 60 participants (42 female, Age $M = 19.43$, SD = 1.33) were included. Thirty-seven participants were randomly assigned to the white
background condition, and 23 participants were randomly assigned to the black parallelogram background condition.\textsuperscript{14}

\textbf{9.1.2 Design and Stimuli}

Flanker stimuli were five black arrows in a horizontal row 2.4 cm wide and 1.6 cm tall superimposed over a white rectangle. Arrows could point either up, down, left, or right. On compatible trials, all arrows pointed in the same direction (e.g., $> > > > >$) whereas on incompatible trials, the four flanking arrows pointed in a different direction than the central arrow (e.g., $< < > < <$). On incompatible trials, the direction of the flanking arrows was equally likely to be any of the three other directions (e.g., for an incompatible stimulus with a left pointing target arrow, the direction of the flanking arrows was equally likely to be up, down, or right). There were four unique compatible stimuli and 12 unique incompatible stimuli.

The background image was randomly assigned between subjects. In the blank background condition, the background image was entirely white (see Figure 9.1, Panel A). In the black parallelogram condition, the background was a white background with a black parallelogram separating the inducer locations from the diagnostic locations (see Figure 9.1, Panel B). This image was presented in a rectangle 33.85 cm wide and 19.05 cm tall. The remainder of the 44.3 cm wide by 25 cm tall screen was gray.

There were four locations at which a trial could appear (see Figure 9.1). These locations were superimposed on an invisible diagonal array that was 19.76 cm long. Each location was 6.58 cm apart from each other. Two distinct kinds of locations were used in the current study: inducer locations and diagnostic locations. The diagnostic location closer to the MC location was

\textsuperscript{14} I relied on the random assignment done through internal randomization function in PsychoPy. In all following experiments, I counterbalanced participants and conditions to assure that an equal number participants participated in each condition.
called the near-MC location, and the diagnostic location closer to the MI location was called the near-MI location.

### 9.1.3 Procedure

Participants performed this experiment in individual cubicles within a group testing space. After consenting to participate, a brief demographic survey was administered. Next, participants began the flanker task. Participants were instructed to indicate the direction of the central arrow by pressing the 2 (down), 4 (left), 6 (right), or 8 (up) key with just their index finger on the number pad of a keyboard, and to return their finger centrally on the keypad between each trial such that their finger was over the 5 key and could press any key on the next trial. Participants were instructed to respond as quickly as possible while maintaining a high level of accuracy.

Participants were instructed to return their attention to the central fixation cross in between each trial. Participants were positioned approximately 60 cm away from the computer screen.

Participants then completed a 20-trial practice block of the flanker task with 10 trials at each of the two inducer locations. The PC of each location was consistent with the PC seen later in the experimental blocks. During this practice block, participants were given feedback as to whether their response was correct or incorrect.

Next, participants completed two inducer blocks and two diagnostic blocks. In the 120-trial inducer blocks, 60 stimuli appeared at each of the two inducer locations. At the 80% compatible MC location, there were 12 repetitions of each of the four compatible stimuli and one repetition of each the 12 incompatible stimuli. At the 20% compatible MI location, there were three repetitions of each of the four compatible stimuli and four repetitions of each of the twelve incompatible stimuli. It was randomly assigned between participants which inducer location was MC and which inducer location was MI. The order of the 120 trials was randomized without replacement in each block.
In each of the two 216-trial diagnostic blocks, in addition to the 120 trials that appeared at the inducer locations, identical sets of 48 PC-unbiased (i.e., 50% compatible) stimuli appeared at two novel locations along the diagonal. In each 50% compatible location, there were six repetitions of each of the four compatible stimuli, and two repetitions of each of the twelve incompatible stimuli. The order of the 216 trials was randomized without replacement each block. Experiments were coded and run using PsychoPy (Pierce et al., 2019). The experiment took approximately 20 minutes to complete.

9.2 Results
For these and all subsequent analyses, an alpha of .05 was used. In addition, only trials with RTs greater than 200 and less than 2000 ms were included. Error trials were excluded from the analysis of RT (cf. Weidler & Bugg, 2016; Colvett & Bugg, 2022). I expressed error rates as probabilities. A participant’s data were excluded from analysis if their error rate was higher than 20% (cf. Colvett et al., 2022). Analyses were completed using JASP version 0.16.3 (JASP Team, 2022) and R (R Core team, 2022).

For null effects, I additionally presented Bayes Factors. I reported Bayesian evidence for the null hypothesis compared to evidence of the alternative hypothesis (BF$_{01}$). A value between 1 and 3 indicates anecdotal evidence for the null hypothesis and a value between 3 and 10 indicates substantial evidence for the null hypothesis (Wagenmakers et al., 2011). I calculated Bayes Factors using the default settings of JASP (see Van Doorn et al., 2020).

I ran separate analyses for reaction time and error rate. For both reaction time and error rate, I analyzed trials at inducer and diagnostic locations separately (cf. Colvett & Bugg, 2022; Weidler & Bugg, 2016; Weidler et al., 2020). For trials at inducer locations in inducer only blocks and for trials at inducer locations across all blocks, I ran 2x2x2 mixed-effects ANOVAs.
with a between-subjects factor of background (blank background or black parallelogram background), and within-subjects factors of PC (MC or MI) and trial type (compatible or incompatible). For trials at diagnostic locations, I ran 2x2x2 mixed-effects ANOVAs with a between-subjects factor of background (blank background or black parallelogram background), and within-subjects factors of near-PC (near-MC or near-MI) and trial type (compatible or incompatible).

For completeness, I decomposed each of the 2x2x2 ANOVAs into separate analyses for the blank background condition and the black parallelogram background condition. Within each condition, I analyzed inducer locations in the inducer only blocks and throughout the experiment using 2x2 repeated-measures ANOVAs with factors location proportion compatibility (MC and MI) and trial type (compatible and incompatible). I analyzed diagnostic locations using 2x2 repeated-measures ANOVAs with factors of location near-PC (near-MC and near-MI) and trial type (compatible and incompatible).

9.2.1 Reaction time
Inducer locations. In the inducer only blocks, there was an interaction between PC and trial type, $F(1, 58) = 17.22, p < .001, \eta_p^2 = .23$, indicating a CSPC effect such that the compatibility effect was larger at the MC location ($M = 174, SE = 11$) compared to the MI location ($M = 140, SE = 7$). There was no interaction between background, PC and trial type, $F(1, 58) = 0.67, p = .416, \eta_p^2 = .01, BF_{01} = 2.67$ (see Figure 9.2 and Table 9.1). In addition to these theoretically important results, there was an effect of trial type, $F(1, 58) = 374.70, p < .001, \eta_p^2 = .87$, such that responses to compatible trials ($M = 641, SE = 17$) were faster than responses to incompatible trials ($M = 798, SE = 16$). There was no effect of PC, $F(1, 58) = 0.92, p = .342, \eta_p^2 = .02, BF_{01} = 6.21$. There was no effect of background, $F(1, 58) = 1.05, p = .310, \eta_p^2 = .18, BF_{01} = 2.13$. 

112
Across all four blocks, there was an interaction between PC and trial type, $F(1, 58) = 30.25$, $p < .001$, $\eta^2_p = .34$, indicating a CSPC effect such that the compatibility effect was larger at the MC location ($M = 171, SE = 6$) compared to the MI location ($M = 144, SE = 6$). Again, there was no interaction between background, PC, and trial type, $F(1, 58) = 0.51$, $p = .478$, $\eta^2_p = .01$, BF$_{01} = 4.49$. There was an effect of trial type, $F(1, 58) = 866.37$, $p < .001$, $\eta^2_p = .937$, such that responses to compatible trials ($M = 635, SE = 16$) were faster than responses to incompatible trials ($M = 793, SE = 16$). There was an effect of PC, $F(1, 58) = 4.31$, $p = .042$, $\eta^2_p = .07$, such that responses at the MC location ($M = 718, SE = 19$) were faster than responses at the MI location ($M = 710, SE = 19$). There was no effect of background, $F(1, 58) = 1.89$, $p = .174$, $\eta^2_p = .03$.

**Diagnostic locations.** For trials at diagnostic locations, there was an interaction between near-PC and trial type, $F(1, 58) = 13.43$, $p < .001$, $\eta^2_p = .19$, such that the compatibility effect was larger at the near-MC location ($M = 168, SE = 7$) compared to the near-MI location ($M = 146, SE = 7$) indicating transfer of the CSPC effect. There was no interaction between background, near-PC and trial type, $F(1, 58) = 0.20$, $p = .656$, $\eta^2_p = .00$, BF$_{01} = 5.31$ (see Figure 9.3). There was an effect of trial type, $F(1, 58) = 559.81$, $p < .001$, $\eta^2_p = .91$, such that responses to compatible trials ($M = 689, SE = 17$) were faster than responses to incompatible trials ($M = 846, SE = 14$). There was no effect of near-PC, $F(1, 58) = 0.22$, $p = .638$, $\eta^2_p < .01$, BF$_{01} = 7.17$. There was also no effect of background, $F(1, 58) = 2.89$, $p = .095$, $\eta^2_p = .05$, BF$_{01} = 1.06$.

### 9.2.2 Error rate

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type, $F(1, 58) = 16.29$, $p < .001$, $\eta^2_p = .22$, such that the compatibility effect was larger at the MC location ($M = 4.90\%, SE = 0.73\%$) compared to the MI location ($M = 2.65\%, SE = 0.47\%$), indicating a CSPC effect. There was no interaction between background, PC and trial type, $F(1,
There was an effect of trial type, $F(1, 58) = 857.16, p < .001, \eta_p^2 = .44$, such that responses to compatible trials ($M = 0.27\%, SE = 0.12\%$) were more accurate than responses to incompatible trials ($M = 4.05\%, SE = 0.62\%$). There was an effect of PC, $F(1, 58) = 9.64, p = .003, \eta_p^2 = .14$, such that responses at the MC location ($M = 2.64\%, SE = 0.61\%$) were less accurate than responses at the MI location ($M = 1.67\%, SE = 0.37\%$). There was no effect of background, $F(1, 58) = 1.09, p = .301, \eta_p^2 = .02, BF_{01} = 4.57$.

Across all four blocks, there was an interaction between PC and trial type, $F(1, 58) = 10.92, p = .002, \eta_p^2 = .16$, such that the compatibility effect was larger at the MC location ($M = 4.43\%, SE = 0.67\%$) compared to the MI location ($M = 3.17\%, SE = 0.49\%$), indicating a CSPC effect. Again, there was no interaction between background, PC and trial type, $F(1, 58) < 0.01, p = .962, \eta_p^2 < .01, BF_{01} = 3.99$. There was an effect of trial type, $F(1, 58) = 8.34, p = .005, \eta_p^2 = .13$, such that responses to compatible trials ($M = 0.29\%, SE = 0.09\%$) were more accurate than responses to incompatible trials ($M = 4.10\%, SE = 0.58\%$). There was an effect of PC, $F(1, 58) = 8.34, p = .005, \eta_p^2 = .13$, such that responses at the MC location ($M = 2.49\%, SE = 0.56\%$) were less accurate than responses at the MI location ($M = 1.90\%, SE = 0.39\%$). There was no effect of background, $F(1, 58) = 0.42, p = .521, \eta_p^2 = .01, BF_{01} = 4.57$.

**Diagnostic locations.** For trials at diagnostic locations, there was an interaction between near-PC and trial type, $F(1, 58) = 5.56, p = .022, \eta_p^2 = .09$, such that the compatibility effect was larger at the near-MC location ($M = 5.52\%, SE = 0.89\%$) compared to the near-MI location ($M = 4.17\%, SE = 0.76\%$), indicating transfer of the CSPC effect. There was no interaction between background, near-PC and trial type, $F(1, 58) = 0.52, p = .473, \eta_p^2 = .01, BF_{01} = 3.50$ (see Figure 9.3). There was an effect of trial type, $F(1, 58) = 1420.99, p < .001, \eta_p^2 = .40$, such that responses
to compatible trials ($M = 0.26\%, \ SE = 0.11\%$) were more accurate than responses to incompatible trials ($M = 5.11\%, \ SE = 0.84\%$). There was no effects of near-PC ($F(1, 58) = 2.41, \ p = .126, \ \eta^2_p = .04, \ BF_{01} = 5.29$) or background ($F(1, 58) = 0.84, \ p = .364, \ \eta^2_p = .01, \ BF_{01} = 3.67$).

**Figure 9.2.** Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and location PC (MC or MI) at inducer locations in the inducer only blocks of the pilot experiment. Error bars represent standard error of the mean. A significant CSPC effect emerged overall, in reaction time and error rate, and no statistical difference between the conditions.

**Figure 9.3.** Mean compatibility effects for reaction time and error rate as a function of background (map or blank) and nearby inducer PC (near-MC or near-MI) at diagnostic locations in the pilot experiment. Error bars represent standard error of the mean. In reaction time, there was a significant CSPC effect in both the blank background and black parallelogram conditions. While a CSPC effect in error rate was only observed in the blank background condition, there was no statistical difference between the background conditions and the pattern of results mirrored reaction time.
Table 9.1

Pilot Experiment Reaction Time (ms) and Error Rate at Inducer and Diagnostic Locations with

Standard Errors in Parentheses

<table>
<thead>
<tr>
<th>BG</th>
<th>Location Type</th>
<th>PC</th>
<th>Trial Type</th>
<th>RT</th>
<th>CE (RT)</th>
<th>Error Rate</th>
<th>CE (Error Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>Inducer</td>
<td>MC</td>
<td>Compatible</td>
<td>663 (38)</td>
<td>150 (22)</td>
<td>0.32% (0.13%)</td>
<td>5.33% (1.35%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>680 (42)</td>
<td>124 (13)</td>
<td>0.36% (0.26%)</td>
<td>3.39% (1.02%)</td>
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<td></td>
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<td>Incompatible</td>
<td>804 (35)</td>
<td></td>
<td>3.76% (0.96%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inducer</td>
<td>MC</td>
<td>Compatible</td>
<td>660 (35)</td>
<td>168 (11)</td>
<td>0.33% (0.11%)</td>
<td>4.94% (1.23%)</td>
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<td></td>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>671 (40)</td>
<td>136 (13)</td>
<td>0.18% (0.13%)</td>
<td>3.70% (0.91%)</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>Incompatible</td>
<td>807 (34)</td>
<td></td>
<td>3.88% (0.89%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diagnostic</td>
<td>Near-MC</td>
<td>Compatible</td>
<td>714 (38)</td>
<td>164 (17)</td>
<td>0.27% (0.21%)</td>
<td>6.11% (1.70%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Incompatible</td>
<td>878 (27)</td>
<td></td>
<td>6.38% (1.76%)</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Near-MI</td>
<td>Compatible</td>
<td>735 (40)</td>
<td>138 (13)</td>
<td>0.37% (0.23%)</td>
<td>5.24% (1.47%)</td>
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<td>Incompatible</td>
<td>873 (32)</td>
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<td>5.60% (1.46%)</td>
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<tr>
<td>Blank</td>
<td>Inducer</td>
<td>MC</td>
<td>Compatible</td>
<td>618 (14)</td>
<td>189 (11)</td>
<td>0.11% (0.07%)</td>
<td>4.64% (0.90%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MI</td>
<td>Compatible</td>
<td>619 (14)</td>
<td>150 (7)</td>
<td>2.52% (0.43%)</td>
<td>2.18% (0.47%)</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Incompatible</td>
<td>808 (21)</td>
<td></td>
<td>2.18% (0.47%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inducer</td>
<td>MC</td>
<td>Compatible</td>
<td>615 (13)</td>
<td>173 (7)</td>
<td>0.24% (0.06%)</td>
<td>4.12% (0.83%)</td>
</tr>
<tr>
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<td></td>
<td>MI</td>
<td>Compatible</td>
<td>618 (14)</td>
<td>149 (5)</td>
<td>0.39% (0.16%)</td>
<td>2.84% (0.59%)</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>Incompatible</td>
<td>767 (15)</td>
<td></td>
<td>3.23% (0.55%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diagnostic</td>
<td>Near-MC</td>
<td>Compatible</td>
<td>664 (13)</td>
<td>171 (7)</td>
<td>0.11% (0.08%)</td>
<td>5.16% (1.05%)</td>
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<td>Incompatible</td>
<td>835 (15)</td>
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<td>5.27% (1.07%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Near-MI</td>
<td>Compatible</td>
<td>670 (15)</td>
<td>151 (8)</td>
<td>0.34% (0.15%)</td>
<td>3.51% (0.90%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Incompatible</td>
<td>822 (15)</td>
<td></td>
<td>3.85% (0.88%)</td>
<td></td>
</tr>
</tbody>
</table>

