Context-Dependent Control of Attention Capture: Evidence From Proportion Congruent Effects

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There are several independent demonstrations that attentional phenomena can be controlled in a context-dependent manner by cues associated with differing attentional control demands. The present set of experiments provide converging evidence that attention-capture phenomena can be modulated in a context-dependent fashion. We determined whether methods from the proportion congruent literature (listwide and item- and context-specific proportion congruent designs) that are known to modulate distractor interference effects in Stroop and flanker tasks are capable of modulating attention capture by salient feature singletons. Across experiments we found evidence that attention capture can be modulated by listwide, item-specific, and context-specific manipulations of proportion congruent. We discuss challenges associated with interpreting results from proportion congruent studies but propose that our findings converge with existing work that has demonstrated context-dependent control of attention capture.

> **Public Significance Statement**
> Visual attention is well known to be captured by salient information in a scene. These experiments demonstrate that attention capture can be controlled by contextual cues in the environment associated with how people focused their attention in those situations in the past. These findings contribute to a better understanding of how learning and memory processes participate in controlling the focus of attention, allowing people to adapt their attentional focus in response to changing environmental demands.

Keywords: attention capture, proportion congruent, contextual control, attention, cognitive control

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Context-dependent attentional control refers to a blend of influences whereby attentional sets—dimensional weights that prioritize selection of information in the environment (Bundesen, 1990)—are cued by associated stimulus triggers. For example,

attentional sets previously applied in a controlled fashion to specific stimuli in specific contexts may become bound to those stimuli and contexts. In turn, those same stimuli and contexts can later cue the retrieval of previously associated attention sets, which adjusts priorities for attention in the present situation.

The possibility of context-dependent attentional control has appeared in several formative theories of memory and attention. For example, Norman's (1968) theory of memory and attention described a pertinence mechanism, whereby early stimulus encoding processes are governed by cue-specific weights controlling further processing. Shiffrin and Schneider (1977) described automatic attention responses, whereby extensive practice pairing particular attentional goals with particular stimulus sets could establish an automatic, stimulus-driven basis for controlling attention. They noted further that automatic attention responses could be sensitive to contextual cues in a task and might therefore be applied in a contingent fashion depending on the presence of cues associated with different attention sets.

Context-dependent attentional control is also consistent with Norman and Shallice's (1980) contention scheduling system, where constellations of environmental cues trigger the application of associated action schemas during performance.

Each of these ideas concerning context-dependent attentional control appears to have lain somewhat dormant after their inception. However, there is now broad empirical support for the view that attention sets can be controlled by contextual cues. This evidence stretches across research groups and attention domains, and together it encourages clarification of how learning and memory processes participate in the contextual cuing of attention (Bugg, 2012; Bugg & Crump, 2012; Chun & Jiang, 1998; Chun & Turk-Browne, 2007; Egner, 2008; Vecera, Cosman, Vatterott, & Roper, 2014).

The present article adds to the empirical support for context-dependent attentional control by determining whether methods used to demonstrate context-dependent control in selective attention paradigms can be successfully employed to modulate attention-capture phenomena. In selective attention paradigms like Stroop (1935) and flanker (Eriksen & Eriksen, 1974), distractor interference effects can be modulated by contextual cues (location, color, font) associated with different proportions of congruent items (for reviews see Bugg, 2012; Bugg & Crump, 2012). More recently, attention capture by feature singletons was shown to be modulated by photograph contexts previously associated with different attentional sets (Cosman & Vecera, 2013a) and by implicit learning of cue–target associations (Cosman & Vecera, 2014; Le Pelley, Vadillo, & Luque, 2013).

On the one hand, these demonstrations could reflect distinct forms of context-dependent attentional control. In the Stroop task, context cues could be associated with different filtering operations that weight the relative contributions of relevant color and irrelevant word dimensions during selection. In the flanker task, context cues could be associated with spatial attention parameters shaping the extent to which an attentional window encompasses distracting items adjacent to a target. In the attention-capture task, context cues could be associated with different modes of visual search (feature vs. singleton search) modulating the extent to which salient feature singletons capture attention. On the other hand, these demonstrations could point to a general context-sensitive process controlling priorities for attention allocation. A generalized view of context-dependent attentional control assumes that specific attentional priorities are set on a task-by-task basis (e.g., to modify dimensional weights, scope of spatial window, or search templates) but associated to and triggered by contextual cues via common learning and memory processes. Discussions of context-dependent control of attention in both of these literatures have proceeded mostly independently from one another, which further motivated our aim to establish points of convergence.

Our experimental strategy was analogical. We traced the methodological path in the proportion congruent literature that developed evidence for context-dependent control of attention and then applied those methods to test for context-dependent control over attention capture. Recently, Cosman, Vecera and colleagues (Cosman & Vecera, 2013a, 2013b, 2014; Vecera et al., 2014) and Le Pelley and colleagues (2013) have established that attention-capture effects can be modulated in a context-dependent fashion. Their experiments involved designs that were different from our own, and we view our present efforts as an opportunity to supply converging evidence and draw in theoretical and methodological considerations from the proportion congruent literature that may be valuable for understanding evidence of contextual control in the attention-capture domain. Finally, our efforts to draw connections between the proportion congruent and attention-capture literatures are spread between this article and a companion article (Thomson, Willoughby, & Milliken, 2014) exploring more detailed aspects of the general methods presented here.

Overview of the Experiments

For brevity we point readers to reviews of the proportion congruent (see Bugg, 2012; Bugg & Crump, 2012) and attention-capture (see Cosman & Vecera, 2013a; Thomson et al., 2014; Vecera et al., 2014) literatures and briefly review relevant background within each experimental section. The proportion congruent literature has used three main procedures to modulate the size of distractor interference effects: listwide, item-specific, and context-specific proportion congruent designs. Our experiments convert a conventional attention-capture procedure (Theeuwes, 1991) into a task allowing the attention-capture effect to be measured as a congruency effect, as is typical in Stroop and flanker tasks. Across experiments we varied the proportion of congruent and incongruent items in listwide, item-specific, and context-specific designs to examine whether attention-capture effects can be modulated in analogous ways as shown for Stroop and flanker tasks. The analyses of each experiment evaluated whether the congruency effect measuring attention capture is modulated by the proportion congruent manipulations. The online supplemental materials section reports secondary analyses for all experiments that rule out possible confounding explanations of the proportion congruent effects.

Experiment 1: Listwide Proportion Congruent

Experiment 1 examined whether a congruency effect could be measured using a variant of Theeuwes's (1991) task for measuring attention-capture and whether that congruency effect would be sensitive to the relative proportions of congruent and incongruent trials. Theeuwes (1991) introduced the procedure for measuring attention-capture effects depicted in Figure 1. A search display might contain six circles and a square situated on the circumference of an imaginary circle, with a short line segment inside each of the shapes. The participants' task is to locate the odd shape and to indicate the orientation of the line (horizontal or vertical) inside that shape. In this case the target would be the singleton square. On some trials, here called the *incongruent trials,* there was a second singleton defined by the color in which the shapes were presented. In the incongruent trial presented in Figure 1, one of the circles is green, whereas the remaining circles and the target square are red. This procedure reliably produces faster responses in the neutral condition with no color singleton (i.e., all the shapes are green) than does the incongruent condition containing a color singleton. Presumably, the color singleton captures attention involuntarily, thereby slowing search for the shape singleton (Theeuwes, 1991, 1992).

