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Event Structure and Cognitive Control

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Recently, a great deal of research has demonstrated that although everyday experience is continuous in nature, it is parsed into separate events. The aim of the present study was to examine whether event structure can influence the effectiveness of cognitive control. Across 5 experiments we varied the structure of events within the AX-CPT by shifting the spatial location of cues and probes on a computer screen. When location shifts were present, a pattern of AX-CPT performance consistent with enhanced cognitive control was found. To test whether the location shift effects were caused by the presence of event boundaries per se, other aspects of the AX-CPT were manipulated, such as the color of cues and probes and the inclusion of a distractor task during the cue-probe delay. Changes in cognitive control were not found under these conditions, suggesting that the location shift effects were specifically related to the formation of separate event models. Together, these results can be accounted for by the Event Horizon Model and a representation-based theory of cognitive control, and suggest that cognitive control can be influenced by the surrounding environmental structure.

Keywords: cognitive control, event structure, event segmentation

Over the past several years there has been a great deal of research on cognitive control. Much of this work has been done under rather constrained laboratory conditions. However, in the world, cognitive control is needed during the ongoing flow and dynamics of everyday events. At this point, it is well known that cognition can be influenced by the structure of the environment and how information is encountered with respect to that structure (e.g., Radvansky & Copeland, 2006). The aim of the current study was to assess whether the efficiency of cognitive control is also influenced by event structure. More specifically, the current study examined whether event structure can influence performance on a standard measure of cognitive control, the AX-CPT (Braver et al., 2001; Cohen, Barch, Carter, & Servan-Schreiber, 1999).

Cognitive Control, Goal Representation, and the AX-CPT

The ability to control one's thought and action is critical for effective cognitive functioning. Although various terms have been used (e.g., executive attention, controlled processing, or supervisory attention), they generally refer to *cognitive control*. Cognitive control includes a number of key functions, including the activation of relevant knowledge or processes needed to complete a task, the suppression of inappropriate thoughts and actions, the maintenance and use of task goal information, and the updating of goals. The focus of the current study is on the representation of task goal information and how it is affected by the structure of events in which a task is embedded.

Controlled behaviors are performed in a "top-down" manner and guided by "internal" information (i.e., goals and how to achieve them). Thus, cognitive control is a set of processes that support goal-directed action including the representation of the task goal, its maintenance over time, the inhibition of goal-irrelevant information, and the updating of goal information during changing task conditions. Braver and his colleagues (Braver, 2012; Braver et al., 2001; Braver & Cohen, 2000, 2001; Braver, Gray, & Burgess, 2007; Paxton, Barch, Racine, & Braver, 2008) have developed a theoretical framework that integrates many components of controlled processing. The central hypothesis is that representing, maintaining, and using task goals (e.g., plans, instructions) in working memory are critical to cognitive control. Specifically, the ability to represent and maintain "context" information allows people to prepare appropriate responses to forthcoming events. Context here is used in a broad sense to include any form of "task-relevant information that is internally represented in such a way that it can bias processing in the pathways responsible

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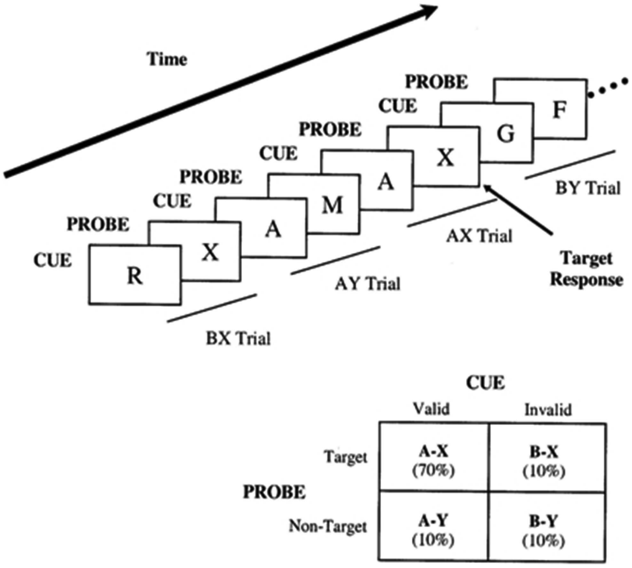
for task performance" (Braver et al., 2007, p. 79). Such context may include prior events, task goals, and any other task-relevant information. Because the representation of task-relevant goals guides the allocation of attention and response selection, it forms the basis of controlled processing.[1]

A continuous performance task (CPT) known as the AX-CPT (see Figure 1; Braver et al., 2001; Cohen et al., 1999) is a widely used measure of cognitive control. In this task, a sequence of letters is presented one-at-a-time as cue—probe pairs. The task goal is to provide a positive response to a target probe ("X"), but only when that probe follows a specific (valid) cue, "A" (hence, the name AX-CPT). For all other cue-probe pairs, a nontarget response is needed. Because a correct response to the probe ("X") depends on the preceding cue (A or not A), effective performance relies on the representation that cue.

Cognitive control in the AX-CPT requires attention and inhibition, with each being dependent on the representation of continuously changing cues. The task presents target cue-probe pairs (AX) with high frequency (70% of the trials), leading people to develop an expectation that "A" will be followed by "X." Attention to a representation of a valid cue (A) facilitates responding to a target probe (X) on AX trials. However, attention to a valid cue (A) comes with a cost on trials when it precedes a nontarget probe (Y) on AY trials (here, Y is any non-X probe). Because the cue (A) primes the target probe (X) on most of the trials, it is difficult to reject nontarget probes on AY trials, leading to slower responses and more errors. Thus, attention to a valid cue leads to benefits on AX trials and costs on AY trials.



		CUE	
		Valid	Invalid
PROBE	Target	A-X (70%)	B-X (10%)
	Non-Target	A-Y (10%)	B-Y (10%)

Figure 1. Schematic overview of the AX-CPT. Individual letters are presented sequentially as cue—probe pairs. Target trials are defined as cue—probe sequences in which an A cue precedes an X probe. Nontarget trials consist of cue—probe sequences in which an invalid cue (i.e., a letter other than A) and/or a nontarget probe (i.e., a letter other than X) are presented. Note that B refers to any non-A cue and Y indicates any non-X probe. Adapted from *Principles of Frontal Lobe Function*, by D. T. Stuss and R. T. Knight, Oxford, England: Oxford University Press, 2002, Fig. 27-2, p. 433. By permission of Oxford University Press, USA (www.oup.com).

Inhibitory processes are needed on BX trials, where B refers to trials with an invalid (non-A) cue. Recall that the high frequency of AX pairs creates a bias to give a target response whenever an "X" probe appears. In the "BX" condition, the cue is needed to inhibit the dominant tendency to make a target response to "X." The person must use the invalid cue (B) to inhibit the tendency to provide a target response to "X." Thus, the use of the invalid cue improves performance on BX trials by aiding in the inhibition of a prepotent response tendency.

Braver et al. (e.g., Braver, 2012; Braver et al., 2001; Paxton et al., 2008) have suggested that comparing performance on AY and BX trials yields important information about the integrity of cognitive control. The efficient use of cue information is characterized by a behavioral signature (Braver et al., 2001) in which performance is worse on AY than BX trials ("worse" here refers to more false alarms and/or slower response times). Such a pattern of performance is based on the ability to represent and maintain information provided by the cue. Recall that a valid cue (A) comes with an expectancy bias (i.e., that "A" will be followed by an "X"). Thus, the ability to efficiently represent the cue leads to increased false alarms and/or slower RTs on AY trials relative to BX trials. However, the ability to represent an invalid cue (B) should lead to the inhibition of the dominant tendency to provide a target response to "X." Thus, efficient representation of cue information on BX trials should enhance performance, resulting in decreased false alarms and/or faster RTs on BX trials relative to AY trials.

Event Structure and Segmentation

Although experience is continuous in nature, it is regularly parsed into events (Barker, 1963; Newtson, 1976; Zacks et al., 2001; Zacks & Swallow, 2007; Zacks & Tversky, 2001). For example, although the task of grocery shopping involves continuous activity, it may be thought of as a sequence of discrete events such as driving to the store, shopping, driving home, and putting the groceries away. The segmentation of event information is typically observed in studies in which people are asked to explicitly segment continuous experience, such as film (e.g., Newtson, 1976; Swallow, Zacks, & Abrams, 2009), or increases in reading time when an event change is encountered (e.g., Zwaan, Magliano, & Graesser, 1995; Zwaan, Radvansky, Hilliard, & Curiel, 1998). The process responsible for separating ongoing, continuous experience into events has been referred to as *event segmentation* (see Kurby & Zacks, 2008; Radvansky & Zacks, 2014; Zacks, Speer, Swallow, Braver, & Reynolds, 2007; Zacks & Swallow, 2007). The Event Horizon Model (Radvansky, 2012; Radvansky & Zacks, 2014) provides a framework for understanding how the segmentation of information into event models influences cognition, and is based on five principles: (a) event boundaries segment activity into event models, (b) there is superior availability of the current working event model, (c) causal networks among event elements are constructed, (d) memory is superior for items stored

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[1] Braver et al.'s theory of cognitive control is similar to Engle and Kane's (Engle, 2002, 2004; Kane, Bleckley, Conway, & Engle, 2001; Kane & Engle, 2003; Redick & Engle, 2011) view of working memory capacity (executive attention), which refers to "the ability to maintain goal-relevant information in a highly active, accessible state under conditions of interference or competition" (Engle, 2004, p. 149).

across multiple event models in noncompetitive attribute retrieval, and (e) retrieval interference is present for items stored across multiple event models in competitive event retrieval.

Principle 1 of the Event Horizon Model indicates that segmentation of event information occurs at boundaries where there are shifts or changes in salient event elements. There are many different types of changes that can be identified as points at which an event boundary may occur. The Event Indexing Model (Zwaan & Radvansky, 1998) specifies that event boundaries may be caused by changes in spatial location, an event's temporal framework, the entities or agents involved in an event, the goals of the characters in a situation, or the occurrence of causal breaks. There is abundant evidence that location shifts may serve as a means of segregating events. For example, people who are asked to segment activities place event boundaries at shifts in location (Magliano, Kopp, McNerney, Radvansky, & Zacks, 2012; Magliano, Miller, & Zwaan, 2001; Zacks, Speer, & Reynolds, 2009; Zacks et al., 2007). Other research has found that there may be increases in reading time when spatial shifts are encountered in texts (Radvansky & Copeland, 2010; Rinck & Bower, 1995; Zwaan et al., 1998), and that narrative elements may be sorted into different categories based on spatial shifts (Zwaan, Langston, & Graesser, 1995). The present study focused exclusively on spatial location shifts as these are most readily applied to the AX-CPT task. In the context of the current study, event changes would be expected where there is a change in the spatial-temporal framework (Radvansky & Zacks, 2014), in which spatial frameworks can define separate events, but not when there are changes that do not influence this framework, or any other aspects that define an event, such as the identity of entities or changes in causal structure.

