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When global and local information about attentional demands collide: evidence for global dominance

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Abstract

This study investigated how global and local information about attentional demands influence attentional control, with a special interest in whether one information source dominates when they conflict. In Experiment 1, we manipulated proportion congruence in two blocks (i.e., mostly congruent versus mostly incongruent) of a Stroop task to create different global demands (i.e., low versus high, respectively). Additionally, we created different local demands by embedding 10-trial lists in each block that varied in their proportion congruence (10% to 90% congruent), and half the lists were preceded by a valid precue explicitly informing participants of upcoming attentional demands. Stroop effects were smaller in mostly incongruent compared with mostly congruent blocks demonstrating the influence of global information. Stroop effects also varied according to the proportion congruence of the abbreviated lists and differed between cued and uncued lists (i.e., cueing effect), demonstrating the influence of local information. Critically, we found that global and local information interacted, such that the cueing effect differed between the two blocks. While there was evidence that participants used the precue to relax control for mostly congruent lists within the mostly congruent block, the cueing effect was absent within the mostly incongruent block. In Experiment 2, we replicated the latter pattern and thereby provided further evidence that participants do not use local precues to relax control when attentional demands are globally high. The findings suggest that both global and local information sources influence the control of attention, and global information dominates local expectations when the information sources collide.

Keywords Cognitive control · Precues · Attentional demands · Global information · Local information

Many facets of daily life require us to use cognitive (attentional) control to flexibly select relevant information while ignoring irrelevant information to achieve our goals (Miller & Cohen, 2001). How we meet attentional challenges has been the subject of much investigation. Humans can cope with attentional challenges in the moment that conflicts arise (e.g., Botvinick et al., 2001), and they also can prepare for future challenges by predicting upcoming attentional demands (e.g., Braver et al., 2007). Quite interestingly, such predictions can be based on various sources of information such as explicit knowledge, experience, and contextual changes, with some sources being more global and others being more local (Abrahamse et al., 2016; Braver, 2012; Egner, 2014; Jiang et al., 2014; Jiang et al., 2018; Shenhav et al., 2013; Waskom et al., 2017). Consider the following example pertaining to driving. Imagine that you are driving to a destination and that destination requires you to travel through both a city and a more rural area. While driving through the city, you learn that in this context there is a globally high likelihood of encountering distraction (i.e., high attentional demands); while driving through the more rural area, you learn that in this context there is a globally low likelihood of encountering distraction (i.e., low attentional demands). Consider further that a passenger is accompanying you on this trip and is closely monitoring traffic flow on a reliable source, such as Google Maps. Imagine that while in the city, your passenger announces, “Awesome, there’s very little traffic for the next several blocks,” or, conversely, while in the rural area, the passenger announces, “Darn, it looks like there is a lot of traffic for the next mile.” The question is will you, as the driver, apply an attentional control state (i.e., the extent to which you focus attention on relevant information and filter out irrelevant information) that coincides with the global probability of distraction (i.e., corresponding to the information you learned about the city overall or the rural area overall) or the local probability of

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distraction (i.e., corresponding to the information about the near future communicated by the passenger). In other words, will attentional control align with global information or local information about attentional demands?[1]

The present study is interested in how humans use different sources of information when facing attentional challenges, with a special interest in the question of whether one source (i.e., global or local) dominates in guiding attentional control when conflicting sources are present. Before introducing the laboratory paradigm that we used to examine these questions, we will first present a selective review of background literature that describes what we know to date about how the global and local information sources investigated in our research affect attentional control. This review will focus primarily on studies that have used the Stroop task (i.e., name ink color while ignoring a color word; MacLeod, 1991; Stroop, 1935) because that is the task we used in the present study.

Global and local information sources guide attentional control

A manipulation that is widely used to induce modulations of attentional control based on global information is the list-wide proportion congruence (LWPC) manipulation (e.g., Logan & Zbrodoff, 1979; for reviews see Bugg, 2017; Bugg & Crump, 2012). The manipulation is simple—in one (low demand) block[2] (that is typically ~100 trials) participants encounter mostly congruent (MC) trials (i.e., trials in which the to-be-named color matches the word such as BLUE in blue ink) and in a separate (high demand) block, participants encounter mostly incongruent (MI) trials (i.e., trials in which the to-be-named color conflicts with the word such as YELLOW in blue ink). The key pattern that emerges is referred to as the LWPC effect and is characterized by a smaller Stroop effect (i.e., calculated as the difference in the mean reaction times between incongruent and congruent trials, with a smaller difference indicating less susceptibility to distraction from the word) in the MI block compared with the MC block. Theoretically, this difference in performance between blocks is consistent with the view that attentional control is heightened in the MI block (i.e., the color is weighted/processed to a greater extent than the word) but relaxed in the MC block (i.e., the word is processed as is the color) based on global information regarding attentional demands. Experiments that have found LWPC effects for diagnostic items, stimuli that are frequency and PC matched across the MI and MC blocks,[3] provide strong support for this interpretation (see Braem et al., 2019; Bugg, 2014; Bugg & Chanani, 2011; Gonthier et al., 2016; Hutchison, 2011; Spinelli et al., 2019; cf. Botvinick et al., 2001; Miller & Cohen, 2001; see Schmidt, 2013, for an alternative account based on temporal learning; but see Cohen-Shikora et al., 2019; Spinelli et al., 2019 for evidence countering the account).

How might global information about attentional demands (i.e., overall PC of the block) produce the LWPC effect? One possibility is that participants become aware of the PC of the block as they experience the congruent and incongruent trials, and they might intentionally (strategically) modulate how attentive they are according to their emergent expectations about the attentional demands (see, e.g., Lowe & Mitterer, 1982, for a strategic account of the LWPC effect). For example, participants might figure out the level of attentional demand in each block and adjust their attention accordingly ("This block has difficult trials most of the time, so I have to focus more on the task"). Adopting a focused attentional control setting for the MI block, and a relaxed attentional control setting for the MC block ("This block has easy trials most of the time, so I can relax my attentional focus") would create a smaller Stroop effect for the MI than for the MC block (i.e., the LWPC effect). On the other hand, participants might learn the global demands without becoming aware of the LWPC, in which case control might be implicitly adjusted based on this global information.

A key piece of evidence in support of the implicit influence of global information (i.e., overall PC of the block) stems from the findings of Blais et al. (2012). They found that participants' accuracy in estimating the relative frequency of trial types in a LWPC paradigm was poor and the accuracy of their estimates did not correspond to the magnitude of their LWPC effect. In other words, explicit awareness of the PC of the blocks was not accompanied by a larger LWPC effect. Given these patterns, they concluded that the LWPC effect reflects subconscious adaptations based on implicitly learning the regularities within each block.

In addition to studies that show how the control of attention varies depending on the PC of an entire block of trials, a global information source, other studies have examined how more local[4] information sources affect control. Most pertinent to the

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[1] Here, use of the terms global and local corresponds to differing temporal contexts (i.e., different blocks or lists of trials) and not differing spatial contexts as in, for example, Navon (1977) stimuli (e.g., a large "global" letter constructed of smaller "local" letters).

[2] In a traditional LWPC paradigm, these might be referred to either as blocks or lists. To reduce confusion when describing the past results and the present study, which includes smaller lists within larger blocks, we will use the label "blocks" in reference to the LWPC manipulation.

[3] In the color-word Stroop task, the typical procedure is to use a separate set of colors and words as diagnostic items, and these items are 50% congruent and presented equally often in the MI and MC blocks. The goal is to isolate control processes from processes such as feature-based priming (e.g., repetition priming; item-level priming of control states) or contingency learning that can masquerade as control (Bugg et al., 2008).

