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The role of relational triggers in event perception

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ABSTRACT

Research exploring visual attention has demonstrated that people are aware of only a small proportion of visual properties, and that people only track these properties over a subset of moments in time. This makes it critical to understand how our perceptual system leverages its limited capacity, such that properties are tracked across views only when they can support an understanding of meaningful events. In this paper, we propose that *relational triggers* induce between-view property comparisons when spatial relationships between objects appear inconsistent across views-moments that are particularly likely to mark the beginning of meaningful events. In these experiments, we activate relational triggers by violating heuristics that filmmakers use to create visuospatial continuity across views. We find that these violations increase change detection when they coincide with visual property changes, demonstrating that relational triggers induce a comparison of properties held in working memory. We also demonstrate that relational triggers increase the likelihood of event segmentation, and that change detection increases both in response to triggers and natural event boundaries. We propose that relational triggers are an effective heuristic cue that facilitates the comparison of properties when they are likely to be useful during event perception.

1. Introduction

Although perceptual experience appears to be continuous and rich, a wide variety of findings suggest that this richness arises from a surprisingly limited amount of concrete visual information. These limits can be documented when viewers fail to report events that fall outside of a narrow focus of visual attention (Mack & Rock, 1998; Simons & Chabris, 1999), when they fail to detect large visual changes in both unattended and attended objects (Levin & Simons, 1997; Rensink, O'Regan, & Clark, 1997; Scholl, 2000; Simons & Levin, 1998), and when they cannot perceive subsequent targets that follow initial targets (Chun & Potter, 1995; Dux, Asplund, & Marois, 2008). However, these limits to visual experience must be reconciled with viewers' clear ability to be aware of almost any visual property they choose to focus upon (Blackmore, 2002), to remember large numbers of objects (Standing, Conezio, & Haber, 1970), and ultimately to effectively understand dynamic visual events that extend over space and time (Magliano, Miller, & Zwaan, 2001; Zacks & Swallow, 2007; Zacks & Tversky, 2001). In part, this reconciliation depends upon processes that efficiently leverage limited visual information in the service of understanding important events.

The effective comprehension of events not only requires an ability to focus attention to informative properties, but also requires representing and tracking properties across space and time (Levin & Saylor, 2008). Research exploring event perception provides a principled basis for temporal selection by hypothesizing that relatively deep, rich encoding processes are limited to the beginnings of meaningful

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events (Swallow, Zacks, & Abrams, 2009; Zacks & Swallow, 2007). However, as we will review below, this work has yet to specify a full set of mechanisms that are needed to support this form of selective encoding. In this paper, we hypothesize a mechanism that relies upon a default encoding of spatial relationships, and induces a comparison of visual properties held in working memory when spatial relationships change. Using a change detection paradigm, we find that *relational triggers* cause between-view comparison of visual properties stored in working memory and induce event segmentation when spatial relationships appear fundamentally altered. Relational triggers are evidence of a perceptual mechanism that not only guides attention, but also elicits comparison and updating of working memory representations. Further, they are a principled mechanism for directing awareness during events.

In the pages that follow, we review previous research documenting limits to visual awareness, and we describe how research on event perception can shape visual selection for more efficient feature encoding. Then, we argue that a key basis for this form of event-based selection is a default encoding of space that is informed both by research in cognitive science and by longstanding real-world practice in visual story telling. Independently of psychological research, filmmakers have developed a simple set of spatial heuristics to combine disparate views that create seemingly continuous, understandable narratives. These heuristics are so prevalent in the film industry that film scholars have argued that "the framework for coherence is spatial" (Kraft, Cantor, & Gottdiener, 1991, p. 603). Not only does this practice highlight the importance of spatial information in visual event perception, but in the present set of experiments it has also inspired a new method for assessing how properties are encoded and compared as events unfold.

1.1. Visual awareness and event perception

Although our experience of an event is rich and compelling, research over the past 15 years has demonstrated that the perceptual basis of this experience is remarkably limited. Viewers can fail to detect unexpected objects, even when they are looking right at them, (e.g. inattention blindness; Mack & Rock, 1998), and they can miss changes ranging from the color of low-level singletons (Scholl, 2000) to replacement of a face-to-face conversational partner (e.g. change blindness; Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1998; for review see: Simons & Rensink, 2005). These phenomena dramatically reveal a perceptual system that continuously monitors relatively few, specific visual properties. However, this limited form of on-line perceptual encoding must be reconciled with people's clear ability not only to remember a large amount of perceptual information (for example, a large number of pictures; Standing et al., 1970), but also with their ability to successfully extract the meaning of the complex visual events that surround them.

A partial explanation for the puzzle of visual awareness is that perceivers are efficient at representing only those properties that are helpful in understanding their surroundings. A number of studies have demonstrated that both subject and task factors can guide attention and awareness to specific sets of properties. Individuals demonstrate increased change detection for features relevant to their expertise (Werner & Thies, 2000) as well as when attention is cued to specific objects (Scholl, 2000) or individual dimensions such as orientation or color (Müller, Heller, & Ziegler, 1995). Another important piece to the puzzle is to recognize that change blindness implies not so much an absence of representation per se, but rather the failure to represent properties *and* effectively compare them between views (Angelone, Levin, & Simons, 2003; Beck & Levin, 2003; Simons, 2000; Simons, Chabris, Schnur, & Levin, 2002). As working memory has limited capacity and is constrained to retain information over limited periods of time, an efficient representational process is likely constrained to relatively few but informative moments (Levin & Saylor, 2008). A possible mechanism for intelligently selective representational tracking is described by theories of event perception, which imply that visual properties may be encoded and updated during disruptions to perceptual continuity, known as *event boundaries* (Magliano et al., 2001; Zacks, Speer, & Reynolds, 2009; Zacks & Tversky, 2001).

Models of event segmentation are particularly interesting because they imply the existence of broadly applicable circumstances where visual properties might receive additional encoding. According to Event Segmentation Theory (Reynolds, Zacks, & Braver, 2007; Zacks, Speer, Swallow, Braver, & Reynolds, 2007; Zacks & Swallow, 2007), new events occur when perceptual predictions fail to match observed events, producing an error signal that in turn induces encoding of visual information in anticipation of a new event. Many studies document the release of working memory representations following event boundaries (Glenberg, Meyer, & Lindem, 1987; Kurby & Zacks, 2012; Morrow, Bower, & Greenspan, 1989; Radvansky & Copeland, 2006; Swallow et al., 2011; Swallow et al., 2009; Zacks et al., 2007). However, the exact consequences of event boundaries for the on-line representation of visual properties are ambiguous. On the one hand, recent research suggests less detection of secondary task stimuli at event boundaries (Huff, Papenmeier, & Zacks, 2012), presumably due to a focusing of attention to event-relevant features and release of working memory for the previous event. Although secondary task stimuli by definition fall outside a primary attended channel, other phenomena such as the attentional blink suggest that some events that reach awareness can lessen detection even for subsequent stimuli within an attended channel (Chun & Potter, 1995). So, if new events are processed in a manner similar to target-detections in the attentional blink paradigm, attention will be drawn away from visual properties by the elaboration necessary to comprehend that new event. If this is the case, observers would be more prone to errors of awareness, such as change blindness or inattentional blindness, during event boundaries. On the other hand, there is also good reason to predict increased comparison of visual features following disruptions on event boundaries. Unpublished research in children suggests increased change detection on event boundaries (Saylor & Baldwin, 2004), and numerous other studies demonstrate increased encoding of objects present at event boundaries (Hanson & Hirst, 1989; Kurby & Zacks, 2008; Swallow & Zacks, 2008; Swallow et al., 2011; Zwaan & Madden, 2004). Thus, it is currently unknown whether working memory representations are compared on event boundaries or simply disposed of when building a new event model.