Principle 4 of the Event Horizon Model specifies how event segmentation influences memory and as has relevance to the present study. In general, segmenting information into events affects the accessibility of previously encountered information (e.g., Kurby & Zacks, 2011; Newtson & Engquist, 1976; Radvansky & Copeland, 2006; Radvansky, Krawietz, & Tamplin, 2011; Radvansky, Tamplin, & Krawietz, 2010; Radvansky & Zacks, 1991; Swallow et al., 2009). For example, segmenting a large set of information into multiple events can reduce sources of interference, thereby improving overall retrieval (Bilodeau & Schlosberg, 1951; Greenspoon & Ranyard, 1957; Jensen, Dibble, & Anderson, 1971; Nagge, 1935; Pettijohn, Krawietz, Tamplin, Thompson, & Radvansky, 2014; Smith, Glenberg, & Bjork, 1978). In the context of the present study, the segmentation of cues and probes into separate event models should reduce sources of interference that may exist between them, making each more distinct. Doing so should increase the accessibility of cues during the AX-CPT.

Present Study

The aim of the present study was to assess the degree to which event structure can influence cognitive control. As previously noted, AX-CPT performance depends on the ability to represent cue information (e.g., Braver et al., 2001; Paxton et al., 2008). Indeed, previous research has demonstrated the importance of cue representation in the AX-CPT. For example, Lorsbach and Reimer (2010) showed that although 3rd- and 6th-grade children did equally well on a version of the AX-CPT that placed lower demands on the ability to represent cues in working memory, younger children performed significantly worse than older children under conditions that placed relatively high demands on cue representation. Thus, the present study was designed to examine whether changes in the spatial structure of events presented within the AX-CPT would affect the way in which cues and probes are represented and processed, and thereby influence the effectiveness of cognitive control.

Shifts in spatial location were accomplished in most of the present experiments by manipulating the spatial location of cues and probes within the AX-CPT (see Table 1 for an overview of the cue-probe manipulations used in each experiment). In the standard version of the AX-CPT (e.g., Braver et al., 2001), cues and probes are shown in the same font (both size and color), setting (e.g., on a black background), and screen location. Thus, cues and probes are distinguished by only a single characteristic—their identity. Therefore, although cues and probes must be encoded separately, their representations are less distinct from each other because they are part of one unsegmented event. However, according to the first principle of the Event Horizon Model, if people were to encounter an event boundary between cues and probes, such as a change in spatial location, cues and probes would be segmented into different event models.

Two predictions can be made regarding how an event boundary between cues and probes will affect cognitive control within the AX-CPT. One possibility is that such segmentation will decrease

Table 1
Overview of the Experimental Manipulations, Predictions, and Results of Experiments 1–5

			Trial type					
			Prediction			Result		
Experiment	Cue-probe delay	Cue-probe manipulation	AX	BX	AY	AX	BX	AY
Experiment 1	5 s	Location shift	Diff < same	Diff < same	Diff > same	✓	✓	✓
Experiment 2	1 s	Location shift	Diff < same	Diff < same	Diff > same	✓	✓	✓
Experiment 3	1 s	Color shift	Diff = same	Diff = same	Diff = same		✓	✓
Experiment 4	5 s	Location shift + dis task	Diff = same	Diff = same	Diff = same		✓	✓
Experiment 5	1 s	Location shift + boxes	Diff < same	Diff < same	Diff > same	✓	✓	

Note. "✓" indicates that the corresponding prediction was confirmed by the results; dis = distractor; diff = different location/color condition; same = same location/color condition; "diff < same" indicates faster RTs and/or fewer error rates in the different, than the same, location/color condition, "diff > same" indicates slower RTs and/or greater error rates in the different, than the same, location/color condition, and "=" indicates comparable RTs and error rates; location shift = cue-probe location shift; color shift = cue-probe color shift.

cognitive control. Given that cues and probes are not stored together, the presence of an event boundary between cues and probes might decrease the availability of cue information at the time a probe response is needed, and thus, lead to a reduction in cognitive control. This possibility may be derived from either the second or fifth principle of the Event Horizon Model. The second principle states that there is superior availability of information in the current working event model. The increased availability of information that is part of the current event is supported, for example, by studies showing that after an event shift, information that is part of a prior event, and not relevant to the current event, is less available (e.g., Zwaan, 1996). This principle, however, does not apply to the present study because multiple components (letters) remain relevant across the event boundaries in the AX-CPT. It is also possible to derive the prediction of decreased cognitive control when an event boundary is present from the fifth principle of the Event Horizon Model. According to this principle, retrieval interference is present for items stored across multiple event models in competitive event retrieval. As with the second principle, however, the fifth principle is also not relevant to the present study. This principle only applies when an event element (e.g., a person or object) is present in more than one event, such as an object being in more than one location. In this case, multiple models containing the shared element compete during retrieval, as evidenced by research on the fan effect (e.g., Radvansky, 1999), and the finding that walking through doorways causes forgetting (Radvansky & Copeland, 2006).

In contrast to the prediction that the segmentation of cues and probes into separate event models will decrease cognitive control, it is also possible that such segmentation may enhance cognitive control. According to the fourth principle of the Event Horizon Model, when attributes (the cue and probe identities in this case) are organized across multiple event models, the processing and retrieval of such attributes is facilitated. Furthermore, in Braver et al.'s framework, efficient cognitive control during the AX-CPT depends on the ability to represent cue information and use it to prepare for an appropriate response to the probe. As a result, the cue and probe representations are to be kept separate in the flow of processing, at least initially, so that they can be later evaluated to make a fast and accurate response. Thus, based on the fourth principle of the Event Horizon Model, the segmentation of cues and probes into separate event models should increase the representational quality of cues by making them more distinct from probes (via a reduction in interference), and thereby enhance cognitive control in the AX-CPT.

Experiment 1

The aim of Experiment 1 was to assess whether the presence of event boundaries created by shifts in the spatial locations of cues and probes on a computer screen will reduce or enhance cognitive control in the AX-CPT. As indicated above, efficient cognitive control in Braver et al.'s framework depends on the ability to represent cue information. When a cue is well represented and maintained it will lead to benefits on AX trials and BX trials, and costs on AY trials. Thus, the behavioral signature of efficient cognitive control involves better performance on AX and BX trials than AY trials (Braver et al., 2001). If the presence of an event boundary between cues and probes reduces cognitive control, performance should be *better* on AX and BX trials that do not contain an event boundary relative to those that do. However, performance should be *worse* on AY trials that do not contain an event boundary than those that do. In contrast, according to the Event Horizon Model (Radvansky, 2012; Radvansky & Zacks, 2014), spatial shifts should segment cues and probes into separate event models, resulting in an improvement in the representational quality of cues. If this is the case, performance should be *better* on AX and BX trials that contain an event boundary relative to those that do not. In contrast, performance should be *worse* on AY trials that contain an event boundary than those that do not.

Method

Participants. Participants were 52 undergraduate students at the California State University, San Bernardino, who received partial course credit for their participation. All had normal or corrected-to-normal vision.

Design. A 4 (Trial Type: AX, AY, BX, and BY) × 2 (Cue-Probe Location: same vs. different) repeated measures design was used. Response time (RT) and accuracy served as dependent variables and were recorded on each trial.

Apparatus and procedure. People were tested individually in a well-lighted room. Letters were presented sequentially on a 15-in monitor. E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) was used to present the sequence of events and to record the accuracy and latency of each response. Figure 1 provides an overview of the sequence of each trial. Cues and probes were red letters shown on a black background using 28-point uppercase Arial font. Each trial began with a cue (500 ms), followed by a centrally located fixation cross ("+") for the cue-probe delay (5,000 ms), and ended with a letter probe (500 ms). A 2,000 ms interval was used between trials and was filled with a blank screen. Target trials (AX) were cue-probe sequences in which a valid letter cue (A) appeared and was followed by the target probe letter (X). Nontarget trials were cue-probe sequences in which an invalid letter cue (i.e., letter cues other than A) and/or a nontarget probe (i.e., a letter other than X) were presented. Because of their visual similarity to X, the letters K and Y were not used as nontarget probes. There were three types of nontarget trials: BX (a cue other than the letter A followed by an X probe), AY (an A cue followed by any letter other than X), and BY (a cue that is any letter other than A followed by a probe that is any letter other than X). The letter sequences were presented randomly, with target trials appearing 77% of the time, and the nontargets trials (AY, BX, and BY) 23% of the time. Each of the nontarget trial types occurred with equal frequency (~7.7% each).

In addition to trial type, the location of the cues and probes was also manipulated. For half of the trials within each trial type, cues and probes were presented in the same screen location. For the other trials, they were in different locations. With "same" location trials, the cue and its corresponding probe were presented either on the far left or the far right side of the screen (see top half of Figure 2). Cues and probes appeared equally often on each side across the same trials. In comparison, with "different" location trials, cues and probes were shown on opposite sides of the screen. That is, on trials in which the cue was presented on the far left side of the screen, its corresponding probe was presented on far right side, and vice versa (see bottom half of Figure 2). Cues and probes were

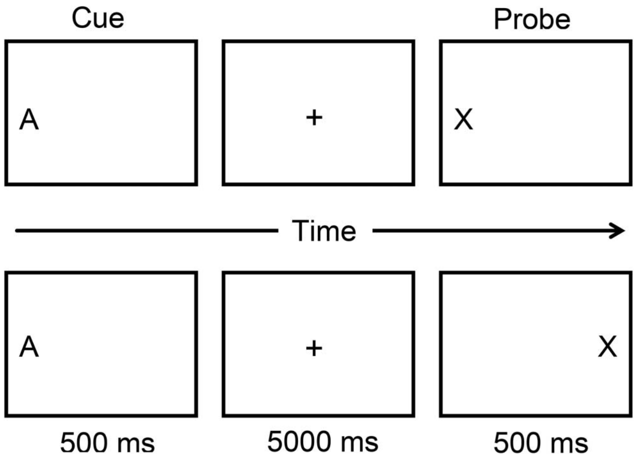

Figure 2. Schematic overview of the sequence of events that were presented in the "same" and "different" location conditions in Experiment 1. The three events presented above the timeline provide one example of trials from the same location condition, whereas the three events presented below the timeline provide one example of trials within the different location condition.

always vertically centered and presented 31.5 cm apart. Furthermore, the relative position of cues and probes was used equally often across "different location" trials within each trial type.