[4] We refer to a "more local" level to contrast it with the global level discussed in the preceding paragraphs and because the local information sources in the present study correspond to small lists and not to the even more local level of individual trials (e.g., trial-by-trial precues announcing congruency of upcoming Stroop trials) that has been examined in some experiments previously (e.g., Bugg & Smallwood, 2016; Jiménez et al., 2021). Hereafter, we simply refer to local.

current study are findings from the precued lists paradigm (Bugg et al., 2015). In this paradigm, participants performed the Stroop task in small 10-trial lists[5] that were embedded within an overall 50% congruent block. Half of the lists were MC and half of the lists were MI, and the lists were randomly intermixed. Critically, in addition to this PC manipulation, there was also a precue manipulation with half of the lists in each PC condition presented with (i.e., cued lists) or without a precue (i.e., uncued lists). In the cued lists, the precues were valid, and they explicitly communicated expectations about upcoming attentional demands (i.e., the next list will be "80% matching" [MC] or "80% conflicting" [MI]). In the uncued lists, an uninformative precue ("??????") was presented at the beginning of the list and participants had to rely on experience to learn the PC of the list. Thus, there were two potential local sources of information that could be used to adjust attentional control in this study, and there was evidence for both. One source was the PC of each 10-trial list (i.e., local PC), and the Stroop effect varied based on local PC with a smaller effect observed in MI than MC lists. The second source, which was of greatest interest, was the explicit information communicated by the precues that signaled what attentional demands to expect in the list (i.e., local expectations). By comparing Stroop effects between the cued and uncued lists for a given PC, Bugg et al. (2015) were able to isolate the role of local expectations. They found that participants consistently used the precues to relax control in the MC lists (as indicated by a larger Stroop effect in cued than uncued lists, i.e., a *cueing effect*) but showed little use of the precues in the MI lists (there was not a smaller Stroop effect in cued than uncued lists, i.e., no *cueing effect*; Bugg & Diede, 2018; also see Liu & Yeung, 2020, for evidence in a task-switching paradigm). These findings demonstrated that, in a 50% congruent block, participants use local expectations based on precues to adjust attentional control, particularly when local attentional demands are anticipated to be low (i.e., MC lists).

In sum, various sources of information can be used to guide attentional control. There is evidence from LWPC paradigms showing that global information about an overall block of trials (i.e., longer lists of ~100 trials) is used to guide control, and the evidence to date lends support to the view that this global information and corresponding adjustments in control are likely implicit (Blais et al., 2012; see Entel et al., 2014, for a global information source that is explicit). Additionally, there is evidence from the precued lists paradigm showing that local information about smaller lists (i.e., 10 trials) within overall 50% congruent blocks also guides control. Critically, for present purposes, this evidence includes a cueing effect in MC lists, which supports a role for local expectations in control adjustments. Additionally, the evidence that Stroop effects differed for MC and MI lists in this paradigm, including in uncued lists, demonstrates that local information (i.e., PC) also may be implicitly learned within the smaller lists (see Suh & Bugg, 2021, for the time course of such learning) and used to guide adjustments in control (see Bugg & Diede, 2018 for awareness data supporting this idea).[6]

Current study

A limitation of prior studies on the role of global and local information is that they were not able to address the key question at the heart of the current study: Which source of information do participants rely upon to adjust attentional control when global and local information sources collide? The studies employing the precued lists paradigm (Bugg et al., 2015; Bugg & Diede, 2018) were not well suited to address this interplay because the global PC of the block of smaller lists was always 50% congruent. This means that the local information in the smaller lists (i.e., 80% matching or 80% conflicting precues) did not strongly conflict with the global information coming from the accumulated PC of the block (i.e., 50% congruent global PC), which was relatively neutral (unbiased information).

To better understand the relative influence of global and local information sources on adjustments in control, we created a new version of the precued lists paradigm in which these information sources were independently manipulated. We varied the global PC between large blocks and embedded smaller lists in those blocks that varied in their PC, with half of these lists being cued. This design enabled us to examine the interplay between more global information (i.e., attentional demands based on the overall experience within a block of the experiment) and more local information (e.g., expected attentional demands based on the explicit precues for smaller lists), including when the sources conflicted (e.g., a local list that was cued as MC within a global block of trials that was MI). To the best of our knowledge, the current study is the first to investigate this interplay by creating conflicting global and local information sources.

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[5] We refer to the smaller lists within an overall larger block as "lists," so as to distinguish these smaller lists from the overall "block" of trials.

[6] A note on the terminology that we have adopted here and henceforth in this manuscript. As aforementioned, there are two possible sources of local information: local PC information, which refers to the different PC levels across the small lists that participants can learn through experience, and local precues that explicitly communicate the PC of a subset of these lists. We use the term "local expectations" to refer to the latter, thereby reserving reference to "expectations" for a source that explicitly communicates expectations (see also Bugg et al., 2015, for a similar use of this term). We use the term "local information" to refer to the local PC information (just as we use the term "global information" to refer to the global PC information associated with the larger blocks). We also use the term "local information" when referring collectively to the influence of the two local sources (local PC or local precues).

Experiment 1

In Experiment 1, we investigated the influence of global and local information sources on the Stroop effect. To do so, we adapted the precued lists paradigm and varied the global and local PC levels independently (please see Fig. 1). Participants performed two large blocks, one that was MC and one that was MI. The MC block included 30%, 50%, 70%, and 90% congruent lists comprising 10 trials each, resulting in an overall global PC of 66% within the block. The MI block included 10%, 30%, 50%, and 70% congruent lists comprising 10 trials each, resulting in an overall global PC of 34% within the block. The 90% lists in the MC block and 10% lists in the MI block were considered inducer lists and presented disproportionately more frequently to create an overall MC or MI bias within each block. The remaining lists (30%, 50%, 70% lists) were considered test lists and presented equally frequently across the MC and MI blocks.

In this study, participants had different sources of information, global and local, that could be utilized to guide attentional control and we had several hypotheses regarding how these sources of information would be used. We begin by describing the hypotheses that correspond to patterns that have been observed previously in the literature.

One hypothesis is that there will be an LWPC effect, such that the Stroop effect will be smaller in the MI block compared with the MC block (i.e., a global PC by trial type interaction), and this pattern should be evident even when examining only the test lists. The LWPC effect would indicate that control was adjusted based on the accumulated PC reflecting the overall experience in each block, that is, based on global information. While such a pattern would be consistent with many prior studies demonstrating LWPC effects, to our knowledge the LWPC effect has not previously been investigated in the context of a paradigm where discrete lists with varying PCs and precues are intermixed within MC and MI blocks thereby affording participants the opportunity to exploit local information sources as well as the global source. Thus, observing the LWPC effect in this study would be a novel though not unexpected finding.

A second hypothesis is that there will be a cueing effect (i.e., cue by trial type interaction) when comparing performance between cued and uncued lists showing an adjustment in control based on the precues and indicating an effect of local expectations. The cueing effect would be evidenced by a larger Stroop effect for the cued condition compared with the uncued condition in MC lists (i.e., PC-90 and PC-70 lists) indicating a relaxation in control in response to the precue, and a smaller Stroop effect for the cued condition compared with the uncued condition in MI lists (i.e., PC-10 and PC-30 lists) indicating a heightening of control in response to the precue. These patterns would indicate that participants utilized local expectations provided by the precues to adjust control in the cued lists, above and beyond any adjustments based on experiencing the trials within the uncued lists. Considering the results of prior studies (Bugg et al., 2015; Bugg & Diede, 2018), we should observe a cueing effect with the MC lists but not the MI lists.

Finally, the novel and most critical question we addressed concerned the interplay between local information and global information, and this question was examined by independently manipulating the two to create conflicting information

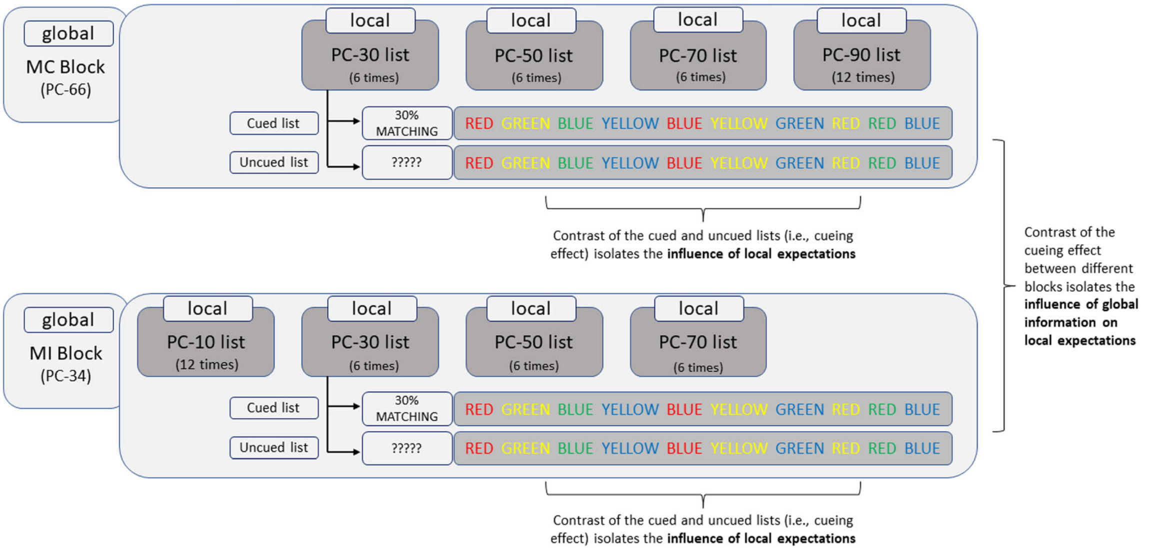

Fig. 1 Illustration of Global and Local Information Sources in the Experiment. *Note.* There were two blocks (MC and MI), and the order was counterbalanced. The PC-90 list in the MC block and PC-10 list in the MI block were considered inducer lists, while the remaining lists were presented both in the MC and the MI blocks (PC-30, PC-50, and PC-70 lists) and considered the test lists. To simplify the figure, the color-word Stroop trials appear in the same order for the cued and uncued conditions. However, during the experiment, the order of the stimuli within a list was random. (Color figure online)