*Note:* BG = background condition; CE = compatibility effect; MC = mostly compatible inducer location; MI = mostly incompatible inducer location. Inducer = locations where trials were 80% PC when the MC object was superimposed and 20% PC when the MI object was superimposed over the location; Diagnostic = locations that were 50% PC regardless of which object was superimposed over the location.
9.3 Discussion

There are two key takeaways from the pilot study. First, a reliable CSPC effect was observed at inducer and diagnostic locations in both background conditions. This result conceptually replicates the effect observed in previous studies (Weidler et al., 2020, Experiments 1 & 2). Indeed, there is strong evidence that a CSPC effect can be learned at inducer locations and transfer to diagnostic locations using this design. This result could be explained by both the spatial proximity hypothesis (i.e., the control setting retrieved at the diagnostic location was consistent with the most proximal inducer location) or the categorical coding hypothesis (i.e., the control setting retrieved at the diagnostic location was consistent with the inducer location in the same area of space). As no meaningful boundaries were used, neither the learning within boundaries or boundaries for retrieval hypothesis was relevant to the pilot study.

Second, none of the key effects interacted with the between subject factor of background. Moreover, the CPSC effect across all four blocks was significant in both the white background condition and, more importantly, the black parallelogram background condition when they were analyzed separately. Consistent with previous studies using a visual boundary (Weidler et al., 2020, Experiment 2), the visual boundary from the black parallelogram background did not discourage transfer from the inducer location to the diagnostic location. Based on these results one can be more confident that any modulations to the learning and retrieval of control setting in the map background conditions of the current study were driven by meaningful boundaries.
Appendix C: Analysis of effects in each background condition

10.1 Pilot study

Black parallelogram background

Reaction time

**Inducer locations.** In the inducer only blocks, there was no interaction between PC and trial type, $F(1, 22) = 3.49, p = .075, \eta^2_p = .14, BF_{01} = 2.21$, though the compatibility effect was nominally larger at the MC location ($M = 150, SE = 21$) compared to the MI location ($M = 124, SE = 13$). There was an effect of trial type, $F(1, 22) = 77.42, p < .001, \eta^2_p = .78$, such that responses to compatible trials ($M = 672, SE = 38$) were faster than responses to incompatible trials ($M = 809, SE = 31$). There was no effect of PC, $F(1, 22) = 0.09, p = .773, \eta^2_p < .01, BF_{01} = 4.37$.

Across all four blocks, there was an interaction between PC and trial type, $F(1, 22) = 13.15, p = .001, \eta^2_p = .37$, such that the compatibility effect was larger at the MC location ($M = 168, SE = 10$) compared to the MI location ($M = 136, SE = 12$), indicating the CSPC effect. There was an effect of trial type, $F(1, 22) = 214.26, p < .001, \eta^2_p = .91$, such that responses to compatible trials ($M = 665, SE = 36$) were faster than responses to incompatible trials ($M = 817, SE = 32$). There was no effect of PC, $F(1, 22) = 0.46, p = .504, \eta^2_p = .02, BF_{01} = 4.47$.

**Diagnostic locations.** For trials at diagnostic locations in the diagnostic blocks, there was an interaction between near-PC and trial type, $F(1, 22) = 5.34, p = .031, \eta^2_p = .20$, such that the compatibility effect was larger at the near-MC location ($M = 164, SE = 16$) compared to the near-MI location ($M = 138, SE = 12$), indicating transfer of the CSPC effect. There was an effect of trial type, $F(1, 22) = 127.82, p < .001, \eta^2_p = .85$, such that responses to compatible trials ($M =
724, $SE = 37$) were faster than responses to incompatible trials ($M = 875, SE = 28$). There was no effect of near-PC, $F(1, 22) = 1.10, p = .306, \eta^2_p = .05, BF_{01} = 4.37$.

**Error rate**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type, $F(1, 22) = 8.90, p = .007, \eta^2_p = .29$, such that the compatibility effect was larger at the MC location ($M = 5.33\%, SE = 1.29\%)$ compared to the MI location ($M = 3.39\%, SE = 0.97\%)$, indicating the CSPC effect. There was an effect of trial type, $F(1, 22) = 15.92, p < .001, \eta^2_p = .42$, such that responses to compatible trials ($M = 0.32\%, SE = 0.12\%)$ were more accurate than responses to incompatible trials ($M = 5.65\%, SE = 1.32\%)$. There was an effect of PC, $F(1, 22) = 5.40, p = .030, \eta^2_p = .20$, such that responses at the MC location ($M = 2.98\%, SE = 1.09\%)$ were less accurate than responses at the MI location ($M = 2.06\%, SE = 0.76\%)$.

Across all four blocks, there was an interaction between PC and trial type, $F(1, 22) = 4.81, p = .039, \eta^2_p = .18$, such that the compatibility effect was larger at the MC location ($M = 4.94\%, SE = 1.18\%)$ compared to the MI location ($M = 3.70\%, SE = 0.87\%)$, indicating the CSPC effect. There was an effect of trial type, $F(1, 22) = 18.83, p < .001, \eta^2_p = .46$, such that responses to compatible trials ($M = 0.26\%, SE = 0.12\%)$ were more accurate than responses to incompatible trials ($M = 4.58\%, SE = 1.03\%)$. There was an effect of PC, $F(1, 22) = 5.61, p = .027, \eta^2_p = .20$, such that responses at the MC location ($M = 2.81\%, SE = 0.99\%)$ were less accurate than responses at the MI location ($M = 2.03\%, SE = 0.71\%)$.

**Diagnostic locations.** For trials at diagnostic locations, there was no interaction between near-PC and trial type, $F(1, 22) = 1.15, p = .295, \eta^2_p = .05, BF_{01} = 3.16$, indicating no transfer of the CSPC effect. There was an effect of trial type, $F(1, 22) = 15.06, p < .001, \eta^2_p = .41$, such that responses to compatible trials ($M = 0.32\%, SE = 0.21\%)$ were more accurate than responses to
incompatible trials \((M = 5.99\%, SE = 1.52\%)\). There was no effect of near-PC, \(F(1, 22) = 0.39, p = .542, \eta_p^2 = .02, BF_{01} = 4.42\).

**Blank background**

**Reaction time**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type, \(F(1, 36) = 19.54, p < .001, \eta_p^2 = .35\), such that the compatibility effect was larger at the MC location \((M = 189, SE = 11)\) compared to the MI location \((M = 150, SE = 7)\), indicating the CSPC effect. There was an effect of trial type, \(F(1, 36) = 457.25, p < .001, \eta_p^2 = .96\), such that responses to compatible trials \((M = 622, SE = 14)\) were faster than responses to incompatible trials \((M = 792, SE = 19)\). There was an effect of PC, \(F(1, 36) = 8.51, p = .006, \eta_p^2 = .19\), such that responses at the MC location \((M = 714, SE = 23)\) were slower than responses at the MI location \((M = 699, SE = 20)\).

Across all four blocks, there was an interaction between PC and trial type, \(F(1, 36) = 16.91, p < .001, \eta_p^2 = .32\), such that the compatibility effect was larger at the MC location \((M = 173, SE = 7)\) compared to the MI location \((M = 149, SE = 5)\), indicating the CSPC effect. There was an effect of trial type, \(F(1, 36) = 896.36, p < .001, \eta_p^2 = .96\), such that responses to compatible trials \((M = 617, SE = 13)\) were faster than responses to incompatible trials \((M = 778, SE = 16)\). There was an effect of PC, \(F(1, 36) = 8.70, p = .006, \eta_p^2 = .20\), such that responses at the MC location \((M = 702, SE = 21)\) were slower than responses at the MI location \((M = 693, SE = 19)\).

**Diagnostic locations.** For trials at diagnostic locations, there was an interaction between near-PC and trial type, \(F(1, 36) = 8.17, p = .007, \eta_p^2 = .19\), such that the compatibility effect was larger at the near-MC location \((M = 171, SE = 7)\) compared to the near-MI location \((M = 151, SE = 7)\).
indicating transfer of the CSPC effect. There was an effect of trial type, $F(1, 36) = 653.01$, $p < .001$, $\eta^2_p = .95$, such that responses to compatible trials ($M = 667$, $SE = 14$) were faster than responses to incompatible trials ($M = 828$, $SE = 15$). There was no effect of near-PC, $F(1, 36) = 0.58$, $p = .453$, $\eta^2_p = .02$, $BF_{01} = 5.66$.

**Error rate**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type, $F(1, 36) = 10.56$, $p = .003$, $\eta^2_p = .23$, such that the compatibility effect was larger at the MC location ($M = 4.64\%$, $SE = 0.89\%$) compared to the MI location ($M = 2.18\%$, $SE = 0.46\%$), indicating the CSPC effect. There was an effect of trial type, $F(1, 36) = 32.29$, $p < .001$, $\eta^2_p = .47$ such that responses to compatible trials ($M = 0.23\%$, $SE = 0.14\%$) were more accurate than responses to incompatible trials ($M = 3.64\%$, $SE = 0.72\%$). There was an effect of PC, $F(1, 36) = 5.66$, $p = .023$, $\eta^2_p = .14$, such that responses at the MC location ($M = 2.43\%$, $SE = 0.73\%$) were less accurate than responses at the MI location ($M = 1.43\%$, $SE = 0.37\%$).

Across all four blocks, there was an interaction between PC and trial type, $F(1, 36) = 6.89$, $p = .013$, $\eta^2_p = .16$, such that the compatibility effect was larger at the MC location ($M = 4.12\%$, $SE = 0.82\%$) compared to the MI location ($M = 2.84\%$, $SE = 0.58\%$), indicating the CSPC effect. There was an effect of trial type, $F(1, 36) = 27.26$, $p < .001$, $\eta^2_p = .43$, such that responses to compatible trials ($M = 0.32\%$, $SE = 0.12\%$) were more accurate than responses to incompatible trials ($M = 3.79\%$, $SE = 0.69\%$). There was no effect of PC, $F(1, 36) = 3.08$, $p = .088$, $\eta^2_p = .08$, $BF_{01} = 3.93$, though responses at the MC location ($M = 2.30\%$, $SE = 0.67\%$) were nominally less accurate than responses at the MI location ($M = 1.81\%$, $SE = 0.46\%$).

**Diagnostic locations.** For trials at diagnostic locations, there was an interaction between near-PC and trial type, $F(1, 36) = 5.97$, $p = .020$, $\eta^2_p = .14$, such that the compatibility effect was
larger at the near-MC location (\(M = 5.16\%, SE = 1.03\%\)) compared to the near-MI location (\(M = 3.51\%, SE = 0.88\%\)), indicating transfer of the CSPC effect. There was an effect of trial type, \(F(1, 36) = 23.17, p < .001, \eta_p^2 = .39\), such that responses to compatible trials (\(M = 0.23\%, SE = 0.12\%\)) were more accurate than responses to incompatible trials (\(M = 4.56\%, SE = 0.97\%\)). There was no effect of near-PC, \(F(1, 36) = 3.22, p = .081, \eta_p^2 = .08, BF_{01} = 4.11\), though responses at the near-MC location (\(M = 2.69\%, SE = 0.86\%\)) were nominally less accurate than responses at the near-MI location (\(M = 2.09\%, SE = 0.69\%\)).

10.2 Experiment 1
Map background

Reaction time

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type (\(F(1, 59) = 26.28, p < .001, \eta_p^2 = .31\)) such that the compatibility effect was larger at the MC location (\(M = 174, SE = 8\)) than the MI location (\(M = 136, SE = 7\)), indicating the CSPC effect. There was an effect of PC, such that responses were slower at the MC location (\(M = 725, SE = 16\)) compared to the MI location (\(M = 716, SE = 14\), \(F(1, 59) = 4.37, p = .041, \eta_p^2 = .07\)). There was an effect of trial type, such that responses to compatible trials (\(M = 643, SE = 11\)) were faster than responses to incompatible trials (\(M = 798, SE = 12\), \(F(1, 59) = 527.80, p < .001, \eta_p^2 = .90\)).

Across all four blocks, there was an interaction between PC and trial type (\(F(1, 59) = 25.08, p < .001, \eta_p^2 = .30\)), such that the compatibility effect was larger at the MC location (\(M = 167, SE = 7\)) than the MI location (\(M = 138, SE = 6\)), indicating the CSPC effect. There was no effect of PC, \(F(1, 59) = 1.38, p = .244, \eta_p^2 = .02, BF_{01} = 6.73\). There was an effect of trial type,
such that responses to compatible trials ($M = 641, SE = 9$) were faster than responses to incompatible trials ($M = 793, SE = 10$), $F(1, 59) = 699.44, p < .001, \eta_p^2 = .92$.

**Diagnostic locations.** There was an interaction between near-PC and trial type ($F(1, 59) = 5.48, p = .023, \eta_p^2 = .09$), such that the compatibility effect was larger at the near-MC location ($M = 179, SE = 6$) than the near-MI location ($M = 166, SE = 6$), indicating transfer of the CSPC effect. There was no effect of near-PC, $F(1, 59) = 0.44, p = .509, \eta_p^2 = .01, BF_{01} = 6.94$. There was an effect of trial type, such that responses to compatible trials ($M = 700, SE = 10$) were faster than responses to incompatible trials ($M = 873, SE = 11$), $F(1, 59) = 1021.70, p < .001, \eta_p^2 = .95$.