Event boundaries themselves are composed of a variety of perceptual and conceptual transitions (Magliano et al., 2001; Zacks & Tversky, 2001; Zacks et al., 2009). Deviations in motion, space, causes or goals are consistent predictors of new events (Baldwin, Andersson, Saffran, & Meyer, 2008; Magliano et al., 2001; Zacks, 2004). Among these features, spatial changes are particularly interesting both because they are relatively easy to define, and also because they may serve as correlates of events in a wide variety of naturalistic situations. Not only do a range of empirical findings suggest that basic spatial information is encoded as a general default when perceiving scenes and objects (Mandler, Seegmiller, & Day, 1977; Rensink, 2010; Schulman, 1973; Tatler & Land, 2011), but artists have created visual narratives for nearly a century using rules of spatial continuity. We are, of course, referring to the practice of cinema, which not only relies on basic spatial heuristics for view-combination, but also provides a means of generating spatial disruptions involving few between-view inconsistencies in object properties, orientations, or relative locations (Cutting, Brunick, DeLong, Iricinschi, & Candan, 2011; Delong, Brunick, & Cutting, 2012; Smith, 2012; Smith, Levin, & Cutting, 2012).

1.2. The spatial basis of cinema as a tool for understanding event representations

Recently, researchers have argued that the perceptual continuity of edited films demonstrates filmmakers' insights into the fundamental nature of human perception (Anderson, 1998; Berliner & Cohen, 2011; Levin & Simons, 2000; Smith, 2012; Smith et al., 2012). Early cinema was faced with the task of telling universally understandable stories to audiences who clamored for immediate entertainment and so could not be trained to understand a media-specific "language." Because it rapidly became apparent that the best means of telling cinematic stories was to combine individual shots from many points of view, cinematic practice has evolved to rely upon hundreds of abrupt cuts from shot to shot. Despite all of these sudden perceptual transitions, with proper editing the sequence appears continuous (Bordwell & Thompson, 2009; Levin & Wang, 2009), making many cuts quite subtle and difficult to detect (Smith & Henderson, 2008). However, achieving this apparent continuity is not a simple matter, and filmmakers have developed a series of guidelines to curb viewer awareness of edits.

One of the most well-known guidelines for producing this visual continuity is the 180° rule (Fig. 1; Arijon, 1976; Bordwell & Thompson, 2009; Murch, 2001; Reisz & Millar, 2010; Salt, 2009). This rule states that camera placements for each shot should remain on the established side of an invisible axis of action drawn between two items of primary interest. The 180° rule maintains continuity by guaranteeing broadly consistent orientations of important objects in a scene across multiple shots. As illustrated in Fig. 1, rule consistent shots of actor A maintain her gaze to the right and the appearance that she is on the left side of the scene. A shot violating the rule gives the impression that she is looking the wrong way or standing on the wrong side of the scene. Filmmakers believe that violations of the 180° rule disrupt continuity by breaking the axis of action, producing a sometimes jarring confusion as to the apparent location of the actors or the apparent target of their gaze (see for example, Arijon, 1976; Murch, 2001). Notably, this effect is not simply due to the sudden spatial transformations caused by cuts between different camera positions, but to the representation of relative object locations within a scene. In fact, rule-consistent spatial transformations can be quite large while appearing continuous. Thus, while

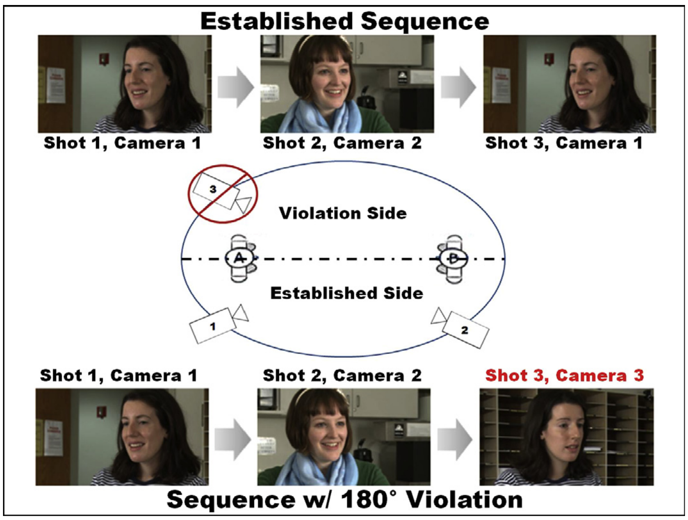

Fig. 1. The 180° rule. After cameras 1 and 2 establish a line of regard between actors A and B, cameras can be placed anywhere on the established side. Camera 3 "jumps the line" and creates a violation shot (Shot 3, Camera 3), violating continuity of eye-line, background and framing.

viewers rarely notice the spatial transformations across shots adhering to the 180° rule, filmmakers have discovered that viewers more readily detect the perceptual inconsistency caused by a viewpoint change across the axis of action. Research has confirmed that violations of the 180° rule degrade recall of scene layout in adults and children (Frith & Robson, 1975; Kraft, 1987; Kraft et al., 1991) and increase response latency for judgments of spatial direction (Huff & Schwan, 2012). Observers saccade more often following 180° violations compared to camera movement adhering to the rule (d'Ydewalle & Vanderbeeken, 1990), and similar eye movement is shown following narrative shifts (d'Ydewalle et al., 1998). Filmmakers have also frequently observed that viewers experience violations of the rule as abrupt, jarring and disorienting (Bordwell, 2002).

Research on the 180° rule converges with research in the spatial cognition literature demonstrating that viewers can accurately represent object layouts across viewpoints (Diwadkar & McNamara, 1997), but seem to do so more effectively when objects are aligned with a spatial reference axis similar to that implicated in the 180° rule (Mou & McNamara, 2002). In addition, recent research suggests that abrupt viewpoint changes result in the spontaneous updating of visual properties (Huff, Meyerhoff, Papenmeier, & Jahn, 2010; Meyerhoff, Huff, Papenmeier, Jahn, & Schwan, 2011). Such evidence implicates an effect of spatial inconsistency on the perception of continuous events and the encoding of event properties.

1.3. The relational trigger hypothesis

The combined evidence from psychological experiments and film practice indicate that spatial relationships are readily perceived indicators of event continuity. Our goal is to identify how spatial discontinuity alters the perception of events. To this end, we propose the *relational trigger hypothesis* whereby inconsistencies in the spatial arrangement of objects are detected by default, and then serve as a trigger to test visual features for consistency across views. Based on previous research documenting the role of working memory representations in event perception (Swallow et al., 2009, 2011; Zacks et al., 2007), and the need for comparison to detect a change (Angelone et al., 2003), we propose that relational triggers induce comparisons of features in the present scene to a previous representation. Thus, it is important to note that trigger-induced comparisons are not simply a matter of increased endogenous attention focused on differences between subsequently encoded properties, but instead they can involve properties that have been represented in working memory prior to the trigger.

The relational trigger hypothesis is similar to recent findings demonstrating that spatial reorientations elicit new encodings of spatial layout (Huff et al., 2010; Meyerhoff et al., 2011), but it clearly diverges from this work by focusing on the impact of novel spatial relationships on property representations rather than layout representations. Unlike this previous work, the relational trigger hypothesis does not assume that representations are necessarily discarded across spatial transformations. Instead, this hypothesis assumes that discontinuous spatial relationships induce a comparison of features held in working memory as a means of supporting event perception. As such, the relational trigger hypothesis describes a mechanism that supports the perception of new events, permitting comparison of shifting properties between changing events.

In five experiments, we demonstrate that relational triggers increase comparisons in working memory in anticipation of new events. Experiment 1 demonstrates increased change detection during disruptions of spatial relationships. Experiment 2 replicates this effect, and verifies that it is not caused by background changes. Experiment 3 demonstrates that relational triggers increase comparisons in working memory. Experiment 4 verifies that relational triggers cause the perception of new events, and Experiment 5 indicates that naturally occurring events induce property comparisons similar to those induced by relational triggers.