sources for the first time in a Stroop task. Of primary interest was the interplay between local precue use (local expectations) and the global attentional demands of the blocks. By contrasting cueing effects for the same local PCs (i.e., the test lists) across the different global PCs (i.e., MC and MI blocks), we can determine whether global information changes the influence of local expectations on the control of attention. Of special interest is the question of which source dominates when the two sources conflict (e.g., PC-70 [MC] list in the MI block and PC-30 [MI] list in the MC block). One hypothesis is that local expectations would dominate meaning that the cueing effect for the PC-70 list in the MI block would be comparable to that observed in the MC block (and the cueing effect for the PC-30 list in the MC block would be comparable to that observed in the MI block). This hypothesis is consistent with a prior study that pitted global information in the form of a LWPC manipulation (MC and MI blocks) against local expectations in the form of trial-by-trial precues that announced the congruency for every trial in each block (Hutchison et al., 2016). The key finding was that there was not a LWPC effect in the condition in which precues were included but there was a LWPC effect when precues were not provided. In other words, when the local expectation was also available to guide control, participants did not exploit the global PCs to establish more focused (MI block) versus more relaxed (MC block) control settings.

The hypothesis that local expectations would dominate in the present study can also be formulated based on the assumption that participants may be more apt to rely on the explicit and valid information provided by the precues rather than the implicitly learned global PCs. This is analogous to relying on the information the passenger in the driving example communicates based on Google Maps rather than learned information about the global likelihood of distraction (i.e., attentional demands) in a certain area (e.g., a city). The alternative hypothesis, though, is that the global information would dominate. This hypothesis is formulated based on the assumption that participants might avoid the cognitive effort associated with intentionally modulating control list-by-list (every 10 trials) based on the precues (Kool et al., 2010; Kool & Botvinick, 2018), and instead adjust control implicitly based on the global PCs (Blais et al., 2012).

While our primary interest was understanding the interplay between local expectations (based on the precues) and global information (global attentional demands), the design also enabled us to examine whether use of local information in the form of the PC of the small lists was influenced by global information. An effect of local PC would be evidenced by smaller Stroop effects for the lists that have relatively fewer congruent trials (i.e., a local PC by trial type interaction). If this effect differs between MC and MI blocks (i.e., there is a global PC by local PC by trial type interaction), it suggests that global attentional demands affect sensitivity and/or adjustments to the local experience of encountering differing frequencies of congruent and incongruent trials in the smaller lists. We did not have strong hypotheses about this but reasoned that, in a global MI block wherein attentional control is high and there may be better filtering of the irrelevant words, the local PC effect may be smaller compared with the MC block (because learning PC requires processing relationships between words and colors; cf. Abrahamse et al., 2013).

Method

Participants The sample size was calculated based on a simulation-based approach (Lakens & Caldwell, 2021) using data from the precued lists paradigm of Experiment 1 and 2 of Bugg et al. (2015), the most comparable study in the literature. With a desired power of 0.8 and an alpha level of 0.05, the required sample size for the critical three-way interaction (Global PC × Cue × Trial Type) was 28. We more than doubled the targeted sample size since the present study involved an additional variable (i.e., local PC). As a result, we collected data from 64 Washington University in St. Louis students (46 females, mean age = 19.31 years, *SD* = 1.07) who participated in the study to fulfill a credit as a partial requirement of psychology courses. All participants were native English speakers and reported that they have normal or corrected-to-normal vision as well as normal color vision. The study was approved by the Institutional Review Board at Washington University in St. Louis.

Apparatus The experiment was programmed and presented on a 17-inch LCD monitor with the E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). A standard keyboard was used to record manual responses.

Stimulus, procedure, and design The stimuli, procedure, and design closely followed those of Bugg et al. (2015)[7] except for the global PC manipulation, use of more than two local PCs, and the response mode. The experiment consisted of two blocks and the overall PC was varied between the blocks as MC (66% congruent) and MI (34% congruent). In the MC block, a 2 (Cue: Cued vs. Uncued) × 4 (Local PC: 30 vs. 50 vs. 70 vs. 90) × 2 (Trial Type: Congruent vs. Incongruent) within-subject design was used. The PC-90 list was presented 12 times and the rest of the PC lists (see Table 1 for details) were presented 6 times configuring the overall PC of 66%. In

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[7] We inherit a limitation of that design, which is that we cannot pinpoint which experience-based process (e.g., adjustments in control, repetition priming, contingency learning) is responsible for performance within a given list (e.g., uncued lists). However, this is not the primary question of interest in this study. The primary question concerns the contribution of global information (as indicated by LWPC effects) and local expectations (as indicated by precueing effects), and especially their interaction (how global information affects precueing effects), and the limitation does not affect interpretation of the patterns that inform this question.

the MI block, a 2 (Cue: Cued vs. Uncued) × 4 (Local PC: 10 vs. 30 vs. 50 vs. 70) × 2 (Trial Type: Congruent vs. Incongruent) within-subject design was used. The PC-10 lists were presented 12 times whereas the rest of the PC lists were repeated 6 times configuring the overall PC of 34%. As explained before, PC-30, PC-50, and PC-70 lists were tests lists existing both within the MC and the MI blocks. The purpose of including PC-10 and PC-90 lists (i.e., inducer lists) and presenting them more than the test lists was to create different global PCs in these blocks. Half of the participants began with the MC block and switched to the MI block, and the remaining participants completed the experiment in the opposite order. Each list within a block was comprised of 10 trials of the color-word Stroop task which were presented in a random order. Importantly, at the beginning of each list, an informative (cued condition) or uninformative (uncued condition) precue was presented. For the cued condition, the precue informed participants about the percentage of the matching trials in the following 10 trials. For example, in the cued PC-70 lists, participants were presented with "In the next list, 70% of trials will be MATCHING. This means that on 7 out of 10 the word will match the color." For the uncued condition, question marks ("?????") were presented indicating that the percentage of the matching trials in the next 10 trials is unknown. Participants were explicitly informed that the precue is always a valid predictor for the upcoming conflict when presented.

All stimuli were presented on a gray background. A color-word (RED, GREEN, BLUE, and YELLOW; font-size: 35) was presented at the center of the screen in red, green, blue, or yellow ink yielding congruent (i.e., the word and the color is matched) or incongruent (i.e., the word and the color is not matched) trials. Participants were asked to press the keys corresponding to the color of the word as quickly and accurately as possible. The colors red, green, blue, and yellow were mapped on the keys "m," "n," "x," and "z," respectively. The color-word was presented on the screen until the response was made. The intertrial interval was 1,000 ms. Participants completed eight trials as the practice to learn the key-color mappings where performance feedback (e.g., "Correct" or "Incorrect") was provided. Following the practice trials, the main test began where no performance feedback was presented. At the beginning of each list, participants were given a screen with either informative or uninformative precues and then asked to press the space bar to begin. Each participant completed 60 lists (Table 1 for details) which took 30 minutes to complete.

Table 1 Lists Counts of Proportion Congruence Conditions in Experiments 1 and 2

Experiment 1	MI Block (PC-34)					MC Block (PC-66)				
	10	30	50	70	90	10	30	50	70	90
Cued	6	3	3	3	0	0	3	3	3	6
Uncued	6	3	3	3	0	0	3	3	3	6
Experiment 2	MI Block 1 (PC-34)					MI Block 2 (PC-34)				
	10	20	50	80		10	20	50	80	
Cued	6	3	3	3		6	3	3	3	
Uncued	6	3	3	3		6	3	3	3	

Note. The block order was counterbalanced between participants in Experiment 1.