To measure a congruency effect in the present study, we replaced the neutral condition with what we label a *congruent condition.* As depicted in Figure 1, in the congruent condition the

Experiment 1: List-Wide Proportion Congruent
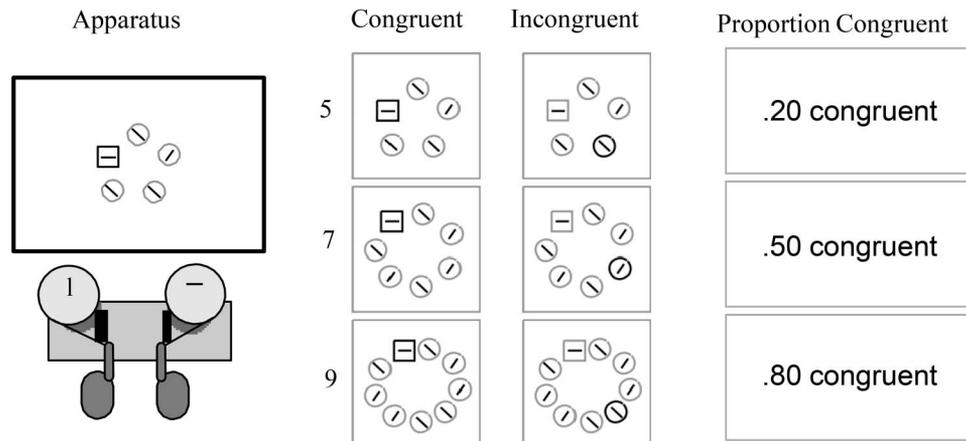
Figure 1. Experiment 1 search task showing congruent and incongruent displays across set sizes and proportioncongruent. The task was to locate the odd shape (e.g., square) and identify whether the line segment was horizontal or vertical using left- and right-hand fingers placed on response keys. Example congruent displays (odd colour singleton is placed on odd-shape target) and incongruent displays (odd colour singleton is placed on a distractor shape) are shown for set-sizes five, seven, and nine. The list-wide proportion congruent manipulation was applied across three levels, .2, .5, and .8.

color singleton coincides with the shape singleton. In this case, if attention allocation were guided by the singleton color, it would be pulled toward the target shape, perhaps facilitating rather than impairing the search. Following the precedent set in studies of Stroop performance (e.g., Lindsay & Jacoby, 1994), we measured attention capture by the singleton color as the difference in performance between incongruent and congruent conditions.

The proportion of congruent items presented within an experimental session is known to modulate the size of the Stroop congruency effect (Logan & Zbrodoff, 1979). Larger congruency effects are found when congruent trials are more frequent than incongruent trials (high proportion congruent) than when the reverse is true (low proportion congruent). These listwide proportion congruent effects can be explained by strategic control of attention (Logan, 1980), whereby participants voluntarily apply different attention-filtering strategies for high and low proportion congruent lists. For example, a participant may choose to pay more attention to distractors in the high relative to low proportion congruent condition because the distractor dimension usually matches the target dimension. Whether listwide proportion congruent effects are driven by strategic or nonstrategic processes is currently a topic of debate (Bugg & Chanani, 2011; Bugg, McDaniel, Scullin, & Braver, 2011; Schmidt, 2013; Schmidt & Besner, 2008). In Experiment 1, the proportions of congruent and incongruent trials were manipulated between groups of participants, with the prediction that the congruency effect would be larger for the high proportion congruent than for the low proportion congruent group.

Method

Participants. All data collection reported in this article was approved by the McMaster Research Ethics Board. Twenty-four undergraduate students from McMaster University provided informed consent and received course credit for their participation in

this study. All participants reported normal color vision and normal or corrected-to-normal visual acuity.

Apparatus and stimuli. Stimuli were presented on a Sony 15-in. color monitor controlled by a Comptech Intel Pentium computer running Micro Experimental Laboratory (MEL2) software (Schneider, 1988). The viewing distance from the monitor was approximately 57 cm.

Each stimulus display included five, seven, or nine shapes positioned with equal spacing around a notional circle (7.8° radius) presented in the center of the screen. Shapes were red and green circles (1.0° radius) and squares (1.9° height and width). A white line segment (.9° length and .1° width) was presented inside each of the shapes. The target shape always contained a vertically or horizontally oriented line segment. The distractor shapes always contained a randomly tilted line segment (22.5° right or left of the vertical or horizontal plane).

The target in each display was defined as the odd-shaped item, which was either a square or circle on any given trial. An example congruent display from the display size five condition included four distractor circles in red and one target square in green. An example incongruent display from the display size five condition included three distractor circles in red, one distractor circle in green, and one target square in red. Example stimulus displays are shown in Figure 1.

Design and procedure. The design included congruency (congruent–incongruent) and display size (five–seven–nine) as within-subject variables and proportion congruent (.80/.50/.20) as the sole between-subjects variables. Eight participants were assigned to each of the proportion congruent groups.

All participants completed 20 practice trials, followed by four blocks of 240 experimental trials (960 total trials). Each block included an equal number of trials in each of the three display size conditions. Participants in the .80 congruent condition completed

192 congruent and 48 incongruent trials per block, and these frequencies were reversed in the .20 congruent condition. Participants in the .50 congruent condition completed 120 congruent trials and 120 incongruent trials in each block. For each participant, displays included a square target among circle distractors on half of all trials and a circle target among square distractors on the remaining half of the trials. In each proportion congruent condition, all conditions were presented in a random order across trials.

Participants were instructed to search for the odd shape on each trial and press one of two response keys to indicate whether the line segment inside the target shape was vertical or horizontal. Vertical responses were made on a QWERTY keyboard pressing a key labeled *V* (placed over the *M* key), and horizontal responses were made by pressing a key labeled *H* (placed over the *C* key). Each trial began with a blank screen for 1,000 ms followed by the onset of the search display, which remained on-screen until a response was made. Each response automatically triggered the next trial.

Results and Discussion

First, correct response times (RTs) longer than 10 s were identified and eliminated from further analyses (36 out of 17,760 observations, or .2%). The remaining correct RTs were then subjected to an outlier elimination procedure that examined RTs on a cell by cell basis (the nonrecursive with moving criterion procedure of Van Selst & Jolicoeur, 1994). This same outlier analysis was applied in all experiments reported here. This procedure led to the exclusion of 3.2% of the observations from further analysis. Mean RTs for each condition were computed from the remaining observations, and these mean RTs and corresponding error rates were submitted to a mixed-variable analysis of variance (ANOVA) that treated congruency (congruent–incongruent), target shape (circle–square), and display size (five–seven–nine) as within-subject variables and proportion congruent (.20/.50/.80) as a between-subjects variable. Mean correct RTs and error rates for each condition, collapsed across participants, are displayed in Appendix A.1 of the online supplemental materials. Mean congruency effects as a function of proportion congruent are displayed in Figure 2. An alpha level of .05 was used for all statistical comparisons.

Listwide proportion congruent effects. In the analysis of RTs, there was a significant main effect of congruency, $F(1, 21) = 221.40$, $MSE = 53,087.63$, $\eta_p^2 = .91$, $p < .001$. As expected, responses were faster for congruent trials (1,199 ms) than for incongruent trials (1,603 ms). More important, the interaction between proportion congruent and congruency was significant, $F(2, 21) = 11.60$, $MSE = 53,087.63$, $\eta_p^2 = .52$, $p < .001$, with the largest congruency effect in the .80 congruent condition (573 ms) and the smallest congruency effect in the .20 congruent condition (254 ms). Separate analyses revealed a significant effect of congruency in all three proportion congruent conditions ($p = .002$, $p < .001$, $p < .001$, for the .20, .50 and .80 congruent conditions, respectively; see Figure 2). In the analysis of error rates, there was also a significant main effect of congruency, $F(1, 21) = 4.97$, $MSE = .005$, $\eta_p^2 = .19$, $p = .037$, with fewer errors for congruent trials (.025) than for incongruent trials (.044).