People were told to respond with a target response as quickly and accurately as possible to a probe (the letter X), but only when it followed a specific, valid cue (the letter A). For all other cue—probe pairs, people were to give a nontarget response, again with speed and accuracy. They were told that the location of cues and probes would vary across trials, and that the relative location of stimuli should have no bearing on their responses. Responses were made using two fingers of the same hand. Right-handers responded with their right hand using their index finger for target trials (*J* key) and their middle finger for nontarget trials (*L* key). Left-handers responded with their left hand using their index finger for target trials (*J* key) and their middle finger for nontarget trials (*G* key). The probe was presented for 500 ms and people were given an additional 2,000 ms to respond. Responses that exceeded the 2,500 ms limit were accompanied by a message reminding people to respond quickly, and were excluded from analyses. Practice and test trials were presented only after people demonstrated their understanding of the procedure during an initial practice period.

Testing occurred in a single session of 208 trials divided into four blocks of 52 trials each. Each block was composed of 40 AX trials, 4 AY trials, 4 BX trials, and 4 BY trials. Ten practice trials were given before testing. People were given the opportunity to rest between trial blocks.

Results and Discussion

Trials in which correct RTs were less than 200 ms or greater than 1,500 ms were excluded from the analyses (2.0% of the trials). Mean RTs and error rates were computed for each person in each trial type (AX, AY, BX, and BY) and cue-probe location condition (same vs. different; see Table 2 for means). Only correct responses were included in the RT data analyses.

Target (AX) trials. For the RT data there was a significant main effect of cue-probe location, $F(1, 51) = 60.57$, $MSE = 387$, $p < .001$, $\eta^2_{\text{partial}} = .54$, in which people were faster when the cues and probes appeared in different locations ($M = 552$ ms) than the same location ($M = 581$ ms). No effect was found in the error rate data, $F < 1$.

Nontarget trials. For the RT data, there was a significant main effect of trial type, $F(2, 102) = 180.92$, $MSE = 9{,}449$, $p < .001$, $\eta^2_{\text{partial}} = .78$. Post hoc comparisons revealed that people were slower on AY trials ($M = 727$ ms) than both BX ($M = 500$ ms) and BY ($M = 510$ ms) trials, however, the latter two did not differ. A main effect of cue-probe location was also found, $F(1, 51) =$

Table 2
Mean Correct Response Times (RT; in Milliseconds) and Error Rates (ER; in Proportions) by Trial Type and Cue-Probe Location/Color in Experiments 1–5

	Trial type							
	AX		AY		BX		BY	
Experiment	RT	ER	RT	ER	RT	ER	RT	ER
Experiment 1								
Same cue-probe location	581 (17)	.03 (0.3)	720 (15)	.08 (1.9)	520 (23)	.08 (1.6)	521 (20)	.02 (0.9)
Different cue-probe location	552 (17)	.03 (0.4)	735 (19)	.15 (2.6)	481 (21)	.06 (1.5)	499 (23)	.01 (0.5)
Experiment 2								
Same cue-probe location	551 (18)	.02 (0.3)	669 (19)	.04 (1.8)	523 (27)	.01 (0.5)	502 (25)	.01 (0.6)
Different cue-probe location	490 (17)	.02 (0.3)	646 (19)	.09 (2.6)	434 (28)	.02 (0.9)	424 (22)	.01 (0.5)
Experiment 3								
Same cue-probe color	539 (29)	.02 (0.6)	677 (24)	.07 (2.2)	520 (33)	.04 (1.9)	520 (34)	.00 (0.4)
Different cue-probe color	564 (32)	.05 (3.4)	665 (23)	.07 (2.3)	531 (30)	.05 (3.1)	550 (36)	.00 (0.0)
Experiment 4								
Same cue-probe location	574 (23)	.10 (3.5)	688 (25)	.15 (2.4)	452 (26)	.08 (3.2)	459 (23)	.02 (1.1)
Different cue-probe location	538 (13)	.11 (3.7)	705 (21)	.15 (2.8)	469 (26)	.11 (0.5)	462 (33)	.04 (1.3)
Experiment 5								
Same cue-probe location	513 (29)	.02 (0.4)	632 (28)	.09 (2.3)	482 (36)	.02 (0.9)	459 (35)	.01 (0.6)
Different cue-probe location	490 (28)	.01 (0.4)	643 (26)	.10 (2.5)	429 (41)	.02 (0.9)	415 (35)	.01 (0.6)

Note. *SE*s are in parentheses.

9.08, *MSE* = 2,056, $p < .01$, $\eta^2_{\text{partial}} = .15$, with people responding faster when the cues and probes were in different locations (*M* = 572 ms) than when they were in the same location (*M* = 587 ms). These main effects were qualified by a significant interaction, *F*(2, 102) = 4.65, *MSE* = 4,162, $p < .05$, $\eta^2_{\text{partial}} = .08$. For BX trials, people were faster in the different location condition than the same location condition, *F*(1, 51) = 16.04, $p < .01$, *MSE* = 2,409, $\eta^2_{\text{partial}} = .24$. In contrast, there was no difference between the same- and different-location conditions for either the AY, *F*(1, 51) = 1.58, *p* = .22, or BY, *F*(1, 51) = 2.98, *MSE* = 4,428, *p* = .09, trial types.

As with the RT data, a main effect of trial type was also found in the error rate data, *F*(2, 102) = 20.72, *MSE* = 0.012, $p < .01$, $\eta^2_{\text{partial}} = .29$. The AY trials (*M* = .12) yielded more errors than BX trials (*M* = .07), which, in turn, yielded more errors than BY trials (*M* = .02). There was also a significant interaction, *F*(2, 102) = 5.36, *MSE* = 0.009, $p < .01$, $\eta^2_{\text{partial}} = .10$. For AY trials, people had more errors when cues and probes were in different (*M* = .15) than the same (*M* = .08) location, *F*(1, 51) = 6.79, *MSE* = 0.016, *p* = .01, $\eta^2_{\text{partial}} = .12$. Error rates in the same- and different-location conditions did not differ for either BX or BY trials, both *F*s < 1.

As predicted by the Event Horizon Model (Radvansky, 2012; Radvansky & Zacks, 2014), these results demonstrated that providing an event boundary in the form of a spatial shift between the cue and target enhanced cognitive control, relative to when there was no such boundary. For target (AX) trials, location shifts improved performance in both the RT and error rate data. A change in cognitive control was also found with nontarget trials. The beneficial effects of a change in event structure were manifested in the interaction of trial type and cue-probe location in the analysis of both RTs and error rates. Specifically, RTs were faster in the different-location condition than the same-location condition for BX trials, and error rates were greater in the different-location than the same-location condition for AY trials.

Experiment 2

The changes in AX-CPT performance found in Experiment 1 indicate that event boundaries altered the effectiveness of cue and probe processing for individuals. According to our view, this was the case because location shifts between the cues and probes served as event boundaries, which resulted in the formation of separate event models. However, it is possible that such boundary effects are present only when locations shifts occur during a relatively long cue-probe delay, which may magnify the distinction between cues and probes. To further examine this, Experiment 2 used the same procedure as in Experiment 1, except that the length of the cue-probe delay was reduced from 5,000 ms to 1,000 ms.

Method

Participants. Participants were 32 undergraduate students at the California State University, San Bernardino, who received partial course credit for their participation. All had normal or corrected-to-normal vision.

Design. As with Experiment 1, a 4 (Trial Type: AX, AY, BX, and BY) × 2 (Cue-Probe Location: same vs. different) repeated measures design was used. RT and accuracy were the dependent variables.

Procedure. The apparatus and procedure were the same as those in Experiment 1, except that the cue-probe delay was shortened from 5,000 ms to 1,000 ms.

Results and Discussion

Trials in which correct RTs were less than 200 ms or greater than 1,500 ms were excluded from the analyses (1.5% of the trials). Mean RTs and error rates were computed for each person in each trial type (AX, AY, BX, and BY) and cue-probe location condition (same vs. different; see Table 2 for means). Only correct responses were included in the RT data analyses.

Target (AX) trials. For the RT data, there was a significant main effect of cue-probe location, *F*(1, 31) = 81.19, *MSE* = 725, $p < .001$, $\eta^2_{\text{partial}} = .72$, with people responding faster when cues and probes were in different locations (*M* = 490 ms) than when they were in the same location (*M* = 551 ms). No effect was found in the error rate data with target trials, $F < 1$.

Nontarget trials. For the RT data, there was a significant main effect of trial type, *F*(2, 62) = 122.00, *MSE* = 6,100, $p < .001$, $\eta^2_{\text{partial}} = .80$. Post hoc comparisons revealed that the AY trials (*M* = 657 ms) were significantly slower than both the BX (*M* = 478 ms) and BY (*M* = 463 ms) trials, with the latter two not differing from each other. There was a main effect of cue-probe location, *F*(1, 31) = 61.02, *MSE* = 3,158, $p < .001$, $\eta^2_{\text{partial}} = .66$, with people responding faster when the cues and probes were in different locations (*M* = 501 ms) than when they were in the same location (*M* = 565 ms). There was also a significant interaction, *F*(2, 62) = 5.07, *MSE* = 3,904, $p < .01$, $\eta^2_{\text{partial}} = .14$. People were faster when cues and probes were in different locations than when they were in the same location for both the BX, *F*(1, 31) = 31.58, $p < .001$,$\eta^2_{\text{partial}} = .51$, and the BY trials, *F*(1, 31) = 21.88, $p < .001$, $\eta^2_{\text{partial}} = .41$. In contrast, RTs associated with the same- and different-location conditions did not differ for AY trials, *F*(1, 31) = 3.43, *p* = .07.