2. Experiment 1

Experiments 1 and 2 tested the basic effects of discontinuous spatial relationships on change detection. In the first experiment, we tested whether 180° violations in edited film sequences increased or decreased change detection. All films depicted a conversation in a series of shots, alternating between two actors as each spoke. The key manipulation was a shot in each film that included either a 180° violation, a property change (in all cases, a color change in a single actor's clothing), or the simultaneous presentation of both. As reviewed above, the literature supports two distinct hypotheses for the effect of relational violations on change detection. On one view, relational violations will trigger perception of an event boundary, leading to increased working memory updating and, ultimately, in increased change detection. However, it is also possible that relational violations will lessen change detection if they draw attention to themselves and away from visual properties. This would be akin to an attentional blink whereby detecting a target induces elaborative processing that prevents immediately following stimuli from entering awareness (Chun & Potter, 1995; Huff et al., 2012).

2.1. Methods

2.1.1. Participants

Participants ($N = 161$, 94 female, mean age = 20.2) volunteered and completed the study in the Vanderbilt student commons in exchange for candy or prizes. Each participant was assigned to one of three experimental conditions or a control condition.

2.1.2. Materials

We created two experimental films, each depicting two actors engaged in conversation, eventually leading to a reference to an item off screen. After an initial "establishing" shot showing both actors in the same setting, shots alternated between actors. The films were 43 and 50 s long, con-

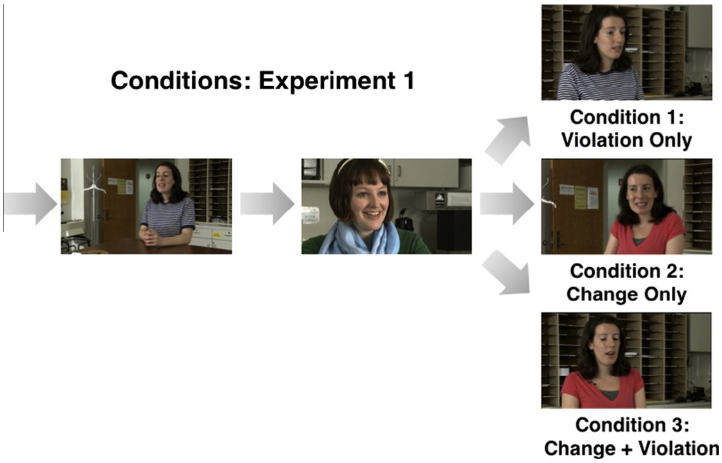

Fig. 2. Conditions for Experiment 1. Participants watched one condition. Violations were created by moving the camera to a previously unused side of the scene. A control video contained neither a change nor a violation. Both sets of videos are available online at sciencedirect.com.

taining 15 shots separated by 13 cuts. Films were edited into four conditions (Fig. 2). In the change-only condition ($n = 50$), one shot contained a clothing change on a single character between edits. The violation-only condition ($n = 50$) contained a 180° violation shot with no clothing change. The violation + change condition ($n = 50$) contained a 180° violation and property change occurring simultaneously in the same shot. Lastly, a control condition ($n = 11$) with no changes or violations was presented to test for false alarms. In film 1, all conditions occurred in shot 5 (13.2 s into the film) and in film 2, all conditions occurred in shot 12 (40.1 s into the film). All films contained an audio track for the dialog, and were formatted to a 1920 × 1080p mp4 video file running at 30 frames per second.

2.1.3. Procedure

After giving consent, participants were seated behind a 72 cm tall × 152 cm wide barrier and wore sound cancelling headphones. The experimenter then played videos on a 15.5-in. laptop with a 1280 × 720 pixel resolution and a refresh rate of 60 Hz. Because participants almost never detect peripheral changes such as these under purely incidental encoding conditions (Levin & Simons, 1997), we designed a short (38 s) video introduction that briefly attuned participants to film editing. This introduction stated that "poor editing often results in inconsistent body positions or props from shot to shot," and informed participants that they would be "tested on memory for the editing and content of the video." After a three second pause, participants watched a single video. Once the video finished, participants received a brief questionnaire assessing change detection and 180° violation detection, adapted from Levin & Simons, 1997, asking whether participants noticed "inconsistent objects, body positions or clothing from shot to shot," or "any unusual, jumpy edits" where actors appeared to be "looking or standing in the wrong location." Participants were prompted to identify explicitly which changes they noticed. Participants were then debriefed and given candy or prizes.

2.2. Results

Written answers to test questions were scored by the first author and a blind rater, with an inter-rater agreement of 100%. Participants were scored as seeing the property change if they accurately stated which property changed and approximately where it changed in the film. Participants were scored as detecting violations if they accurately noted the anomalous camera movement or a disorientation of the specific character shown in the violation shot. An initial analysis of the data indicated that the 11 participants in the control condition showed no false alarms for detecting 180° violations or changes and so this condition was terminated early.

The proportion of changes detected (68%) with 180° violations present was significantly greater than the proportion of changes detected (48%) without violations, $\chi^2(1, N = 100) = 4.11$, $p = .043$, $w = .256$. We also analyzed how the presence of changes affected detection of 180° violations. The proportion of 180° violations detected with changes (64%) was marginally greater than the proportion of violations detected without changes (46%), $\chi^2(1, N = 100) = 3.841$, $p = .070$, $w = .206$.

The effects of discontinuity on change detection were similar whether or not participants actually reported seeing the 180° violation. Among participants who did detect the 180° violation, 71.9% (23/32) saw the change, while participants who were unable to report the violation detected the change 61.1% (11/18) of the time, $\chi^2(1, N = 50) = 0.613$, $p = .434$. Change detection concurrent with 180° violation detection was significantly higher than the 48% no-violation baseline, $\chi^2(1, N = 82) = 4.546$, $p = .033$, $w = .328$, while change detection without violation detection was not higher than baseline, $\chi^2(1, N = 68) = .911$, $p = .340$.

2.3. Discussion

When a violation of spatial continuity was included at the onset of the property change, change detection increased significantly. These findings support a process of comparing event properties following a relational trigger. Results indicated that change detection may occur without explicit awareness of the 180° violation, though change detection was highest when the participants were fully aware of the violation.

3. Experiment 2

As reviewed in the introduction, most authors attribute the disruptive effects of 180° violations to the spatial inconsistency that it induces. However, Hochberg and Brooks (1978) suggest that the disorientation caused by 180° violations may stem from large, unexpected changes in background. For example, in the film depicted in Fig. 2, the background in the violation shot was globally similar to the other backgrounds, but it did show more of the mailboxes than the nonviolation shot. In some sense, then, additional static properties changed in the violation shot, and this may have increased change detection (although the prediction that one change will induce increased detection of another change is not straightforward). To control for this possibility, 180° violations were generated in Experiment 2 without the associated background change. This was done by subtly rotating to actor on the violation shot so that he switched from looking to the rule-consistent side of the screen to the rule-inconsistent side. Thus, 180° violations were generated without an accompanying background change and in Experiment 2 we tested whether these violations would also increase change detection. Additionally, minor adjustments of actor and camera location in Experiment 1 resulted in small deviations in the proportion of changed features visible in the frame (see Fig. 2). Although no participants explicitly reported these variations, we ensured that the pre-change and changed shot were taken from the exact same actor and camera positions in all subsequent films.

3.1. Methods

3.1.1. Participants

Experiment 2 utilized Amazon's Mechanical Turk website to recruit online participants for a $.50 reward. Mechanical Turk has previously been validated by researchers for use in cognition research (e.g. Germine et al., 2012; Paolacci, Chandler, & Ipeirotis, 2010). Participants ($N = 116$, 68 males, mean age = 33.78) were randomized into the same four conditions as Experiment 1: change only ($n = 28$), violation only ($n = 27$), change + violation ($n = 24$), and control ($n = 37$).