Other significant effects. There were several other significant effects in the analysis of less theoretical importance reported

completely in Appendix A.2 of the online supplemental materials. We also conducted trial-to-trial sequence analyses of the RT data to determine whether the proportion congruent effects observed here depend in any way on sequential congruency (Gratton, Coles, & Donchin, 1992) or on priming of popout (Maljkovic & Nakayama, 1994) effects. The analyses revealed no such dependence but did reveal several other trial-to-trial influences that may be of interest to some readers (see Appendix A.2 of the online supplemental materials).

The important take-home from Experiment 1 was that the size of the congruency effect measuring attention capture was modulated by the listwide proportion congruent manipulation. Specifically, the congruency effect increased as the proportion of congruent displays in the block of trials increased. Listwide proportion congruent effects have been explained in terms of voluntary control strategies (Logan & Zbrodoff, 1979), where participants prepare an experiment-wide strategy of attending more or less to distracting information, as a function of whether it accurately signals target information. It is important to note that all of the remaining proportion congruent manipulations employed item-specific or context-specific designs that ruled out an explanation of proportion congruent effects solely in terms of voluntary strategies.

Experiment 2a and 2b: Item-Specific Proportion Congruent

Proportion congruent manipulations at the level of specific items can also modulate Stroop effects (Jacoby, Lindsay, & Hessels, 2003). Item-specific proportion congruent (ISPC) designs manipulate proportion congruent between different sets of items. For example, Stroop items made up from the color words *BLUE* and *RED* could be high proportion congruent, whereas items made up from *GREEN* and *YELLOW* could be low proportion congruent. Of importance, items from the two sets are mixed together and presented in a randomized fashion across trials. This design ensures that participants cannot accurately predict whether an upcoming trial will be drawn from the high or low proportion congruent set. As a result, the application of an experiment-wide strategy to focus more (or less) on distracting information would be expected to
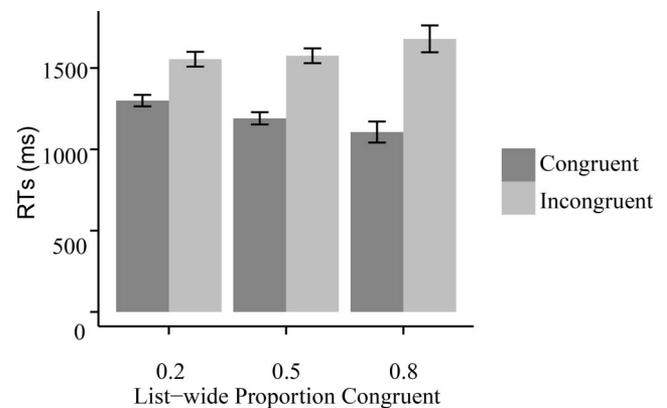
Figure 2. Mean response times (RTs in milliseconds) for correct trials as a function of congruency and listwide proportion congruent in Experiment 1, showing the congruency effect increases as a function of increasing the proportion of congruent trials.

uniformly increase or decrease the congruency effect for all items. However, ISPC designs reliably show item-specific congruency effects, with congruency effects that were larger for items from the high proportion congruent sets than for items from the low proportion congruent sets.

The ISPC effect is consistent with context-dependent control of attention. Here, when an item is presented on-screen, attributes of the item serve as a cue to retrieve the attentional control settings associated with that item, which are then applied to attentional processing of the item. In other words, the item cues its own attentional control settings.

The purpose of Experiments 2a and 2b was to examine whether the congruency effect measured with our attention-capture task would be modulated by an item-specific proportion congruent manipulation. We used the same general materials as in Experiment 1, except that the proportion congruent manipulation was applied to different item types that were mixed randomly across trials.

Method

Participants. Forty-six undergraduate students from McMaster University provided informed consent and received course credit for their participation in this study (Experiment 2a = 30; Experiment 2b = 16). All participants reported normal color vision and normal or corrected-to-normal visual acuity.

Apparatus and stimuli. The apparatus and search displays for Experiment 2a were identical to those in Experiment 1. Experiment 2b used the same apparatus but introduced a different set of search displays. Specifically, in Experiment 2b one item class consisted of search displays in which either a tall oval or short oval was the odd-shaped target presented with either square or diamond distractors. The other item class consisted of search displays in which either a square or diamond was the odd-shaped target presented with either tall oval or short oval distractors. As such, the two item classes consisted of a round target (i.e., tall or short

oval) among angular distractors (i.e., diamond or square) or an angular target among round distractors. As in Experiments 1 and 2a, each search display contained one oddball target shape that differed from the rest and one oddball distractor color that either coincided with the oddball target shape (congruent trials) or coincided with one of the common distractor shapes (incongruent trials). The general design for Experiments 2a and 2b is depicted in Figure 3.

Design and procedure. Participants were given the same instructions and followed the same general procedure described in Experiment 1. The task was to find the odd-shaped target and indicate the orientation of the line segment presented inside that target. The major change from Experiment 1 involved the within-subject manipulation of proportion congruent. All participants completed 20 practice trials, followed by four blocks of 240 experimental trials. Each block of trials had equal proportions of the two item sets (square vs. circle targets in Experiment 2a; round vs. angular targets in Experiment 2b), equal proportions of displays with five, seven, or nine search items, and equal proportions of congruent and incongruent items. The key manipulation concerned proportion congruent varied at the level of item. In Experiment 2a, the proportion congruent was .80 for square target items and .20 for circle target items for half of the participants and vice versa for the other half of participants. In Experiment 2b, the proportion congruent was .80 for round target items and .20 for angular target items for half of the participants and vice versa for the other half of participants. In both experiments, the two items sets were mixed randomly across trials.

Results and Discussion

The outlier analysis resulted in removal of 3.0% of the observations from further analysis. Mean correct RTs and error rates for each condition in Experiments 2a and 2b were then submitted to separate mixed-design ANOVAs with the counterbalancing variable high proportion congruent target type (round–angular) as the

Experiment 2a: Item-specific proportion congruent
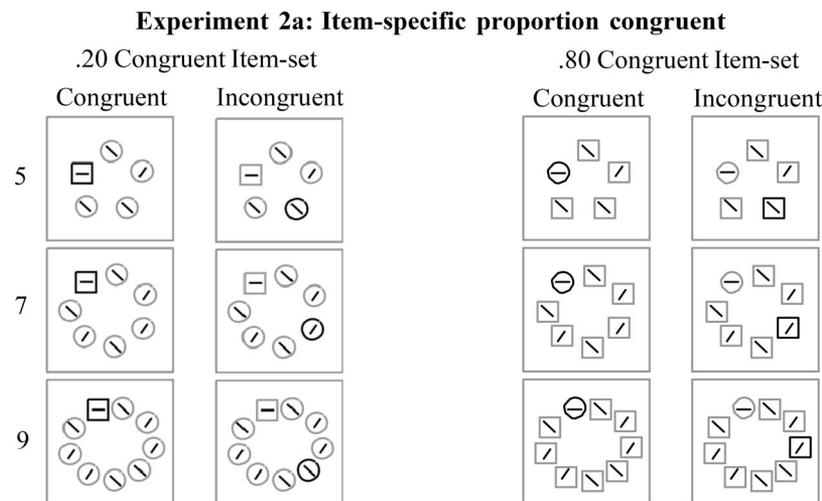
Figure 3. Example displays for each set-size for congruent and incongruent trials used for the Experiment 2a item-specific manipulation of proportion congruent. In the counterbalancing condition shown, displays with square targets were more likely to be incongruent than congruent, and displays with circle targets were more likely to congruent than incongruent.

sole between-subjects variable and display size (five–seven–nine), proportion congruent (.20/.80), and congruency (congruent–incongruent) as the within-subject variables. Figure 4 displays congruency effects as a function of proportion congruent. Appendix B.1 in the online supplemental materials contains mean RTs, standard errors, and error rates for all conditions in the design.