For the error rate data, there was a main effect of trial type, *F*(2, 62) = 6.20, *MSE* = 0.010, $p < .01$, $\eta^2_{\text{partial}} = .17$, with people making more errors in the AY (*M* = .07) than the BX (*M* = .01) and BY (*M* = .01) trials, however, the latter two did not differ. There was also a main effect of cue-probe location, *F*(1, 31) = 8.31, *MSE* = 0.002, $p < .01$,$\eta^2_{\text{partial}} = .21$, with people making more errors in the different locations condition (*M* = .04) than the same location condition (*M* = .02). These main effects, however, were qualified by a marginally significant interaction, *F*(2, 62) = 3.13, *MSE* = 0.003, *p* = .05, $\eta^2_{\text{partial}} = .09$. For the AY trial type, people made more errors in the different location condition (*M* = .09) than the same location condition (*M* = .04), *F*(1, 31) = 5.90, $p < .05$, $\eta^2_{\text{partial}} = .16$. However, error rates did not differ for either the BX, *F*(1, 31) = 2.00, *p* = .17, or the BY, $F < 1$, trials.

Despite the use of a shorter (1,000 ms) cue-probe delay, the results of Experiment 2 replicated those of Experiment 1. Specifically, responses were faster and more accurate in the different-location condition than the same-location condition on the target (AX) trials of both experiments. Moreover, RTs were faster in the different-location condition than the same-location condition on both BX and BY nontarget trials. Finally, similar to Experiment 1, AY performance was worse in the different-location condition than in the same-location condition with the error rate data. These results further support the idea that location shifts between the cues and probes are sufficient to induce event boundaries, and cause the formation of separate event models for cues and probes presented within the AX-CPT.

Experiment 3

The results of Experiments 1 and 2 indicate that presenting cues and probes in different screen locations supports the formation of event boundaries and thereby leads to greater cognitive control in the AX-CPT. An alternative account is that improvements in controlled performance on the AX-CPT were not brought about by the event boundary nature of the spatial shifts, but by a more general change in an aspect of cues and probes. If so, similar performance changes should be observed in the AX-CPT if some other, nonevent-based aspect of the cues and probes was altered. To this end, Experiment 3 manipulated whether cues and probes appeared in the same color or different colors. Although color is a salient property of the letters, it is typically not considered a characteristic that would define an event in this context (Zwaan & Radvansky, 1998). If the performance changes observed in Experiments 1 and 2 were merely because of any kind of change between cues and probes, then the pattern of results should be replicated here. However, if the results of Experiments 1 and 2 were specific to changes in the spatial locations of cues and probes, no boundary effects should be observed.

Method

Participants. Participants were 29 undergraduate students at the California State University, San Bernardino, who received partial course credit for their participation. All had normal or corrected-to-normal vision.

Design. A 4 (Trial Type: AX, AY, BX, and BY) × 2 (Cue-Probe Color: same vs. different) repeated measures design was used. RT and accuracy were the dependent variables.

Procedure. The stimuli and procedures used in Experiment 3 were the same as the previous experiments with the following exceptions: (a) cues and probes were always presented in the same location of the screen, and (b) the color of cues and probes were varied across trials. For the same color condition, cues and probes were presented in the same font color. For half of the same color trials, the cues and probes were both presented in red, and in green for the other half, counterbalanced within each trial type. For the different color condition, cues and probes were in different colors. Therefore, if the cue was in red, the probe was in green, and vice versa. Across different trials, red and green were used equally often with cues and probes within each trial type. People were told that the color of cues and probes would vary, and that this should have no bearing on their decisions. Finally, a cue-probe delay of 1,000 ms was used.

Results and Discussion

Trials in which correct RTs were less than 200 ms or greater than 1,500 ms were excluded from the analyses (2.6% of the trials). Mean RTs and error rates were computed for each person in each trial type (AX, AY, BX, and BY) and cue-probe color condition (same vs. different; see Table 2 for means). Only correct responses were included in the analyses of RT data.

Target (AX) trials. For the RT data, there was a significant effect of cue-probe color, $F(1, 28) = 5.62$, $MSE = 1{,}510$, $p < .001$, $\eta^2_{\text{partial}} = .17$, with people responding faster in the same color condition ($M = 539$ ms) than in the different color condition ($M = 564$ ms). Note that this effect is in the opposite direction of the shift effects found in Experiments 1 and 2 with AX trials. There was no significant effect in the error rate data, $F < 1$.

Nontarget trials. For the RT data, there was a significant main effect of trial type, $F(2, 56) = 46.60$, $MSE = 8{,}266$, $p < .001$, $\eta^2_{\text{partial}} = .63$, with people being slower on the AY trials ($M = 671$ ms) than on both the BX ($M = 526$ ms) and BY ($M = 535$ ms) trials. The latter two did not differ from one another. More important, neither the main effect of cue-probe color, $F < 1$, nor the interaction, $F(2, 56) = 1.07$, $MSE = 5{,}859$, $p = .35$, was significant.

For the error rate data, there was a main effect of trial type, $F(2, 56) = 4.26$, $MSE = 0.015$, $p < .05$, $\eta^2_{\text{partial}} = .13$, with greater error rates for the AY trials ($M = .07$) than the BY trials ($M = .00$). Although the error rate for BX trials ($M = .05$) was smaller than for the AY trials, the difference was not significant. More important, as with the RT data, neither the main effect of color nor its interaction with trial type was significant, both Fs < 1.

As with Experiments 1 and 2, the behavioral signature of efficient cognitive control was also found in Experiment 3, with RTs being slower in AY trials than in BX trials. However, unlike Experiments 1 and 2, this pattern was not affected by changes in the color of cues and probes. Thus, the enhancement of cognitive control observed in Experiments 1 and 2 was likely because of the presence of an event boundary brought about by location shifts.

Cross-experiment comparisons. To directly examine differences in the patterns of results found in Experiments 1 and 2 and those in Experiment 3, two sets of cross-experiment analyses were done. The first set of analyses compared AX-CPT performance in Experiment 1 and Experiment 3. RTs and error rates were submitted to a 2 (Experiment: Experiment 1 vs. Experiment 3) × 3 (Trial Type: AY vs. BX vs. BY) × 2 (Cue-Probe Relationship: same vs. different) mixed-design analysis of variance (ANOVA).[2] The experiment factor varied between-participants, whereas trial type and cue-probe relationship varied within-participant.

For the RT data from nontarget trials, there was a significant main effect of trial type, $F(2, 118) = 152.36$, $MSE = 7{,}128$, $p < .01$, $\eta^2_{\text{partial}} = .72$. Post hoc comparisons revealed that the AY trials ($M = 664$ ms) were significantly slower than both the BX ($M = 502$ ms) and BY ($M = 499$ ms) trials, with the latter two not differ. A main effect of cue-probe relationship was also found, $F(1, 59) = 15.79$, $MSE = 4{,}145$, $p < .01$, $\eta^2_{\text{partial}} = .21$, with people responding faster in the different condition ($M = 542$ ms) than the same condition ($M = 568$ ms). There were also significant Experiment × Trial Type, $F(2, 118) = 3.60$, $MSE = 7{,}128$, $p < .05$, $\eta^2_{\text{partial}} = .06$, and Experiment × Cue-Probe Relationship interactions, $F(1, 59) = 29.47$, $MSE = 4{,}145$, $p < .01$, $\eta^2_{\text{partial}} = .33$. Most critically, a significant Experiment × Trial Type × Cue-Probe

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[2] Note that for the cue-probe relationship factor, the "same" versus "different" conditions refer to whether or not the cues and probes were presented in the same or different locations with Experiments 1 and 2. However, with Experiment 3, the same versus different cue-probe relationship conditions refer to whether or not the cues and probes were presented in the same or different colors.

Relationship interaction was found, $F(2, 118) = 4.51$, $MSE = 4{,}832$, $p < .05$, $\eta^2_{\text{partial}} = .07$. For this three-way interaction, simple effects tests revealed significant Experiment × Cue-Probe Relationship interactions for BX, $F(1, 59) = 14.38$, $MSE = 5{,}252$, $p < .01$, $\eta^2_{\text{partial}} = .20$, and BY, $F(1, 59) = 15.52$, $MSE = 5{,}747$, $p < .01$, $\eta^2_{\text{partial}} = .21$, trials, but not for AY trials ($F < 1$). In both cases, RTs were faster in Experiment 1 than Experiment 3 in the different condition, but not in the same condition. For target (AX) trials there was also a significant Cue-Probe Relationship × Experiment interaction, $F(1, 59) = 49.88$, $MSE = 1{,}098$, $p < .01$, $\eta^2_{\text{partial}} = .46$. Again, simple effects tests revealed that RTs were significantly faster in Experiment 1 than Experiment 3 in the different condition, but not in the same condition. These analyses provide strong statistical support for the claim that shifts in the location of cues and probes (Experiment 1) had a different effect on AX-CPT performance than shifts in the color of cues and probes (Experiment 3).

In the error rate data, only a significant main effect of trial type was found with nontarget trials, $F(2, 118) = 9.23$, $MSE = .013$, $p < .01$, $\eta^2_{\text{partial}} = .14$. Post hoc comparisons revealed that AY trials ($M = 6.7\%$) yielded more errors, than BX trials (3.0%), which in turn yielded more errors than BY trials (.05%). Unlike the RT data, a significant Experiment × Trial Type × Cue-Probe Relationship interaction was not found ($F < 1$).

For the second set of cross-experiment analyses, performance in Experiments 2 and 3 were compared, using the same types of ANOVAs as in the previous comparison. For the RT data with nontarget trials, there was a main effect of trial type, $F(2, 158) = 181.31$, $MSE = 9{,}030$, $p < .01$, $\eta^2_{\text{partial}} = .70$. Post hoc comparisons revealed that the AY trials ($M = 699$ ms) were slower than both the BX ($M = 512$ ms) and BY ($M = 522$ ms) trials, with the latter two did not differ. Not only were the Experiment × Type, $F(2, 118) = 9.02$, $MSE = 9{,}030$, $p < .01$, $\eta^2_{\text{partial}} = .10$, and Experiment × Cue-Probe Relationship interactions significant, $F(1, 79) = 5.60$, $MSE = 3{,}184$, $p < .05$, $\eta^2_{\text{partial}} = .07$, but so was the three-way interaction, $F(2, 158) = 3.90$, $MSE = 4{,}763$, $p < .05$, $\eta^2_{\text{partial}} = .05$. Simple effects tests revealed significant Experiment × Cue-Probe Relationship interactions with BX, $F(1, 79) = 5.86$, $MSE = 3{,}919$, $p < .05$, $\eta^2_{\text{partial}} = .07$, and BY, $F(1, 79) = 4.75$, $MSE = 5{,}387$, $p < .05$, $\eta^2_{\text{partial}} = .06$, trials, but not with AY trials, $F(1, 79) = 1.89$, $MSE = 3{,}404$, $p = .17$. In both cases, RTs were numerically faster in Experiment 2 than Experiment 3 in the different condition, but not in the same condition. For target (AX) trials there was also a significant Experiment × Cue-Probe Relationship interaction, $F(1, 79) = 34.85$, $MSE = 785$, $p < .01$, $\eta^2_{\text{partial}} = .31$. Again, simple effects tests revealed that RTs were faster in Experiment 2 than Experiment 3 in the different condition, but faster in the Experiment 3 than Experiment 2 in the same condition. As with the previous set of comparisons, these results provide statistical support for the claim that shifts in the location of cues and probes (Experiment 2) had a different effect on AX-CPT performance than shifts in the color of cues and probes (Experiment 3).