3.1.2. Materials

Experiment 2 followed the same basic design as Experiment 1. A new 39-s video was created according to the same parameters: two actors in conversation, 15 shots, and 13 cuts. All experimental conditions were implemented on shot 9 (21.4 s from the start of the video), close to the mean time of condition onset from films 1 and 2. Each actor had the same number of lines as the actors in the two previous videos. The critical difference was in the experimental conditions. Fig. 3 shows the violation manipulation of Experiment 2. Rather than moving the camera by 60° over the line, the actor rotated 60° away from the line. The result is a perceptually similar background with a noticeable difference in actor orientation that still violates the 180 rule but, crucially, maintains the same background. Films were again presented with a sound track.

3.1.3. Procedure

The videos and survey questions were automated and randomized using an online survey tool. After confirming digital consent, participants viewed the same introduction used in Experiment 1 followed by a randomly assigned video condition. After completion of the video, participants completed the same survey questions as Experiment 1. The entire experiment took an average of 4.5 min.

3.2. Results

The proportion of changes detected with violations present (83%) was significantly greater than the proportion of changes detected without violations (43%), $\chi^2(1, N = 52) = 8.95$, $p = .003$, $w = .455$. The proportion of violations detected with changes present (54%) was not signifi-

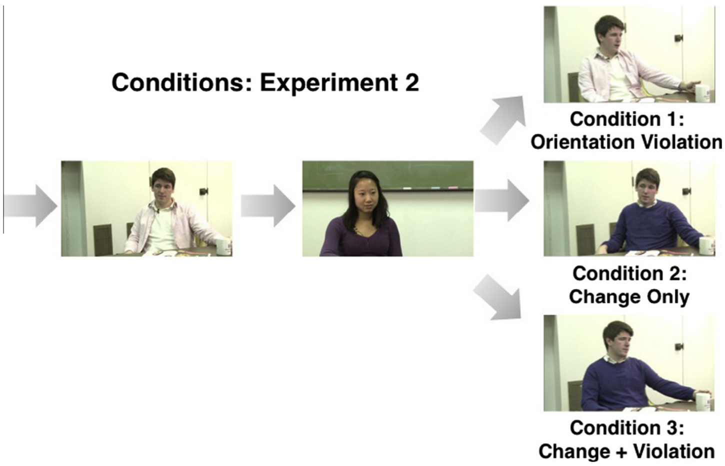

Fig. 3. Conditions for Experiment 2. Violations in Exp 1 were formed by moving the camera. Exp 2 instead rotated the orientation of the actor to produce 180 violations (labeled an orientation violation) without producing an associated background change. Videos are available online at sciencedirect.com.

cantly higher than when changes were absent (70%), $\chi^2(1, N = 51) = 1.427$, $p = .232$. Participants in the control condition rarely false-alarmed for change detection (8%) or violation detection (3%).

Because of the subdivided sample size, it was difficult to determine whether explicit awareness of the 180° violation led to increased property change detection. Of participants in the change + violation condition of Experiment 2, 13/13 participants who were aware of the 180° violation detected the change, while 7/11 participants who were not aware of the 180° violation detected the change $\chi^2(1, N = 24) = 0.530$, $p = .467$. As an exploratory analysis, we combined data from the change + violation conditions of Experiments 1 and 2 to determine the effect of detecting a violation on detecting a property change. Overall, when participants detected violations, they detected changes 80% (36/45) of the time, compared to detecting 62.7% (18/29) of changes when 180° violations were present but *not* explicitly reported, $\chi^2(1, N = 74) = 2.875$, $p = .090$. Participants who explicitly reported the violation detected significantly more changes than participants in change-only conditions (combined change only detection = 46.2%), $\chi^2(1, N = 123) = 13.469$, $w = .416$, $p < .001$. Participants who did not explicitly detect the violation did not detect significantly more changes than the change-only conditions, $\chi^2(1, N = 107) = 2.142$, $p = .143$.

3.3. Discussion

Experiment 2 closely replicated the violation-induced increase in change detection observed in Experiment 1 without a background change. It is worthwhile to note that change detection increased for the orientation violations of Experiment 2, even though orientation violations were arguably subtler than the whole-background violations of Experiment 1.

Of secondary interest is the dependence of change detection on explicit violation *detection*, as opposed to mere presence of the violation. Results across Experiments 1 & 2 indicated that explicit detection of discontinuous spatial relationships clearly increased change detection, and that undetected violations appeared to increase change detection, but this trend was nonsignificant. This implies that the impact of 180° violations had to be sufficient to produce some level of awareness if the violations were to induce a property comparison. This adds an important element to the relational trigger hypothesis – small spatial changes that go unnoticed can fail to induce property comparisons.

The next step is to determine how relational triggers cause increased change detection. The relational trigger hypothesis states that relational triggers induce comparison of features in working memory. However, it is ambiguous from the first two experiments whether increased change detection results from comparisons in working memory stored prior to the violation or from spatial discontinuity promoting search for changed features. Experiment 3 tests whether relational triggers affect working memory comparisons or instead promote observers to search for changes in properties following the violation.

4. Experiment 3

Experiments 1 and 2 provide support for the relational trigger hypothesis by demonstrating increased change detection when visual changes were accompanied by a spatial discontinuity. However, an important element of the hypothesis is that these disruptions induce a comparison either between a feature held in working memory and a feature in the current scene, or between two features held in working memory. Although comparison is the most straightforward explanation of the violation-induced increases in change detection, the specific changes that occurred in Experiments 1 and 2 leave open a range of alternatives for how this comparison operates. Because the critical feature changed to a new value (property A → property B), and then changed back two shots later (from B back to A), it is possible that the violation did not increase any comparison with features already in working memory, but instead primed participants to search for subsequent changes. This might have increased change detection if participants were actually reporting the change back from B to A instead of the initial change from A to B.

To test this possibility, we introduced violations both before the critical A → B change, and after it. As illustrated in Fig. 4, violations before the critical A → B change on shot 9 (e.g. violations on cuts to shots 7 and 8) afford increased change detection if the violation induces participant to be vigilant enough to encode the pre-change shirt on shot 7 (for comparison with the post-change shirt on shot 9) or even the post-change shirt on shot 9 (in which case, they could compare it with the return to the prechange shirt visible in shot 11). In contrast, for violations to increase change detection when they occur *after* the A → B change, the violation must induce the participant to compare at least one feature that had previously been represented in working memory. So, for violations occurring on shots 10 or 11 to increase change detection, they must either induce participants to compare two features that have already been represented, or to compare one already-represented feature with one feature in the current scene because the post-change B feature will not be visible again after the violation. Thus, if a violation increases change detection solely because it causes participants to search for changing features, then we should see increased change detection only when the violation precedes the critical change on shot 9, but if the violation induces a comparison with features already represented in working memory, then violations should increase change detection even if they follow the initial A → B change.

4.1. Methods

4.1.1. Participants

Participants ($N = 302$, 184 males, mean age = 29.1) were assigned to one of five conditions via Amazon's Mechanical Turk website for a \$.40 reward. A filter ensured that individuals had not participated in previous change detection experiments.

