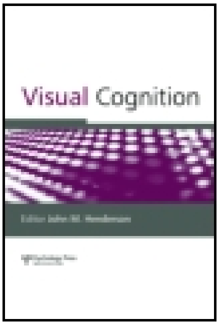

Visual Cognition
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pvis20

Visual target detection is impaired at event boundaries

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Version of record first published: 30 Jul 2012

To cite this article: Markus Huff, Frank Papenmeier & Jeffrey M. Zacks (2012): Visual target detection is impaired at event boundaries, Visual Cognition, DOI:10.1080/13506285.2012.705359

To link to this article: http://dx.doi.org/10.1080/13506285.2012.705359

VISUAL COGNITION, 2012, iFirst, 1–17

Psychology Press
Taylor & Francis Group

Visual target detection is impaired at event boundaries

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Boundaries between meaningful events are key moments in comprehending human action. At these points, viewers may focus on the event's contents at the expense of other information. We tested whether visual detection was impaired at those moments perceivers judged to be boundaries between events. Short animated football clips were used as stimulus material, and event boundaries were imposed by having the ball change possession. In a first experiment, we found that possession changes were perceived to be event boundaries. In a second experiment, participants were asked to keep track of 4 of 10 players and to watch for 120 ms probes appearing either at an event boundary or a nonboundary. Probe detection was less accurate at event boundaries. This result suggests that the segmentation of ongoing activity into events corresponds with the regulation of attention over time.

Keywords: Event cognition; Dynamic attention; Multiple object tracking; Probe detection.

Perceiving changes in goal-directed actions is a crucial ability to humans. In team sports, for example, it is necessary for a player to react to sudden counterattacks or unexpected pass interceptions. Such observations of changes in goal-directed in dynamic activities may trigger processes regulating visual attention over time. In two experiments we present evidence that such changes are perceived as event boundaries and that they cooccur with the flexible allocation of visual attention over time.

Observers of dynamic activities segment them into meaningful events (Newtson, 1976; see Zacks, Speer, Swallow, Braver, & Reynolds, 2007, for a review). For example, in a football game, interested viewers structure the game

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http://www.psypress.com/viscog http://dx.doi.org/10.1080/13506285.2012.705359

in attacks, counterattacks, goals, and penalty kicks. The perception that one event has ended and another has begun is associated with changes in physical features including object movement (Hard, Tversky, & Lang, 2006; Zacks, 2004, Zacks, Kumar, Abrams, & Mehta, 2009) and also with conceptual changes including characters and their goals (Zacks, Speer, & Reynolds, 2009). Event boundaries are known to affect memory encoding and updating (Swallow, Zacks, & Abrams, 2009). Objects present at an event boundary are better recognized than other objects, suggesting that segmentation covaries with the deployment of processing resources over time. Here, we investigate whether event boundaries also affect the regulation of visual attention over time.

Visual attention is dynamically regulated over time and highly sensitive to changes. A classic paradigm to study regulation of attention over time is attentional blink. Typically, participants are instructed to search for one or two targets in a long stream of distractors in a rapid serial visual presentation (RSVP). All items are presented on a fixed and restricted area on the display. Using a presentation rate of 100 ms/item and the instruction to search for two targets participants often fail to detect the second target if it is presented shortly after the first target (Broadbent & Broadbent, 1987; Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1992). This impairment for the second target is nullified if participants are instructed to search for the second target only. Hence, searching for the first target disrupted the search for the second target. More recently, Swallow and Jiang (2010) showed—using a modified version of the RSVP task—that searching for a target not only influences subsequent task performance but also can influence performance in a concurrent task. In their experiments participants viewed a stream of small black and white squares, presented at a 500-ms-per-item rate, and were asked to respond to one of the two colours, which was presented infrequently. The squares were superimposed on scene photographs, which the participants were told to encode for later memory. Background images that were simultaneous with a target square were recognized better than images presented with a nontarget square. Swallow and Jiang argued that the appearance of the target caused an orienting response, facilitating processing of concurrently attended information. Further, they proposed that this attentional boost effect is due to the opening of an attentional gate that facilitates processing of the secondary task.

These studies show that visual attention is highly sensitive to changes, and that searching for a target in a long stream of distractors modulates attention. However, the stimuli in studies of the attentional blink and attentional boost have been rather artificial; they were presented only for a short time on a specific area on the display and the stimuli are inherently static. By contrast, the duration of real world events is typically longer and often encompasses multiple dynamic objects of interest. Hence, it is necessary to maintain visual attention across a certain time period in space.