Significant main effects of congruency were observed in Experiment 2a, $F(1, 28) = 260.36$, $MSE = 35,408.17$, $p < 001$, $\eta_p^2 = .90$, and in Experiment 2b, $F(1, 14) = 84.8$, $MSE = 51,444.28$, $p < .001$, $\eta_p^2 = .86$. In Experiment 2a, RTs were faster for congruent (1,118 ms) than for incongruent (1,438 ms) trials, and the same was true for congruent (1,130 ms) and incongruent (1,431 ms) trials in Experiment 2b.

The central question was whether larger congruency effects would be observed for the .80 congruent than for the .20 congruent items. Indeed, in Experiment 2a the Proportion Congruent × Congruency interaction was significant, $F(1, 28) = 10.37$, $MSE = 12,279.06$, $p = .003$, $\eta_p^2 = .27$, with larger congruency effects for .80 congruent (358 ms) than for .20 congruent (282 ms) items, producing an ISPC effect of 76 ms (see Figure 4). Similarly, in Experiment 2b, the Proportion Congruent × Congruency interaction was significant, $F(1, 14) = 6.94$, $MSE = 13,412.07$, $p = .019$, $\eta_p^2 = .33$, with larger congruency effects for .80 congruent (345 ms) than for .20 congruent (257 ms) items, producing an ISPC effect of 88 ms (see Figure 4).

Parallel analyses of error rates in Experiment 2a showed no significant main effects or higher order interactions. Mean error rate averaged across all conditions was less than .03. In Experiment 2b the sole significant main effect was that of display size, $F(2, 28) = 5.52$, $MSE = .00034$, $p = .009$, $\eta_p^2 = .28$, with mean error rates of .010, .020, and .007, in the five-, seven-, and nine-item display size conditions, respectively.

Additional analyses of higher order interactions involving the shape variable and analyses of trial-to-trial sequence effects are described in Appendix B.2 of the online supplemental materials. These analyses show that the ISPC effects in Experiments 2a and 2b are robust and not a by-product of search asymmetries for popout targets or driven by sequential congruency effects.
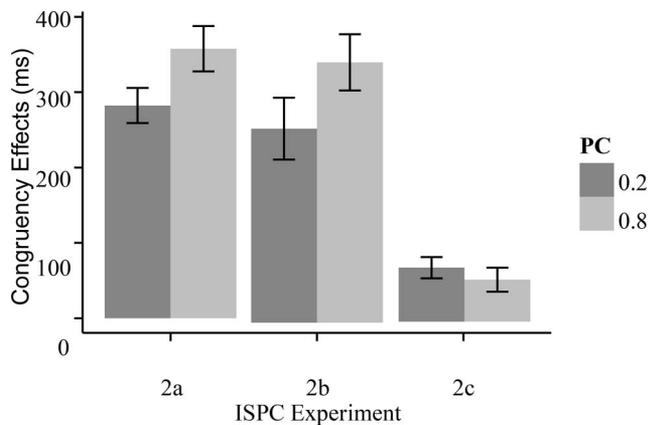
Figure 4. Mean congruency effects (incongruent–congruent) as a function of item-specific proportion congruent across Experiments 2a, 2b, and 2c. Error bars indicate standard error of the mean. PC = proportion congruent; ISPC = item-specific proportion congruent; ms = milliseconds.

The take-home message here is that the congruency effect measuring attention capture was modulated by the item-specific proportion congruent manipulation. The congruency effect was larger for displays that were more likely to be congruent than incongruent (.80/.20), compared to displays that were less likely to be congruent than incongruent (.20/.80).

Experiment 2c: ISPC and Attention to Color

ISPC effects have been argued to reflect stimulus-driven control of attention filtering. An assumption inherent in this idea is that the learning of distinct attentional control settings for different item types ought to depend on how much interference is produced by those items. If a task produces only minimal distractor interference, then there is likely to be little in the way of attentional control to be adapted in response to the ISPC manipulation—incongruent items that produce little distractor interference offer little room for learning that will reduce distractor interference further.

This assumption can be tested in tasks that produce asymmetric distractor interference effects. For example, in the conventional Stroop task, attending to the color dimension produces robust interference from the word dimension on incongruent trials, whereas attending to the word dimension produces little interference from the color dimension on incongruent trials. A proportion congruent manipulation applied to two distinct Stroop item sets should therefore produce an ISPC effect when the task requires attention to the color dimension but not when the task requires attention to the word dimension (Crump, Vaquero, & Milliken, 2008).

A similar opportunity was afforded by the task used in the present study. Theeuwes (1992) noted that attention capture from an irrelevant singleton is robust when participants attend to the less salient of two singleton dimensions but not when participants attend to the more salient of two singleton dimensions. With the task parameters used in Experiments 2a and 2b, the task-relevant shape singleton was clearly the less salient of the two singletons, and a reliable ISPC effect was observed. In the present experiment, participants were asked to attend and respond to the more salient color singleton, with the prediction that a significant ISPC effect would not be observed.

Method

Participants. Sixteen undergraduate students from McMaster University provided informed consent and received course credit for their participation in this study. All participants reported normal color vision and normal or corrected-to-normal visual acuity.

Apparatus and stimuli. The apparatus and search displays for Experiment 2c were identical to those in Experiment 2a.

Design and procedure. The design and procedure closely followed that of Experiment 2a, with the important exception that participants were given different instructions for identifying the target stimulus. Rather than being defined by the odd shape, the target stimulus was defined by the odd color in the display, with the odd shape acting as the distracting feature singleton. As such, the participant's task was to find the singleton color target and indicate whether the line segment inside that target was horizontal or vertical.

Results and Discussion

The outlier analysis resulted in removal of less than 2% of the data from subsequent analyses. Mean correct RTs and error rates for each condition were then submitted to mixed-design ANOVAs with high proportion congruent target color (red–green) as a between-subjects variable and display size (five–seven–nine), proportion congruent (.20/.80), and congruency (congruent–incongruent) as within-subject variables. Figure 4 displays congruency effects for each proportion congruent condition. Appendix B.3 of the online supplemental materials lists mean RTs and error rates for all conditions in the analyses.

The main effect of congruency was significant, $F(1, 14) = 21.69$, $MSE = 8,997.38$, $p < .001$, $\eta_p^2 = .61$, with faster RTs for congruent (978 ms) than incongruent (1,042 ms) trials. It is worth noting that this 64-ms congruency effect was substantially smaller than the 320-ms congruency effect observed in Experiment 2a (see Figure 4). The main effect of display size was also significant, $F(2, 28) = 12.83$, $MSE = 4,558.95$, $p < .001$, $\eta_p^2 = .48$; RTs were 1,044; 1,002; and 985 ms for the five-, seven-, and nine-item display size conditions, respectively.

However, the central question of interest was whether an ISPC effect would be observed when participants searched for an odd-colored singleton, rather than an odd-shaped singleton as in Experiments 2a and 2b. Critically, the Proportion Congruent × Congruency interaction was not significant, $F(1, 14) = 1.21$, $MSE = 2,522.4$, $p = .289$, $\eta_p^2 = .08$ (see Figure 4). No other main effects or interactions were significant.

In summary, attention to odd-colored targets produced a much smaller congruency effect than did attention to the less salient odd-shaped targets in Experiment 2a. Further, whereas an ISPC effect was observed in Experiments 2a and 2b, no such effect was observed here. This result suggests ISPC effects hinge on use of a task that produces substantial congruency effects in the first place. Here, the attention-capture effect of the distracting odd-shaped singleton was minimal, and as a result the ISPC manipulation appears not to have resulted in significant adaptation of attentional control settings.