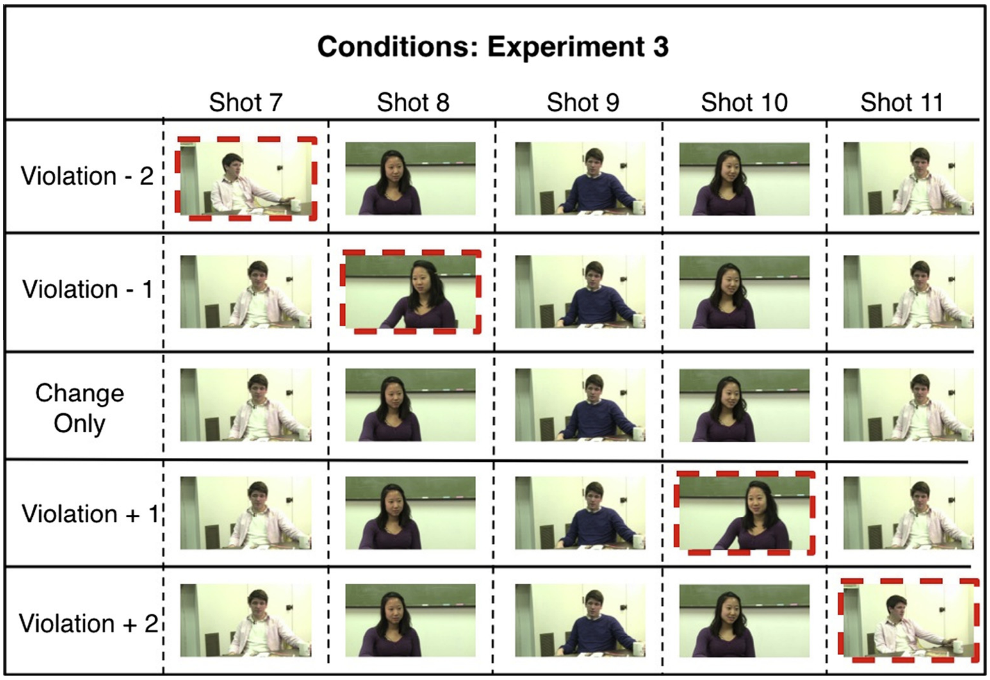

Fig. 4. Design of Experiment 3. 180° violations are emphasized by dashes. Increased change detection in the Violation-1 and Violation-2 conditions cannot be attributed to vigilance for changes.

4.1.2. Procedure

The video from Experiment 2 was edited into five conditions. In two pre-change conditions (n's = 63 and 58), a violation occurred one or two shots before the onset of the change (−3.8 and −5.7 s, respectively). In the same way, two post-change conditions (n's = 62 and 58) occurred one and two shots after the onset of a change (+4.7 and +7.2 s). A control condition (n = 61) contained a change with no accompanying violation. The remainder of the procedure was identical to Experiment 2.

4.2. Results

Fig. 5 plots change detection and violation detection across conditions. Change detection increased for the combination of all four violation conditions compared to the no-violation control condition, $\chi^2(1, N = 302) = 5.754$, $p = .017$, $w = .678$. Critically, violations after the change significantly increased change detection, $\chi^2(1, N = 181) = 6.175$, $p = .0130$, $w = .452$, with marginal increases when violations occurred before the change, $\chi^2(1, N = 182) = 3.454$, $p = .063$, $w = .400$. There were no differences in change detection between the four violation conditions $\chi^2(3, N = 241) = 1.891$, $p = .5953$.

Violation detection increased with later onsets of the violation $\chi^2(3, N = 241) = 39.629$, $p < .001$, $w = .267$. Although this contrasts with change detection, which was unaffected by the changes' specific temporal relationship to violation onset, it is important to point out that violations occurred at different times in the film across conditions, while the change occurred at the same time within the film for all conditions.

Across all violation conditions, 76% of participants who explicitly saw the violation also saw the change, significantly higher than the 48% of changes detected in the change-only condition $\chi^2(1, N = 245) = 13.729$, $p < .001$, $w = .584$. Conversely, only 51% of participants who did not explicitly report the violation detected the change, which was not a significant increase from the change-only condition $\chi^2(1, N = 177) = 0.165$, $p = .684$.

4.3. Discussion

Experiment 3 demonstrated that violations in all experimental conditions increased detection of changes to a similar degree. Most importantly, violations that occurred after the change significantly increased change detection. This supports a key element of the relational trigger hypothesis, which is that relational triggers can induce viewers to draw upon already-represented visual properties when making trigger-induced comparisons. Therefore, the increase in change detection was not solely due to a strategy shift in which violations led viewers to increase representation and comparison only for features that followed the violation. In addition, Experiment 3 again demonstrated that participants were more likely to detect changes if they explicitly detected violations, while undetected violations did not increase change detection, further supporting the hypothesis that relatively salient spatial disruptions are necessary to create a trigger sufficient to induce property comparison.

Experiment 3 has shown that discontinuous spatial relationships trigger comparison of features. We hypothesize that violations of spatial continuity act as a heuristic

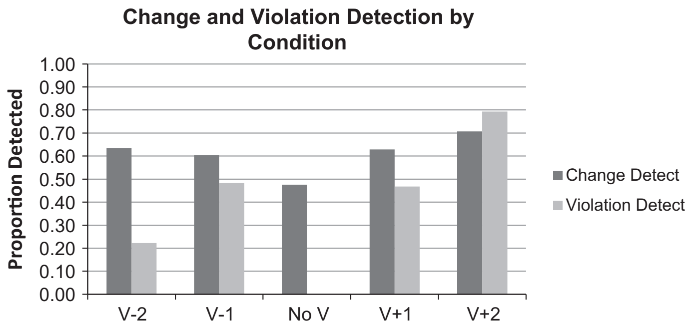

Fig. 5. Results for Experiment 3. Change detection increased when relational violations occurred one or two shots before or after onset of the change versus the no violation condition. Report of violations increased with time.

cue that a new event has occurred, and that working memory comparisons are a natural component of event perception. Experiments 4 and 5 tested two predictions about the effect of discontinuous spatial relationships on working memory comparisons occurring on event boundaries. First, Experiment 4 tested whether relational triggers have a direct impact on discriminating multiple events. Experiment 5 then tested whether naturally occurring event boundaries also generate working memory comparisons.

5. Experiment 4

Experiments 1–3 demonstrate that relational triggers cause increased change detection through working memory comparisons. Generally, spatial change is a strong predictor of event segmentation, and previous research has documented this effect in situations where characters and objects move from one location to another (Magliano et al., 2001; Reynolds et al., 2007; Zwaan & Madden, 2004). A key part of the relational trigger hypothesis is that 180° violations induce a similar effect without literal depictions of new locations. If relational violations induce comparison of features in anticipation of new events, then these violations should induce the perception of multiple events during ambiguous sequences. In Experiment 4 we tested this prediction by showing participants simple films that could easily be interpreted as depicting one event or two events. If induced relational violations trigger the perception of a new event, then participants should be more likely to report that violation films depict two events than similar no-violation films.

5.1. Methods

5.1.1. Participants

Participants ($n = 80$, 51 males, mean age = 30.1) were recruited from Amazon's Mechanical Turk website for a $.35 reward. All participants responded to all four conditions.

5.1.2. Materials

Experiment 4 used four films edited into four conditions. The films were made using a subset of footage shot for a separate research project. Each film contained three shots depicting a conversation between two actors, edited into a sequence showing Actor A followed by Actor B and then returning to Actor A. All films were edited without a sound track. Importantly, all shots in each film were taken from the same scene, but not from sequential footage in that scene. For instance, the three shots comprising Film 1 are an average of 12 s apart in the source material. This was done so that films did not objectively depict one event. The films were globally similar in that they all depicted simple interactions between two characters, but depicted different characters in different settings. Films ranged in duration from 6.26 s to 8.93 s. All films had a 1.5 s black screen before and after the event sequence so that participants would not see any part of the film before or after playback.

In Experiment 4 we created four versions of each of four different 3-shot films to generate discontinuous spatial relationships similar to those in Experiments 1–3. Fig. 6 presents variations of stimuli used in Experiment 5. In the *consistent* condition, the orientations of actors were consistent, and actors faced each other in keeping with the 180° rule. The remaining conditions were created by mirroring one or more shots in the sequence using an effect filter in Final Cut Pro. Mirroring the shots effectively reoriented an actor, reversing their direction of gaze, emulating the relational violations used in Experiments 1–3. In the *violation 1* condition, Actor A was always oriented in the same direction, but did not face Actor B, thus creating an eye-line mismatch. The second violation condition mirrored the first shot, so that Actor A was oriented differently between shots, but maintained an eye-line with Actor B across the 2nd and 3rd shots. The third and final violation condition features the same type of relational violation used in the previous experiments, where the third shot shows Actor A oriented in the opposite direction. Four groups of 20 participants watched all four experimental films, with each film instantiating one of the four conditions. The condition represented by each film was rotated across participants.