Results

The data are available online (https://osf.io/xfrw9/). Two participants were excluded due to overall slower RT (three standard deviations above the mean of all participants) and low accuracy (three standard deviations below the mean of all participants). In line with Bugg et al. (2015), trials slower than 3,000 ms or faster than 200 ms were excluded from all analyses (eliminated 0.97% of total trials). Only correct responses were included in the RT analysis. We performed a set of analyses to characterize how global and local information affected Stroop performance and how they interacted. To test our first hypothesis (i.e., the influence of global information manifested by the LWPC effect), we examined performance in the test lists (local PC levels of PC-30, PC-50, and PC-70) across MC and MI blocks. This analysis also enabled us to test whether the cueing effect in the test lists showed different patterns depending on the global PC level. Then, in subsequent analyses, we performed separate analyses for the MC and MI blocks to test our second (i.e., the influence of local expectations manifested by the cueing effect) and final hypothesis (i.e., to understand how the local information was used in each global block). Mean RTs and error rates are presented in Table 2.

Reaction time A 2 (Global PC: MC vs. MI) × 2 (Cue: Cued vs. Uncued) × 3 (Local PC: 30 vs. 50 vs. 70) × 2 (Trial Type: Congruent vs. Incongruent) repeated-measures ANOVA was conducted on the test lists. The overall RT was slower for the incongruent ($M = 685$ ms) compared with the congruent ($M = 610$ ms) trials, demonstrated by the main effect of trial type, $F(1, 61) = 200.85$, $p < .001$, $\eta_p^2 = 0.77$. A significant main effect of local PC, $F(2, 122) = 4.78$, $p = .010$, $\eta_p^2 = 0.07$, indicated that the overall RT increased as local PC increased. The main effect of global PC, $F < 1$, and the main effect of cue, $F(1, 61) = 2.12$, $p = .151$, $\eta_p^2 = 0.03$, were not significant. The Global PC × Trial Type interaction was significant, $F(1, 61) = 8.49$, $p = .005$, $\eta_p^2 = 0.12$, showing a typical LWPC pattern and demonstrating the influence of global information. The overall Stroop effect was smaller in the MI block ($M = 58$) compared with the MC block ($M = 92$).

The Cue × Trial Type interaction (i.e., cueing effect averaged across all test lists) was not significant, $F(1, 61) = 3.04$, $p = .086$, $\eta_p^2 = 0.05$, but more critically, the three-way

Table 2 Mean and Standard Deviations (in Parentheses) of RT and Error Rate in Experiment 1

			Global PC							
			MC Block (PC-66)				MI Block (PC-34)			
			Local PC				Local PC			
			PC-30	PC-50	PC-70	PC-90	PC-10	PC-30	PC-50	PC-70
RT (*SD*, ms)	Cued	Congruent	603 (96)	607 (91)	605 (81)	591 (78)	617 (105)	619 (104)	618 (89)	616 (83)
		Incongruent	673 (88)	696 (99)	712 (127)	758 (128)	666 (85)	667 (82)	671 (86)	699 (113)
		Stroop	71	89	107	168	49	48	53	83
	Uncued	Congruent	603 (106)	611 (91)	607 (87)	601 (85)	616 (92)	614 (99)	612 (90)	620 (85)
		Incongruent	673 (94)	683 (108)	673 (102)	693 (123)	661 (80)	671 (89)	673 (109)	691 (104)
		Stroop	70	73	66	92	45	57	62	71
	Cueing effect		**1**	**16**	**41****	**76*****	**4**	**−9**	**−9**	**12**
Error rate (*SD*, %)	Cued	Congruent	2.55 (5.18)	2.90 (4.62)	3.31 (3.85)	2.90 (3.04)	2.80 (7.40)	3.41 (6.23)	3.02 (4.47)	3.25 (3.66)
		Incongruent	4.43 (5.43)	5.45 (6.00)	5.04 (8.71)	8.25 (12.89)	3.36 (2.92)	4.03 (4.78)	6.26 (7.15)	6.74 (8.30)
		Stroop	1.87	2.54	1.73	5.35	0.56	0.62	3.24	3.50
	Uncued	Congruent	3.76 (6.02)	3.90 (5.79)	2.92 (3.59)	3.73 (3.59)	3.50 (6.84)	4.86 (7.71)	3.34 (4.64)	3.48 (4.75)
		Incongruent	4.25 (5.21)	4.02 (5.13)	3.97 (7.02)	7.80 (11.18)	4.00 (3.69)	4.88 (4.95)	5.17 (6.32)	4.70 (7.79)
		Stroop	0.49	0.12	1.05	4.07	0.5	0.02	1.83	1.23
	Cueing effect		**1.39**	**2.43**	**0.68**	**1.28**	**0.06**	**0.61**	**1.41**	**2.27**

Note. The block order was counterbalanced between participants. PC = proportion congruence; Cueing effect = Stroop effect in cued − Stroop effect in uncued. $^{**}p < .01$, $^{***}p < .001$.

interaction between global PC, cue, and trial type was significant, $F(1, 61) = 6.13, p = .016, \eta_p^2 = 0.09$. This indicates that the cueing effect varied depending on the global PC.[8] The cueing effect on average was 34 ms in the MC block and 0 ms in the MI block. To better characterize the nature of the cueing effects within each block (MC and MI) and thereby better understand why the cueing effect was larger in the MC than the MI blocks, we analyzed the MC and MI blocks separately (see below).

Additionally, the Local PC × Trial Type interaction was significant, $F(2, 122) = 3.27, p = .041, \eta_p^2 = 0.05$, since the Stroop effect decreased as the local PC decreased (PC-70: 82 ms, PC-50: 69 ms, PC-30: 61 ms). The Global PC × Local PC × Trial Type interaction was not significant, $F < 1$, indicating that the effect of local PC information did not vary across MC and MI blocks. The Cue × Local PC × Trial Type interaction, $F(2, 122) = 2.74, p = .076, \eta_p^2 = 0.04$, and the four-way interaction, $F < 1$, also were not significant.

MC block (PC-66) A 2 (Cue: Cued vs. Uncued) × 4 (Local PC: 30 vs. 50 vs. 70 vs. 90)[9] × 2 (Trial Type: Congruent vs. Incongruent) repeated-measures ANOVA revealed a significant main effect of trial type with slower RT in the incongruent ($M = 695$) compared with the congruent ($M = 603$) trials, $F(1, 61) = 208.72, p <. 001, \eta_p^2 = 0.77$. The mean RT was slower in the cued ($M = 655$ ms) compared with the uncued ($M = 643$ ms) condition, indicated by the main effect of cue, $F(1, 61) = 8.80, p = .004, \eta_p^2 = 0.13$. Also, the main effect of local PC was significant showing that the mean RT increased as local PC increased, $F(3, 183) = 5.18, p = .002, \eta_p^2 = 0.08$.

A significant Local PC × Trial Type interaction, $F(3, 183) = 11.83, p <.001, \eta_p^2 = 0.16$, showed that the magnitude of the Stroop effect decreased as local PC decreased. Specifically, the Stroop effect was 130 ms for PC-90, 87 ms for PC-70, 91 ms for PC-50, and 70 ms for PC-30 lists, showing a decremental trend. The two-way interaction between cue and local PC was also significant, $F(3, 183) = 2.77, p = .043, \eta_p^2 = 0.04$. Importantly, the two-way interaction between cue and trial type was significant, $F(1, 61) = 31.94, p < .001, \eta_p^2 = 0.34$, indicating that there was a cueing effect such that the Stroop effect was larger for the cued condition ($M = 109$) compared

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[8] Our research question guided this interpretation, but the three-way interaction could also be interpreted as showing that the LWPC effect was larger in the cued lists ($M = 28$ ms; MC block = 89 ms vs. MI block = 61 ms Stroop effect) than the uncued lists *(*$M = 7$ ms; MC block = 70 ms vs. MI block = 63 ms). Of course, this difference occurs because cueing effects were selectively found for cued MC lists within MC blocks (and not MI blocks), as our analyses of MC and MI blocks show, thereby exacerbating the Stroop effect in that condition.

[9] When analyzing each block separately, we included the test lists and the inducer list to fully characterize the nature of the cueing effect within each type of block.

with the uncued condition ($M = 75$ ms). Of our primary interest, the Cue × Local PC × Trial Type interaction was significant, $F(3, 183) = 5.11$, $p = .002$, $\eta_p^2 = 0.08$. To disentangle this three-way interaction, separate ANOVAs were conducted for each level of local PC. The Cue × Trial Type interaction was significant for PC-70, $F(1, 61) = 9.73$, $p = .003$, $\eta_p^2 = 0.14$, and PC-90 lists, $F(1, 61) = 19.16$, $p < .001$, $\eta_p^2 = 0.24$, but not for PC-30 ($F < 1$) and PC-50 lists, $F(1, 61) = 2.16$, $p = .146$, $\eta_p^2 = 0.03$ (please see left panel of Fig. 2). In other words, there was a cueing effect for the MC lists (PC-70 and PC-90) within the MC block but not for the neutral, PC-50, or the MI (PC-30) lists.