Experiment 3: Context-Specific Proportion Congruent

The ISPC effects observed in Experiments 2a and 2b depend on the association between distinct item types and proportion congruent and suggest that attentional control settings appropriate for a particular item type can be cued online at trial onset.

In the Stroop domain, Crump, Gong, and Milliken (2006) demonstrated that an association between proportion congruent and a task-irrelevant contextual dimension can produce a similar effect. Rather than manipulating proportion congruent between different item types, they manipulated proportion congruent between different location contexts. In this case congruency effects were larger in the high than low proportion congruent location context, referred to as a context-specific proportion congruent (CSPC) effect. This effect suggests that, in addition to features of items, the features of the context in which items appear can trigger the application of associated attentional control settings in a rapid, online fashion. The CSPC effect has since been replicated several times in Stroop and other domains (for a review see Bugg & Crump, 2012).

To examine whether the methods used in studies of the CSPC effect can be used to study context-specific control of attention capture (see also Cosman & Vecera, 2013a, 2014; Vecera et al., 2014), we implemented a CSPC design with the task used in Experiments 1, 2a, and 2c. In the present experiment, search displays appeared to either the left or right of fixation. Search displays on one side of fixation were high proportion congruent (.80 congruent, .20 incongruent), and search displays on the other side of fixation were low proportion congruent (.20 congruent, .80 incongruent). All trial types were mixed randomly within each block. As a result, participants could not predict whether an upcoming search display would appear on the left or right of the screen and therefore were unable to predict whether the upcoming search display was likely to be congruent or incongruent. The central issue was whether the attention-capture effect would be larger in the high proportion congruent location context than in the low proportion congruent location context.

Method

Participants. Forty-two undergraduate students from McMaster University provided informed consent and received course credit for their participation in this study. All participants reported normal color vision and normal or corrected-to-normal visual acuity.

Apparatus. The experiment was controlled by in-house software developed in MetaCard and run on Macintosh G5 computers. A 21-in. widescreen Apple liquid crystal display monitor was used to present search displays to participants. Participants were seated approximately 57 cm from the computer monitor.

Stimuli. Because the proportion congruent effects were not affected by display size in prior experiments, we used a single display size of seven shapes. Circle and square shapes from Experiment 2a were used in this experiment. Search displays were presented on the left or right of the screen, with the imaginary midpoint of each search display 13 degrees from fixation in a horizontal direction, as illustrated in Figure 5. Search displays contained either six squares and one circle or six circles and one square. For all search displays, the target singleton was the odd-shaped object. The task-irrelevant feature singleton was the odd-colored object. All objects in each display were colored red or blue; the lines presented inside each object were white. The colors and shapes of particular objects in each search display were assigned randomly as appropriate for the particular condition at the beginning of each trial.

Design and procedure. A 2 (proportion congruent: .80 vs. .20) × 2 (congruency: congruent vs. incongruent) × 6 (block: 1–6) repeated-measures design was used in this experiment. The proportion congruent variable was defined by the location in which a search display appeared, to either the left or right of fixation. The assignment of proportion congruent to the left or right of fixation was counterbalanced across participants so that for half of the participants high proportion congruent displays appeared on the left, and for the other half of the participants high proportion congruent displays appeared on the right. Participants completed six blocks of 128 trials each. Each of the 128 trials in each block contained 64 trials in which displays appeared on the right of fixation, and 64 trials in which displays appeared on the left of fixation. Of the 64 trials in the high proportion congruent location, 48 of the displays were congruent, and the re-

Experiment 3: Context-specific Proportion Congruent
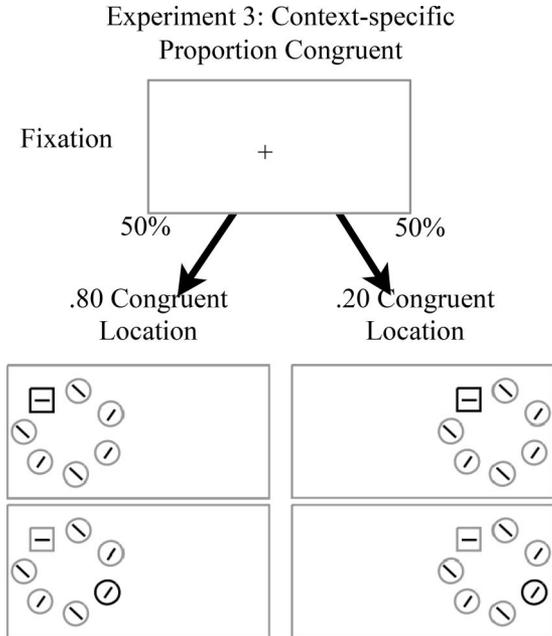
Figure 5. Depiction of the apparatus for Experiment 3 showing that search displays appeared in one of two location contexts, to the left or right of fixation. Each location was associated with a high or low proportion of congruent search displays.

maining 16 displays were incongruent. Similarly, of the 64 trials in the low proportion congruent location, 48 of the displays were incongruent, and the remaining 16 displays were congruent. The procedure was the same as in prior experiments, with the exception that participants pressed the *Z* key for vertical responses and the *M* key for horizontal responses.

Results and Discussion

The outlier analysis resulted in removal of 3% of the RTs from analysis. Mean RTs and error rates for each condition, collapsed across participants, are displayed in Table 1. An alpha criterion of .05 was used for all statistical tests unless otherwise reported.

Mean RTs and error rates were submitted to separate repeated-measures ANOVAs that treated proportion congruent (.80/.20) and congruency (congruent–incongruent) as variables. The critical issue in this analysis was whether the congruency effect (incongruent–congruent) would vary as a function of proportion congruent (i.e., location context).

In the analysis of RTs, the main effect of congruency was significant, $F(1, 41) = 462.8$, $MSE = 2,797.99$, $p < .001$, $\eta_p^2 = .92$. Responses were faster for congruent (841 ms) than incongruent (1,016 ms) trials. More important, the Proportion Congruent × Congruency interaction was significant, $F(1, 41) = 7.01$, $MSE = 787.07$, $p = .011$, $\eta_p^2 = .15$. Congruency effects were larger in the high (187 ms) than low (164 ms) proportion congruent location context, producing a CSPC effect of 23 ms. Parallel analyses of error rates showed no significant main effects or higher order interactions. Mean error rates in all conditions were less than .04.

As in prior experiments, an additional analysis of RTs examined trial-to-trial sequence effects. This analysis revealed no evidence that the CSPC effect reported previously depended on either sequential congruency or location context repetition (see King, Korb, & Egner, 2012). The results of this analysis are described in Appendix C of the online supplemental materials.

The results of Experiment 3 demonstrate that the CSPC method generalizes to the visual search domain and in particular that the CSPC method can be used as a tool to study context-specific control over attention capture (see also Cosman & Vecera, 2013a, 2014). These findings add to those found in tasks of attention filtering (Corballis & Gratton, 2003; Crump et al., 2006), task switching (Crump & Logan, 2010; Leboe, Wong, Crump, & Stobbe, 2008), and trial-to-trial repetition effects (Heinemann, Kunde, & Kiesel, 2009). We view these parallel results as strong evidence that contextual features can cue the retrieval of associated attentional control settings.