**Error rate**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type ($F(1, 59) = 9.50, p = .003, \eta_p^2 = .14$), such that the compatibility effect was larger at the MC location ($M = 5.56\%, SE = 0.88\%$) than the MI location ($M = 3.13\%, SE = 0.42\%$), indicating transfer of the CSPC effect. There was an effect of PC, such that responses were less accurate at the MC location ($M = 3.25\%, SE = 0.80\%$) compared to the MI location ($M = 2.00\%, SE = 0.44\%$), $F(1, 59) = 9.23, p = .003, \eta_p^2 = .14$. There was an effect of trial type, such that responses to compatible trials ($M = 0.45\%, SE = 0.27\%$) were more accurate than responses to incompatible trials ($M = 4.79\%, SE = 0.78\%$), $F(1, 59) = 60.38, p < .001, \eta_p^2 = .14$.

Across all four blocks, there was an interaction between PC and trial type ($F(1, 59) = 13.98, p < .001, \eta_p^2 = .19$), such that the compatibility effect was larger at the MC location ($M = 4.62\%, SE = 0.59\%$) than the MI location ($M = 2.99\%, SE = 0.38\%$), indicating transfer of the CSPC effect. There was an effect of PC, such that responses were less accurate at the MC location ($M = 2.80\%, SE = 0.60\%$) compared to the MI location ($M = 2.18\%, SE = 0.53\%$), $F(1,
There was an effect of trial type, such that responses to compatible trials ($M = 0.59\%, SE = 0.37\%$) were more accurate than responses to incompatible trials ($M = 4.39\%, SE = 0.62\%$), $F(1, 59) = 74.07, p < .001, \eta^2_p = .56$.

**Diagnostic locations.** There was no interaction between near-PC and trial type, $F(1, 59) = 2.00, p = .162, \eta^2_p = .03, BF_{01} = 3.51$, indicating no transfer of the CSPC effect. There was no effect of near-PC, $F(1, 59) = 0.93, p = .338, \eta^2_p = .02, BF_{01} = 6.42$. There was an effect of trial type, such that responses to compatible trials ($M = 0.47\%, SE = 0.33\%$) were more accurate than responses to incompatible trials ($M = 5.67\%, SE = 0.79\%$), $F(1, 59) = 78.27, p < .001, \eta^2_p = .57$.

**Blank background**

**Reaction time**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type ($F(1, 59) = 20.86, p < .001, \eta^2_p = .26$), such that the compatibility effect was larger at the MC location ($M = 171, SE = 7$) than the MI location ($M = 140, SE = 6$), indicating a CSPC effect. There was no effect of PC, $F(1, 59) = 0.67, p = .417, \eta^2_p = .01, BF_{01} = 7.00$. There was an effect of trial type, such that responses to compatible trials ($M = 642, SE = 11$) were faster than responses to incompatible trials ($M = 797, SE = 13$), $F(1, 59) = 717.53, p < .001, \eta^2_p = .92$.

Across all four blocks, there was an interaction between PC and trial type ($F(1, 59) = 10.73, p = .002, \eta^2_p = .15$), such that the compatibility effect was larger at the MC location ($M = 163, SE = 6$) than the MI location ($M = 144, SE = 5$), indicating the CSPC effect. There was no effect of PC, $F(1, 59) = 0.18, p = .673, \eta^2_p < .01, BF_{01} = 7.28$. There was an effect of trial type, such that responses to compatible trials ($M = 647, SE = 9$) were faster than responses to incompatible trials ($M = 801, SE = 11$), $F(1, 59) = 943.13, p < .001, \eta^2_p = .94$. 

124
**Diagnostic locations.** There was an interaction between near-PC and trial type ($F(1, 59) = 12.08, p < .001, \eta^2_p = .17$), such that the compatibility effect was larger at the near-MC location ($M = 170, SE = 6$) than the near-MI location ($M = 145, SE = 7$), indicating transfer of the CSPC effect. There was no effect of near-PC, $F(1, 59) = 0.21, p = .645, \eta^2_p < .01, BF_01 = 6.85$. There was an effect of trial type, such that responses to compatible trials ($M = 703, SE = 11$) were faster than responses to incompatible trials ($M = 860, SE = 11$), $F(1, 59) = 796.86, p < .001, \eta^2_p = .93$.

**Error rate**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type ($F(1, 59) = 17.53, p < .001, \eta^2_p = .23$), such that the compatibility effect was larger at the MC location ($M = 5.07\%, SE = 0.80\%$) than the MI location ($M = 2.25\%, SE = 0.34\%$), indicating a CSPC effect. There was an effect of PC, such that responses were less accurate at the MC location ($M = 2.80\%, SE = 0.66\%$) compared to the MI location ($M = 1.40\%, SE = 0.30\%$), $F(1, 59) = 16.05, p < .001, \eta^2_p = .21$. There was an effect of trial type, such that responses to compatible trials ($M = 0.27\%, SE = 0.11\%$) were more accurate than responses to incompatible trials ($M = 3.93\%, SE = 0.65\%$), $F(1, 59) = 51.79, p < .001, \eta^2_p = .47$.

Across all four blocks, there was an interaction between PC and trial type ($F(1, 59) = 12.17, p < .001, \eta^2_p = .17$), such that the compatibility effect was larger at the MC location ($M = 4.75\%, SE = 0.67\%$) than the MI location ($M = 2.86\%, SE = 0.38\%$), indicating a CSPC effect. There was an effect of PC, such that responses were less accurate at the MC location ($M = 2.92\%, SE = 0.59\%$) compared to the MI location ($M = 1.92\%, SE = 0.38\%$), $F(1, 59) = 15.84, p < .001, \eta^2_p = .21$. There was an effect of trial type, such that responses to compatible trials ($M = 0.52\%, SE = 0.17\%$) were more accurate than responses to incompatible trials ($M = 4.32\%, SE = 0.59\%$), $F(1, 59) = 66.08, p < .001, \eta^2_p = .53$. 

125
Diagnostic locations. There was an interaction between near-PC and trial type ($F(1, 59) = 10.03, p = .002, \eta_p^2 = .15$), such that the compatibility effect was larger at the near-MC location ($M = 5.83\%, SE = 0.80\%$) than the near-MI location ($M = 4.28\%, SE = 0.69\%$), indicating transfer of the CSPC effect. There was an effect of near-PC, such that responses were less accurate at the near-MC location ($M = 3.58\%, SE = 0.77\%$) compared to the near-MI location ($M = 2.60\%, SE = 0.66\%$), $F(1, 59) = 11.26, p = .001, \eta_p^2 = .16$. There was an effect of trial type, such that responses to compatible trials ($M = 0.56\%, SE = 0.23\%$) were more accurate than responses to incompatible trials ($M = 5.62\%, SE = 0.87\%$) $F(1, 59) = 52.36, p < .001, \eta_p^2 = .47$.

10.3 Experiment 2
Map background

Reaction time

Inducer locations. In the inducer only blocks, there was an interaction between PC and trial type ($F(1, 59) = 25.91, p < .001, \eta_p^2 = .31$), such that the compatibility effect was larger at the MC location ($M = 162, SE = 6$) than the MI location ($M = 136, SE = 6$), indicating a CSPC effect. There was an effect of PC, such that responses were slower at the MC location ($M = 713, SE = 18$) compared to the MI location ($M = 703, SE = 17$), $F(1, 59) = 5.56, p = .022, \eta_p^2 = .09$. There was an effect of trial type, such that responses to compatible trials ($M = 633, SE = 14$) were faster than responses to incompatible trials ($M = 782, SE = 15$), $F(1, 59) = 853.96, p < .001, \eta_p^2 = .31$.

Across all four blocks, there was an interaction between PC and trial type ($F(1, 59) = 42.49, p < .001, \eta_p^2 = .42$), such that the compatibility effect was larger at the MC location ($M = 161, SE = 5$) than the MI location ($M = 135, SE = 5$), indicating a CSPC effect. There was no effect of PC, $F(1, 59) = 1.49, p = .227, \eta_p^2 = .03, BF_{01} = 6.98$. There was an effect of trial type,
such that responses to compatible trials \((M = 635, SE = 13)\) were faster than responses to incompatible trials \((M = 783, SE = 14)\), \(F(1, 59) = 900.53, p < .001, \eta^2 = .94.\)

**Diagnostic locations.** There was an interaction between near-PC and trial type \((F(1, 59) = 12.37, p < .001, \eta^2 = .17)\), such that the compatibility effect was larger at the near-MC location \((M = 167, SE = 5)\) than the near-MI location \((M = 144, SE = 6)\), indicating transfer of the CSPC effect. There was no effect of near-PC, \(F(1, 59) = 0.56, p = .458, \eta^2 = .01, BF_{01} = 7.03.\) There was an effect of trial type, such that responses to compatible trials \((M = 691, SE = 13)\) were faster than responses to incompatible trials \((M = 847, SE = 14)\), \(F(1, 59) = 1047.73, p < .001, \eta^2 = .95.\)

**Error rate**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type \((F(1, 59) = 4.63, p = .035, \eta^2 = .07)\), such that the compatibility effect was larger at the MC location \((M = 4.37\%, SE = 0.61\%)\) than the MI location \((M = 3.10\%, SE = 0.55\%)\), indicating a CSPC effect. There was an effect of PC, such that responses were less accurate at the MC location \((M = 2.47\%, SE = 0.56\%)\) compared to the MI location \((M = 1.70\%, SE = 0.49\%)\), \(F(1, 59) = 7.21, p = .009, \eta^2 = .11.\) There was an effect of trial type, such that responses to compatible trials \((M = 0.21\%, SE = 0.12\%)\) were more accurate than responses to incompatible trials \((M = 3.95\%, SE = 0.65\%)\), \(F(1, 59) = 57.28, p < .001, \eta^2 = .50.\)

Across all four blocks, there was an interaction between PC and trial type \((F(1, 59) = 7.66, p = .008, \eta^2 = .12)\), such that the compatibility effect was larger at the MC location \((M = 4.52\%, SE = 0.52\%)\) than the MI location \((M = 3.30\%, SE = 0.50\%)\), indicating a CSPC effect. There was an effect of PC, such that responses were less accurate at the MC location \((M = 2.59\%, SE = 0.52\%)\) compared to the MI location \((M = 2.01\%, SE = 0.49\%)\), \(F(1, 59) = 7.03, p = \)
There was an effect of trial type, such that responses to compatible trials (M = 0.35%, SE = 0.15%) were more accurate than responses to incompatible trials (M = 4.26%, SE = 0.60%), F(1, 59) = 73.94, p < .001, ηp² = .56.

**Diagnostic locations.** There was an interaction between near-PC and trial type (F(1, 59) = 6.63, p = .013, ηp² = .10), such that the compatibility effect was larger at the near-MC location (M = 5.61%, SE = 0.83%) than the near-MI location (M = 4.16%, SE = 0.88%), indicating transfer of a CSPC effect. There was an effect of near-PC, such that responses were less accurate at the near-MC location (M = 3.34%, SE = 0.77%) compared to the near-MI location (M = 2.55%, SE = 0.71%), F(1, 59) = 9.30, p < .003, ηp² = .14. There was an effect of trial type, such that responses to compatible trials (M = 0.50%, SE = 0.19%) were more accurate than responses to incompatible trials (M = 5.38%, SE = 0.93%), F(1, 59) = 37.36, p < .001, ηp² = .39.

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**Reaction time**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type (F(1, 59) = 19.41, p < .001, ηp² = .25), such that the compatibility effect was larger at the MC location (M = 152, SE = 6) than the MI location (M = 125, SE = 6), indicating a CSPC effect. There was no effect of PC, F(1, 59) = 0.51, p = .478, ηp² = .01, BF01 = 7.01. There was an effect of trial type, such that responses to compatible trials (M = 636, SE = 14) were faster than responses to incompatible trials (M = 774, SE = 15), F(1, 59) = 756.30, p < .001, ηp² = .93.

Across all four blocks, there was an interaction between PC and trial type (F(1, 59) = 19.78, p < .001, ηp² = .25), such that the compatibility effect was larger at the MC location (M = 153, SE = 5) than the MI location (M = 130, SE = 5), indicating a CSPC effect. There was no effect of PC, F(1, 59) = 0.30, p = .586, ηp² = .01, BF01 = 7.07. There was an effect of trial type,
such that responses to compatible trials \((M = 636, SE = 13)\) were faster than responses to incompatible trials \((M = 778, SE = 14)\), \(F(1, 59) = 1255.60, p < .001, \eta_p^2 = .96\).

**Diagnostic locations.** There was an interaction between near-PC and trial type \(F(1, 59) = 22.64, p < .001, \eta_p^2 = .28\), such that the compatibility effect was larger at the near-MC location \((M = 161, SE = 6)\) than the near-MI location \((M = 131, SE = 6)\), indicating transfer of a CSPC effect. There was no effect of near-PC, \(F(1, 59) = 0.52, p = .474, \eta_p^2 = .01, BF_{01} = 6.96\). There was an effect of trial type, such that responses to compatible trials \((M = 691, SE = 14)\) were faster than responses to incompatible trials \((M = 837, SE = 14)\), \(F(1, 59) = 829.52, p < .001, \eta_p^2 = .93\).

**Error rate**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type \(F(1, 59) = 9.74, p = .003, \eta_p^2 = .14\), such that the compatibility effect was larger at the MC location \((M = 4.39\%, SE = 0.89\%)\) than the MI location \((M = 2.24\%, SE = 0.38\%)\), indicating a CSPC effect. There was an effect of PC, such that responses were less accurate at the MC location \((M = 2.47\%, SE = 0.69\%)\) compared to the MI location \((M = 1.40\%, SE = 0.33\%)\), \(F(1, 59) = 11.70, p < .001, \eta_p^2 = .17\). There was an effect of trial type, such that responses to compatible trials \((M = 0.27\%, SE = 0.11\%)\) were more accurate than responses to incompatible trials \((M = 3.59\%, SE = 0.70\%)\), \(F(1, 59) = 31.90, p < .001, \eta_p^2 = .14\).