MI block (PC-34) A 2 (Cue: Cued vs. Uncued) × 4 (Local PC: 10 vs. 30 vs. 50 vs. 70) × 2 (Trial Type: Congruent vs. Incongruent) repeated-measures ANOVA showed a significant main effect of trial type with slower incongruent trials ($M = 675$ ms) compared with the congruent trials ($M = 616$ ms), $F(1, 61) = 134.94$, $p < .001$, $\eta_p^2 = 0.69$. The main effect of local PC was significant, $F(3, 183) = 3.23$, $p = .033$, $\eta_p^2 = 0.05$, showing a pattern that RT increased as PC increased (PC-10: 640 ms, PC-30: 643 ms, PC-50: 643 ms, PC-70: 656 ms). The main effect of cue was not significant, $F < 1$. A significant Local PC × Trial Type interaction, $F(3, 183) = 3.20$, $p = .025$, $\eta_p^2 = 0.05$, showed that the Stroop effect decreased as local PC decreased, PC-70: 77 ms, PC-50: 57 ms, PC-30: 52 ms, PC-10: 47 ms. Most importantly, the Cue × Trial Type, Cue × Local PC, and Cue × Trial Type × Local PC interactions were not significant, Fs < 1.[10] In other words, there was not a significant cueing effect overall or for any of the lists (PC-10, PC-30, PC-50, PC-70), regardless of their PC.

Error rate A 2 (Global PC: MC vs. MI) × 2 (Cue: Cued vs. Uncued) × 3 (Local PC: 30 vs. 50 vs. 70) × 2 (Trial Type: Congruent vs. Incongruent) repeated-measures ANOVA was conducted. Participants made more errors for the incongruent ($M = 4.91$) than the congruent ($M = 3.39$) trials, $F(1, 61) = 22.57$, $p < .001$, $\eta_p^2 = 0.27$, demonstrated by the main effect of trial type. The two-way interaction between cue and trial type was significant (i.e., cueing effect), showing that the Stroop effect was larger for cued ($M = 3.25$) compared with uncued ($M = 1.79$) lists, $F(1, 61) = 5.69$, $p = .020$, $\eta_p^2 = 0.09$. The Cue × Local PC interaction was significant, $F(2, 122) = 3.23$, $p = .043$, $\eta_p^2 = 0.05$, because the average error rate in the cued condition was lower than the uncued condition for the PC-30 list ($M = 3.60$ vs. $M = 4.44$), but higher in the cued than uncued condition for the PC-50 ($M = 4.41$ vs. $M = 4.11$) and PC-70 ($M = 4.59$ vs. $M = 3.77$) lists. None of the remaining main effects (Fs < 3.63) or interactions (Fs < 2.09) were significant. To keep the analyses consistent with the RT analyses, we analyzed the MC and the MI blocks separately.

MC block (PC-66) A 2 (Cue: Cued vs. Uncued) × 4 (Local PC: 30 vs. 50 vs. 70 vs. 90) × 2 (Trial Type: Congruent vs. Incongruent) repeated-measures ANOVA revealed that the main effect of trial type, $F(1, 61) = 28.79$, $p < .001$, $\eta_p^2 = 0.32$, was significant with a larger error rate for the incongruent ($M = 5.40$) compared with the congruent ($M = 3.25$) trials. The main effect of local PC was significant, $F(3, 183) = 5.22$, $p = .003$, $\eta_p^2 = 0.08$, showing that the error rate increased as PC increased (PC-30: 3.75, PC-50: 4.07, PC-70: 3.81, PC-90: 5.67). The main effect of cue was not significant, $F < 1$. The Local PC × Trial Type interaction was significant, $F(3, 183) = 5.13$, $p = .004$, $\eta_p^2 = 0.08$, showing that the Stroop effect decreased as local PC decreased (PC-90: 4.71, PC-70: 1.39, PC-50: 1.33, PC-30: 1.18). However, the Cue × Trial Type interaction, $F(1, 61) = 2.52$, $p = .118$, $\eta_p^2 = 0.04$, the Cue × Local PC interaction, $F < 1$, and the three-way interaction, $F < 1$, were not significant.

MI block (PC-34) A 2 (Cue: Cued vs. Uncued) × 4 (Local PC: 10 vs. 30 vs. 50 vs. 70) × 2 (Trial Type: Congruent vs. Incongruent) repeated-measures ANOVA revealed that the main effect of trial type, $F(1, 61) = 11.01$, $p = .002$, $\eta_p^2 = 0.15$, was significant with a larger error rate for the incongruent ($M = 4.89$) compared with the congruent ($M = 3.45$) trials. The main effect of cue, $F < 1$, and the main effect of local PC, $F(3, 183) = 2.03$, $p = .112$, $\eta_p^2 = 0.03$, were not significant. The Local PC × Trial Type interaction was significant, $F(3, 183) = 2.93$, $p = .035$, $\eta_p^2 = 0.05$, showing that the Stroop effect decreased as local PC decreased (PC-70: 2.36, PC-50: 2.53, PC-30: 0.32, PC-10: 0.53). The Cue × Trial Type interaction, $F(1, 61) = 2.66$, $p = .108$, $\eta_p^2 = 0.04$, Cue × Local PC interaction, $F(3, 183) = 1.93$, $p = .126$, $\eta_p^2 = 0.03$, and the three-way interaction, $F < 1$, were not significant.

Discussion

In Experiment 1, we examined the influence of local and global information on the adjustment of attentional control settings. Our primary interest was testing whether global attentional demands would influence the use of local information afforded by the precues in a Stroop task. Consistent with prior studies, we found evidence for an LWPC effect. The Stroop effect was larger in the MC block than the MI block when examining the matched test lists indicating that participants had a more relaxed attentional control setting for the MC

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[10] Even though the three-way interaction was not significant, for completeness, separate ANOVAs were conducted for each level of local PC to test if there was a significant cueing effect for any list when analyzed separately. The Cue × Trial Type interaction was not significant for PC-10, PC-30, PC-50, and even for PC-70 lists, all Fs < 1.

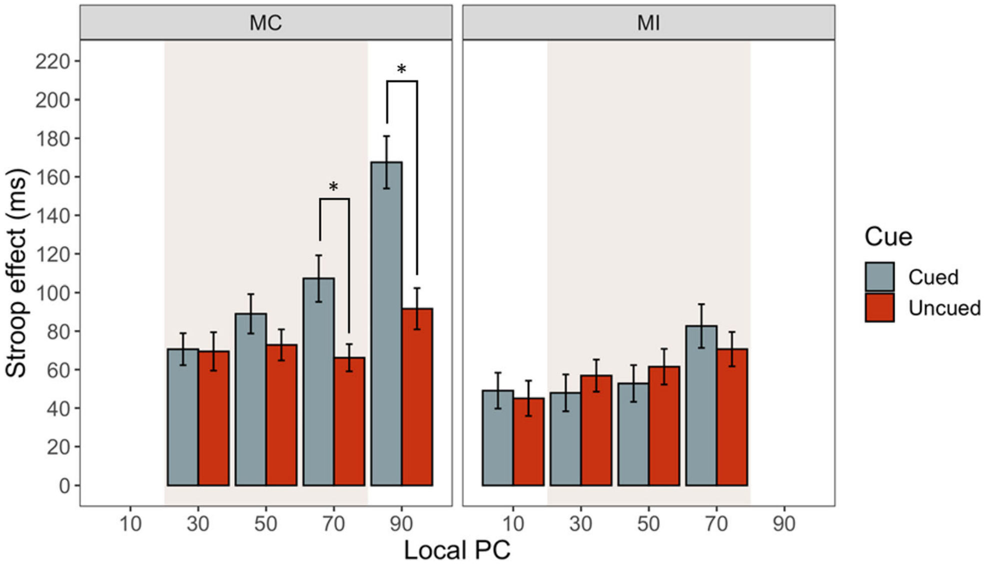

Fig. 2 Mean Stroop Effect in RT (ms) for Cued and Uncued lists in the MC and the MI Blocks of Experiment 1. *Note.* Error bars depict ±1 within-subject standard error. The highlighted area indicates the local PC levels that were identical between MC and MI blocks. MC = mostly congruent; MI = mostly incongruent. The cueing effect is reflected in the difference between the cued (gray) and uncued (red) bars for each local PC level. (Color figure online)

block and a more focused attentional control setting for the MI block. This LWPC effect indicates an influence of global information on control and confirms that global information influences performance even when local information within a list (i.e., PC and cueing) varies.