5.1.3. Procedure

Upon giving digital consent, each participant followed a link to an online survey, where basic demographic information was collected. Participants read an instruction page that stated "Directors use edits ("cuts") to show several

Fig. 6. Design of Experiment 4. Orientation of actors was adjusted to manipulate consistency of actor location and the facilitation of an eye-line match in shots 2 and 3. Videos are available online at sciencedirect.com.

views of the same event. However, directors also use cuts between two different events. We want you to figure out whether a video clip is from one event or two events that have been spliced together." An event was further defined as "a moment of time with a clear beginning and end" (Zacks & Tversky, 2001). Participants then watched a sample video of a single event taken from a film in Experiment 1. The sample film presented three shots in an A–B–A sequence and followed consistency of actor location and eye-line. The sample video was taken from sequential shots in a scene and unlike the experimental films there was no ambiguity of the interaction between actors across the cut. Participants were informed that the differences between one- and two-event edits could be subtle, and that they should go with their instinct.

Participants watched each film once and then marked a box stating whether they thought it contained one-event or two-events. Participants' answers were recorded upon completion of all four experimental films. Afterwards, participants completed two catch trials. Catch trials were two short films that clearly denoted two events by cutting from an indoor scene to an outdoor scene. After completing the catch trials, participants then rated their understanding of the instructions and their confidence in their responses on a Likert-type scale.

5.2. Results

Fig. 7 plots the distribution of event ratings by condition. A McNemar test found that a significant proportion of participants who saw one event in the control condition saw two events in at least two of the three experimental conditions $\chi^2(1, N = 80) = 10.929$, $p < .001$, odds ratio is 3.714. A McNemar test compared the number of events seen in the control condition to each of the violation conditions by participant. On a scale from 1 to 2 events, significantly more participants saw one event in the control condition (mean = 1.20) and two events in the Violation 1 condition (mean = 1.438), $\chi^2(1, N = 80) = 10.314$, $p = .001$, odds ratio is 3.375; the Violation 2 condition (mean = 1.400), $\chi^2(1, N = 80) = 8.000$, $p = .005$, odds ratio is 3.000; or the Violation 3 condition (mean = 1.413), $\chi^2(1, N = 80) = 9.323$, $p = .002$, odds ratio is 3.429. Note that all comparisons are below the Bonferroni correction of $\alpha = .017$. There was no significant change in the number of events seen between any of the experimental conditions.

To ensure that the sample film viewed before the experiment did not bias participants' responding, we ran a replication with two slight alterations. First, the sample video was removed from participant instructions. Second, to control for consistent positioning of Actor A in Shot 1 across all conditions, the Violation 1 condition was altered so that only the second shot was flipped, rather than both shots 1

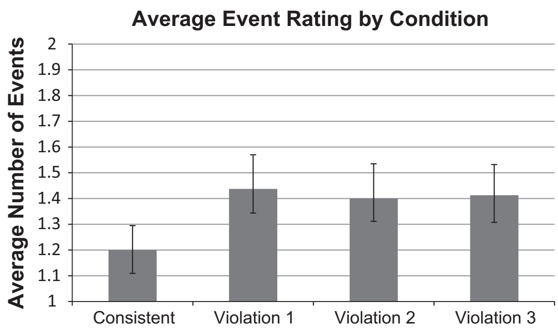

Fig. 7. Results from Experiment 5. Participants rated the control condition (Consistent-Match) more often as one event than any of the three experimental conditions. Error bars denote Clopper–Pearson 95% binomial confidence intervals.

and 3. Participants again saw significantly more events in the three violation conditions (mean = 1.44) than in the consistent condition (mean = 1.20), $\chi^2(1, N = 84) = 4.829$, $p = .028$, odds ratio is 2.182. Again, we find that participants judge inconsistent spatial information as indicative of multiple events.

5.3. Discussion

These results support the hypothesis that discontinuous spatial relationships at any point in a three shot scene increase the likelihood of perceiving new events. Data from this experiment further constrain the relational trigger hypothesis by showing increased event segmentation when there is no clear change to detect in an ambiguous scene. As we will examine further in the general discussion, this means that relational triggers are not so much a cue for change detection that makes the perception of a new event more likely. Rather, relational triggers result in the recruitment of visual information to understand a potential new event, leading to change detection.

Before continuing it is important to discuss two potential issues with the stimuli used in Experiment 4. The violations in this experiment were created by laterally reversing one or more shots in the sequence, which in some cases has induced small perceptual changes between different views of the same character for the violation films. Thus in some cases, these small changes (for example faces and hairstyles look slightly different in normal and reversed versions) may have increased event segmentation, even though no participant appears to have noticed these particular inconsistencies. However, these property inconsistencies are not present in all of the violation conditions because *both* shots of the first actor were reversed in the violation 1 condition. This eliminated any violation-induced between-view inconsistency. Nonetheless, viewers judged there to be two events in this condition just as frequently as they did so for the other violation conditions.

Another caveat is that the audiovisual films of Experiments 1–3 contrast with the purely visual films of Experiment 4. In order for the number of events in Experiment 4's films to be ambiguous, shots were taken out of regular sequence from the source material, thereby controlling for asynchronies in sound and dialogue across shots. Including the misordered dialogue would have overwhelmed any perceptual effect of spatial triggers on the perception of events. Therefore, caution should be exercised when applying these findings to audiovisual presentations, as continuity of sound may eliminate ambiguities created by spatial inconsistencies. Although researchers have used both visual and audiovisual stimuli in event perception research, little research has explored interpretations of these different modalities. Regardless, many real world events lack dialogue or linking sound and yet still must be segmented using visual cues and spatial relationships.

6. Experiment 5

Experiments 1–3 demonstrated that change detection increased at the onset of relational violations and that increased detection was due to comparisons in working memory. Experiment 4 further indicated that relational triggers induce the perception of new events. Experiment 5 tested whether new events replicate the effect of increased change detection caused by relational triggers. Raters watched and segmented new films according to standard event segmentation protocol (Newtson & Engquist, 1976; Zacks & Tversky, 2001). Using this segmentation data, changes were inserted across a cut that included the event boundary, and on a within-event cut with relatively little segmentation. If event boundaries cause comparisons as working memory representations are updated, we would expect greater change detection on the event boundary than during an ongoing event. Additionally, if relational violations simulate event boundaries, change detection should increase if we include a relational violation during the ongoing event.

6.1. Methods

6.1.1. Participants

Sixteen adult volunteers segmented one of two possible films. Raters were reimbursed with candy or prizes. Participants for the change detection experiment ($N = 197$) were recruited from Mechanical Turk for \$.40–\$.50 per trial.

6.1.2. Materials

Two films were made using similar scripts and plots. The films were written to contain at least two different events that clearly occurred in the same location, and were presented with an audio track. Each film involved Character A interrupting Character B to ask for help. After help was given, Character B grabs an off-screen item that becomes the new topic of conversation. A single edit of these films with no property changes was used in the event segmentation procedure. Both films contained 20 shots, running 99.5 s and 101.2 s each. The average shot length for Film 1 was 5.24 s (min = 2.36 s, max = 8.53 s), while the average shot length for Film 2 was 5.34 s (min = 2.46 s, max = 8.97 s).

The event segmentation procedure was conducted using the Psychophysics Toolbox for MATLAB (Brainard, 1997). Participants made their responses on a 15.5″ monitor with a 1280 × 720 resolution and 60 Hz refresh rate.