Finally, for the error rate data, a main effect of trial type was found with nontarget trials, $F(2, 158) = 19.01$, $MSE = .013$, $p < .01$, $\eta^2_{\text{partial}} = .20$. Post hoc comparisons revealed that AY trials ($M = 9.2\%$) yielded more errors, than BX trials (5.7%), which in turn yielded more errors than BY trials (.09%). In addition, there was a significant three-way interaction, $F(2, 158) = 3.10$, $MSE = .007$, $p < .05$, $\eta^2_{\text{partial}} = .04$. Simple effects tests revealed a marginally significant Trial Type × Cue-Probe Relationship interaction with AY trials, $F(1, 79) = 3.36$, $MSE = .012$, $p = .07$, $\eta^2_{\text{partial}} = .04$, but not with either BX, $F(1, 79) = 1.24$, $MSE = .006$, $p = .27$, or BY ($F < 1$) trials. Post hoc comparisons revealed that with AY trials significant more errors were produced in Experiment 2 than Experiment 3 in the different condition, but not in the same condition. No other effects were significant in the error rate data.

Taken together, these analyses demonstrate that there are quantitative as well as qualitative differences between the results of Experiments 1 and 2 and those of Experiment 3. Quantitative differences were evident by the presence of a three-way interaction in the RT data when comparing Experiments 1 and 3, and in both the RT and error rate data when comparing Experiments 2 and 3. Critically, these interactions were driven by the superior performance for the AX, BX, and BY trials, and worse performance for the AY trials, when cues and probes were presented in different locations (Experiments 1 and 2), but not when they were presented in different colors (Experiment 3). These results provide support for the idea that event boundaries occurred when the cues and probes were in different locations, but not when they were in different colors. Thus, the enhancement of cognitive control observed in Experiments 1 and 2 appears to be because of event shifts, as opposed to being a result of just any property change.

Experiment 4

The aim of Experiment 4 was to further test the claim that the improvements in cognitive control found in Experiments 1 and 2 were related to the presence of event boundaries that were defined by shifts in the location of cues and probes. As noted earlier, when people encounter an event boundary, they need to update their event models. This updating requires cognitive resources, which is why reading times can increase at event boundaries during narrative comprehension (Zwaan et al., 1995). As such, if cognitive resources are otherwise occupied, it should be more difficult for people to update their event models, and the benefit of the location shift on cognitive control should not be observed. To assess this interpretation, people in Experiment 4 performed a brief distractor task during the cue-probe delay within the AX-CPT. Specifically, people were told to remember the location of a darkened cell within a 3 × 3 grid. As with Experiments 1 and 2, cues and probes were presented either in the same or different location on the computer screen. If the location shift effects observed in Experiments 1 and 2 were because of event-model updating, any concurrent processing associated with the distractor task should selectively eliminate the beneficial effects of shifting location on cognitive control (i.e., performance on BX and AY trials should no longer be affected by shifts in cue-probe location).

Method

Participants. Participants were 35 undergraduate students at the California State University, San Bernardino, who received partial course credit for their participation. All had normal or corrected-to-normal vision.

Design. A 4 (Trial Type: AX, AY, BX, and BY) × 2 (Cue-Probe Location: same vs. different) repeated measures design was used. RT and accuracy were the dependent variables.

Procedure. The apparatus, stimuli, and procedure were identical to Experiment 1 except that before the presentation of probes, people performed a spatial working memory task during the delay. Each trial began with the presentation of the cue (500 ms) on either the left or right edge of the screen. The cue was followed by a central fixation cross ("+") for 500 ms, which, in turn, was followed by a red 3 × 3 "study" grid for 500 ms. The grid was 22.9 cm × 22.9 cm in size and contained a single (solid red) darkened cell (see Figure 3). A 2.5 s retention interval followed the study grid during which time the screen was blank. Following the retention interval, a "test" grid was shown with the same dimensions of the study grid. Again, one cell was darkened. For half of the trials, the same cell was darkened in the study and test grids, and for the other half, they were different. This was counterbalanced across the cue-probe location conditions. Each cell was darkened equally often across the nine positions. Additionally, across the four trial types (AX, AY, BX, and BY) the darkened cells in the study and test grids were in the same and different locations an equal number of times. People were told to press the *J* key as quickly but as accurately as possible upon presentation of the test grid if it was the same as the study grid, and to press the *L* key if it was not. A 1,000 ms response window was provided, during which the test grid remained on the screen. If a response was made within the 1,000 ms response window, the test grid disappeared and was replaced by a central fixation cross. If, however, 1,000 ms elapsed before a response was made, the test grid disappeared and was replaced by the fixation cross for 500 ms, and no response was recorded. As a result, the cue-probe delay was 5,000 ms for every trial, regardless of the how quickly a person responded. Following the fixation cross, a probe letter appeared for 500 ms on the left or right edge of the screen and people were given an additional 2,000 ms to respond. Responses that exceeded the 2,500 ms time limit were accompanied by a message reminding the person to respond quickly, and were excluded from analyses. As with Experiments 1 and 2, probe letters were presented, either in the same location on the screen as the cue or in a different location. On each trial, people were expected to give two responses, one for the spatial task and one for the AX-CPT task.

Results and Discussion

Trials in which correct RTs were less than 200 ms or greater than 1,500 ms were excluded from the analyses (4.4% of the trials). Mean RTs and error rates were computed for each person in each trial type (AX, AY, BX, and BY) and cue-probe location condition (same vs. different; see Table 2 for means). Only correct responses were included in the RT analyses.

Spatial memory task. Participants made a response within the 1,000 ms response window on 90% of the trials. For those responses, the error rate was 4.0% (SE = 3.2%).

Target (AX) trials. Although responses to the AX trials were faster in the different (M = 538 ms) than the same (M = 574 ms) location condition, this difference was only marginally significant, $F(1, 34) = 3.55$, $MSE = 6{,}370$, $p = .068$, $\eta^2_{\text{partial}} = .09$. The main effect of trial type was not significant in the error rate data, $F(1, 34) = 1.761$, $MSE = 0.001$, $p = .19$. Thus, although there was some evidence of the boundary effects observed in Experiments 1 and 2, it was attenuated with the presence of a distractor task during the model-updating period.

Nontarget trials. For the RT data, there was a significant main effect of trial type, $F(2, 68) = 91.58$, $MSE = 14{,}222$, $p < .001$, $\eta^2_{\text{partial}} = .73$, with people being slower on AY trials (M = 697 ms) than both BX (M = 460 ms) and BY (M = 460 ms) trials. The latter two did not differ. Neither the main effect of cue-probe location nor the interaction was significant, both Fs < 1. For the error rate data, there was a main effect of trial type, $F(2, 68) = 7.63$, $MSE = 0.030$, $p < .01$, $\eta^2_{\text{partial}} = .18$, with more errors for the AY trials (M = .15) than the BX trials (M = .10), which, in turn, had more errors than the BY trials (M = .03). As with the RT data, neither the main effect of cue-probe location, $F(2, 68) = 1.96$, $MSE = 0.009$, $p = .55$, nor the interaction ($F < 1$) was significant. Thus, overall, while there was very weak evidence for the influence of event structure on processing during the target trials, it was completely absent with the nontarget trials.

The results of Experiment 4 revealed that the event-updating process was disrupted by the inclusion of a distractor task. Unlike Experiments 1 and 2, the location shift effect was only marginally significant for the target (AX) trials. More important, performance on nontarget (AY, BX, and BY) trials was unaffected by shifts in cue-probe location. Thus, Experiment 4 provides further evidence that the changes in cognitive control found in Experiments 1 and 2 are specific to the processing of event boundaries at location shifts. When event model updating is disrupted, the effects of such processing are reduced.

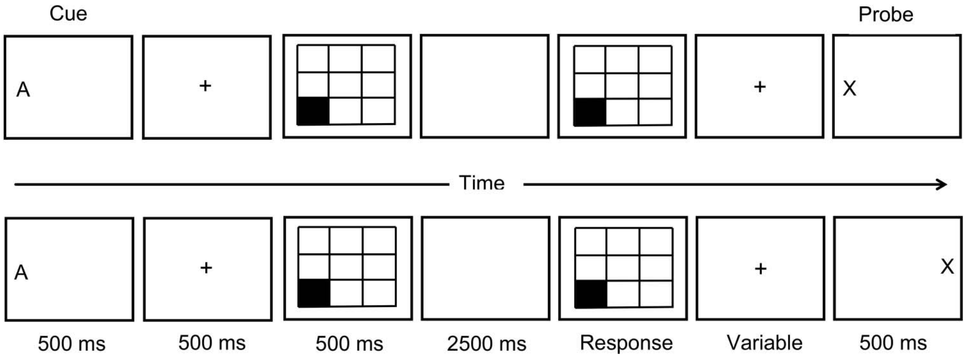

Figure 3. Examples of the sequence of events that were presented in the "same" location condition (events presented above the timeline) and "different" location condition (events presented below the timeline) in Experiment 4.

According of the Event Horizon Model, the updating of event models that occurs in response to shifts in the location of stimuli is a resource demanding process. When resources associated with such updating are consumed by processing associated with another task, the effectiveness of event model updating should suffer. Therefore, according to this account, the location shift effects were disrupted in the present study because the distractor task consumed resources that would have been otherwise used by processes associated with event model updating. While the distractor task disrupted the shift effects, however, it did not disrupt the behavioral signature of efficient cognitive control (i.e., responses were slower and less accurate on AY than BX trials). Interestingly, this was the case despite the fact that efficient cognitive control has been shown to involve resource-demanding processes (e.g., Lorsbach & Reimer, 2010). Thus, given that the distractor task was highly spatial in nature, it is possible that rather than consuming general resources, the distractor task consumed only those resources related specifically to spatial processing. If that was the case, it follows that the distractor task would disrupt the spatial updating of event models, without interfering with processes related to the representation of nonspatial aspects cues and probes, such as letter identity.