While there was not a cueing effect overall in the omnibus ANOVA, there was a three-way interaction between global PC, cue, and trial type indicating the cueing effect varied depending on the global PC. In other words, the global PC of the block influenced the use of the local precue, such that a cueing effect was observed in the MC block but not the MI block. Consistent with this interpretation, follow-up analyses showed that, in the MC block, the Stroop effect was larger in the cued than the uncued condition for both the PC-70 and PC-90 lists indicating that participants used these precues to relax their attentional control. Interestingly and in contrast, there was no hint of cueing effects in the MI block. This suggests the cueing effect was specific to the MC block.

Considering our primary question of whether global information influences adjustments in control based on local expectations, particularly striking is the pattern whereby a cueing effect was observed for the PC-70 lists in the MC block but not in the MI block. This is striking considering both that participants were precued in the same way regardless of the block (i.e., for a PC-70 list, they would have been told “In the next list, 70% of trials will be MATCHING. This means that on 7 out of 10 the word will match the color”) and cueing effects in local MC lists have been observed consistently in previous studies (see Bugg et al., 2015; Bugg & Diede, 2018, for evidence in 50% congruent blocks). This finding provides insight into the question of which source dominates when conflicting information sources are present. The local information provided by the PC-70 precue signals low attentional demand and a relaxed attentional control setting. However, when this precue is presented in the MI block, the global information signals high attentional demand and a different control setting, namely one that is focused. The fact that participants did not use the PC-70 precue to relax control in the MI blocks (but did use the precue in MC blocks and in PC-50 blocks in prior studies) indicates that global information affects precue use. The global information appears to have dominated when conflicting sources were present, given the absence of the cueing effect for PC-70 lists in the MI block. However, please note that the dominance of global information in this sense does not indicate that local information was never utilized. Local expectations based on the precues did affect performance in the MC block as evidenced by the cueing effects and additionally, local information in the form of the local PC of the lists, affected the magnitude of the Stroop effects in general (in both blocks). Rather, dominance refers specifically to the fact that the global information and not the local expectations based on the precue guided adjustments in control when conflicting information sources were present, as in the cued PC-70 list within the MI block.

Of course, there is another condition in which the global and local information sources conflicted and that is the PC-30 list in the MC block. While there was no evidence for precue use in this condition, which could be interpreted as providing further support for global dominance, the results from this condition are more difficult to interpret because of the absence of the cueing effect in the MI lists in general (i.e., as expected, there was not even a cueing effect for PC-30 lists in the MI block). Thus, the critical evidence for the interaction between local and global information, and the dominance of global information over local expectations comes from the striking absence of the cueing effect in the PC-70 lists within the MI block.

Finally, as noted previously, the current study also allowed us to examine whether local information in the form of the PC of the smaller lists led to adjustments in attentional control, and whether these adjustments were affected by global PC. There was an effect of local PC such that there was an incremental decrease in the Stroop effect as local PC decreased (as participants encountered more incongruent trials within a 10-trial list). However, this effect did not differ between the MC and MI blocks, suggesting that it was relatively immune to the influence of global attentional demands. In other words, even though the LWPC effect indicated that participants overall were more focused in the MI block and more relaxed in the MC block, in both blocks they were still sensitive to and adjusted attentional control in response to the local attentional demands of a given list.

Experiment 2

In Experiment 1, when the global PC was manipulated between blocks, we did not find evidence of a cueing effect in the PC-70 (MC) list within the MI block, which contrasts with the cueing effect that was observed for this list in the MC block and prior findings that consistently showed a robust cueing effect for MC lists in blocks that were 50% congruent (Bugg et al., 2015; Bugg & Diede, 2018). Given that this is the first report of the absence of a cueing effect in an MC list and given the significance of this finding with respect to the theoretical question of whether local expectations or global information dominates in guiding control, we attempted to replicate the performance patterns from the MI block in Experiment 2. The design of the experiment was identical to that of the MI block in Experiment 1 except for the local PC levels. Instead of PC-30 and PC-70, we used PC-20 and PC-80 to match the local PC levels to those used in previous studies (which had 80% congruent and 20% congruent lists; Bugg et al., 2015, Bugg & Diede, 2018).

Participants

48 Washington University in St. Louis students (30 Females, mean age = 19.48 years, *SD* = 1.25) participated in the study to fulfill a credit as a partial requirement of psychology courses. Considering the power analysis explained in Experiment 1 which revealed a sample size of 28 and simplification of the design (we no longer varied global PC), we targeted 48 participants for Experiment 2. All participants were native English speakers and reported that they have a normal or corrected-to-normal vision as well as a normal color vision. The study was approved by the Institutional Review Board at Washington University in St. Louis.

Apparatus The apparatus was identical to that of Experiment 1.

Stimulus, procedure, and design The stimuli, procedure, and design were identical to that of the MI block in Experiment 1. However, PC-30 was replaced by PC-20, and PC-70 was replaced by PC-80 (see Table 1).

Results

Two participants were excluded due to overall slower RT (3-standard deviation above the mean of all participants) and high error rate (3-standard deviation below the mean of all participants). Trials slower than 3,000 ms or faster than 200 ms were excluded from all analyses (eliminated 0.74% of total trials). Only correct responses were included in the RT analysis. Mean RTs and error rates for all conditions are presented in Table 3.

Reaction time A 2 (Cue: Cued vs. Uncued) × 4 (Local PC: 10 vs. 20 vs. 50 vs. 80) × 2 (Trial Type: Congruent vs. Incongruent) repeated-measures ANOVA was conducted. The results highlighted that participants were faster to respond to the congruent ($M = 617$) compared with the incongruent ($M = 686$) trials, $F(1, 45) = 133.89, p < .001, \eta_p^2 = 0.75$, indicating a typical Stoop effect. The mean RT was longer as PC increased, $F(3, 135) = 6.40$, $p = .002$, $\eta_p^2 = 0.12$, shown by the main effect of local PC. The main effect of cue was not significant, $F < 1$. The two-way interaction between trial type and local PC was significant, which indicated that the Stroop effect decreased as local PC decreased (PC-80: 99 ms, PC-50: 68 ms, PC-20: 53 ms, PC-10: 58 ms), $F(3, 135) = 11.33$, $p < .001$, $\eta_p^2 = 0.20$. The Cue × Local PC interaction, $F(3, 135) = 2.27$, $p = .084$, $\eta_p^2 = 0.05$, and Cue × Trial Type interaction (i.e., cueing effect), $F < 1$, and the three-way interaction, $F < 1$, were not significant (please see Figure 3).[11] In other words, again there was not a significant cueing effect overall or for any of the lists (PC-10, PC-20, PC-50, PC-80), regardless of their PC.

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[11] Even though the three-way interaction was not significant, separate ANOVAs, again, were conducted for completeness to examine whether there was a significant cueing effect when each local PC level was analyzed separately. The Cue × Trial Type interaction was not significant for PC-10, PC-20, PC-50, and even for PC-80 lists, all *F*s < 1.23.

Table 3 Mean and Standard Deviations (in Parentheses) of RT and Error Rate in Experiment 2

			MI Block (PC-34)			
			Local PC			
			PC-10	PC-20	PC-50	PC-80
RT (*SD*, ms)	Cued	Congruent	615 (107)	615 (71)	626 (76)	604 (76)
		Incongruent	668 (87)	670 (75)	700 (88)	708 (106)
		Stroop	53	55	74	104
	Uncued	Congruent	606 (100)	629 (107)	620 (76)	620 (73)
		Incongruent	669 (76)	680 (81)	682 (73)	713 (80)
		Stroop	63	51	62	93
	Cueing effect		**−10**	**4**	**12**	**11**
Error rate (*SD*, %)	Cued	Congruent	4.89 (10.70)	4.48 (7.76)	4.87 (4.68)	4.06 (4.43)
		Incongruent	5.23 (5.99)	4.43 (4.23)	6.66 (5.89)	8.82 (9.18)
		Stroop	.34	-0.06	1.80	4.76
	Uncued	Congruent	3.84 (7.44)	3.44 (5.42)	4.26 (4.33)	4.62 (4.63)
		Incongruent	4.78 (4.28)	4.34 (4.89)	5.95 (6.15)	7.16 (7.40)
		Stroop	0.94	0.90	1.70	2.54
	Cueing effect		**-0.60**	**−0.95**	**0.10**	**2.22**

Note. The block order was counterbalanced between participants. PC = proportion congruence; Cueing effect = Stroop effect in cued − Stroop effect in uncued.