6.1.3. Event segmentation procedure

After obtaining consent, raters were given a brief but purposely open-ended description of events. Coarse-grained and fine-grained events were defined as the largest or smallest possible meaningful units within a scene (Zacks & Tversky, 2001). An example was given that an event could be described globally as "making lunch" or finely as "setting the table", "picking up a butter knife" and "cutting bread." Raters were informed that they would watch a single film three times. Raters passively watched the film in the first viewing. In the second viewing, raters pressed a key every time they believed a new coarse-grained event had begun. On the third and final viewing, raters pressed a key every time they believed a fine-grained event had begun.

Fig. 8 plots the frequency of segmentation for both films. Segmentation data was binned by shot, as our

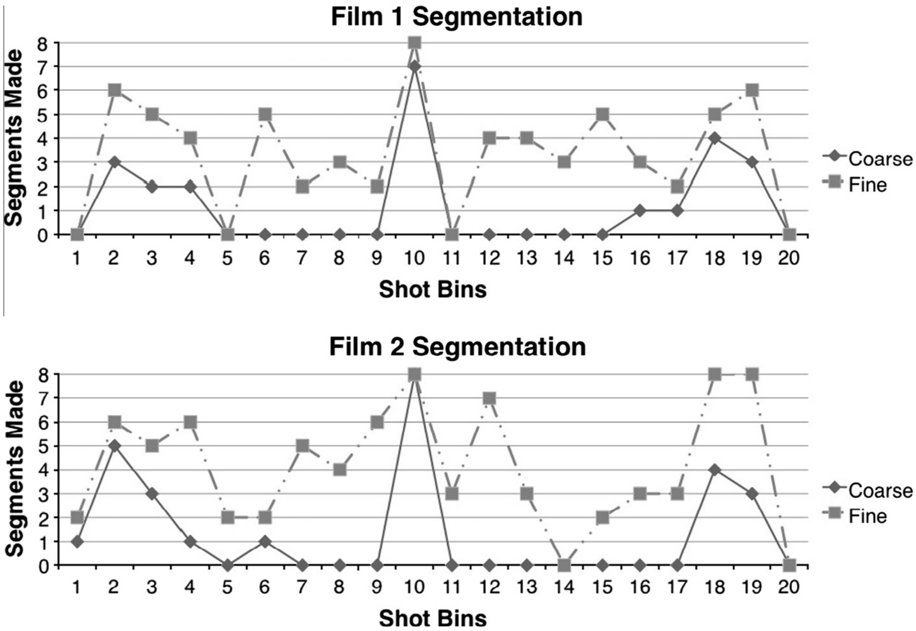

Fig. 8. Segmentaiton data for the two films used in Experiment 5. Raters unanimously identified fine- and coarse-grained event boundaries in shot 10 of both films. Both films followed the same overall event structure.

change detection manipulation had a temporal specificity of one shot length. Segmentation for coarse- and fine-grained events was compared across raters using Cronbach's alpha. Raters were in high agreement for both Film 1 (Coarse $\alpha = .8218$; Fine $\alpha = .7602$) and Film 2 (Coarse $\alpha = .8772$; Fine $\alpha = .8334$). Excluding one rater who made no coarse-grained segmentations, 100% of raters for Film 1 made a coarse-grained segmentation during Shot 10. All eight raters for Film 2 made a coarse-grained segmentation during Shot 10 as well.

6.1.4. Change detection procedure

Films were edited into three conditions based on rater segmentation data (see Fig. 9). Once again, changes were bright, bold color changes in clothing on a single actor. For the *event-boundary* condition ($n = 71$), changes were inserted at the most agreed upon point of an event boundary (Film 1: Shot 10 at 42.3 s, duration = 8.53 s; Film 2: Shot 10 at 46.60 s, duration = 7.57 s). For clarity, the change occurred in the shot where the new event *eventually* began. Increased change detection for the event-boundary condition would not be due to surface features at the onset of the change, but to comparisons made when the new event was initiated.

Previous research has demonstrated reduced recall after event boundaries (Radvansky, Tamplin, & Krawietz, 2010; Swallow et al., 2011). It was therefore crucial that all other conditions appeared before the event boundary, to ensure that representations of the pre-change feature were not discarded before the change occurred. In the *ongoing event* condition ($n = 68$), a change was edited two shots previous to the location of the event boundary at a point of little segmentation (Film 1: Shot 8, 33.47 s, duration = 6.0 s; Film2: Shot 8, 34.63 s, duration = 8.6 s). In the *event-boundary* condition, the change occurred at the event boundary. Finally, in the *violation* condition ($n = 58$) a change and a violation were edited two shots previous to the event boundary, in the same location as the ongoing event condition. All property changes occurred on the same actor.

The procedure otherwise resembled that from Experiments 1–3. Participants on Mechanical Turk watched a single film in a single condition and then completed a survey of their experience.

6.2. Results

Participants detected significantly fewer changes in the ongoing event condition versus the two experimental conditions, $\chi^2(2, N = 197) = 13.385$, $p = .001$, $w = .423$. Paired chi-squared tests indicated that participants detected significantly more changes on event boundaries (45.1%) versus ongoing events (16.2%), $\chi^2(1, N = 139) = 10.104$, $p = .0015$, $w = .474$. Participants also detected significantly more changes in the violation condition (43.1%) than in the ongoing event condition $\chi^2(1, N = 126) = 8.402$, $p = .004$, $w = .530$. There was no significant difference in change detection between the event-boundary and violation groups, $\chi^2(1, N = 129) = 0.035$, $p = .850$. There were no significant differences between films for each condition.

6.3. Discussion

This experiment demonstrated two key concepts. First, change detection on an event boundary was significantly higher than change detection during an ongoing event only 10 s previous. These changes were nearly identical, so increased detection likely does not reflect static perceptual

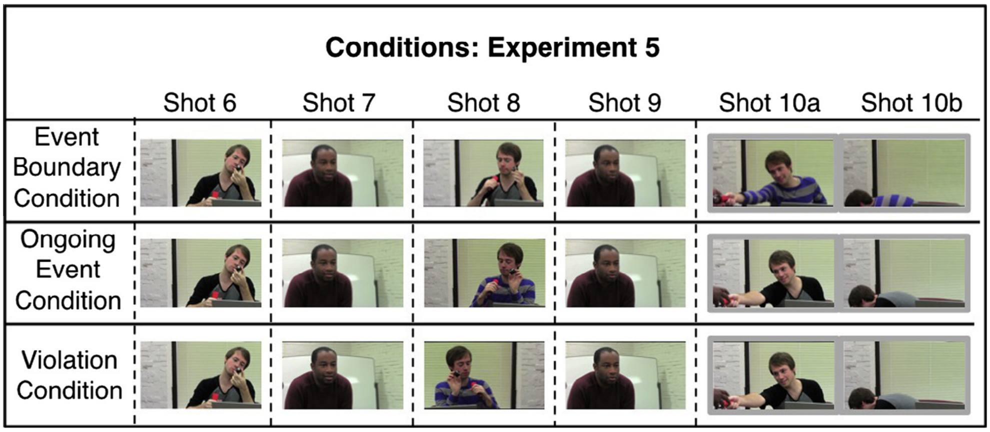

Fig. 9. Conditions for Experiment 5. Shot 10 included an event boundary, where the topic of conversation shifted and a character moved off screen (the first and last frames of the shot are shown here). Videos are available online at sciencedirect.com.

differences from shot-to-shot. A second key finding was the similarity of event boundaries and violations in facilitating change detection. By simply adjusting the angle of visual presentation of an ongoing event, we find change detection levels rising to those of event boundaries.

Collectively, Experiments 1–4 demonstrated that relational triggers increased both change detection and event boundaries. However, a range of specific relationships among change detection, relational triggers and event boundaries are possible. It is possible that relational triggers have no impact on event perception per se, and both relational triggers and event boundaries increase change detection through different channels. However, given that relational violations induced a perception of multiple events in Experiment 4, we find this unlikely. If relational triggers do causally interact with event boundaries, two possibilities remain. On the one hand, relational triggers may elicit the comparison of features, which in turn induces an event boundary. On the other hand, relational triggers may directly induce both event perception, and increased change detection. Experiment 5 lends credence to this latter model, demonstrating that change detection increases for event boundaries that do not include a relational violation, and that few changes are detected during an ongoing event.