Across all four blocks, there was an interaction between PC and trial type \(F(1, 59) = 7.18, p = .010, \eta_p^2 = .11\), such that the compatibility effect was larger at the MC location \((M = 3.94\%, SE = 0.63\%)\) than the MI location \((M = 2.72\%, SE = 0.41\%)\), indicating a CSPC effect. There was an effect of PC, such that responses were less accurate at the MC location \((M = 2.34\%, SE = 0.53\%)\) compared to the MI location \((M = 1.68\%, SE = 0.36\%)\), \(F(1, 59) = 10.47, p = .002, \eta_p^2 = .14\).
=.002, \eta_p^2 = .15. There was an effect of trial type, such that responses to compatible trials (M = 0.34%, SE = 0.11%) were more accurate than responses to incompatible trials (M = 3.67%, SE = 0.56%), \(F(1, 59) = 48.48, p < .001, \eta_p^2 = .45.\)

**Diagnostic locations.** There was an interaction between near-PC and trial type (\(F(1, 59) = 17.14, p < .001, \eta_p^2 = .23\)), such that the compatibility effect was larger at the near-MC location (M = 5.52%, SE = 0.86%) than the near-MI location (M = 2.70%, SE = 0.55%), indicating transfer of the CSPC effect. There was an effect of near-PC, such that responses were less accurate at the near-MC location (M = 3.08%, SE = 0.73%) compared to the near-MI location (M = 1.95%, SE = 0.43%), \(F(1, 59) = 11.30, p = .001, \eta_p^2 = .16\). There was an effect of trial type, such that responses to compatible trials (M = 0.46%, SE = 0.15%) were more accurate than responses to incompatible trials (M = 4.57%, SE = 0.75%), \(F(1, 59) = 42.43, p < .001, \eta_p^2 = .42.\)

**10.4 Experiment 3**

**Map background**

**Reaction time**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type (\(F(1, 59) = 6.31, p = .015, \eta_p^2 = .10\)), such that the compatibility effect was larger at the MC location (M = 139, SE = 7) than the MI location (M = 122, SE = 6), indicating a CSPC effect. There was no effect of PC, \(F(1, 59) = 2.00, p = .162, \eta_p^2 = .03, BF_{01} = 6.54\). There was an effect of trial type, such that responses to compatible trials (M = 656, SE = 14) were faster than responses to incompatible trials (M = 786, SE = 15), \(F(1, 59) = 520.52, p < .001, \eta_p^2 = .90.\)

Across all four blocks, there was an interaction between PC and trial type (\(F(1, 59) = 14.42, p < .001, \eta_p^2 = .20\)), such that the compatibility effect was larger at the MC location (M = 144, SE = 6) than the MI location (M = 127, SE = 5), indicating a CSPC effect. There was no
effect of PC, $F(1, 59) = 1.25$, $p = .265$, $\eta^2_p = .02$, $BF_{01} = 6.79$. There was an effect of trial type, such that responses to compatible trials ($M = 657$, $SE = 14$) were faster than responses to incompatible trials ($M = 792$, $SE = 15$), $F(1, 59) = 668.30$, $p < .001$, $\eta^2_p = .92$.

**Diagnostic locations.** There was no interaction between near-PC and trial type, $F(1, 59) = 3.01$, $p = .088$, $\eta^2_p = .05$, $BF_{01} = 2.81$, indicating no transfer of the CSPC effect. There was no effect of near-PC, $F(1, 59) = 1.19$, $p = .279$, $\eta^2_p = .02$, $BF_{01} = 6.74$. There was an effect of trial type, such that responses to compatible trials ($M = 726$, $SE = 15$) were faster than responses to incompatible trials ($M = 858$, $SE = 15$), $F(1, 59) = 636.12$, $p < .001$, $\eta^2_p = .92$.

**Error rate**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type ($F(1, 59) = 10.12$, $p = .002$, $\eta^2_p = .15$), such that the compatibility effect was larger at the MC location ($M = 3.65\%$, $SE = 0.61\%$) than the MI location ($M = 2.11\%$, $SE = 0.34\%$), indicating a CSPC effect. There was an effect of PC, such that responses were less accurate at the MC location ($M = 2.39\%$, $SE = 0.56\%$) compared to the MI location ($M = 1.33\%$, $SE = 0.34\%$), $F(1, 59) = 17.72$, $p < .001$, $\eta^2_p = .23$. There was an effect of trial type, such that responses to compatible trials ($M = 0.42\%$, $SE = 0.23\%$) were more accurate than responses to incompatible trials ($M = 3.30\%$, $SE = 0.56\%$), $F(1, 59) = 45.45$, $p < .001$, $\eta^2_p = .44$.

Across all four blocks, there was no interaction between PC and trial type, such that the compatibility effect was only nominally larger at the MC location ($M = 3.34\%$, $SE = 0.48\%$) than the MI location ($M = 2.73\%$, $SE = 0.40\%$), $F(1, 59) = 3.83$, $p = .055$, $\eta^2_p = .06$, $BF_{01} = 3.08$. There was an effect of PC, such that responses were less accurate at the MC location ($M = 2.11\%$, $SE = 0.43\%$) compared to the MI location ($M = 1.51\%$, $SE = 0.35\%$), $F(1, 59) = 14.78$, $p < .001$, $\eta^2_p = .20$. There was an effect of trial type, such that responses to compatible trials ($M =
0.29%, \( SE = 0.13\% \) were more accurate than responses to incompatible trials (\( M = 3.33\%, SE = 0.47\% \)), \( F(1, 59) = 55.12, p < .001, \eta^2_p = .48. \)

**Diagnostic locations.** There was no interaction between near-PC and trial type, \( F(1, 59) = 0.01, p = .926, \eta^2_p < .01, BF_{01} = 5.49 \), indicating no transfer of the CSPC effect. There was no effect of near-PC, \( F(1, 59) = 0.03, p = .856, \eta^2_p < .01, BF_{01} = 6.69 \). There was an effect of trial type, such that responses to compatible trials (\( M = 0.49\%, SE = 0.18\% \)) were more accurate than responses to incompatible trials (\( M = 3.62\%, SE = 0.58\% \)), \( F(1, 59) = 45.39, p < .001, \eta^2_p = .44. \)

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**Reaction time**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type (\( F(1, 59) = 36.89, p < .001, \eta^2_p = .39 \)), such that the compatibility effect was larger at the MC location (\( M = 173, SE = 7 \)) than the MI location (\( M = 132, SE = 6 \)), indicating a CSPC effect. There was no effect of PC, \( F(1, 59) = 0.99, p = .323, \eta^2_p = .02, BF_{01} = 6.79 \). There was an effect of trial type, such that responses to compatible trials (\( M = 642, SE = 14 \)) were faster than responses to incompatible trials (\( M = 794, SE = 14 \)), \( F(1, 59) = 811.89, p < .001, \eta^2_p = .93. \)

Across all four blocks, there was an interaction between PC and trial type (\( F(1, 59) = 24.20, p < .001, \eta^2_p = .29 \)), such that the compatibility effect was larger at the MC location (\( M = 169, SE = 5 \)) than the MI location (\( M = 144, SE = 5 \)), indicating a CSPC effect. There was no effect of PC, \( F(1, 59) = 3.20, p = .079, \eta^2_p = .05, BF_{01} = 6.39 \). There was an effect of trial type, such that responses to compatible trials (\( M = 638, SE = 13 \)) were faster than responses to incompatible trials (\( M = 795, SE = 13 \)), \( F(1, 59) = 1252.85, p < .001, \eta^2_p = .96. \)

**Diagnostic locations.** There was no interaction between near-PC and trial type, \( F(1, 59) = 3.36, p = .072, \eta^2_p = .05, BF_{01} = 1.58 \), indicating no transfer of the CSPC effect. There was no
effect of near-PC, $F(1, 59) = 0.01, p = .908, \eta^2_p < .01, BF_{01} = 7.07$. There was an effect of trial type, such that responses to compatible trials ($M = 688, SE = 14$) were faster than responses to incompatible trials ($M = 845, SE = 14$), $F(1, 59) = 756.44, p < .001, \eta^2_p = .93$.

**Error rate**

**Inducer locations.** In the inducer only blocks, there was no interaction between PC and trial type, $F(1, 59) = 1.98, p = .165, \eta^2_p = .03, BF_{01} = 2.69$. There was an effect of PC, such that responses were less accurate at the MC location ($M = 2.43\%, SE = 0.60\%$) compared to the MI location ($M = 1.75\%, SE = 0.44\%), F(1, 59) = 5.18, p = .027, \eta^2_p = .08$. There was an effect of trial type, such that responses to compatible trials ($M = 0.33\%, SE = 0.11\%$) were more accurate than responses to incompatible trials ($M = 3.84\%, SE = 0.66\%), F(1, 59) = 35.89, p < .001, \eta^2_p = .38$.

Across all four blocks, there was an interaction between PC and trial type ($F(1, 59) = 5.94, p = .018, \eta^2_p = .09$), such that the compatibility effect was larger at the MC location ($M = 4.45\%, SE = 0.72\%$) than the MI location ($M = 3.41\%, SE = 0.53\%$), indicating the CSPC effect. There was an effect of PC, such that responses were less accurate at the MC location ($M = 2.64\%, SE = 0.60\%$) compared to the MI location ($M = 1.91\%, SE = 0.43\%), F(1, 59) = 11.73, p = .001, \eta^2_p = .17$. There was an effect of trial type, such that responses to compatible trials ($M = 0.31\%, SE = 0.09\%$) were more accurate than responses to incompatible trials ($M = 4.24\%, SE = 0.64\%), F(1, 59) = 44.82, p < .001, \eta^2_p = .43$.

**Diagnostic locations.** There was an interaction between near-PC and trial type ($F(1, 59) = 4.68, p = .035, \eta^2_p = .08$), such that the compatibility effect was larger at the near-MC location ($M = 5.29\%, SE = 0.75\%$) than the near-MI location ($M = 3.74\%, SE = 0.56\%$), indicating transfer of the CSPC effect. There was no effect of near-PC, $F(1, 59) = 0.41, p = .526, \eta^2_p = .01$, 133
BF$_{01} = 5.67$. There was an effect of trial type, such that responses to compatible trials ($M = 0.45\%, SE = 0.15\%$) were more accurate than responses to incompatible trials ($M = 4.97\%, SE = 0.71\%$), $F(1, 59) = 68.61, p < .001, \eta^2_p = .54$.

### 10.5 Experiment 4

#### Map background

**Reaction time**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type ($F(1, 59) = 11.20, p = .001, \eta^2_p = .16$), such that the compatibility effect was larger at the MC location ($M = 135, SE = 6$) than the MI location ($M = 114, SE = 6$), indicating a CSPC effect. There was no effect of PC, $F(1, 59) = 0.05, p = .824, \eta^2_p < .01, BF_{01} = 7.23$. There was an effect of trial type, such that responses to compatible trials ($M = 665, SE = 14$) were faster than responses to incompatible trials ($M = 789, SE = 16$), $F(1, 59) = 597.31, p < .001, \eta^2_p = .91$.

Across all four blocks, there was an interaction between PC and trial type ($F(1, 59) = 14.36, p < .001, \eta^2_p = .20$), such that the compatibility effect was larger at the MC location ($M = 138, SE = 5$) than the MI location ($M = 122, SE = 5$), indicating a CSPC effect. There was no effect of PC, $F(1, 59) = 0.20, p = .660, \eta^2_p < .01, BF_{01} = 7.13$. There was an effect of trial type, such that responses to compatible trials ($M = 668, SE = 14$) were faster than responses to incompatible trials ($M = 798, SE = 16$), $F(1, 59) = 868.08, p < .001, \eta^2_p = .94$.

**Diagnostic locations.** There was an interaction between near-PC and trial type ($F(1, 59) = 7.45, p = .008, \eta^2_p = .11$), such that the compatibility effect was larger at the near-MC location ($M = 148, SE = 5$) than the near-MI location ($M = 128, SE = 6$), indicating transfer of the CSPC effect. There was no effect of near-PC, $F(1, 59) = 0.35, p = .555, \eta^2_p = .01, BF_{01} = 6.80$. There was an effect of trial type, such that responses to compatible trials ($M = 731, SE = 14$) were
faster than responses to incompatible trials ($M = 869, SE = 16$), $F(1, 59) = 1030.17, p < .001, \eta_p^2 = .95$.

**Error rate**

**Inducer locations.** In the inducer only blocks, there was no interaction between PC and trial type, $F(1, 59) = 2.55, p = .116, \eta_p^2 = .04, BF_{01} = 1.98$. There was no effect of PC, $F(1, 59) = 0.31, p = .580, \eta_p^2 = .01, BF_{01} = 6.54$. There was an effect of trial type, such that responses to compatible trials ($M = 0.86\%, SE = 0.41\%$) were more accurate than responses to incompatible trials ($M = 3.08\%, SE = 0.54\%$), $F(1, 59) = 31.55, p < .001, \eta_p^2 = .35$.

Across all four blocks, there was no interaction between PC and trial type, such that the compatibility effect was only nominally larger at the MC location ($M = 2.72\%, SE = 0.42\%$) than the MI location ($M = 1.99\%, SE = 0.36\%$), $F(1, 59) = 3.81, p = .056, \eta_p^2 = .06, BF_{01} = 1.91$. There was no effect of PC, $F(1, 59) = 1.10, p = .300, \eta_p^2 = .02, BF_{01} = 5.74$. There was an effect of trial type, such that responses to compatible trials ($M = 0.75\%, SE = 0.35\%$) were more accurate than responses to incompatible trials ($M = 3.10\%, SE = 0.43\%$), $F(1, 59) = 48.73, p < .001, \eta_p^2 = .45$.

**Diagnostic locations.** There was no interaction between near-PC and trial type, $F(1, 59) = 0.02, p = .902, \eta_p^2 < .01, BF_{01} = 5.03$. There was no effect of near-PC, $F(1, 59) = 0.89, p = .350, \eta_p^2 = .02, BF_{01} = 5.85$. There was an effect of trial type, such that responses to compatible trials ($M = 0.73\%, SE = 0.34\%$) were more accurate than responses to incompatible trials ($M = 3.78\%, SE = 0.50\%$), $F(1, 59) = 55.85, p < .001, \eta_p^2 = .49$.

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**Reaction time**
**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type \( F(1, 59) = 11.46, p = .001, \eta_p^2 = .16 \), such that the compatibility effect was larger at the MC location \( (M = 164, SE = 8) \) than the MI location \( (M = 136, SE = 7) \), indicating a CSPC effect. There was no effect of PC, \( F(1, 59) = 0.53, p = .470, \eta_p^2 = .01, BF_{01} = 6.98 \). There was a significant effect of trial type, such that responses to compatible trials \( (M = 646, SE = 14) \) were faster than responses to incompatible trials \( (M = 796, SE = 16) \), \( F(1, 59) = 603.90, p < .001, \eta_p^2 = .91 \).

Across all four blocks, there was an interaction between PC and trial type \( F(1, 59) = 7.98, p = .006, \eta_p^2 = .12 \), such that the compatibility effect was larger at the MC location \( (M = 156, SE = 5) \) than the MI location \( (M = 140, SE = 6) \), indicating a CSPC effect. There was no effect of PC, \( F(1, 59) = 2.30, p = .135, \eta_p^2 = .04, BF_{01} = 6.55 \). There was an effect of trial type, such that responses to compatible trials \( (M = 642, SE = 13) \) were faster than responses to incompatible trials \( (M = 790, SE = 15) \), \( F(1, 59) = 1111.36, p < .001, \eta_p^2 = .95 \).

**Diagnostic locations.** There was an interaction between near-PC and trial type \( F(1, 59) = 9.63, p = .003, \eta_p^2 = .14 \), such that the compatibility effect was larger at the near-MC location \( (M = 164, SE = 6) \) than the near-MI location \( (M = 141, SE = 6) \), indicating transfer of a CSPC effect. There was no effect of near-PC, \( F(1, 59) = 1.92, p = .171, \eta_p^2 = .03, BF_{01} = 6.30 \). There was an effect of trial type, such that responses to compatible trials \( (M = 690, SE = 14) \) were faster than responses to incompatible trials \( (M = 843, SE = 15) \), \( F(1, 59) = 869.31, p < .001, \eta_p^2 = .94 \).