Error rate A 2 (Cue: Cued vs. Uncued) × 4 (Local PC: 10 vs. 20 vs. 50 vs. 80) × 2 (Trial Type: Congruent vs. Incongruent) repeated-measures ANOVA was conducted. The main effect of trial type was significant, $F(1, 45) = 11.94$, $p = .001$, $\eta_p^2 = 0.21$, showing that the error rates were higher for the incongruent trials ($M = 5.92$) compared with congruent trials ($M = 4.31$). The main effect of local PC was significant, $F(3, 135) = 6.23$, $p = .002$, $\eta_p^2 = 0.12$, indicating that participants made more errors as local PC increased (PC-10: 4.69, PC-20: 4.17, PC-50: 5.44, PC-80: 6.17). The main effect of cue was not significant, $F < 1$. The Local PC × Trial Type interaction was significant, $F(3, 135) = 4.38$, $p = .006$, $\eta_p^2 = 0.09$, indicating that the Stroop effect decreased as local PC decreased (PC-80: 3.65, PC-50: 1.75, PC-20: 0.42, PC-10: 0.64). However, the Cue × Trial Type interaction, Cue × Local PC interaction, and the three-way interaction were not significant, *F*s < 1.

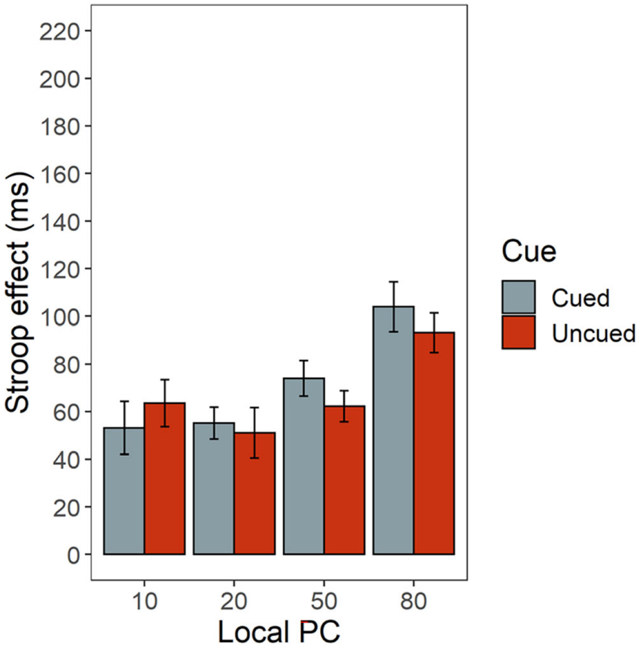

Fig. 3 Mean Stroop Effect in RT (ms) for Cued and Uncued lists in the MI Block of Experiment 2. Note. Error bars depict ±1 within-subject standard error. The cueing effect is reflected in the difference between the cued (gray) and uncued (red) bars for each local PC level. (Color figure online)

Discussion

In Experiment 2, we aimed to replicate a key finding from Experiment 1, the absence of the cueing effect for an MC list within the MI block. We replicated this finding by presenting the list as 80% congruent (rather than 70% congruent as in Experiment 1) following the previous precue studies. Still, the cueing effect in the PC-80 list, as well as the other lists (as expected), was absent. The results again showed a sharp contrast to the cueing effect found in the MC block of Experiment 1, and the previous findings of Bugg et al. (2015) and Bugg and Diede (2018) where a cueing effect in MC lists was robustly observed in a PC-50 block. Even though there was a numerical cueing effect for the PC-80 list (11 ms) in this experiment, it was not significant and was much smaller than the previous cueing effects (e.g., the cueing effects were 41 and 76 ms for the PC-70 and PC-90 lists in the MC block in Experiment 1, and the cueing effects were 39 and 61 ms for the PC-80 lists in Experiments 1 and Experiment 2 of Bugg et al., 2015). In conjunction with the results of Experiment 1, Experiment 2 provided further evidence that global information changes the impact of local expectations on attentional control, and more specifically that global information dominates over local precue use when they are conflicting. Notably, just as in Experiment 1, local information in the form of the local PC of the lists affected the magnitude of the Stroop effect, again suggesting that some local information is used even in blocks with globally high attentional demands.

General discussion

Creating a novel version of the precued lists paradigm, we investigated the interplay between global and local information sources that were independently manipulated to create conflicting information sources for the first time in the Stroop task. By comparing the Stroop effects across conditions yielding different global and local attentional demands, we aimed to disentangle the unique influence of global and local information on adjustments in control.

The contrast of the Stroop effects between test lists (PC-30, PC-50, PC-70) in the MC and the MI blocks isolated the overall influence of global information. We found a larger Stroop effect in the MC block compared with the MI block in Experiment 1, indicating that global information about attentional demands influenced control. While this was not surprising, the finding is novel in the sense that LWPC effects are typically observed in paradigms in which large lists of trials are presented continuously. In the current paradigm, trials were presented in smaller, discrete lists that varied in PC and cueing, affording participants the opportunity to adjust control exclusively based on local information if they wished (in which case an LWPC effect would not have been observed for the test lists).

The contrast of the Stroop effects in the cued and the uncued lists (i.e., the cueing effect) isolated the influence of local expectations on the control of attention. We observed that the cueing effect differed depending on the global PC of the block, with the cueing effect being larger in the MC than the MI block. Follow-up analyses that examined cueing effects separately within each block revealed several interesting patterns. First, the influence of local expectations was specific to the MC precues in the MC block. Within the MC block, when participants were explicitly informed about the upcoming conflict for the PC-70 and the PC-90 lists, they adopted a more relaxed attentional control setting showing a larger Stroop effect compared with the uncued lists. Second, the MI precues (PC-10, PC-20, and PC-30 lists) did not influence the Stroop effect (i.e., the Stroop effect was equivalent for these lists in the cued and uncued conditions) in either block (MC or MI) suggesting participants did not heighten attentional control in response to these precues. The absence of the cueing effect for MI lists is compatible with previous findings (Bugg et al., 2015; Bugg & Diede, 2018), and extends them by demonstrating this pattern outside of an equally congruent (PC-50) block context. A possible explanation is that participants default to a focused attentional control state in the Stroop task since they expect to face conflict on incongruent trials and consequently, they do not have room to further heighten attentional control when they receive an MI precue. Yet participants also did not use the MI precues in the global MC block where attentional control was overall more relaxed. Thus, another possible explanation is that participants tried to use the precues but did not know how to heighten control or they chose not to use the precues since doing so presumably would require relatively high effort (compared with relaxing control in response to an MC precue). Third, and most critically, participants did not use the MC precue (PC-70 in Experiment 1 or PC-80 in Experiment 2) within the MI block, which contrasts with the finding that participants used the MC precues (PC-70 and PC-90) in the MC block in Experiment 1. Taken together, these findings demonstrate the interaction between global information and local expectations.

This interaction between global and local information (i.e., the existence of the cueing effect only within the MC block but not within the MI block) suggests that participants used the local information afforded by the PC-70 precue to relax attentional control within the MC block, but they did not relax control when the same precue was provided within the MI block. The latter finding was replicated with a more powerful PC manipulation in Experiment 2, demonstrating the absence of the cueing effect for a PC-80 list within an MI block. The lack of cueing effects for MC lists (i.e., in response to MC precues) in MI blocks represents a sharp contrast to previous findings that consistently demonstrated a robust cueing effect for MC lists (Bugg et al., 2015; Bugg & Diede, 2018). The critical difference between the previous studies and the current study is that, in the previous studies there was not global information that might bias the adjustment of control (toward more relaxed or focused) since the overall PC of the block was always 50% (i.e., relatively neutral). However, in the current study, the overall PC of the block was biased to be MC or MI affording participants the opportunity to adjust control based on global information. The fact that a cueing effect was not found for the MC lists in the MI blocks suggests participants prioritized the global information rather than local expectations when adjusting control in this condition in which the two information sources conflicted.

The dominance of global information over local expectations might reflect the *relatively* effortless nature of adjustments in control based on global PC information. The mental effort perspective of cognitive control shows that people consider the possible costs and benefits when making decisions about engaging control (Kool & Botvinick, 2018; Shenhav et al., 2017; Westbrook & Braver, 2015). That is, people aim to maximize the benefit of actions and decide to employ cognitively taxing behaviors considering the possible payoffs of mental effort that is expended for the behavior. To use local information in the form of a precue, participants need to dynamically adjust their attentional control settings for each precue and switch between different control settings from list to list throughout a block. However, using the global information is presumably less effortful since it is thought to lead to implicit adjustments and a single attentional control setting can be applied to a whole block (Blais et al., 2012). Especially for the MI block, adopting a focused attentional control setting relying on the global information is beneficial for all lists and results in good performance. Accordingly, the cost of switching to a relaxed attentional control setting within the MI block when a MC precue was given (and the costs of having to switch back to a focused attentional control setting for subsequent lists) might have deterred participants from using the precue.