7. General discussion

In five experiments, we presented evidence in support of the relational trigger hypothesis of event updating, whereby discontinuous spatial relationships trigger comparison of features in working memory. Experiments 1–3 examined the effect of relational triggers on working memory comparisons, and Experiments 4–5 generalized the effects of relational triggers to naturally occurring event boundaries. Experiment 1 demonstrated that relational triggers increase change detection, and Experiment 2 replicated this effect, even with a stable background. We additionally showed in Experiment 3 that relational triggers increase change detection by inducing working memory comparisons. We found in Experiment 4 that relational triggers induce the perception of multiple visual events. Lastly, Experiment 5 indicated that change detection increased at the onset of naturally occurring events, and that induced relational triggers simulated event boundaries.

A key issue in interpreting these experiments is to consider what exact causal links our data support, and what causal links remain to be tested. Our experiments demonstrated that relational triggers induce property comparisons and the perception of new events. In addition we demonstrated that both actual event boundaries and violations increased change detection to a similar degree. Although we tested the effect of relational triggers on change detection and event perception separately, and tested the effect of event perception on change detection, these experiments did not test the hypothesis that relational triggers increase change detection, which in turn leads to event perception. This causal chain is clearly important but it is not crucial to the specific hypothesis we aimed to establish. There are at least two roles property comparisons could play in event perception – they can induce the perception of new events when properties mismatch, and they can serve as a guide to determine what has changed once a new event has been perceived. We suspect that trigger-induced property comparisons primarily serve the latter role, because the ubiquity of change blindness suggests that property changes are by themselves a poor initiator of event perception, and because Experiment 5 demonstrated that event boundaries increased change detection well above the control. Thus, our hypothesis is that relational triggers initiate a series of processes that increase the likelihood that a new event will be perceived and that help the viewer draw upon visual representation to understand that event.

The present findings address several important questions in event perception. First, what cognitive mechanisms underlie the updating of features at event boundaries? While previous research has demonstrated a working memory "flush" at event boundaries, the current findings suggest that features in working memory may instead be briefly held and compared before erasure. This implies that established event models might have encoded visual properties that are not brought to awareness until new-event signals occur (such as a relational trigger). It would be particularly interesting to test whether contextual factors affect what information is lost and what information is retained during different sorts of new events. Researchers have consistently found evidence that memory of an event quickly degrades following the identification of a new event (Radvansky et al., 2010; Swallow et al., 2009, 2011). However, recent research has investigated an alternative system of event updating. Kurby and Zacks (2012) investigated on-line access to properties while reading a story. In addition to the global updating suggested by event segmentation theory, they found evidence for incremental updating. It appears that individual features (such as characters, objects, space and time), may be updated in an event model while other features remain undisturbed. The relational violations in our experiments may have promoted an incremental rather than global updating process, leading to more intact working memory representations and increased change detection. As such, the current experiments are not in opposition to existing theories of working memory release following boundaries, but highlight the need for further investigation into the updating process.

In addition to implying that recently encoded features may remain available for integration into new events, the relational trigger hypothesis suggests that it might be useful to add more retrospective processes to the predictive processes that are hypothesized to drive event perception. As reviewed above, event segmentation theory relies on the idea that event boundaries are perceived when internally generated predictions fail to match observed events and therefore generate error signals that result in the (at least partial) flushing of information from working memory and the creation of a new event model (Kurby & Zacks, 2008; Zacks et al., 2007). Our data suggest that an important part of this process is a response to signals (e.g. relational triggers) that induce comparisons between currently visible visual properties and properties that have been encoded in the past, enabling the intelligent allocation of resources to new and changing features while investing fewer resources in stable features. On this view, memory comparisons anchor perception in the recent past, activating previously seen visual properties, while predictive processes anticipate future properties and events.

One important issue in interpreting these experiments is whether the specific trigger we have used represents a common form of spatial inconsistency that underlies a large proportion of event perception. As discussed in the introduction, modern Hollywood film leverages the human visual system to give a realistic impression of events despite apparent differences between edited films and real-world perception (for review see Smith et al., 2012). Therefore, viewers' sensitivity to 180° violations in film is likely mirrored in many other settings, some of which were reviewed in the introduction. In another recent example, Huff and Schwan (2012) asked participants to view simple computer-generated animations and to gauge whether two cars, each depicted in its own non-overlapping view, were moving towards or away from each other. Crucially, the views were ambiguous and on one interpretation some pairs of views crossed the line of action (thus violating the 180° rule) but were only 60° apart, while on another interpretation they did not cross the line of action but were 120° apart. Huff and Schwann found that participants preferred to represent viewpoints consistent with the 180° rule, even if it meant combining views across a larger viewpoint rotation. It is also useful to consider the degree to which relational triggers might be activated during everyday real-world events. For example, it is possible that many transitions between events involve changes in spatial relationships among a common set of actors and objects: a pair of office workers might change from making copies to stapling by rearranging themselves and the objects they are working with, and an efficient visual process might rely upon relational triggers to guide attention to properties at specific moments when qualitative rearrangements have occurred. Furthermore, it would be worthwhile to explore the common usages of 180° violations in commercial films. For instance, Hollywood editors may utilize the attention-grabbing nature of relational violations to punctuate important moments in a scene (e.g., Levin & Wang, 2009). Whereas the number of stimuli in the current study was limited as a consequence of the time required to design, film and edit multiple movies, the ever-enlarging body of Hollywood films offers ample opportunities for narrower hypotheses.

It would also be worthwhile to explore relational triggers as members of a broader category of discontinuities. As reviewed in the introduction, research in narrative comprehension suggests that individuals update representations of written and visual stories using a number of features, of which spatial information is a subset (e.g. Magliano et al., 2001; Zwaan & Madden, 2004). It is likely that the documented spatial effects here are part of a broader category of casual and temporal breaks. Indeed, the results of Experiment 5 suggest that a non-spatial transition in conversation led to increased updating and change detection. While these experiments demonstrated that spatial discontinuities are sufficient to trigger event updating, future research should investigate whether and how other narrative features, such as breaks in action or addition of a new actor, might produce the kinds of property comparisons that induce change detection.

Future research might proceed by identifying whether the properties of relational triggers documented here apply to other predictors of new events. Event updating may be specific to the discordant modality, for instance. A change in atmospheric sound might induce an event boundary without inducing visual property comparisons. Furthermore, events in both film and the real world can transition between non-connecting or non-adjacent spaces, or across a large span of time. This may occur when exiting a location, or while shifting attention from a near event (e.g. one's computer screen) to a distant event (e.g. outside one's office window). In these cases, property comparisons between alignable objects are not realistic, reducing the utility of relational triggers, at least as we have described them here. In contrast, many instances of event perception – including the stimuli from this study – involve changes in the relationships, orientation, and status of a continuously visible set of objects. In such cases, new spatial relationships, especially among actors, or between actors and objects, might signal new events that could effectively be identified by focusing on changes to visual properties.

In five studies we have repeatedly shown that relational triggers serve as a heuristic mechanism for the updating and comparison of event properties. We propose that relational triggers induce a comparison of features in working memory as the event model is updated. These triggers offer a mechanism for leveraging limited cognitive resources to attend to events and compare features when changes to objects are likely to be informative preparing observers for the upcoming event as well as alerting them to the changing features of their environment.

Authorship

LJB and DTL co-developed the study concept. Both authors contributed to the study design. Testing, data collection and data analysis were performed by LJB and interpreted under the supervision of DTL. LJB drafted the paper and DTL provided critical revisions. All authors approved the final version of the paper for submission.

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