**Error rate**

**Inducer locations.** In the inducer only blocks, there was no interaction between PC and trial type, \( F(1, 59) = 2.13, p = .150, \eta_p^2 = .04, BF_{01} = 3.35 \). There was an effect of PC, such that
responses were less accurate at the MC location ($M = 2.21\%, SE = 0.52\%$) compared to the MI location ($M = 1.54\%, SE = 0.39\%$), $F(1, 59) = 4.17, p = .046, \eta_p^2 = .07$. There was an effect of trial type, such that responses to compatible trials ($M = 0.45\%, SE = 0.20\%$) were more accurate than responses to incompatible trials ($M = 3.29\%, SE = 0.56\%$), $F(1, 59) = 46.46, p < .001, \eta_p^2 = .44$.

Across all four blocks, there was no interaction between PC and trial type, such that the compatibility effect was only nominally larger at the MC location ($M = 3.48\%, SE = 0.53\%$) than the MI location ($M = 2.55\%, SE = 0.32\%$), $F(1, 59) = 3.59, p = .063, \eta_p^2 = .06, BF_{01} = 1.49$. There was an effect of PC, such that responses were less accurate at the MC location ($M = 2.33\%, SE = 0.48\%$) compared to the MI location ($M = 1.77\%, SE = 0.35\%$), $F(1, 59) = 7.75, p = .007, \eta_p^2 = .12$. There was an effect of trial type, such that responses to compatible trials ($M = 0.54\%, SE = 0.18\%$) were more accurate than responses to incompatible trials ($M = 3.55\%, SE = 0.50\%$), $F(1, 59) = 70.04, p < .001, \eta_p^2 = .54$.

**Diagnostic locations.** There was no interaction between near-PC and trial type, such that the compatibility effect was only nominally larger at the near-MC location ($M = 4.63\%, SE = 0.58\%$) than the near-MI location ($M = 3.39\%, SE = 0.58\%$), $F(1, 59) = 3.22, p = .078, \eta_p^2 = .05, BF_{01} = 1.47$. There was an effect of near-PC, such that responses were less accurate at the near-MC location ($M = 2.92\%, SE = 0.58\%$) compared to the near-MI location ($M = 2.33\%, SE = 0.52\%$), $F(1, 59) = 4.98, p = .029, \eta_p^2 = .08$. There was an effect of trial type, such that responses to compatible trials ($M = 0.62\%, SE = 0.24\%$) were more accurate than responses to incompatible trials ($M = 4.63\%, SE = 0.64\%$), $F(1, 59) = 76.06, p < .001, \eta_p^2 = .56$.

**10.6 Experiment 5**

Map background
**Reaction time**

**Inducer locations.** In the inducer only blocks, there was no interaction between PC and trial type, $F(1, 59) = 0.04, p = .838, \eta_p^2 < .01, BF_{01} = 4.82$. There was an effect of PC, such that responses were faster at the MC location ($M = 746, SE = 16$) compared to the MI location ($M = 758, SE = 15$), $F(1, 59) = 5.54, p = .022, \eta_p^2 = .09$. There was an effect of trial type, such that responses to compatible trials ($M = 690, SE = 12$) were faster than responses to incompatible trials ($M = 813, SE = 14$), $F(1, 59) = 495.81, p < .001, \eta_p^2 = .89$.

Across all four blocks, there was no interaction between PC and trial type, $F(1, 59) = 2.93, p = .092, \eta_p^2 = .05, BF_{01} = 3.26$. There was no effect of PC, such that responses were only nominally faster at the MC location ($M = 749, SE = 14$) compared to the MI location ($M = 757, SE = 14$), $F(1, 59) = 4.00, p = .050, \eta_p^2 = .06, BF_{01} = 5.47$. There was an effect of trial type, such that responses to compatible trials ($M = 694, SE = 10$) were faster than responses to incompatible trials ($M = 815, SE = 12$), $F(1, 59) = 603.31, p < .001, \eta_p^2 = .91$.

**Diagnostic locations.** There was no interaction between near-PC and trial type, $F(1, 59) = 0.03, p = .863, \eta_p^2 < .01, BF_{01} = 4.72$. There was no effect of near-PC, $F(1, 59) = .82, p = .369, \eta_p^2 = .01, BF_{01} = 6.61$. There was an effect of trial type, such that responses to compatible trials ($M = 694, SE = 10$) were faster than responses to incompatible trials ($M = 801, SE = 12$), $F(1, 59) = 430.26, p < .001, \eta_p^2 = .88$.

**Error rate**

**Inducer locations.** In the inducer only blocks, there was no interaction between PC and trial type, such that the compatibility effect was nominally smaller at the MC location ($M = 3.04\%, SE = 0.69\%$) than the MI location ($M = 3.98\%, SE = 0.57\%$), $F(1, 59) = 3.17, p = .080, \eta_p^2 = .05, BF_{01} = 2.63$. There was no effect of PC, $F(1, 59) = 0.89, p = .350, \eta_p^2 = .02, BF_{01} =  

138
6.23. There was an effect of trial type, such that responses to compatible trials ($M = 0.52\%, SE = 0.15\%$) were more accurate than responses to incompatible trials ($M = 4.04\%, SE = 0.66\%$), $F(1, 59) = 38.42, p < .001, \eta^2_p = .39$.

Across all four blocks, there was no interaction between PC and trial type, $F(1, 59) < 0.01, p = .966, \eta^2_p < .01, BF_{01} = 5.12$. There was no effect of PC, $F(1, 59) = 1.23, p = .273, \eta^2_p = .02, BF_{01} = 6.27$. There was an effect of trial type, such that responses to compatible trials ($M = 0.77\%, SE = 0.20\%$) were more accurate than responses to incompatible trials ($M = 5.36\%, SE = 0.61\%$), $F(1, 59) = 82.40, p < .001, \eta^2_p = .58$.

**Diagnostic locations.** There was no interaction between near-PC and trial type, $F(1, 59) = 0.12, p = .730, \eta^2_p < .01, BF_{01} = 5.02$. There was no effect of near-PC, $F(1, 59) = 2.26, p = .138, \eta^2_p = .04, BF_{01} = 4.44$. There was an effect of trial type, such that responses to compatible trials ($M = 1.23\%, SE = 0.41\%$) were more accurate than responses to incompatible trials ($M = 4.22\%, SE = 0.65\%$), $F(1, 59) = 48.71, p < .001, \eta^2_p = .45$.

**Blank background**

**Reaction time**

**Inducer locations.** In the inducer only blocks, there was an interaction between PC and trial type ($F(1, 59) = 22.25, p < .001, \eta^2_p = .27$), such that the compatibility effect was larger at the MC location ($M = 160, SE = 7$) than the MI location ($M = 131, SE = 6$), indicating a CSPC effect. There was no effect of PC, $F(1, 59) = 0.10, p = .756, \eta^2_p < .01, BF_{01} = 7.15$. There was an effect of trial type, such that responses to compatible trials ($M = 666, SE = 12$) were faster than responses to incompatible trials ($M = 812, SE = 12$), $F(1, 59) = 607.71, p < .001, \eta^2_p = .91$.

Across all four blocks, there was an interaction between PC and trial type ($F(1, 59) = 16.49, p < .001, \eta^2_p = .22$), such that the compatibility effect was larger at the MC location ($M =$
165, \( SE = 6 \) than the MI location \( (M = 142, SE = 5) \), indicating a CSPC effect. There was no effect of PC, \( F(1, 59) = 0.16, p = .694, \eta_p^2 < .01, BF_{01} = 7.05 \). There was an effect of trial type, such that responses to compatible trials \( (M = 658, SE = 10) \) were faster than responses to incompatible trials \( (M = 811, SE = 12) \), \( F(1, 59) = 1050.16, p < .001, \eta_p^2 = .95 \).

**Diagnostic locations.** There was no interaction between near-PC and trial type, \( F(1, 59) = 0.84, p = .364, \eta_p^2 = .01, BF_{01} = 3.68 \), indicating no transfer of the CSPC effect. There was no effect of near-PC, \( F(1, 59) < 0.01, p = .969, \eta_p^2 < .01, BF_{01} = 7.07 \). There was an effect of trial type, such that responses to compatible trials \( (M = 653, SE = 11) \) were faster than responses to incompatible trials \( (M = 784, SE = 12) \), \( F(1, 59) = 643.42, p < .001, \eta_p^2 = .92 \).

**Error rate**

**Inducer locations.** In the inducer only blocks, there was no interaction between PC and trial type, such that the compatibility effect was only nominally larger at the MC location \( (M = 5.27\%, SE = 0.82\%) \) than the MI location \( (M = 4.03\%, SE = 0.58\%) \), \( F(1, 59) = 3.72, p = .058, \eta_p^2 = .06, BF_{01} = 2.14 \). There was an effect of PC, such that responses were less accurate at the MC location \( (M = 3.20\%, SE = 0.70\%) \) compared to the MI location \( (M = 2.51\%, SE = 0.56\%) \), \( F(1, 59) = 4.55, p = .037, \eta_p^2 = .07 \). There was an effect of trial type, such that responses to compatible trials \( (M = 0.53\%, SE = 0.22\%) \) were more accurate than responses to incompatible trials \( (M = 5.17\%, SE = 0.76\%) \), \( F(1, 59) = 55.39, p < .001, \eta_p^2 = .48 \).

Across all four blocks, there was no interaction between PC and trial type, \( F(1, 59) = 2.81, p = .099, \eta_p^2 = .05, BF_{01} = 2.89 \). There was an effect of PC, such that responses were less accurate at the MC location \( (M = 3.60\%, SE = 0.73\%) \) compared to the MI location \( (M = 3.04\%, SE = 0.62\%) \), \( F(1, 59) = 4.41, p = .040, \eta_p^2 = .07 \). There was an effect of trial type, such that
responses to compatible trials ($M = 0.81\%, SE = 0.26\%$) were more accurate than responses to incompatible trials ($M = 5.83\%, SE = 0.79\%$), $F(1, 59) = 69.64, p < .001, \eta_{p}^2 = .54$.

**Diagnostic locations.** There was no interaction between near-PC and trial type, $F(1, 59) = 1.51, p = .224, \eta_{p}^2 = .03, BF_{01} = 3.67$. There was no effect of near-PC, $F(1, 59) = 0.01, p = .938, \eta_{p}^2 < .01, BF_{01} = 6.57$. There was an effect of trial type, such that responses to compatible trials ($M = 1.25\%, SE = 0.40\%$) were more accurate than responses to incompatible trials ($M = 5.73\%, SE = 0.86\%$), $F(1, 59) = 57.35, p < .001, \eta_{p}^2 = .49$. 
Appendix D: Linear mixed-effects models

As planned pre-registered analyses, all studies were separately analyzed using linear mixed-effects models. ANOVAs were used as the primary analysis due to their nearly ubiquitous use within the CSPC literature. However, linear mixed-effects models allow for the same hypotheses to be tested using a method that has been shown to capture subtle effects with greater power and greater ease of including additional continuous factors that potentially explain variance in the data (see e.g., Brown 2021). Potentially, including these models would allow for potentially subtle effects that were not found with an ANOVA to emerge. These analyses were completed using RStudio version 2022.12.0 (R Core Team), the lme4 package (Bates et al., 2014) and the lmerTest package (Kuznetsova et al., 2017).

Data were fitted to a linear model with fixed effect factors of background (blank or map), PC (MC or MI), and trial type (compatible or incompatible), as well as all interactions of the above factors. The model used separate random effect factors of participant id (1 | id) and stimuli (1 | stimuli). The random effect factor of stimuli captures variance related to each of the four responses (i.e., up, down, left, and right) as well as each combination of target and distractor arrows (cf. Suh & Bugg, 2021 for similar random effects in a proportion congruence manipulation). Although including additional explanation of variance by including additional factors or slopes in the random effects structure is preferable (e.g., Barr et al., 2013; Matuschek et al., 2017), the models failed to converge upon inclusion of those factors.

As with the repeated-measures ANOVAs, separate analyses were run for trials at inducer locations in the inducer only blocks, trials at inducer locations across all blocks, and trials at diagnostic locations during the diagnostic blocks. These analyses were run exclusively for reaction time, as performance close to ceiling affects interpretability of effects in error rate. To
account for the positive skew in reaction time data, RT was transformed as (-1/RT). I reported the effect from the linear mixed-effects model if a difference emerged from repeated-measures ANOVAs for the main effect of background, the interaction between PC and trial type, or the interaction between background, PC, and trial type.

As part of a linear mixed-effects model analysis, I separately ran analyses including participants responses to the map survey. Knowledge of maps or of the specific areas included on the map may have modulated how meaningful the boundaries were to the participant. In Experiments 1 & 2, this analysis included categorical predictors of whether the participant was born in the United States and whether the state in which they lived the longest was present on the map used in the experiment. The models also included an aggregate score of their map knowledge and an aggregate score of their confidence and experience using maps. In Experiments 3 and 4, the analysis included categorical predictors of whether the participant was born in the United States and whether they have been to the ocean depicted on the background image in the map background condition. These models also included an aggregate score of a survey of their confidence and experience using maps. The models used in Experiment 5 were identical to those used in Experiments 3 and 4, but they removed the predictor of whether the participant was born in the United States. See Appendix A for each map survey and the scoring procedures.

11.1 Experiment 1
For trials at inducer locations in inducer only blocks, results from the linear mixed-effects models were consistent with the effects observed using repeated-measures ANOVAs. The linear mixed-effects model indicated an effect of background for both inducer locations across all blocks (β = -17.78, t = 4.87, p = .001) such that responses were faster on the map background
than the blank background. Otherwise, all other effects were consistent with the effects observed using a repeated-measures ANOVA. At diagnostic locations there was an effect of background ($\beta = 14.37, t = 2.21, p = .027$), such that responses were slower on the map background than the blank background. Otherwise, all other effects were consistent with the effects observed using repeated-measures ANOVAs (see Tables 11.1 and 11.2).

Across all analyses, none of the predictors from the map survey interacted with the interaction between map, PC, and trial type from the linear mixed-effects models.