Experiment 5

Given the principles of the Event Horizon Model, the shift effects found in Experiments 1 and 2 may be attributed to the presence of event boundaries. An alternative view is that the shift effects in these experiments reflected differences in spatial screen position per se, not changes in events as defined by screen locations. That is, merely presenting cues and probes in physically different locations in space may have produced shift effects, not their division into two events. To test this view, the AX-CPT was modified in Experiment 5 so that two “boxes” were shown on each trial, which defined regions of the computer screen (see Figure 4). Although cues and probes were presented in different screen locations on every trial, for half of the trials, cues and probes were presented within the same region (i.e., the same “box”), and for the other half, cues and probes were presented in different regions of the screen (i.e., different “boxes”). Therefore, here, the spatial framework that defines an event is the box in which a letter appeared, not the far sides of a computer screen.

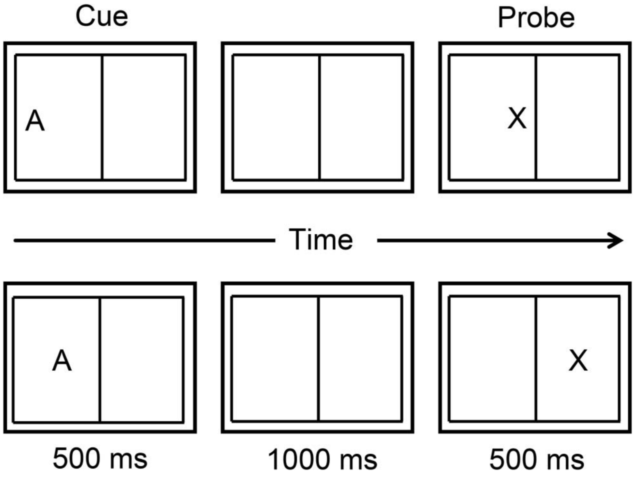

Figure 4. Examples of the sequence of events that were presented in the “same” location condition (events presented above the timeline) and “different” location condition (events presented below the timeline) in Experiment 5.

If the pattern of results found Experiments 1 and 2 were caused by the cues and probes being in different specific screen locations, then the boundary effects should be comparable on trials in which cues and probes are presented in the same box and in different boxes, and trial type should not interact with cue-probe location (same vs. different box). However, if the prior results were because of separate event models being formed when cues and probes changed locations, this pattern should be observed in the different box condition (different events) relative to the same box condition (same event), and an interaction with trial type should be observed.

Method

Participants. Participants were 26 undergraduate students at the California State University, San Bernardino, who received partial course credit. All had normal or corrected-to-normal vision.

Design. A 4 (Trial Type: AX, AY, BX, and BY) × 2 (Cue-Probe Location: same vs. different) repeated measures design was used. RT and accuracy were the dependent variables.

Procedure. The apparatus, stimuli, and procedure were the same as Experiment 1 except that two boxes were shown on the screen during the presentation of cues and probes, as well as during the 1,000 ms cue-probe delay (see Figure 4). As with Experiments 1, 2, and 4, people were shown the cues and probes in the same or different locations. However, unlike the previous experiments, here “location” does not refer to a screen location, but whether they were in the same box or different boxes. For the same location condition, cues and probes were in the same box, but not the same screen location. For example, if the cue was at the far left side of a given box, the cue would be at the far right side of the same box, and vice versa. For the different location condition, the cue and probe were always in the center of the two boxes (i.e., if the cue was in the left box, the probe was in the right box and vice versa). In both conditions, the relative positioning of a cue and its respective probe, on the right or left, was alternated within and between the boxes. Therefore, for half of the same location trials, cues were on the right and probes on the left, and for the remaining same location trials cues were on the left and probes on the right. Similarly, for half of the trials in the different location condition cues were in the right box and probes in the left box, and for the remaining different location trials the opposite was true. More important, the physical distance between cues and probes (13 cm) was held constant in the same-location condition and the different-location condition. What varied across trials was whether the cue and probe appeared in the same box or in different boxes.

Results and Discussion

Trials in which correct RTs were less than 200 ms or greater than 1,500 ms were excluded from the analyses (1.8% of the trials). Mean RTs and error rates were computed for each person in each trial type (AX, AY, BX, and BY) and cue-probe location condition (same vs. different boxes; see Table 2 for means). Only correct responses were included in the RT analyses.

Target (AX) trials. For the RT data, people were faster in the different locations condition (M = 490 ms) than in the same location condition (M = 513 ms), $F(1, 25) = 29.63$, $MSE = 251$, $p = .001$, $\eta^2_{\text{partial}} = .54$. The main effect of trial type was not significant in the error rate data, $F(1, 34) = 1.17$, $MSE = 0.0003$, $p = .29$.

Nontarget trials. There was a significant main effect of trial type, $F(2, 50) = 81.65$, $MSE = 7{,}798$, $p < .001$, $\eta^2_{\text{partial}} = .77$, in the RT data, with people responding slower on the AY trials (M = 637 ms) than both the BX (M = 455 ms) and BY (M = 436 ms) trials, which did not differ. There was also a main effect of cue-probe location, $F(1, 25) = 15.89$, $MSE = 2{,}022$, $p < .01$, $\eta^2_{\text{partial}} = .39$, with people responding faster in the different locations condition (M = 496 ms) than the same location condition (M = 524 ms). These main effects were qualified by a significant interaction, $F(2, 50) = 5.96$, $MSE = 2{,}606$, $p < .01$, $\eta^2_{\text{partial}} = .19$. People responded faster in the different locations condition than the same location condition for the BX, $F(1, 25) = 11.08$, $MSE = 3{,}231$, $p < .01$, $\eta^2_{\text{partial}} = .31$, and the BY, $F(1, 25) = 12.17$, $MSE = 2{,}127$, $p < .01$, $\eta^2_{\text{partial}} = .33$, trials. This difference was not significant for the AY trials, $F < 1$.

For the error rate data, there was a main effect of trial type, $F(2, 50) = 11.81$, $MSE = 0.010$, $p < .001$, $\eta^2_{\text{partial}} = .32$, with the AY trials ($M$ = .09) having more errors than BX trials (M = .02), which, in turn, had more errors than BY trials (M = .01). Neither the main effect of cue-probe location nor the interaction were significant, both Fs < 1.

In general, the results of Experiment 5 are consistent with an event cognition account of the changes in cognitive control that are found when cues and probes shift locations. As with Experiments 1 and 2, performance was better on AX trials when cues and probes were presented in different locations, than when they were presented in the same location. Similarly, for BX trials, RTs were faster when cues and probes were presented in different locations than in the same location. Critically, these effects were found despite the fact that the physical distance between cues and probes was equal in the same- and different-location conditions. Thus, the pattern of results found with AX and BX trials provide further support for the idea that the separation of cue and probe information into distinct events can enhance cognitive control in the AX-CPT. Finally, although the shift effects found in Experiments 1 and 2 were replicated with AX and BX trials, this was not the case with AY trials. Unlike Experiments 1 and 2 where more errors were produced in the different-location than the same-location condition with AY trials, in the present experiment this shift effect was absent.

To more directly compare the results of the Experiment 5 with those of the previous experiments, cross-experiment analyses were done. RTs and error rates from Experiment 5 and Experiment 2 were submitted to a 2 (Experiment: Experiment 2 vs. Experiment 5) × 3 (Trial Type: AY vs. BX vs. BY) × 2 (Cue-Probe Location: same vs. different) mixed ANOVA. With the RT data from nontarget trials (AY, BX, and BY), there was a main effect of trial type, $F(2, 112) = 199.7$, $MSE = 6{,}858$, $p < .01$, $\eta^2_{\text{partial}} = .78$. Post hoc comparisons revealed that the AY trials (M = 647 ms) were slower than BX trials (M = 467 ms), which, in turn, were slower than BY trials (M = 449 ms). A main effect of cue-probe location was also found, $F(1, 56) = 68.8$, $MSE = 2{,}651$, $p < .01$, $\eta^2_{\text{partial}} = .55$, with people responding faster in the different (M = 498 ms) than the same condition (M = 544 ms). There were also significant Experiment × Cue-Probe Location, $F(1, 56) = 9.75$, $MSE = 2{,}651$, $p < .05$, $\eta^2_{\text{partial}} = .15$, and Trial Type × Cue-Probe Location, $F(2, 112) = 10.50$, $MSE = 3{,}325$, $p < .01$, $\eta^2_{\text{partial}} = .16$, interactions. For the Trial Type × Cue-Probe Location interaction, simple effects tests revealed that RTs were faster when cues and probes were in different locations than when they were in the same location for BX, $F(1, 57) = 40.6$, $MSE = 3{,}741$, $p < .01$, $\eta^2_{\text{partial}} = .42$, and BY trials, $F(1, 57) = 33.0$, $MSE = 3{,}520$, $p < .01$, $\eta^2_{\text{partial}} = .37$, but not for AY trials ($F < 1$). Critically, the three-way interaction was not significant ($F < 1$). Finally, for target (AX) trials, people were faster when cues and probes were in different locations (M = 490 ms) than the same location (M = 534 ms), $F(1, 57) = 84.0$, $MSE = 674$, $p < .01$, $\eta^2_{\text{partial}} = .60$.

For the error rate data from nontarget trials, there was a main effect of trial type, $F(2, 112) = 17.6$, $MSE = .010$, $p < .01$, $\eta^2_{\text{partial}} = .24$. Post hoc comparisons revealed that the AY trials (M = 8.0%) produced more errors than both BX (M = 1.5%) and BY (M = 1%) trials. A main effect of cue-probe location was also found, $F(1, 56) = 5.63$, $MSE = .002$, $p < .05$, $\eta^2_{\text{partial}} = .09$, with more errors being made in the different (M = 4.0%) than the same condition (M = 2.8%). No other effects, including the three-way interaction between experiment, trial type, and cue-probe location, were significant in the error rate data. The results of these analyses verify that there were no significant differences between the pattern of results found in Experiments 2 and 5. Thus, the effect of location shifts on cognitive control was not simply because of changes in the physical distance of cues and probes, but instead, was because of the representation of cues and probes as distinct events.