The finding that participants did not use the MC precues in the MI block may seem surprising from the perspective of accounts that view the proactive control processes operating within the MI block as metabolically costly or resource demanding (i.e., dual mechanisms of control account; Braver et al., 2007). On that view, one might have expected participants to exploit the opportunity to relax control within the MI block when the MC precue was presented (i.e., take a break from an otherwise high level of control engagement). One possibility is that the adjustments in control occurring based on global information within the MI block, though perhaps operating proactively (De Pisapia & Braver, 2006; Gonthier et al., 2016; Spinelli & Lupker, 2021), were relatively effortless given their implicit nature (Blais et al., 2012). Another possibility is that it was relatively less effortful to proactively maintain a high level of control engagement in the MI block than to a) use the MC precues to relax control, which also entails a proactive mechanism, or b) switch to a more relaxed control setting and thereafter to a more focused control setting, as discussed above. Considering the shifting nature of local expectations (i.e., lists with differing precues and PCs were randomly intermixed), another possibility that a reviewer pointed out is that the tendency to rely on global information rather than local information when the two sources conflicted may have reflected the greater volatility of local information. Local information was fast changing compared with global information, which changed more slowly (accumulated over time within a block) and thus may have been perceived as a more reliable source leading participants not to use the MC precues in the MI block (for evidence of a long[er] timescale of control in MI blocks, see Aben et al., 2017; Dey & Bugg, 2021).

The current results can also be interpreted within the related framework of the distinction between explicit and implicit information. A widely discussed question is whether cognitive control processes are explicit or implicit (Blais, 2010; Hommel, 2017; Kunde et al., 2012). Early theories posited that control processes were deliberate (Atkinson & Shiffrin, 1968; Norman & Shallice, 1986), and adjustments in control were accompanied by conscious awareness (Dehaene & Naccache, 2001; Jack & Shallice, 2001) consistent with an explicit view. Earlier explanations of the LWPC effect also tended to focus on the strategic control of attention, assuming participants were aware of and adjusted to the PC of the list (Braver et al., 2002; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; Miller & Cohen, 2001; Posner & Snyder, 1975; West & Baylis, 1998). While explicit control seems intuitive, people do not need to be aware of contextual features like PC to control attention, and implicit control can guide performance without explicit control (Blais et al., 2007; Blais et al., 2012; Crump et al., 2006; Crump & Milliken, 2009; Diede & Bugg, 2017; Verguts & Notebaert, 2008). Explicit control might be shaped by awareness or external cues (Badre & Wagner, 2006; Dreisbach et al., 2002; Rogers & Monsell, 1995), whereas implicit control might be shaped by a learning mechanism through repetitive experience (Bugg & Crump, 2012; Chiu & Egner, 2017; Dreisbach & Haider, 2006; Egner, 2014; Suh & Bugg, 2021).

In our study, the dominance of global information over local expectations might signal the dominance of implicit information (overall experience of conflict in a block) over explicit information (precues signaling conflict for an upcoming list) in guiding control. A related study investigating the relative influence of explicit and implicit information on the guidance of attentional control in task switching yielded a comparable pattern of results (Jiang et al., 2018). They investigated how explicit (i.e., provided by external cues) and implicit (i.e., overall experienced conflict) information are reconciled in the human brain using a probabilistic task-switching paradigm. They found both information sources were used to guide control, while there was a dominance of internally generated implicit information over explicit information provided by precues. While the predictive value of the explicit precues was higher, participants relied on the implicit expectations more. Our findings follow a highly similar pattern. We also found evidence of the joint influence of local and global information, with a tendency to rely on implicit global information in the face of conflict.

On the other hand, there are some prior findings that contrast with our finding that the global information dominated when global and local information conflicted (Hutchison et al., 2016; see also Colvett et al., 2020, for a contrasting finding in an alternative paradigm). As aforementioned, Hutchison et al. (2016) combined an LWPC manipulation with even more local precues. The

LWPC manipulation was of the traditional type (one long list of MC trials and one separate long list of MI trials) affording participants the opportunity to learn the global probability of conflict within each long list and relax or heighten attention accordingly. The precue manipulation was "even more local" than that used in our study in that a precue was presented prior to *each* trial within the longer lists, and participants were told whether the trial would be congruent or incongruent. The key findings for present purposes were that there was no LWPC effect in the lists that included trial-by-trial precues, but an LWPC effect was found when no precues were provided. These patterns provided evidence suggesting that participants might preferentially guide control based on local rather than global information about the likelihood of conflict. Given these patterns, it may be surprising that there was evidence for the dominance of global information in our study. However, it should be noted that there are at least two key differences between Hutchison et al. (2016) and our study. In Hutchison et al. (2016) the local information was not probabilistic (e.g., 70% of the upcoming trials will be conflicting) but deterministic (e.g., the upcoming trial will be incongruent). In our study, when a participant relaxed their attentional control setting after a "70% MATCHING" precue, this attentional control setting was optimal for most but not all the trials in the list, which might have weakened the tendency to utilize local information. In addition, in Hutchison et al., a precue occurred on every trial in the lists that included precues. Accordingly, it may have been less effortful to use the precues because participants did not have to switch between using and not using them as in the present study where the cued and uncued lists were randomly intermixed. The contrasting findings signal that there are likely boundary conditions for the dominance of global information over local information (or vice versa) that should be investigated further.

As noted previously, when concluding that global information dominated when the global and local information conflicted, the suggestion is not that local information was ignored. The local expectations based on the precues were used in the MC block (cueing effect for PC-70 and PC-90 lists). Additionally, though not the primary focus of the current study, it is notable that participants adjusted control based on local experience within the lists in each block. We observed that the Stroop effect decreased (increased) as local PC decreased (increased) in the MC and the MI blocks, and this effect of local PC did not differ between the two blocks. This pattern suggests a fine tuning of attentional control to local attentional demands within each list (e.g., increasing attentional focus incrementally based on the frequency of encountering incongruent trials within a list) regardless of whether global attentional demands were low or high. Said differently, at the extremes (PC-90 in MC block and PC-10 in MI block), attentional control was more relaxed/focused than in intermediate lists (i.e., PC-70 and PC-30).

As an exploratory analysis, we examined whether there was also evidence that the "extremeness" of local information influenced the magnitude of the cueing effect. We examined whether there was a difference in the cueing effect for the two local PCs for which we found cueing effects in the MC block (PC-90 and PC-70) with the PC-90 of course being the more extreme list. A 2 (Cue: Cued vs. Uncued) × 2 (Local PC: 70 vs. 90) × 2 (Trial Type: Congruent vs. Incongruent) repeated-measures ANOVA was conducted for the MC block. The cueing effect observed for the PC-90 list (M = 76 ms) was larger compared with that of the PC-70 list (M = 41 ms) as indicated by a significant Trial Type × Cue × Local PC interaction, $F(1, 61) = 5.21$, $p = .026$, $\eta_p^2 = 0.08$. This suggests participants may rely more on local expectations the more extreme they are (as indicated by the precue in this study), which may also relate to the mental effort perspective on cognitive control discussed earlier. That is, participants may be more likely to justify the effort needed to adjust control and more fully do so to the extent that the adjustment is likely to produce a benefit (a PC-90 list means that relaxing control should benefit 9 out of 10 trials [harm 1 trial] whereas a PC-70 list means that relaxing control should benefit 7 out of 10 [harm 3 trials]). Future studies might examine whether participants would use MC precues in a MI block if the list (precue) was more extreme (i.e., PC-90) than investigated here (the most extreme was PC-80).

Conclusion

The purpose of the current study was to explore the interplay between global and local information by independently manipulating them. We showed that global information acquired through repetitive exposure to the congruent and the incongruent items within MC and MI blocks and local information acquired through explicit precues (local expectations) and experience within the smaller lists (local PC) influenced the control of attention. Most interestingly, global information dominated over local expectations as evidenced by the reliance on the global information rather than the local precue in the face of conflict between the two information sources. That is, participants did not relax control in response to an MC precue when in an MI block; that relaxation was limited to the MC block. We posit that the interaction between local and global information, and more specifically, the dominance of the global information over local expectations might be a result of the mental effort it takes to exploit explicit local information (precues) combined with a tendency to prioritize implicit global information.

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