Table 11.1

*Linear Mixed-Effects Model Output for Trials at Inducer Locations in Experiment 1*

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimates</th>
<th>CI</th>
<th>t</th>
<th>p</th>
<th>Estimates</th>
<th>CI</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-1658.26</td>
<td>-1753.86–-1562.66</td>
<td>34.00</td>
<td>&lt;.001</td>
<td>-1647.65</td>
<td>-1743.00–-1552.30</td>
<td>33.87</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Trial Type</td>
<td>356.35</td>
<td>251.07–461.64</td>
<td>6.63</td>
<td>&lt;.001</td>
<td>346.58</td>
<td>241.51–451.64</td>
<td>6.47</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>PC</td>
<td>27.01</td>
<td>11.12–42.89</td>
<td>3.33</td>
<td>&lt;.001</td>
<td>20.43</td>
<td>9.10–31.75</td>
<td>3.54</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Background</td>
<td>-7.11</td>
<td>-17.17–2.95</td>
<td>1.38</td>
<td>.166</td>
<td>-17.78</td>
<td>-24.94–-10.62</td>
<td>4.87</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Trial Type X PC</td>
<td>-60.71</td>
<td>-83.49–-37.93</td>
<td>5.22</td>
<td>&lt;.001</td>
<td>-44.87</td>
<td>-61.10–-28.64</td>
<td>5.42</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Trial Type X Background</td>
<td>17.46</td>
<td>-5.58–40.50</td>
<td>1.49</td>
<td>.138</td>
<td>14.83</td>
<td>-1.54–31.20</td>
<td>1.78</td>
<td>.076</td>
</tr>
<tr>
<td>PC X Background</td>
<td>-0.34</td>
<td>-22.84–22.16</td>
<td>0.03</td>
<td>.977</td>
<td>6.86</td>
<td>-9.17–22.88</td>
<td>0.84</td>
<td>.402</td>
</tr>
<tr>
<td>Trial Type X PC X Background</td>
<td>-14.0173</td>
<td>-46.27–18.24</td>
<td>0.85</td>
<td>.394</td>
<td>-15.28</td>
<td>-38.22–7.66</td>
<td>1.31</td>
<td>.192</td>
</tr>
</tbody>
</table>

*Note. PC= proportion congruency, CI = 95% confidence interval. Factors were dummy coded such that compatible was the baseline level in trial type, MC was the baseline level in PC, and blank background was the baseline level in background.*
Table 11.2
Linear Mixed-Effects Model Output for Trials at Diagnostic Locations in Experiment 1

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimates</th>
<th>CI</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-1523.99</td>
<td>-1607.57 – -1440.41</td>
<td>35.74</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial Type</td>
<td>312.93</td>
<td>221.16 – 404.71</td>
<td>6.68</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Near-PC</td>
<td>32.90</td>
<td>20.12 – 45.68</td>
<td>5.05</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Background</td>
<td>14.37</td>
<td>1.61 – 27.13</td>
<td>2.21</td>
<td>.027</td>
</tr>
<tr>
<td>Trial Type X Near-PC</td>
<td>-43.89</td>
<td>-62.22 – -25.55</td>
<td>4.69</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial Type X Background</td>
<td>7.62</td>
<td>-10.74 – 25.98</td>
<td>0.81</td>
<td>.416</td>
</tr>
<tr>
<td>Near-PC X Background</td>
<td>-12.48</td>
<td>-30.52 – 5.56</td>
<td>1.36</td>
<td>.175</td>
</tr>
<tr>
<td>Trial Type X Near-PC X Background</td>
<td>14.09</td>
<td>-11.82 – 39.99</td>
<td>1.07</td>
<td>.287</td>
</tr>
</tbody>
</table>

Note. Near-PC = near proportion congruence, CI = 95% confidence interval. Factors were dummy coded such that compatible was the baseline level in trial type, near-MC was the baseline level in near-PC, and blank background was the baseline level in background.

11.2 Experiment 2
For trials at inducer locations in inducer blocks, there was an effect of background ($\beta = 11.78$, $t = 2.42$, $p = .015$), such that responses were slower in the map background condition than the blank background condition. Otherwise, all results from the linear mixed-effects models were consistent with the effects observed using repeated-measures ANOVAs (see Tables 11.3 & 11.4). All results from the linear mixed-effects models at inducer locations across blocks and at diagnostic locations were consistent with the effects using repeated-measures ANOVAs.
Across all analyses, none of the predictors from the map survey interacted with the interaction between background, PC, and trial type from the linear mixed-effects models.

Table 11.3

Linear Mixed-Effects Model Output for Trials at Inducer Locations in Experiment 2

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Inducer Blocks Only</th>
<th>Across All Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimates</td>
<td>CI</td>
</tr>
<tr>
<td>(Intercept)</td>
<td>-1690.92</td>
<td>-1782.62 - 1599.22</td>
</tr>
<tr>
<td>Trial Type</td>
<td>348.23</td>
<td>256.61 - 439.84</td>
</tr>
<tr>
<td>PC</td>
<td>45.83</td>
<td>30.77 - 60.88</td>
</tr>
<tr>
<td>Background</td>
<td>11.78</td>
<td>2.25 - 21.31</td>
</tr>
<tr>
<td>Trial Type X PC</td>
<td>-67.75</td>
<td>-89.30 - 46.19</td>
</tr>
<tr>
<td>Trial Type X Background</td>
<td>5.72</td>
<td>-16.04 - 27.48</td>
</tr>
<tr>
<td>PC X Background</td>
<td>-28.70</td>
<td>-50.00 - 7.40</td>
</tr>
<tr>
<td>Trial Type X PC X Background</td>
<td>10.33</td>
<td>-20.16 - 40.82</td>
</tr>
</tbody>
</table>

*Note.* PC = proportion congruency, CI = 95% confidence interval. Factors were dummy coded such that compatible was the baseline level in trial type, MC was the baseline level in PC, and blank background was the baseline level in background.
Table 11.4

*Linear Mixed-Effects Model Output for Trials at Diagnostic Locations in Experiment 2*

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimates</th>
<th>CI</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-1551.05</td>
<td>-1635.88 – -1466.21</td>
<td>35.84</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Trial Type</td>
<td>309.61</td>
<td>222.51 – 396.71</td>
<td>6.97</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Near-PC</td>
<td>37.08</td>
<td>24.92 – 49.25</td>
<td>5.98</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Background</td>
<td>9.29</td>
<td>-2.88 – 21.45</td>
<td>1.50</td>
<td>.135</td>
</tr>
<tr>
<td>Trial Type X Near-PC</td>
<td>-55.41</td>
<td>-72.80 – -38.01</td>
<td>6.24</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Trial Type X Background</td>
<td>5.29</td>
<td>-22.76 – 12.18</td>
<td>0.59</td>
<td>.553</td>
</tr>
<tr>
<td>Near-PC X Background</td>
<td>-3.32</td>
<td>-20.54 – 13.89</td>
<td>0.38</td>
<td>.705</td>
</tr>
<tr>
<td>Trial Type X Near-PC X Background</td>
<td>7.16</td>
<td>-17.49 – 31.80</td>
<td>0.57</td>
<td>0.569</td>
</tr>
</tbody>
</table>

*Note.* Near-PC= near proportion congruence, CI = 95% confidence interval. Factors were dummy coded such that compatible was the baseline level in trial type, near-MC was the baseline level in near-PC, and blank background was the baseline level in background.

### 11.3 Experiment 3

For trials at inducer locations in the inducer blocks, no interaction between background, PC, and trial type emerged in the linear mixed-effects model (β = 24.26, *t* = 1.60, *p* = .109), whereas that interaction was significant when analyzed using a repeated-measures ANOVA.\(^1\)\(^5\) There was also a significant effect of background for trials at inducer locations in just the inducer blocks (β = 49.66, *t* = 10.48, *p* < .001) and across all blocks (β = 54.49, *t* = 16.12, *p* < .001) such that

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\(^1\)\(^5\) When analyzing the model without applying the (-1 / RT) transformation to reaction time, the interaction between background, PC, and trial type was significant (β = 23.22, *t* = 2.43, *p* = .015). It should be noted that reaction time is skewed without applying the transformation.
responses were slower on the map background than the blank background. Otherwise, all results at the inducer locations from the linear mixed-effects models were consistent with the effects observed using repeated-measures ANOVAs. All results from the linear mixed-effects model at diagnostic locations were consistent with the effects observed using repeated-measures ANOVAs (see Tables 11.5 & 11.6).

There was a significant interaction between whether the participant has been to the ocean present in the map background (in the case of Experiment 3, the Atlantic Ocean), background, PC, and trial type for trials at the inducer location in just the inducer blocks ($\beta = 89.81$, $t = 2.18$, $p = .030$) and across all blocks ($\beta = 84.58$, $t = 2.87$, $p = .004$). This effect indicates that CSPC effects at inducer locations were smaller on the map background than the blank background for participants who had been to the ocean presented on that background. Otherwise, the map survey predictors did not significantly affect the relationship between background, PC, and trial type from the linear mixed-effects models.
Table 11.5

Linear Mixed-Effects Model Output for Trials at Inducer Locations in Experiment 3

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Inducer Blocks Only</th>
<th>Across All Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimates</td>
<td>CI</td>
</tr>
<tr>
<td>(Intercept)</td>
<td>-1675.75</td>
<td>-1771.36 — -1580.14</td>
</tr>
<tr>
<td>Trial Type</td>
<td>367.73</td>
<td>269.97 — 465.49</td>
</tr>
<tr>
<td>PC</td>
<td>39.62</td>
<td>24.95 — 54.29</td>
</tr>
<tr>
<td>Background</td>
<td>49.66</td>
<td>40.37 — 58.94</td>
</tr>
<tr>
<td>Trial Type X PC</td>
<td>-74.45</td>
<td>-95.43 — -53.47</td>
</tr>
<tr>
<td>Trial Type X Background</td>
<td>-68.22</td>
<td>-89.66 — -46.77</td>
</tr>
<tr>
<td>PC X Background</td>
<td>-14.30</td>
<td>-35.05 — 6.44</td>
</tr>
<tr>
<td>Trial Type X PC X Background</td>
<td>24.26</td>
<td>-5.41 — 53.93</td>
</tr>
</tbody>
</table>

Note. PC = proportion congruency, CI = 95% confidence interval. Factors were dummy coded such that compatible was the baseline level in trial type, MC was the baseline level in PC, and blank background was the baseline level in background.
Table 11.6

Linear Mixed-Effects Model Output for Trials at Diagnostic Locations in Experiment 3

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimates</th>
<th>CI</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-1551.90</td>
<td>-1636.68 − -1467.11</td>
<td>-35.87</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial Type</td>
<td>317.64</td>
<td>229.65 − 405.62</td>
<td>7.08</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Near-PC</td>
<td>25.56</td>
<td>14.09 − 37.04</td>
<td>4.37</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Background</td>
<td>108.70</td>
<td>97.23 − 120.17</td>
<td>18.57</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial Type X Near-PC</td>
<td>-33.00</td>
<td>-49.45 − -16.55</td>
<td>-3.93</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial Type X Background</td>
<td>-89.29</td>
<td>-105.71 − -72.87</td>
<td>10.66</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Near-PC X Background</td>
<td>-19.87</td>
<td>-36.10 − -3.63</td>
<td>2.39</td>
<td>.017</td>
</tr>
<tr>
<td>Trial Type X Near-PC X Background</td>
<td>17.02</td>
<td>-6.21 − 40.24</td>
<td>1.43</td>
<td>.150</td>
</tr>
</tbody>
</table>

Note. Near-PC= near proportion congruence, CI = 95% confidence interval. Factors were dummy coded such that compatible was the baseline level in trial type, near-MC was the baseline level in near-PC, and blank background was the baseline level in background.

11.4 Experiment 4

For trials at inducer locations in inducer only blocks, there was an effect of background ($\beta = 56.86, t = 11.37, p < .001$), such that responses were slower in the map background condition than the blank background condition.\(^\text{16}\) Otherwise, all results from the linear mixed-effects models were consistent with the effects observed using repeated-measures ANOVAs (see Tables...

\(^\text{16}\) The observed difference between RT in the blank background condition and the map background condition was significant in the repeated-measures ANOVA analysis for trials at inducer locations across all blocks and for trials at diagnostic locations.
11.7 & 11.8). All results from the linear mixed-effects models at inducer locations across all blocks and at diagnostic locations were consistent with the effects using repeated-measures ANOVAs.

Across all analyses, none of the predictors from the map survey interacted with the interaction between background, PC, and trial type from the linear mixed-effects models.

Table 11.7

Linear Mixed-Effects Model Output for Trials at Inducer Locations in Experiment 4

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Inducer Blocks Only</th>
<th>Across All Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimates</td>
<td>CI</td>
</tr>
<tr>
<td>(Intercept)</td>
<td>-1672.27</td>
<td>-1765.40 to -1579.14</td>
</tr>
<tr>
<td>Trial Type</td>
<td>362.32</td>
<td>267.53 to 457.10</td>
</tr>
<tr>
<td>PC</td>
<td>45.73</td>
<td>30.27 to 61.19</td>
</tr>
<tr>
<td>Background</td>
<td>56.86</td>
<td>47.06 to 66.66</td>
</tr>
<tr>
<td>Trial Type X PC</td>
<td>-72.41</td>
<td>-94.51 to -50.30</td>
</tr>
<tr>
<td>PC X Background</td>
<td>74.13</td>
<td>51.88 to 96.38</td>
</tr>
<tr>
<td>Trial Type X PC X Background</td>
<td>18.50</td>
<td>-12.78 to 49.77</td>
</tr>
</tbody>
</table>

Note. PC = proportion congruency, CI = 95\% confidence interval. Factors were dummy coded such that compatible was the baseline level in trial type, MC was the baseline level in PC, and blank background was the baseline level in background.
Table 11.8
*Linear Mixed-Effects Model Output for Trials at Diagnostic Locations in Experiment 4*

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimates</th>
<th>CI</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-1554.27</td>
<td>-1638.39 – 1470.15</td>
<td>36.22</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial Type</td>
<td>317.22</td>
<td>230.60 – 403.85</td>
<td>7.18</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Near-PC</td>
<td>37.44</td>
<td>25.37 – 49.51</td>
<td>6.08</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Background</td>
<td>101.49</td>
<td>89.43 – 113.56</td>
<td>16.49</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial Type X Near-PC</td>
<td>-50.95</td>
<td>-68.21 – -33.69</td>
<td>5.79</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial Type X Background</td>
<td>-69.76</td>
<td>-87.04 – -52.49</td>
<td>7.92</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Near-PC X Background</td>
<td>-10.95</td>
<td>-28.02 – 6.12</td>
<td>1.26</td>
<td>.209</td>
</tr>
<tr>
<td>Trial Type X Near-PC X Background</td>
<td>17.14</td>
<td>-7.26 – 41.54</td>
<td>1.38</td>
<td>.169</td>
</tr>
</tbody>
</table>

*Note.* Near-PC = near proportion congruence, CI = 95% confidence interval. Factors were dummy coded such that compatible was the baseline level in trial type, near-MC was the baseline level in near-PC, and blank background was the baseline level in background.

### 11.5 Experiment 5

For trials at inducer locations in inducer blocks, there was an effect of background ($\beta = 56.93$, $t = 4.86$, $p < .001$), such that responses were slower in the map background condition than the blank background condition. Otherwise, all results from the linear mixed-effects models were consistent with the effects observed using repeated-measures ANOVAs.\(^{17}\) All results from the

\(^{17}\) Consistent with the repeated measures ANOVA, the linear mixed-effects models observed an effect of background for trials at inducer locations across all blocks ($\beta = 80.94$, $t = 23.45$, $p < .001$) and for trials at the diagnostic locations ($\beta = 118.02$, $t = 16.76$, $p < .001$). Also consistent with the repeated measures ANOVA, an
linear mixed-effects models at inducer locations across all blocks and at diagnostic locations were consistent with the effects using repeated-measures ANOVAs (see Tables 11.9 & 11.10).

Across all analyses, none of the predictors from the map survey interacted with the interaction between background, PC, and trial type from the linear mixed-effects models.

For inducer trials at inducer locations, there was an interaction between confidence using a map, background, PC, and trial type ($\beta = 46.17$, $t = 3.16$, $p = .002$), such that participants who rated their confidence and experience using maps more highly showed a larger difference between the CSPC effect in the map background condition and the blank background condition.