General Discussion

The purpose of the present study was to examine whether event structure influences the operation of cognitive control in adults. More specifically, we assessed the degree to which shifts in the spatial framework of events affect the way those events are represented, and thereby influence cognitive control. This question was assessed in five experiments by manipulating the relative location and color of cues and probes presented within the AX-CPT, as well as aspects of the cue-probe delay such as length, and whether it contained a distractor task. Table 1 provides an overview of the experimental manipulations, predictions, and results of the five experiments. When there were shifts in the relative location of cues and probes a pattern of performance consistent with enhanced cognitive control was found, regardless of whether a long (5,000 ms; Experiment 1) or short (1,000 ms; Experiment 2) cue-probe delay was used. Similar changes were found when shifts in the location of cues and probes were varied between, but not within, visually defined regions of the computer screen (Experiment 5). In contrast, clear performance changes were not found when a feature of cues and probes not related to location (i.e., font color) was altered (Experiment 3), or when a distractor task was included during the cue-probe delay (Experiment 4). Taken together, the results of these experiments demonstrate that event structure can influence cognitive control in adults.

The results of the present study can be accounted for by the combined principles of the Event Horizon Model (Radvansky, 2012; Radvansky & Zacks, 2014) and Braver et al.'s theory of cognitive control (Braver, 2012; Braver et al., 2001; Braver & Cohen, 2000, 2001; Braver et al., 2007; Paxton et al., 2008). For the Event Horizon Model, the segmentation of events occurs at points in time when there are shifts or changes in event elements (Zacks & Swallow, 2007). Such changes serve as event boundaries, and may occur when there are changes in spatial location (Zwaan & Radvansky, 1998). When people encounter an event boundary, like a change in spatial location, a new event model is created. According to Braver et al.'s (2001; Braver, 2012) theory of cognitive control, improvements in the representational properties of cues and probes should result in improved cognitive control on the AX-CPT. This is the case because cognitive control in Braver et al.'s theory involves the ability to effectively separate out context information. The critical context that needs to be represented in the AX-CPT is information related to continuously changing cue stimuli. Thus, efficient cognitive control depends upon the ability to effectively represent cue information on each trial, and use such representations to direct attention to the forthcoming probe. Braver et al. (2001; Braver et al., 2007; Paxton et al., 2008) and others (e.g., Lorsbach & Reimer, 2008, 2010) have demonstrated that the ability to effectively represent cue-related information leads to improved cognitive control. Indeed, a pattern of AX-CPT performance consistent with improved cognitive control was found in the present study (Experiments 1 and 2) when the representational quality of cues was enhanced via the presence of event boundaries that made cues and probes more distinct by causing their corresponding representations to be stored in separate event models.

It is important to note that the present study provided evidence that the performance changes found in the AX-CPT were not simply the result of differences in the spatial distance between cues and probes, but were instead the result of cues and probes being represented as separate event models. Specifically, while cues and probes in Experiment 5 were always presented in different locations, changes in AX-CPT performance were found only when cues and probes were presented in locations defined as separate regions of the screen, not when they were presented in different locations within the same region of the screen. Thus, the improvements in cognitive control that were found in the present study appear to be the result of the specific structure of internal representations, as opposed to merely being the result of changes in a perceptual attribute (location) of AX-CPT stimuli.

One additional aspect of the present results that should be mentioned is related to the fact the location shift effects found in AY and BX trials emerged in different behavioral measures. Specifically, in Experiments 1 and 2, the effect of location shifts on AY performance emerged in the error rate data, while the effect of location shifts on BX performance emerged in the RT data. Although it is not entirely clear why this occurred, it is important to note that similar patterns have been found in previous studies. For example, Braver, Satpute, Rush, Racine, and Barch (2005) found age-related improvements in AY performance that were reflected in reduced error rates, and BX impairments that were reflected in slowed RTs. Although a strict interpretation of Braver et al.'s cognitive control theory would predict comparable effects in both error rates and RTs, the theory is "agnostic as to which behavioral measure would be most impacted by context-processing disruption" (Braver et al., 2005, p. 41). Therefore, although it may be important at some point to examine why behavioral measures are differentially impacted by the presence of event boundaries, we do not believe that this limits our claim that event boundaries can influence cognitive control.

The results of the present study have important implications for current models of event cognition and theories of cognitive control. Regarding event cognition models, the present study reinforces some of the fundamental principles of the Event Horizon Model (Radvansky, 2012; Radvansky & Zacks, 2014) and shows how these principles can be applied to cognitive domains outside of the areas that have been the traditional focus of this work, such as narrative comprehension (Zwaan et al., 1995), film perception (e.g., Zacks et al., 2009), and long-term memory retrieval (e.g., Newtson & Engquist, 1976; Swallow et al., 2009). First, the results of the present study show that changes in spatial location can serve as event boundaries that segment information into different mental representations. Second, and more importantly, the present study demonstrates that performance can be improved significantly when information is distributed across multiple event models. Such improvement may be a result of increased organization and structure of the information, reductions in interference, a combination of these, or some other factor. Regardless, the basic finding that the segregation of information into multiple event models can facilitate the processing of event attributes (letters in this case) is reaffirmed and generalized far more broadly than before.

The present results also have implications for current theories of cognitive control. As previously noted, the representation and maintenance of goal information plays a central role in multiple theories of cognitive control (e.g., Blair, Zelazo, & Greenberg, 2005; Braver et al., 2007; Miller & Cohen, 2001; Oberauer, 2005). Evidence supporting the role of goal representation and maintenance has been provided in both the developmental (e.g., Lorsbach & Reimer, 2008, 2010; Marcovitch, Boseovski, & Knapp, 2007; Towse, Lewis, & Knowles, 2007) and adult aging (e.g., Braver et al., 2007; Paxton et al., 2008) literatures. In contrast, other theories of cognitive control focus on dedicated inhibitory mechanisms (e.g., Bjorklund & Harnishfeger, 1995; Diamond, 2006; Diamond & Kirkham, 2005; Harnishfeger & Bjorklund, 1993; Hasher & Zacks, 1988). For example, Diamond and Kirkham (e.g., 2005; Kirkham & Diamond, 2003) have used the term "attentional inertia" to label the tendency to respond to a stimulus on the basis of its previously relevant attribute, and overcoming attentional inertia requires the use of an inhibition mechanism. In Experiments 1, 2, and 5 of the present study, cognitive control was affected by the representational structure of event models. For example, when cues and probes were represented in separate event models, cognitive control was enhanced such that people used cue information more effectively to inhibit a prepotent tendency so that a correct nontarget response could be made. If cognitive control is merely dependent upon a nonrepresentation based inhibitory mechanism, it is unclear why changes in the structure of event representations would impact performance as it did here.

Conclusion

The current study explored the extent to which aspects of cognitive control can be influenced by the structure of events that a person is processing. More specifically, our focus was on the management of cue and target information within the context of a continuous performance task known as the AX-CPT. We observed that performance was altered when an event boundary occurred between the cue and the probe. We suggest that this change led to the cue and target being stored in separate event models, which made this information easier to coordinate and process in the context of this task. The present results provide support for the idea that cognitive control can be influenced by the surrounding environmental structure, and that principles of event cognition have a broad range of applicability in cognitive science.

References

Barker, R. G. (1963). The stream of behavior as an empirical problem. In R. G. Barker (Ed.), *The stream of behavior* (pp. 1–22). New York, NY: Appleton-Century-Crofts. http://dx.doi.org/10.1037/11177-001

Bilodeau, I. M., & Schlosberg, H. (1951). Similarity in stimulating conditions as a variable in retroactive inhibition. *Journal of Experimental Psychology, 41,* 199–204. http://dx.doi.org/10.1037/h0056809

Bjorklund, D. F., & Harnishfeger, K. K. (1995). The evolution of inhibition mechanisms and their role in human cognition. In F. N. Dempster & C. J. Brainerd (Eds.), *Interference and inhibition in cognition* (pp. 141–175). New York, NY: Academic Press. http://dx.doi.org/10.1016/B978-012208930-5/50006-4

Blair, C., Zelazo, P. D., & Greenberg, M. (2005). The assessment of executive function in early childhood: Prospects and progress. *Developmental Neuropsychology, 28,* 561–571. http://dx.doi.org/10.1207/s15326942dn2802_1

Braver, T. S. (2012). The variable nature of cognitive control: A dual mechanisms framework. *Trends in Cognitive Sciences, 16,* 106–113. http://dx.doi.org/10.1016/j.tics.2011.12.010

Braver, T. S., Barch, D. M., Keys, B. A., Carter, C. S., Cohen, J. D., Kaye, J. A., . . . Reed, B. R. (2001). Context processing in older adults: Evidence for a theory relating cognitive control to neurobiology in healthy aging. *Journal of Experimental Psychology: General, 130,* 746–763. http://dx.doi.org/10.1037/0096-3445.130.4.746

Braver, T. S., & Cohen, J. D. (2000). On the control of control: The role of dopamine in regulating prefrontal function and working memory. In S. Monsell & J. Driver (Eds.), *Attention and performance XVIII* (pp. 713–738). Cambridge, MA: MIT Press.

Braver, T. S., & Cohen, J. D. (2001). Working memory, cognitive control, and the prefrontal cortex: Computational and empirical studies. *Cognitive Processing, 2,* 25–55.

Braver, T. S., Cohen, J. D., & Barch, D. M. (2002). The role of the prefrontal cortex in normal and disordered cognitive control: A cognitive neuroscience perspective. In D. T. Stuss & R. T. Knight (Eds.), *Principles of frontal lobe function* (pp. 428–447). Oxford, England: Oxford University Press. http://dx.doi.org/10.1093/acprof:oso/9780195134971.003.0027

Braver, T. S., Gray, J. R., & Burgess, G. C. (2007). Explaining the many varieties of working memory: Dual mechanisms of cognitive control. In A. Conway, C. Jarrold, M. Kane, A. Miyake, & J. N. Towse (Eds.), *Variation in working memory* (pp. 76–106). New York, NY: Oxford University Press.

Braver, T. S., Satpute, A. B., Rush, B. K., Racine, C. A., & Barch, D. M. (2005). Context processing and context maintenance in healthy aging and early stage Dementia of the Alzheimer's Type. *Psychology and Aging, 20,* 33–46. http://dx.doi.org/10.1037/0882-7974.20.1.33

Cohen, J. D., Barch, D. M., Carter, C., & Servan-Schreiber, D. (1999). Context-processing deficits in schizophrenia: Converging evidence from three theoretically motivated cognitive tasks. *Journal of Abnormal Psychology, 108,* 120–133. http://dx.doi.org/10.1037/0021-843X.108.1.120

Diamond, A. (2006). The early development of executive functions. In E. Bialystok & F. I. M. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 70–95). New York, NY: Oxford University Press. http://dx.doi.org/10.1093/acprof:oso/9780195169539.003.0006

Diamond, A., & Kirkham, N. (2005). Not quite as grown-up as we like to think: Parallels between cognition in childhood and adulthood. *Psychological Science, 16,* 291–297. http://dx.doi.org/10.1111/j.0956-7976.2005.01530.x

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science, 11,* 19–23. http://dx.doi.org/10.1111/1467-8721.00160

Engle, R. W. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. In B. H. Ross (Ed.), *The Psychology of Learning and Motivation* (pp. 145–199). Boston, MA: Elsevier Academic Press.