Experiments 4a and 4b: Transfer of Context-Specific Control

In studies of Stroop ISPC and CSPC effects, a key issue is that proportion congruent is varied by presenting some stimuli more than others. For example, in the CSPC Stroop method, when the word *blue* is presented centrally, the color blue might appear three times above fixation in the high proportion congruent context for every one time it appears below fixation in the low proportion congruent context (Crump et al., 2006). Larger congruency effects in the high proportion congruent context are then attributed to attentional control settings that are learned through experience with these biased item frequencies. If indeed the CSPC effect owes to adaptation of attentional control settings for a particular class of items, then attentional control settings might be expected to generalize to items that share a key contextual feature with the frequency-biased items that were directly responsible for the adaptation.

This issue was addressed by Crump and Milliken (2009) using two distinct sets of items. One set of Stroop items (e.g., red and green items) were frequency-biased, with congruent items appearing with higher frequency in one location than the other. Another set of Stroop items (e.g., yellow and blue items) appeared in the high and low proportion congruent contexts but with equal frequency. The critical question was whether contextual cueing of attentional control would generalize from the frequency-biased to the frequency-unbiased

Table 1

Mean Correct Response Latencies and Error Rates for All Conditions in Experiment 3

Proportion congruent	Congruent	Incongruent	Incongruent–congruent	CSPC
.20				
Response time (ms)	849	1,013	164	
SE	30	31	9	
Error rate	.03	.04		
.80				
Response time (ms)	833	1,020	187	23
SE	28	31	10	9
Error rate	.03	.04		

Note. CSPC = context-specific proportion congruent.

items. This result occurred in two experiments, providing evidence that attentional control settings learned with one set of items can be applied to another set of items that share a key contextual feature.

The purpose of Experiments 4a and 4b was to test this same issue for the attention-capture effect observed in Experiment 3 using the transfer-based design of Crump and Milliken (2009). This extension is particularly relevant given recent debate about whether the CSPC effect for frequency-unbiased items is reproducible (Crump, Brosowsky, & Milliken, 2017; Hutcheon & Spieler, 2017). We created two distinct search display types: context displays and transfer displays, as illustrated in Figure 6. For the context displays, the location of the display was perfectly (100%) predictive of congruency. For example, in one counterbalancing condition, context displays were 100% congruent on the left and 100% incongruent on the right. For the transfer displays, the location of the display was not predictive of congruency. Transfer displays appearing on the left and right were 50% congruent and 50% incongruent. The context and transfer displays were mixed together and presented randomly within blocks. Because transfer displays appeared in locations that were predictive of congruency for the context displays, performance for the transfer displays allowed us to assess whether attentional control settings learned through experience with the context displays would generalize to the transfer displays.

Experiment 4a used the same shapes and colors for context and transfer items. Experiment 4b was an extension using distinct shapes and colors so there was no feature overlap between the context and transfer items.

Method

Participants. Fifty undergraduate students (Experiment 4a = 20, Experiment 4b = 30) from McMaster University provided informed consent and received course credit for their participation in this study. All participants reported normal color vision and normal or corrected-to-normal visual acuity.

Apparatus and stimuli. The apparatus and stimuli were the same as in Experiment 3.

Design. We constructed two separate sets of displays: context and transfer displays. Display types were defined by the assignment of specific shapes to target and distractor roles. In Experiment 4a, squares and circles were used as targets and distractors. For example, in one counterbalancing condition context displays always had square targets and circle distractors and transfer displays always had circle targets and square distractors. The color of the target and distractors in each display was red or blue and varied on a trial-to-trial basis.

In Experiment 4b, one set of displays was constructed using squares and circles that were colored blue or yellow, and the other set was constructed using a seven-sided star and a six-sided triangular bell, colored red or green. Across counterbalancing conditions, one set was assigned to the context displays, and the other to the transfer displays.

The context-specific proportion manipulation was applied to only the context displays. Specifically, context displays appearing on one side of the screen were congruent (e.g., six red circles, one blue square) 100% of the time, whereas context displays appearing on the other side of the screen were incongruent (e.g., five red circles, one blue circle, one red square) 100% of the time. Transfer displays also appeared on either the left or right of the screen. However, transfer displays appearing on both the left and right sides of the screen were 50% congruent and 50% incongruent.

Procedure. Participants completed six blocks of 128 trials each. Each of the 128 trials in each block contained 64 trials in which displays appeared to the right of fixation and 64 trials in which displays appeared to the left of fixation. Of the 64 trials in each of the high and low proportion congruent locations, 32 trials involved context displays and 32 trials involved transfer displays. In the high proportion congruent location, all 32 context displays were congruent, whereas 16 transfer displays were congruent and 16 transfer displays were incongruent. Similarly, in the low proportion congruent location,

Experiment 4a and 4b: Near and Far Transfer
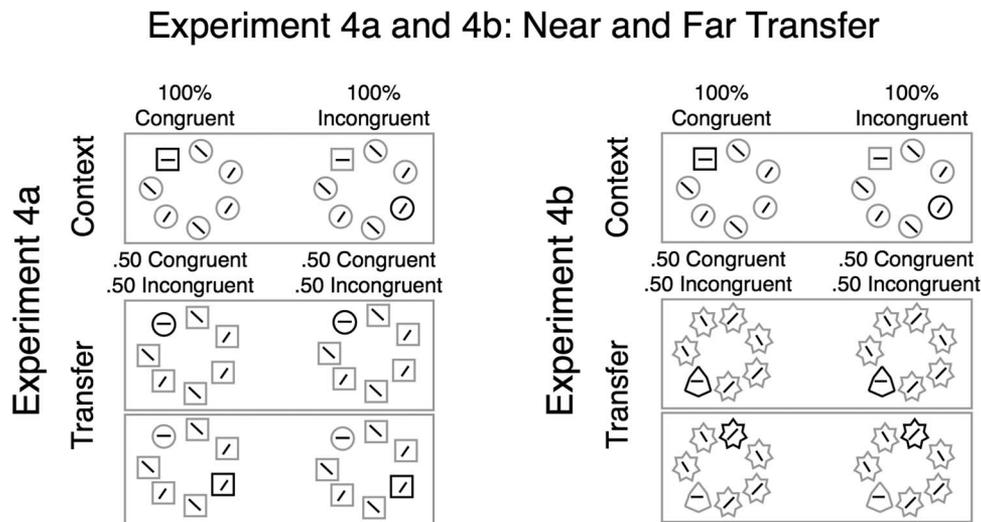
Figure 6. Depiction of search displays and design in Experiments 4a and 4b to create frequency-biased (context) items, which carry the context-specific proportion congruent manipulation, and frequency-unbiased (transfer) items to determine whether the context-specific proportion congruent effect generalizes across item sets. Experiment 4a (near) used similar shapes between item sets, and Experiment 4b (far) used dissimilar shapes.

all 32 context displays were incongruent, whereas 16 transfer displays were congruent and 16 transfer displays were incongruent.

Results and Discussion

Experiment 4a: Context-specific proportion congruent effects. One participant was omitted for making more than 20% errors. The outlier analysis removed 3% of the RTs from further analysis. Mean RTs were computed using the remaining observations. Mean RTs and error rates for each condition, collapsed across participants, are displayed in Table 2.

The central question was whether the congruency effect for the frequency-unbiased transfer items would differ for the two proportion congruent location contexts. Mean RTs and error rates for the transfer items were submitted to a repeated-measures ANOVA that treated proportion congruent (high–low) and congruency (congruent–incongruent) as variables.

For RTs, the main effect of congruency was significant, $F(1, 18) = 46.83$, $MSE = 33,271.49$, $p < .001$, $\eta_p^2 = .72$. Responses for congruent trials (935 ms) were faster than responses for incongruent trials (1,221 ms). More important, the Proportion Congruent × Congruency interaction was significant, $F(1, 18) = 10.94$, $MSE = 1,776.26$, $p = .004$, $\eta_p^2 = .38$. The congruency effect for transfer items was larger in the high (318 ms) than low (254 ms) proportion congruent location context, producing a CSPC effect for transfer items of 64 ms. A corresponding analysis of error rates yielded no significant effects, and mean error rates were less than .05 in all conditions.