For trials at inducer locations across all blocks, there was an interaction between whether participants had been to the ocean present on the map background (in the case of Experiment 5, the Pacific Ocean) map, PC, and trial type ($\beta = -49.83$, $t = 1.98$, $p = .048$), such that participants who had not been to the Pacific ocean showed a larger difference between the CSPC effect in the map background condition and the blank background condition than participants who had.\(^\text{18}\)

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\(^{18}\) It should be noted that 41 participants had been to the Pacific Ocean and 19 participants had not.
Table 11.9

Linear Mixed Model Output for Trials at Inducer Locations in Experiment 5

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Inducer Blocks Only</th>
<th>Across All Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimates</td>
<td>CI</td>
</tr>
<tr>
<td>(Intercept)</td>
<td>-1606.52</td>
<td>-1699.67 – 1513.37</td>
</tr>
<tr>
<td>Trial Type</td>
<td>328.01</td>
<td>229.03 – 427.00</td>
</tr>
<tr>
<td>PC</td>
<td>37.72</td>
<td>22.66 – 52.78</td>
</tr>
<tr>
<td>Background</td>
<td>56.93</td>
<td>47.40 – 66.45</td>
</tr>
<tr>
<td>Trial Type X PC</td>
<td>-63.53</td>
<td>-74.54 – -52.51</td>
</tr>
<tr>
<td>Trial Type X Background</td>
<td>-84.70</td>
<td>-95.77 – -73.63</td>
</tr>
<tr>
<td>PC X Background</td>
<td>0.14</td>
<td>-10.73 – 11.00</td>
</tr>
<tr>
<td>Trial Type X PC X Background</td>
<td>51.55</td>
<td>36.01 – 67.09</td>
</tr>
</tbody>
</table>

Note. PC = proportion congruency, CI = 95% confidence interval. Factors were dummy coded such that compatible was the baseline level in trial type, MC was the baseline level in PC, and blank background was the baseline level in background.
Table 11.10

*Linear Mixed Model Output for Trials at Diagnostic Locations in Experiment 5*

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Estimates</th>
<th>CI</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-1635.83</td>
<td>-1730.96 - -1540.69</td>
<td>33.70</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Trial Type</td>
<td>301.37</td>
<td>199.23 - 403.50</td>
<td>5.78</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Near-PC</td>
<td>14.33</td>
<td>0.51 - 28.15</td>
<td>2.03</td>
<td>.042</td>
</tr>
<tr>
<td>Background</td>
<td>118.02</td>
<td>104.22 - 131.82</td>
<td>16.76</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Trial Type X Near-PC</td>
<td>-17.85</td>
<td>-37.64 - 1.93</td>
<td>-1.77</td>
<td>.077</td>
</tr>
<tr>
<td>Trial Type X Background</td>
<td>-91.65</td>
<td>-111.35 - -71.94</td>
<td>9.11</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Near-PC X Background</td>
<td>-15.93</td>
<td>-35.44 - 3.59</td>
<td>1.60</td>
<td>.110</td>
</tr>
<tr>
<td>Trial Type X Near-PC X Background</td>
<td>14.66</td>
<td>-13.23 - 42.55</td>
<td>1.03</td>
<td>.303</td>
</tr>
</tbody>
</table>

*Note.* Near-PC= near proportion congruence, CI = 95% confidence interval. Factors were dummy coded such that compatible was the baseline level in trial type, near-MC was the baseline level in near-PC, and blank background was the baseline level in background.
Appendix E: Effect of condition order

While the primary analyses assess a difference between map and blank background conditions, it remains possible that some carryover between the map background condition and the blank background condition affected results. For example, participants could have strongly learned the difference between the MC and MI locations in the blank background in the first half of the experiment, then continued to retrieve those control setting in the second half of the experiment with the map background. I used a between-subjects analysis to compare performance in the first half of the experiment for participants who had the map background condition first to participants who had the blank background condition first. I also compared performance in the second half of the experiment for participants who had the map background condition second to participants who had the blank background condition second. Across all experiments, I conducted a mixed-effects ANOVA with repeated measures of PC (MC and MI) and trial type (compatible and incompatible), and a between-subjects factor of map condition (map and blank). I conducted separate analyses for the 1st half and the 2nd half of the experiment, and for reaction time and error rate. A three-way interaction would provide evidence that participants learned or retrieved control settings differently in the map background condition and the blank background condition.

12.1 Experiment 1

In the inducer only blocks, there was no three-way interaction of PC, trial type, and background in either the 1st or 2nd half of the experiment, and in RT or error rate. At inducer locations across all blocks, there was no three-way interaction of PC, trial type, and background in either the 1st or 2nd half of the experiment, and in RT or error rate. At diagnostic locations, there was no three-
way interaction of PC, trial type, and background in either the 1\textsuperscript{st} or 2\textsuperscript{nd} half of the experiment in RT or error rate.

12.2 Experiment 2
In the inducer only blocks, there was no three-way interaction of PC, trial type, and background in either the first or second half of the experiment in RT or error rate. At inducer locations across all blocks, there was no three-way interaction of PC, trial type, and background in either the 1\textsuperscript{st} or 2\textsuperscript{nd} half of the experiment in RT or error rate. At diagnostic locations, there was no three-way interaction of PC, trial type, and background in either the 1\textsuperscript{st} or 2\textsuperscript{nd} half of the experiment in RT or error rate.

12.3 Experiment 3
In the inducer only blocks, there was no three-way interaction of PC, trial type, and background in either the 1\textsuperscript{st} or 2\textsuperscript{nd} half of the experiment in RT or error rate. It should be noted that the trend in the first half was consistent with the effect observed in the main analysis, such that the CSPC effect was smaller in the map condition ($M = 16, SE = 10$) than the blank condition ($M = 43, SE = 10$), $F(1, 58) = 3.82, p = .055, \eta^2_p = .06, BF_{01} = 1.00$. At inducer locations across all blocks, there was no three-way interaction of PC, trial type, and background in either the 1\textsuperscript{st} or 2\textsuperscript{nd} half of the experiment in RT or error rate. At diagnostic locations, there was no three-way interaction of PC, trial type, and background in either the 1\textsuperscript{st} or 2\textsuperscript{nd} half of the experiment in RT or error rate.

12.4 Experiment 4
In the inducer only blocks, there was no three-way interaction of PC, trial type, and background in either the 1\textsuperscript{st} or 2\textsuperscript{nd} half of the experiment in RT or error rate. At inducer locations across all blocks, there was no three-way interaction of PC, trial type, and background in either the 1\textsuperscript{st} or 2\textsuperscript{nd} half of the experiment in RT or error rate. At diagnostic locations, there was no three-way interaction of PC, trial type, and background in either the first or second half of the experiment in
RT. In the first half of the experiment in error rate, the CSPC effect was smaller in the map condition \((M = 0.19\%, SE = 0.67\%)\) than the blank condition \((M = 2.43\%, SE = 1.01\%)\), \(F(1, 58) = 5.03, p = .029, \eta^2 = .08\).

### 12.5 Experiment 5

In the inducer only blocks, there was no three-way interaction of PC, trial type, and background in the first half of the experiment in RT or the second half of the experiment in error rate. In the first half of the experiment, there was a three-way interaction in error rate, such that the CSPC effect was smaller in the map condition \((M = -1.75\%, SE = 0.50\%)\) than the blank condition \((M = 0.74\%, SE = 0.87\%)\), \(F(1, 58) = 6.56, p = .013, \eta^2 = .10\). In the second half of the experiment, there was a three-way interaction in RT, such that the CSPC effect was larger for participants who completed the map condition \((M = 31, SE = 9)\) second compared to participants who were doing the blank condition second\(^{19}\) \((M = 2, SE = 11), F(1, 58) = 5.16, p = .027, \eta^2 = .08\). At inducer locations across all blocks, there was no three-way interaction of PC, trial type, and background in either the 1\(^{st}\) or 2\(^{nd}\) half of the experiment in RT or error rate. At diagnostic locations, there was no three-way interaction of PC, trial type, and background in either the 1\(^{st}\) or 2\(^{nd}\) half of the experiment in RT or error rate.

---

\(^{19}\) Though not statistically significant, the opposite effect emerged in the first half of the experiment, such that CSPC effects were larger in the blank condition \((M = 27, SE = 10)\) than the map condition \((M = 2, SE = 12), F(1, 58) = 2.75, p = 103, \eta^2 = .05\).
Appendix F: Effect of location and category repetition

Previous studies in the CSPC literature have found that context-specific effects sometimes differ depending on whether the previous trial was in the same context as the current trial or a different context. Specifically, location-specific adjustments have been observed selectively for location repetitions and not location switches (e.g., Hutcheon et al., 2017; King et al., 2012). Potentially, the \( n - 1 \) trial in a context retrieves previous associations with the context and allows participants to implement the control setting associated with that context on the subsequent trial. In the case of the current study, there are two potentially interesting contexts that may repeat or switch. First, locations may repeat or switch between trials. Second, the meaningful area of space may repeat or switch between trials in the map background condition. In Experiments 1 and 2, the meaningful areas of space were the specific states. In Experiments 3, 4, and 5, the meaningful areas of space were land or water.

Across all experiments, category repetition analyses for inducer locations in the inducer blocks could not be calculated as all trials were either category repetitions (as in Experiments 1 & 3) or category switches (as in Experiments 2, 4, & 5). I included location repetition and category repetition as a within-subject factors in separate four-way repeated measures ANOVAs along with within-subject factors of PC, trial type, and background. I additionally separately analyzed category repetitions after excluding all location repetitions which were definitionally also category repetitions. Note that background is included as a factor, and an interaction including background would indicate that an effect of location or category repetition differed by background condition.
13.1 Experiment 1

**Location repetition.** For inducer locations in the inducer only blocks, there was an effect of location repetition, such that responses on location repetitions ($M = 704, SE = 16$) were faster than responses on location switches ($M = 736, SE = 16$), $F(1, 59) = 122.37, p < .001, \eta^2_p = .68$. Location repetition did not interact with any other factors.

For inducer locations across all four blocks, there was an effect of location repetition, such that responses on location repetitions ($M = 705, SE = 15$) were faster than responses on location switches ($M = 730, SE = 14$), $F(1, 59) = 105.70, p < .001, \eta^2_p = .64$. Location repetition did not interact with any other factors.

For diagnostic locations, there was an effect of location repetition, such that responses on location repetitions ($M = 764, SE = 16$) were faster than responses on location switches ($M = 789, SE = 15$), $F(1, 59) = 52.80, p < .001, \eta^2_p = .47$. Location repetition did not interact with any other factors.

**Category repetition.** In Experiment 1, the two inducer locations shared a category (i.e., within Arkansas) and the two diagnostic locations were each in their own category. Analysis of category repetition was not useful above and beyond the effects observed for location repetitions at diagnostic locations, as there were no category repetitions that were not also location repetitions.

For inducer locations across all four blocks, there was no effect of category repetition, such that responses on category repetitions ($M = 718, SE = 14$) were only nominally faster than responses on category switches ($M = 725, SE = 15$), $F(1, 59) = 3.95, p = .052, \eta^2_p = .06$. There was an interaction between category repetition, PC, and trial type, such that CSPC effects were larger for category repetitions ($M = 30, SE = 6$) than category switches ($M = 8, SE = 12$), $F(1,
59) = 6.85, \( p = .011, \eta^2_p = .10 \). Otherwise, category repetition did not interact with any other factors.

**Category repetition (excluding location repetitions).** For inducer locations across all four blocks, there was an interaction between category repetition, PC, and trial type such that the CSPC effect was larger for category repetitions \((M = 39, SE = 10)\) than category switches \((M = 8, SE = 8)\), \( F(1, 59) = 4.87, p = .031, \eta^2_p = .08 \). Category repetition did not interact with any other factors.

### 13.2 Experiment 2

**Location repetition.** For inducer locations in the inducer only blocks, there was an effect of location repetition, such that responses on location repetitions \((M = 691, SE = 17)\) were faster than responses on location switches \((M = 721, SE = 18)\), \( F(1, 59) = 118.82, p < .001, \eta^2_p = .67 \). There was an interaction between location repetition and background, such that the difference between location repetitions and location switches was smaller in the blank background condition \((M = 22, SE = 6)\) than in the map background condition \((M = 37, SE = 7)\), \( F(1, 59) = 8.74, p = .004, \eta^2_p = .13 \). Location repetition did not interact with any other factors.

For inducer locations across all four blocks, there was an effect of location repetition, such that responses on location repetitions \((M = 692, SE = 17)\) were faster than responses on location switches \((M = 717, SE = 16)\), \( F(1, 59) = 119.42, p < .001, \eta^2_p = .67 \). There was an interaction between location repetition and trial type, such that compatibility effects were smaller for location repetitions \((M = 138, SE = 7)\) than location switches \((M = 149, SE = 6)\), \( F(1, 59) = 8.08, p = .006, \eta^2_p = .12 \). There was an interaction between location repetition and PC, such that MC locations were slower than MI locations for location repetitions \((M = -2, SE = 4)\), but MC
locations were faster than MI locations for location switches ($M = 6$, $SE = 3$), $F(1, 59) = 4.53$, $p = .037$, $\eta^2_p = .07$. Location repetition did not interact with any other factors.

For diagnostic locations, there was an effect of location repetition, such that responses on location repetitions ($M = 746$, $SE = 17$) were faster than responses on location switches ($M = 772$, $SE = 17$), $F(1, 59) = 56.70$, $p < .001$, $\eta^2_p = .49$. There was an interaction between location repetition and background, such that the difference between location repetitions and location switches was smaller in the blank background condition ($M = 19$, $SE = 8$) than in the map background condition ($M = 32$, $SE = 8$), $F(1, 59) = 4.87$, $p = .031$, $\eta^2_p = .08$. Location repetition did not interact with any other factors.

**Category repetition.** In Experiment 2, the inducer and diagnostic locations within Texas shared one meaningful category and the inducer and diagnostic locations within Arkansas shared another meaningful category.

For inducer locations across all four blocks, there was an effect of category repetition, such that responses on category repetitions ($M = 695$, $SE = 16$) were faster than responses on category switches ($M = 718$, $SE = 17$), $F(1, 59) = 87.55$, $p < .001$, $\eta^2_p = .58$. There was an interaction between category repetition and trial type, such that the compatibility effect was smaller for category repetitions ($M = 141$, $SE = 6$) than category switches ($M = 149$, $SE = 6$), $F(1, 59) = 4.73$, $p = .034$, $\eta^2_p = .07$. Category repetition did not interact with any other factors.

For diagnostic locations, there was an effect of category repetition, such that responses on category repetitions ($M = 755$, $SE = 17$) were faster than responses on category switches ($M = 776$, $SE = 17$), $F(1, 59) = 53.15$, $p < .001$, $\eta^2_p = .47$. There was an interaction between category repetition and background, such that the difference between category repetitions and category switches was smaller in the blank background condition ($M = 15$, $SE = 7$) than in the map.
background condition ($M = 27, SE = 7$), $F(1, 59) = 6.36, p = .013, \eta^2_p = .10$. Category repetition did not interact with any other factors.