Greenspoon, J., & Ranyard, R. (1957). Stimulus conditions and retroactive inhibition. *Journal of Experimental Psychology, 53,* 55–59. http://dx.doi.org/10.1037/h0042803

Harnishfeger, K. K., & Bjorklund, D. F. (1993). The ontogeny of inhibition mechanisms: A renewed approach to cognitive development. In M. L. Howe & R. P. Pasnak (Eds.), *Emerging themes in cognitive development. Volume 1*: *Foundations* (pp. 28–49). New York, NY: Springer-Verlag. http://dx.doi.org/10.1007/978-1-4613-9220-0_2

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 22, pp. 193–225). San Diego, CA: Academic Press. http://dx.doi.org/10.1016/S0079-7421(08)60041-9

Jensen, L., Dibble, J., & Anderson, D. C. (1971). Effects of a contextual change upon retroactive inhibition. *Psychological Reports, 29,* 39–46. http://dx.doi.org/10.2466/pr0.1971.29.1.39

Kane, M. J., Bleckley, M. K., Conway, A. R. A., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General, 130,* 169–183. http://dx.doi.org/10.1037/0096-3445.130.2.169

Kane, M. J., & Engle, R. W. (2003). Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132,* 47–70. http://dx.doi.org/10.1037/0096-3445.132.1.47

Kirkham, N. Z., & Diamond, A. (2003). Sorting between theories of perseveration: Performance in conflict tasks requires memory, attention and inhibition. *Developmental Science, 6,* 474–476. http://dx.doi.org/10.1111/1467-7687.00303

Kurby, C. A., & Zacks, J. M. (2008). Segmentation in the perception and memory of events. *Trends in Cognitive Sciences, 12,* 72–79. http://dx.doi.org/10.1016/j.tics.2007.11.004

Kurby, C. A., & Zacks, J. M. (2011). Age differences in the perception of hierarchical structure in events. *Memory & Cognition, 39,* 75–91. http://dx.doi.org/10.3758/s13421-010-0027-2

Lorsbach, T. C., & Reimer, J. F. (2008). Context processing and cognitive control in children and young adults. *The Journal of Genetic Psychology: Research and Theory on Human Development, 169,* 34–50. http://dx.doi.org/10.3200/GNTP.169.1.34-50

Lorsbach, T. C., & Reimer, J. F. (2010). Developmental differences in cognitive control: Goal representation and maintenance during a continuous performance task. *Journal of Cognition and Development, 11,* 185–216. http://dx.doi.org/10.1080/15248371003699936

Magliano, J., Kopp, K., McNerney, M. W., Radvansky, G. A., & Zacks, J. M. (2012). Aging and perceived event structure as a function of modality. *Neuropsychology, Development, and Cognition: A Journal on Normal and Dysfunctional Development, 19,* 264–282. http://dx.doi.org/10.1080/13825585.2011.633159

Magliano, J. P., Miller, J., & Zwaan, R. A. (2001). Indexing space and time in film understanding. *Applied Cognitive Psychology, 15,* 533–545. http://dx.doi.org/10.1002/acp.724

Marcovitch, S., Boseovski, J. J., & Knapp, R. J. (2007). Use it or lose it: Examining preschoolers' difficulty in maintaining and executing a goal.

Developmental Science, 10, 559–564. http://dx.doi.org/10.1111/j.1467-7687.2007.00611.x

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 24,* 167–202. http://dx.doi.org/10.1146/annurev.neuro.24.1.167

Nagge, J. W. (1935). An experimental test of the theory of associative interference. *Journal of Experimental Psychology, 18,* 663–682. http://dx.doi.org/10.1037/h0054006

Newtson, D. (1976). Foundations of attribution: The perception of ongoing behavior. In J. H. Harvey, W. J. Ickes, & R. F. Kidd (Eds.), *New directions in attribution research* (Vol. 1, pp. 223–247). Hillsdale, NJ: Erlbaum.

Newtson, D., & Engquist, G. (1976). The perceptual organization of ongoing behavior. *Journal of Experimental Social Psychology, 12,* 436–450. http://dx.doi.org/10.1016/0022-1031(76)90076-7

Oberauer, K. (2005). Executive functions, working memory, verbal ability, and theory of mind—Does it all come together? In W. Schneider, R. Schumann-Hengsteler, & B. Sodian (Eds.), *Young children's cognitive development: Interelationships among executive functioning, working memory, verbal ability, and theory of mind* (pp. 285–299). Mahwah, NJ: L. Erlbaum Associates.

Paxton, J. L., Barch, D. M., Racine, C. A., & Braver, T. S. (2008). Cognitive control, goal maintenance, and prefrontal function in healthy aging. *Cerebral Cortex, 18,* 1010–1028. http://dx.doi.org/10.1093/cercor/bhm135

Pettijohn, K. A., Krawietz, S. A., Tamplin, A. K., Thompson, A. N., & Radvansky, G. A. (2014). *Walking through doorways improves memory*. Manuscript in preparation.

Radvansky, G. A. (1999). The fan effect: A tale of two theories. *Journal of Experimental Psychology: General, 128,* 198–206. Chicago. http://dx.doi.org/10.1037/0096-3445.128.2.198

Radvansky, G. A. (2012). Across the event horizon. *Current Directions in Psychological Science, 21,* 269–272. http://dx.doi.org/10.1177/0963721412451274

Radvansky, G. A., & Copeland, D. E. (2006). Walking through doorways causes forgetting: Situation models and experienced space. *Memory & Cognition, 34,* 1150–1156. http://dx.doi.org/10.3758/BF03193261

Radvansky, G. A., & Copeland, D. E. (2010). Reading times and the detection of event shift processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36,* 210–216. http://dx.doi.org/10.1037/a0017258

Radvansky, G. A., Krawietz, S. A., & Tamplin, A. K. (2011). Walking through doorways causes forgetting: Further explorations. *The Quarterly Journal of Experimental Psychology, 64,* 1632–1645. http://dx.doi.org/10.1080/17470218.2011.571267

Radvansky, G. A., Tamplin, A. K., & Krawietz, S. A. (2010). Walking through doorways causes forgetting: Environmental integration. *Psychonomic Bulletin & Review, 17,* 900–904. http://dx.doi.org/10.3758/PBR.17.6.900

Radvansky, G. A., & Zacks, J. M. (2014). *Event Cognition*. New York, NY: Oxford University Press. http://dx.doi.org/10.1093/acprof:oso/9780199898138.001.0001

Radvansky, G. A., & Zacks, R. T. (1991). Mental models and the fan effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 940–953. http://dx.doi.org/10.1037/0278-7393.17.5.940

Redick, T. S., & Engle, R. W. (2011). Integrating working memory capacity and context-processing views of cognitive control. *The Quarterly Journal of Experimental Psychology, 64,* 1048–1055. http://dx.doi.org/10.1080/17470218.2011.577226

Rinck, M., & Bower, G. H. (1995). Anaphora resolution and the focus of attention in situation models. *Journal of Memory and Language, 34,* 110–131. http://dx.doi.org/10.1006/jmla.1995.1006

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime user's guide*. Pittsburgh, PA: Psychology Software Tools.

Smith, S. M., Glenberg, A., & Bjork, R. A. (1978). Environmental context and human memory. *Memory & Cognition, 6,* 342–353. http://dx.doi.org/10.3758/BF03197465

Swallow, K. M., Zacks, J. M., & Abrams, R. A. (2009). Event boundaries in perception affect memory encoding and updating. *Journal of Experimental Psychology: General, 138,* 236–257. http://dx.doi.org/10.1037/a0015631

Towse, J. N., Lewis, C., & Knowles, M. (2007). When knowledge is not enough: The phenomenon of goal neglect in preschool children. *Journal of Experimental Child Psychology, 96,* 320–332. http://dx.doi.org/10.1016/j.jecp.2006.12.007

Zacks, J. M., Braver, T. S., Sheridan, M. A., Donaldson, D. I., Snyder, A. Z., Ollinger, J. M., . . . Raichle, M. E. (2001). Human brain activity time-locked to perceptual event boundaries. *Nature Neuroscience, 4,* 651–655. http://dx.doi.org/10.1038/88486

Zacks, J. M., Speer, N. K., & Reynolds, J. R. (2009). Segmentation in reading and film comprehension. *Journal of Experimental Psychology: General, 138,* 307–327. http://dx.doi.org/10.1037/a0015305

Zacks, J. M., Speer, N. K., Swallow, K. M., Braver, T. S., & Reynolds, J. R. (2007). Event perception: A mind-brain perspective. *Psychological Bulletin, 133,* 273–293. http://dx.doi.org/10.1037/0033-2909.133.2.273

Zacks, J. M., & Swallow, K. M. (2007). Event segmentation. *Current Directions in Psychological Science, 16,* 80–84. http://dx.doi.org/10.1111/j.1467-8721.2007.00480.x

Zacks, J. M., & Tversky, B. (2001). Event structure in perception and conception. *Psychological Bulletin, 127,* 3–21. http://dx.doi.org/10.1037/0033-2909.127.1.3

Zwaan, R. A. (1996). Processing narrative time shifts. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 1196–1207. http://dx.doi.org/10.1037/0278-7393.22.5.1196

Zwaan, R. A., Langston, M. C., & Graesser, A. C. (1995). The construction of situation models in narrative comprehension: An event-indexing model. *Psychological Science, 6,* 292–297. http://dx.doi.org/10.1111/j.1467-9280.1995.tb00513.x

Zwaan, R. A., Magliano, J. P., & Graesser, A. C. (1995). Dimensions of situation model construction in narrative comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 386–397. http://dx.doi.org/10.1037/0278-7393.21.2.386

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin, 123,* 162–185. http://dx.doi.org/10.1037/0033-2909.123.2.162

Zwaan, R. A., Radvansky, G. A., Hilliard, A. E., & Curiel, J. M. (1998). Constructing multidimensional situation models during reading. *Scientific Studies of Reading, 2,* 199–220. http://dx.doi.org/10.1207/s1532799xssr0203_2

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