Although of less theoretical importance, the data from the context items were also subject to analysis. Note that proportion congruent was not a variable in this analysis, because all context trials were either congruent or incongruent for each of the two proportion congruent contexts. This analysis revealed a significant

Table 2
Mean Correct Line-Orientation-Judgment Response Latencies and Error Rates for Transfer Displays in Experiment 4a

Item and context	Congruent	Incongruent	Incongruent–congruent	CSPC
Transfer				
Low proportion congruent				
Response time (ms)	963	1,218	254	
SE	64	100	42	
Error rate	.04	.04		
High proportion congruent				
Response time (ms)	906	1,224	318	64
SE	53	92	47	20
Error rate	.03	.04		
Context				
Low proportion congruent				
Response time (ms)	—	1,213		
SE	—	93		
Error rate	—	.04		
High proportion congruent				
Response time (ms)	923	—	290	
SE	53	—	48	
Error rate	.03	—		

Note. Dashes indicate no data. CSPC = context-specific proportion congruent.

effect of congruency, $F(1, 18) = 38.48$, $MSE = 20,708$, $p < .001$, $\eta_p^2 = 0.68$. Responses to congruent trials (923 ms) were faster than responses to incongruent trials (1,213 ms). The effect of congruency was not significant in the analysis of error rates. A sequential analysis showed the CSPC effect for transfer items did not depend on trial-to-trial context repetitions and is reported in Appendix D of the online supplemental materials.

Experiment 4b: Context-specific proportion congruent effects. The outlier analysis eliminated 3% of the RTs from further analysis. Mean RTs were computed using the remaining observations. RTs and error rates for each condition, collapsed across participants, are displayed in Table 3.

For RTs, the main effect of congruency was significant, $F(1, 29) = 84.3$, $MSE = 10,691.81$, $p < .001$, $\eta_p^2 = .74$. Responses on congruent trials (796 ms) were faster than responses on incongruent trials (970 ms). More important, the Proportion Congruent × Congruency interaction was significant, $F(1, 29) = 5.38$, $MSE = 876.06$, $p = .027$, $\eta_p^2 = .16$. The congruency effect for transfer items was larger in the high (186 ms) than low (161 ms) proportion congruent location context, producing a CSPC effect of 25 ms. A corresponding analysis of error rates yielded no significant effects, and mean error rates were less than .04 in all conditions.

For the context displays, the effect of congruency was significant, $F(1, 29) = 73.79$, $MSE = 8,426.41$, $p < .001$, $\eta_p^2 = .72$. Responses were faster for congruent trials (807 ms) than for incongruent trials (1,011 ms). There was no effect of congruency for error rates. Finally, as reported in Appendix E of the online supplemental materials, the CSPC effect for transfer items did not depend on trial-to-trial context repetitions.

The critical finding from Experiments 4a and 4b was that a CSPC effect was observed for the frequency-unbiased transfer items. It is important to note that in Experiment 4b, this generalization of learning from the context to the transfer items occurred despite the absence of feature overlap between the shapes and colors used to define the context and transfer items. This finding rules out the view that learning processes sensitive to the biased frequencies of the context items are specific to strictly those same items. Instead, learning related to attention control for the context items generalized to the transfer items that shared their location as a key contextual feature. To be clear, we do not deny the role of item frequency in mediating visual search but suggest that an account relying solely on such a learning process is not sufficient to explain our current findings. In our opinion, the CSPC attention-capture effect for the transfer displays licenses consideration of how specific processing experiences (i.e., experience with particular context displays) affords generalized control over behavior.

General Discussion

We drew upon prior work from the proportion congruent literature to investigate whether procedures used to investigate context-dependent control in classic selective attention tasks extend to the attention-capture domain. We implemented listwide (Experiment 1), item-specific (Experiments 2a, 2b, and 2c), and context-specific (Experiments 3, 4a, and 4b) proportion congruent designs as methods to modulate attention-capture phenomena.

Experiment 1 showed that attention-capture effects increased as the proportion of congruent displays increased. Experiments 2a, 2b, and 2c (and those in our companion article, Thomson et al.,

Table 3

Mean Correct Line-Orientation-Judgment Response Latencies and Error Rates for Transfer Displays in Experiment 4b

Item and context	Congruent	Incongruent	Incongruent–congruent	CSPC
Transfer				
Low proportion congruent				
Response time (ms)	806	967	161	
SE	25	35	20	
Error rate	.03	.03		
High proportion congruent				
Response time (ms)	787	972	186	25
SE	25	35	20	11
Error rate	.03	.03		
Context				
Low proportion congruent				
Response time (ms)	—	1,011		
SE	—	58		
Error rate	—	.04		
High proportion congruent				
Response time (ms)	807	—	204	
SE	40	—	24	
Error rate	.03	—		

Note. Dashes indicate no data. CSPC = context-specific proportion congruent.

2014) showed that attention capture can be modulated in an item-specific fashion, with capture effects for displays associated with high proportion congruent being larger than those for displays associated with low proportion congruent. Both effects are consistent with a role for experience-based learning and memory processes to tune attentional sets as a function of the proportion of congruent displays. However, listwide effects can be explained by voluntary search strategies, and item-specific effects by frequency-sensitive learning and transitory trial-to-trial influences.

Experiments 3, 4a, and 4b showed that attention capture can be modulated in a context-specific fashion, with capture effects in location contexts being associated with larger high than low proportion congruent. These experiments, and in particular the transfer designs of Experiments 4a and 4b, showed unique support for context-dependent control of attention capture that cannot be explained by trial-to-trial influences or a frequency-driven learning process.

Addressing Alternative Explanations

Voluntary strategies. It is uncontroversial that people can control attention in a voluntary goal-directed manner (Posner & Snyder, 1975; Schneider & Shiffrin, 1977). An important requirement for investigations of context-dependent attentional control is to produce evidence that cannot be explained by voluntary sources of control. Listwide proportion congruent effects are open to a voluntary control account. Participants may become aware that a task-irrelevant dimension usually signals a task-relevant dimension and may adopt a general strategy to attend more or less to either dimension.

For example, Bacon and Egeth (1994) and Leber and Egeth (2006) have argued that the mode in which participants engage in visual search modulates the size of the attention-capture effect.

Specifically, the attention-capture effect is smaller when participants are encouraged to search for a specific feature (feature-search mode) than when participants are encouraged to search for a salient oddball (singleton-search mode). Leber and Egeth (2006) trained participants in one of two conditions to induce a feature- or singleton-search mode and showed this training persisted in influencing attention capture in a transfer session, with smaller attention-capture effects for participants initially trained in feature-search mode. It is possible that the listwide proportion congruent manipulation had a similar influence on search modes, causing participants to develop and apply a sustained mode of search over the course of the experiment.

Item-specific and context-specific proportion congruent designs partly rule out voluntary control accounts by randomly intermixing high and low proportion congruent conditions in the same block of trials. At a minimum, this manipulation prevents participants from accurately predicting the congruency status of an upcoming trial. However, even if participants prepared a single, sustained attentional set prior to the onset of a given trial, such a strategy would have a uniform influence on congruency effects and would not explain item-specific or context-specific effects. Alternatively, it is possible that participants voluntarily maintained multiple attentional sets and were capable of rapidly switching between them in response to stimulus cues associated with different sets. Prior work in the Stroop domain has argued against rapid voluntary switching by showing that participants were unable to explicitly report on the proportion congruent manipulation (Crump et al., 2006). Although we did not assess awareness in the present experiments, we assume that participants were similarly unaware of the proportion manipulation. This inference fits with Cosman and Vecera's (2013a) evidence of context-dependent control of attention capture using background pictures as contexts associated with different search modes. Their participants did not claim to use a switching strategy, and participants' reports of explicit strategy use did not account for their results. However, it is worth noting that the contexts paired with different search modes in their study were presented 1,000 ms prior to the presentation of each search display, which could have given participants enough time to encode the context as a cue for switching their search mode. In our experiments, contextual cues were simultaneous with search display onset, further supporting the view that cues rapidly trigger a more automatic, rather than deliberate, adjustment of attentional control.