**Category repetition (excluding location repetitions).** For inducer locations across all four blocks, there was an effect of category repetitions, such that responses on category repetitions ($M = 706, SE = 19$) were faster than responses on category switches ($M = 720, SE = 17$), $F(1, 54) = 15.39, p < .001, \eta^2_p = .22$. Category repetition did not interact with any other factors.

For diagnostic locations there was an effect of category repetitions, such that responses on category repetitions ($M = 753, SE = 17$) were faster than responses on category switches ($M = 767, SE = 17$), $F(1, 59) = 23.64, p < .001, \eta^2_p = .29$. Category repetition interacted with PC, such that responses at MC locations were slower than MI locations for category repetitions ($M = -12, SE = 5$) and responses at MC locations were faster than MI locations for category switches ($M = 2, SE = 4$), $F(1, 59) = 6.55, p = .013, \eta^2_p = .10$. Category repetition did not interact with any other factors.

### 13.3 Experiment 3

**Location repetition.** For inducer locations in the inducer only blocks, there was an effect of location repetition, such that responses on location repetitions ($M = 704, SE = 17$) were faster than responses on location switches ($M = 733, SE = 18$), $F(1, 59) = 57.31, p < .001, \eta^2_p = .49$. There was an interaction between location repetition, background, and trial type, such that the difference between compatibility effects of location repetitions and location switches was larger in the blank background condition ($M = 14, SE = 10$) than in the map background condition ($M = -5, SE = 9$), $F(1, 59) = 4.86, p = .031, \eta^2_p = .08$. Location repetition did not interact with any other factors.
For inducer locations across all four blocks, there was an effect of location repetition, such that responses on location repetitions ($M = 705$, $SE = 17$) were faster than responses on location switches ($M = 730$, $SE = 17$), $F(1, 59) = 97.35$, $p < .001$, $\eta^2_p = .62$. There was an interaction between location repetition and trial type, such that compatibility effects were smaller for location repetitions ($M = 140$, $SE = 7$) than location switches ($M = 149$, $SE = 6$), $F(1, 59) = 6.38$, $p = .014$, $\eta^2_p = .10$. There was an interaction between location repetition and PC, such responses at MC locations were slower than MI locations for location repetitions ($M = -4$, $SE = 4$) and responses at MC locations were faster than MI locations for location switches ($M = 9$, $SE = 3$), $F(1, 59) = 13.09$, $p < .001$, $\eta^2_p = .18$. There was an interaction between location repetition and background, such that the difference between location switches and repetitions was smaller in the blank background condition ($M = 21$, $SE = 6$) than in the map background condition ($M = 28$, $SE = 5$), $F(1, 59) = 5.17$, $p = .027$, $\eta^2_p = .08$. There was an interaction between location repetition, PC, and trial type, such that CSPC effects were larger for location repetitions ($M = 34$, $SE = 8$) than for location switches ($M = 11$, $SE = 6$), $F(1, 59) = 10.97$, $p = .002$, $\eta^2_p = .16$. There was an interaction between location repetition, background, and trial type, such that the difference in compatibility effects for location repetitions and location switches was larger in the blank background condition ($M = 19$, $SE = 9$) than in the map background condition ($M = 2$, $SE = 7$). $F(1, 59) = 5.83$, $p = .019$, $\eta^2_p = .09$. There was an interaction between location repetition, background, and PC, such that the degree to which responses at MC locations were faster than responses at MI locations was larger in the blank background condition ($M = 21$, $SE = 6$) than in the map background condition ($M = 4$, $SE = 5$), $F(1, 59) = 4.34$, $p = .042$, $\eta^2_p = .07$. At diagnostic locations, there was an effect of location repetition, such that location repetitions ($M = 759$, $SE =
18) were faster than location switches ($M = 785, SE = 17$), $F(1, 59) = 66.15, p < .001, \eta_p^2 = .53$. Location repetition did not interact with any other factors.

**Category repetition.** In Experiment 3, the two inducer locations shared one meaningful category (i.e., water, specifically the Gulf of Mexico) and the two diagnostic locations shared another meaningful category (i.e., land, specifically North America).

For inducer locations across all four blocks, there was an effect of category repetition, such that responses on category repetitions ($M = 717, SE = 17$) were faster than responses on category switches ($M = 727, SE = 18$), $F(1, 59) = 7.54, p = .008, \eta_p^2 = .11$. There was an interaction between category repetition and trial type, such that compatibility effects were smaller for category repetitions ($M = 143, SE = 6$) than category switches ($M = 155, SE = 8$), $F(1, 59) = 8.87, p = .004, \eta_p^2 = .13$. There was an interaction between category repetition, PC, and trial type, such that CSPC effects were larger for category repetitions ($M = 25, SE = 6$) than category switches ($M = 4, SE = 11$), $F(1, 59) = 8.28, p = .006, \eta_p^2 = .12$. Category repetition did not interact with any other factors.

For diagnostic locations, there was an effect of category repetition, such that responses on category repetitions ($M = 773, SE = 17$) were faster than responses on category switches ($M = 783, SE = 18$), $F(1, 59) = 23.15, p < .001, \eta_p^2 = .28$. Category repetition did not interact with any other factors.

**Category repetition (excluding location repetitions).** For inducer locations across all blocks, category repetition interacted with trial type, such that compatibility effects were smaller for category repetitions ($M = 145, SE = 5$) than category switches ($M = 155, SE = 5$), $F(1, 59) = 5.17, p = .027, \eta_p^2 = .08$. Category repetition did not interact with any other factors.
For diagnostic locations, category repetition interacted with background, such that the
degree to which performance in blank background condition was faster than the map background
condition was larger for category repetitions ($M = 33, SE = 9$) than category switches ($M = 21,$
$SE = 10$), $F(1, 59) = 4.07, p = .048, \eta^2_p = .07$. Category repetition did not interact with any other factors.

13.4 Experiment 4

Location repetition. For inducer locations in the inducer only blocks, there was an effect
of location repetition, such that responses on location repetitions ($M = 710, SE = 17$) were faster
than responses on location switches ($M = 737, SE = 19$), $F(1, 59) = 79.52, p < .001, \eta^2_p = .57$.
There was an interaction between location repetition and background, such that difference
between location repetitions and switches were smaller in the blank background condition ($M =$
$20, SE = 8$) than in the map background condition ($M = 35, SE = 7$), $F(1, 59) = 10.92, p = .002,$
$\eta^2_p = .16$. There was an interaction between location repetition, background, and PC, such that
the effect of location switching was larger for MI locations than MC locations in the blank
background condition ($M = -16, SE = 8$) but the effect of location switching was larger for MC
locations than MI locations in the map background condition ($M = 5, SE = 7$), $F(1, 59) = 4.68, p$
$= .035, \eta^2_p = .07$. There was an interaction between location repetition, PC, and trial type, such
that CSPC effects were larger for location repetitions ($M = 38, SE = 9$) than for location switches
($M = 10, SE = 11$), $F(1, 59) = 6.44, p = .014, \eta^2_p = .10$. Location repetition did not interact with
any other factors.

For inducer locations across all four blocks, there was an effect of location repetition,
such that responses on location repetitions ($M = 709, SE = 17$) were faster than responses on
location switches ($M = 734, SE = 17$), $F(1, 59) = 112.55, p < .001, \eta^2_p = .66$. There was an
interaction between location repetition and background, such that the difference between location repetitions and switches were smaller in the blank background condition \((M = 15, SE = 5)\) than in the map background condition \((M = 35, SE = 5)\), \(F(1, 59) = 35.05, p < .001, \eta_{p}^2 = .37\). There was an interaction between location repetition and trial type, such that the compatibility effect was smaller for location repetitions \((M = 134, SE = 7)\) than location switches \((M = 142, SE = 6)\), \(F(1, 59) = 5.04, p = .028, \eta_{p}^2 = .08\). There was also an interaction between location repetition, PC, and trial type, such that CSPC effects were larger for location repetitions \((M = 26, SE = 8)\) than location switches \((M = 9, SE = 7)\), \(F(1, 59) = 4.81, p = .032, \eta_{p}^2 = .08\). Location repetition did not interact with any other factors.

For diagnostic locations, there was an effect of location repetition, such that responses on location repetitions \((M = 765, SE = 19)\) were faster than responses on location switches \((M = 789, SE = 18)\), \(F(1, 59) = 38.41, p < .001, \eta_{p}^2 = .39\). There was an interaction between location repetition and background, such that the difference between location repetitions and switches was larger on a blank background \((M = 13, SE = 9)\) than a map background \((M = 33, SE = 9)\), \(F(1, 59) = 10.39, p = .002, \eta_{p}^2 = .15\). There was an interaction between location repetition and trial type, such that compatibility effect was smaller on location repetitions \((M = 134, SE = 12)\) than location switches \((M = 148, SE = 7)\), \(F(1, 59) = 4.80, p = .033, \eta_{p}^2 = .08\). Location repetition did not interact with any other factors.

**Category repetition.** In Experiment 4, the inducer and diagnostic locations within the Atlantic Ocean shared one meaningful category and the inducer and diagnostic locations within North America shared another meaningful category.

For inducer locations across all four blocks, there was an effect of category repetition, such that responses on category repetitions \((M = 713, SE = 17)\) were faster than responses on
category switches ($M = 733, SE = 18$), $F(1, 59) = 91.88, p < .001, \eta^2_p = .61$. There was an interaction between category repetition and background, such that the difference between category repetitions and switches was smaller in the blank background condition ($M = 15, SE = 6$) than in the map background condition ($M = 26, SE = 5$), $F(1, 59) = 8.38, p = .005, \eta^2_p = .12$. There was an interaction between category repetitions and trial type, such that compatibility effects were smaller for category repetitions ($M = 134, SE = 6$) than category switches ($M = 143, SE = 7$), $F(1, 59) = 6.47, p = .014, \eta^2_p = .10$. Category repetition did not interact with any other factors.

For diagnostic locations, there was an effect of category repetition, such that responses on category repetitions ($M = 774, SE = 18$) were faster than responses on category switches ($M = 791, SE = 18$), $F(1, 59) = 39.78, p < .001, \eta^2_p = .40$. Category repetition interacted with background, such that the difference between category repetitions and category switches was smaller in the blank background condition ($M = 8, SE = 8$) than in the map background condition ($M = 27, SE = 7$), $F(1, 59) = 16.43, p < .001, \eta^2_p = .22$. Category repetition did not interact with any other factors.

**Category repetition (excluding location repetitions).** For inducer locations across all blocks, category repetition did not interact with any factors.

For diagnostic locations, there was an effect of category repetition, such that responses on category repetitions ($M = 781, SE = 19$) were faster than responses on category switches ($M = 791, SE = 18$), $F(1, 59) = 14.73, p < .001, \eta^2_p = .20$. There was an interaction between category switch and background, such that the degree to which responses in the blank background condition were faster than responses in the map background condition was smaller for category
repetitions \(M = 28, SE = 7\) than category switches \(M = 42, SE = 7\), \(F(1, 59) = 7.37, p = .009, \eta_p^2 = .11\). Category repetition did not interact with any other factors.

13.5 Experiment 5

**Location repetition.** For inducer locations in the inducer only blocks, there was an effect of location repetition, such that responses on location repetitions \(M = 730, SE = 16\) were faster than responses on location switches \(M = 761, SE = 16\), \(F(1, 59) = 87.95, p < .001, \eta_p^2 = .60\). There was an interaction between location repetition, PC, and trial type, such that CSPC effects were larger for location repetitions \(M = 30, SE = 11\) than location switches \(M = 14, SE = 10\), \(F(1, 59) = 7.73, p = .007, \eta_p^2 = .12\). Location repetition did not interact with any other factors.

For inducer locations across all four blocks, there was an effect of location repetition, such that responses on location repetitions \(M = 727, SE = 15\) were faster than responses on location switches \(M = 754, SE = 15\), \(F(1, 59) = 77.60, p < .001, \eta_p^2 = .57\). There was an interaction between location repetition and background, such that the difference between location repetitions and switches was smaller in the blank background condition \(M = 20, SE = 6\) than in the map background condition \(M = 34, SE = 6\), \(F(1, 59) = 12.11, p < .001, \eta_p^2 = .17\). There was an interaction between location repetition, PC, and trial type, such that the CSPC effect was larger for location repetitions \(M = 31, SE = 9\) than location switches \(M = 8, SE = 6\), \(F(1, 59) = 8.05, p = .006, \eta_p^2 = .12\). Location repetition did not interact with any other factors.

For diagnostic locations, there was an effect of location repetition, such that responses on location repetitions \(M = 705, SE = 14\) were faster than responses on location switches \(M = 741, SE = 14\), \(F(1, 59) = 104.41, p < .001, \eta_p^2 = .64\). There was an interaction between location repetition and background, such that the difference between location repetitions and switches was smaller in the blank background condition \(M = 29, SE = 8\) than in the map background.
condition ($M = 41, SE = 9$), $F(1, 59) = 4.15, p = .046, \eta_p^2 = .07$. Location repetition did not interact with any other factors.

**Category repetition.** In Experiment 5, the inducer and diagnostic locations within the Pacific Ocean shared one meaningful category and the inducer and diagnostic locations within South America shared another meaningful category.

For inducer locations across all four blocks, there was an effect of category repetition, such that responses on category repetitions ($M = 732, SE = 15$) were faster than responses on category switches ($M = 753, SE = 15$), $F(1, 59) = 65.51, p < .001, \eta_p^2 = .53$. There was an interaction between category repetition and background, such that the difference between category repetitions and category switches was smaller in the blank background condition ($M = 17, SE = 6$) than in the map background condition ($M = 26, SE = 6$), $F(1, 59) = 4.72, p = .034, \eta_p^2 = .07$. There was also an interaction between category repetition, PC, and trial type, such that the CSPC effect was larger for category repetitions ($M = 26, SE = 8$) than category switches ($M = 10, SE = 7$), $F(1, 59) = 5.67, p = .020, \eta_p^2 = .09$. Category repetition did not interact with any other factors.

For diagnostic locations, there was an effect of category repetition, such that responses on category repetitions ($M = 727, SE = 14$) were faster than responses on category switches ($M = 738, SE = 14$), $F(1, 59) = 25.90, p < .001, \eta_p^2 = 31$. There was an interaction between category repetition, background, and trial type, such that compatibility effects were smaller for location repetitions in the blank background condition ($M = -15, SE = 9$) and compatibility effects were larger for category repetitions in the map background condition ($M = 5, SE = 11$), $F(1, 59) = 5.41, p = .024, \eta_p^2 = .08$. Category repetition did not interact with any other factors.
**Category repetition (excluding location repetitions).** For inducer locations across all blocks, there was an interaction of category repetition and PC, such that the responses were faster at MC locations than MI locations for category repetitions ($M = 8, SE = 6$) but smaller for MC locations than MI locations for category switches ($M = -6, SE = 4$), $F(1, 52) = 4.07, p = .049, \eta_p^2 = .07$. Category repetition did not interact with any other factors,

For diagnostic locations, category repetition did not interact with any other factors.