Trial-to-trial influences. Measures of attentional control are well known to be influenced by carryover of processing from immediately preceding trials. Trial-to-trial influences take many forms but are generally divided into short-lasting carryover of activation states (priming) or control states (i.e., conflict-monitoring) from trial $n - 1$ to the current trial n. Listwide proportion congruent designs also bias the relative proportions of specific trial sequences. For example, high proportion congruent lists increase the likelihood that a congruent item precedes an incongruent item, and vice versa for low proportion congruent lists. Congruency effects are larger when trial $n - 1$ contains a congruent rather than an incongruent trial (Gratton et al., 1992), and such trial-to-trial influences could account for the aggregate listwide proportion congruent effect, which collapses over trial-to-trial effects. The randomization inherent to item- and context-specific designs roughly equates potential biases due to sequential effects, and whether sequential influences alone can account for

these proportion congruent phenomena becomes an empirical question.

Across all of our experiments we reported analyses of trial-to-trial effects in the online supplemental materials. As expected, we found consistent sequential effects across experiments. However, we did not find that any of these influences interacted with the proportion congruent effects. We take this as evidence that transitory carryover of recent processing does not provide an emergent explanation of item-specific and context-specific proportion congruent effects.

Frequency-driven learning. It is well known that practice with specific stimulus–response pairs speeds responding (Logan, 1988, 2002). Most proportion congruent designs are confounded with item frequency, and thus modulations to congruency effects by proportion congruent may be driven by a process that speeds responding to more frequent rather than less frequent items (Schmidt & Besner, 2008; Schmidt, Crump, Cheesman, & Besner, 2007). Thus, item- and context-specific proportion congruent effects may not reflect memory-driven contributions to attentional control but rather conventional stimulus–response learning.

One of the critical findings speaking against a simple frequency-based account is the finding that context-specific proportion congruent effects generalize to frequency-unbiased transfer items (Crump & Milliken, 2009; see also Crump et al., 2017; Hutcheon & Spieler, 2017). The present work extends this transfer effect in two experiments (4a and 4b) showing that the context-specific proportion congruent effect in attention capture generalizes from one set of frequency-biased displays to frequency-unbiased displays containing both similar and dissimilar shape and color information. These transfer effects cannot be explained by a learning process sensitive to the frequency of specific displays and thus license consideration of the idea that contextual cues can control the application of generalized attentional control settings.

Alternative mechanisms of contextual control. Evidence of context-dependent attentional control could implicate a role for cue-driven learning and memory processes to feed attentional control (Crump, 2016). In broad terms, experience with applying goal-directed attentional sets in specific stimulus environments establishes a contextually bound history or record of attentional control. In this way, the memorial record of attentional control is drawn upon to update and adjust selective attention operations. Critically, updating is cue-driven, by aspects of either a stimulus or the context in which it appears. Contextual cues retrieve associated attentional sets that are then applied to adjust online attentional processing. This allows cues to not only capture attention (Jonides, 1981) but also modulate how attention is controlled.

The view just discussed implies that high-level attentional sets are preserved along with contextual cues for later retrieval by memory processes. It is worth considering an alternative view that could explain item- and context-specific control phenomena without the involvement of high-level attentional control sets. For example, the perceptual representations of stimulus displays may themselves adapt in a manner sensitive to the proportion congruent manipulation, potentially allowing a learning process to modify saliency maps for specific displays in a context-specific fashion. Or, as suggested by one reviewer, item and context cues could become associated with the general application of inhibitory attentional control and, rather than retrieving whole attentional sets with varying dimensional weights, could simply gate whether or not some level of inhibitory control is applied to processing of the display. We think pursuing these alternatives and considering how they explain contextual control phenomena, including evidence of generalization of contextual control over attention, is a worthwhile avenue for future work.

Implications for Attention Capture

Theeuwes and colleagues (Theeuwes, 1991, 1992, 2004; Theeuwes, Kramer, Hahn, & Irwin, 1998) forwarded the view that attention capture is purely bottom-up and is subject to top-down influences only in circumstances that permit serial or partly serial search (Theeuwes, 2004). The bottom-up view holds that attentional resources within an attentional window are automatically deployed to regions of a perceptual saliency map containing the most salient discontinuities in the visual scene. People can restrict the focus of the attentional window, which can eliminate attention capture (as in serial or partly serial search) when the attentional window does not encompass salient stimuli.

A productive area for future research would be to investigate whether changes to an attentional window, or changes to a perceptual saliency map, are responsible for the contextual control effects reported here. The size of the attentional window could be controlled by contextual cues. For example, the high proportion congruent context could rapidly increase the size of the attentional window, thereby increasing the likelihood that a feature singleton captures attention, and vice versa for the low proportion congruent context. Also, the profile of the perceptual saliency map could be controlled by contextual cues. For example, the perceptual saliency map in the high proportion congruent location may register larger discontinuities than those recorded for the same stimuli presented in the low proportion congruent location.

Conclusion

The concept of context-dependent attentional control has been discussed in early theories of memory (Norman, 1968), attention (Shiffrin & Schneider, 1977), and action (Norman & Shallice, 1980), and it has received substantial empirical support and renewed interest across domains in attention (Bugg & Crump, 2012; Chun & Turk-Browne, 2007; Egner, 2008; Vecera et al., 2014). The varied manifestations of context-dependent control open questions about whether common learning and memory processes operate according to general principles in controlling attention across domains. Understanding this issue requires integrative work exploring relations between context-dependent control phenomena in different paradigms. We took steps toward this synthesis by examining context-dependent control of attention capture using proportion congruent as a tool.

Résumé

Plusieurs sources indépendantes démontrent que le phénomène attentionnel peut être contrôlé d'une manière dépendante du contexte en utilisant des repères associés à différentes intensités de contrôle attentionnel. La présente série d'expériences fournit des données convergentes selon lesquelles le phénomène de capture de l'attention peut être modulé de manière reliée au contexte. Nous avons déterminé si les méthodes tirées de la littérature traitant du

rapport d'éléments congruents/incongruents (conceptions de rapport de congruence dans l'ensemble d'une liste, propre aux éléments et propre au contexte) qui sont reconnues pour moduler les effets d'interférence de distracteurs lors de la tâche de Stroop ou d'une tâche de contrôle de l'inhibition (Eriksen flanker task) peuvent moduler la capture de l'attention au moyen de modèles d'ensembles de traits saillants à un élément. D'une expérience à l'autre, nous avons trouvé des indications selon lesquelles la capture de l'attention peut être modulée par des manipulations du rapport d'éléments congruents/incongruents parmi l'ensemble d'une liste, par rapport à des éléments spécifiques et par rapport au contexte. Nous discutons des défis que pose l'interprétation des résultats issus des études sur le rapport éléments congruents/incongruents. Toutefois, nous postulons que nos constatations convergent avec les travaux actuels qui ont permis de démontrer le contrôle de capture de l'attention selon le contexte.

Mots-clés : capture de l'attention, rapport d'éléments congruents/incongruents, contrôle contextuel, attention, contrôle cognitif.

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