With the multiple-object tracking paradigm (MOT; Pylyshyn & Storm, 1988) it is possible to examine attentional processing with longer events at spatially distributed locations (Cavanagh & Alvarez, 2005). Participants visually track a limited number of arbitrarily moving objects among identical-looking distractors. As in the experiments with static stimuli (attentional blink and attentional boost effects) attention is flexibly allocated during this moment-to-moment tracking of multiple arbitrary moving objects. Recently, eyetracking and dual task methods contributed to the understanding of the (spatial) distribution of (visual) attention in dynamic scenes. When tracking multiple objects, gaze is directed much more often to target than distractor objects, suggesting that more attention is allocated to targets than distractors (Fehd & Seiffert, 2008, 2010; Huff, Papenmeier, Jahn, & Hesse, 2010; Zelinsky & Neider, 2008). A more direct approach to measure attentional processes in MOT is probe detection (Pylyshyn, 2006). Small visual probes are presented for a short time on target or distractor objects. Participants are asked to track the targets and watch out for the probes. The findings resemble those of the eyetracking studies. Probe detection performance is higher for probes on targets than for probes on distractors. Recent electrophysiological experiments presenting probe dots suggest the involvement of early attentional processes during MOT (Doran & Hoffmann, 2010; Drew, McCollough, Horowitz, & Vogel, 2009). Using a blank-screen paradigm in which participants had to localize a target object after the screen turned blank, Iordanescu, Grabowecky, and Suzuki (2009) showed that targets closer to distractors are localized more precisely and therefore focus more attentional resources. More generally, Tombu and Seiffert (2008) examined whether transiently increased tracking difficulty creates higher attentional demands. They introduced periods during which tracking was made harder by reducing interobject spacing or increasing object speed, and found that doing so slowed detection of auditory probes.

Taken together, dynamic scenes are segmented into events over time causing a varying deployment of processing resources. Additionally, visual attention is flexibly allocated while tracking multiple objects in dynamic scenes according to concurrent demands. In the present study, we asked whether the segmentation of dynamic scenes into events cooccurs with the flexible allocation of visual attention over time. Therefore, we asked participants to track multiple players in animated football clips showing multiple passes and one pass interception. The pass interception was induced to elicit an event boundary. Using a probe dot detection task we measure the dynamic allocation of attention over time.

Thus, the present research had two goals. First, we want to test whether introducing a pass interception caused an event boundary. Second, we want to test whether event boundaries corresponded with changes in the allocation of visual attention.

EXPERIMENT 1

In this experiment, we examined if observers perceive meaningful changes in goal-directed actions in football games as event boundaries. The particular changes we studied were changes in ball possession due to a pass interception.

Method

Participants. Twenty students (11 female; 19–30 years) of the University of Tübingen participated in two sessions, spaced 1–2 days apart. Each session lasted approximately 60 minutes. All participants reported normal or corrected to normal vision. They received course credit or compensation for their participation.

Apparatus, stimuli, and procedure. All stimuli were presented on a notebook with a 15.4-inch LCD-monitor with an unrestricted viewing distance of approximately 55 cm. Stimuli were short football scenes, lasting 5.2–11.0 s ($M = 9.1$ s, $SD = 1.1$), programmed with custom software using Java, Blender, and Python. Each scene showed players from two teams (five players and a goalkeeper each) that could be differentiated by the colours of their shirts (blue or yellow) and a ball (see Figure 1). Scenes were presented from a viewpoint angle of 20 degrees to the x-y plane. A single player subtended 0.34 to 0.49 degrees of visual angle in width and 0.97 to 1.42

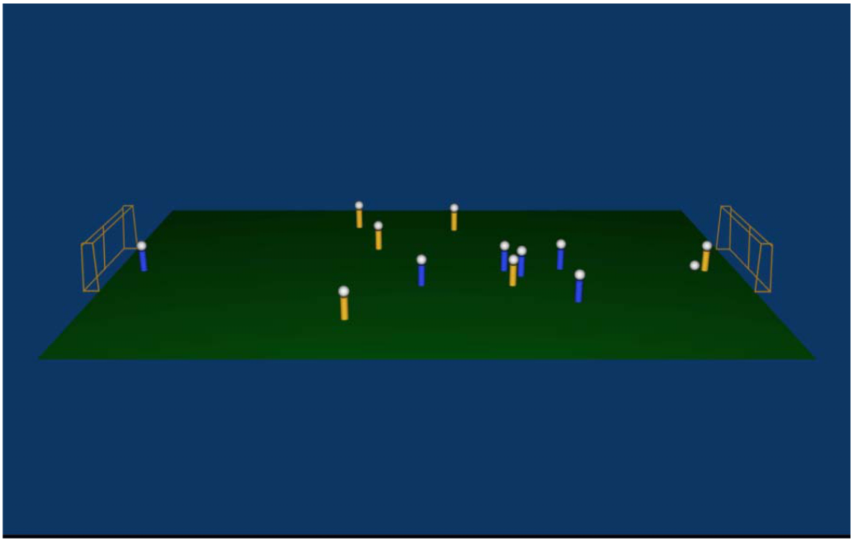

Figure 1. Example of the stimulus material. A video clip is available at http://www.iwm-kmrc.de/cybermedia/event/. To view this figure in colour, please see the online issue of the Journal.

degrees of visual angle in height depending on the position on the floor plane. The floor plane occupied 18.68 to 28.29 degrees of visual angle horizontally and 5.51 degrees vertically. Each trial began with the static presentation of the first frame of the scene for 4600 ms. Thereafter, all players started to move at a speed between 1.80 and 2.20 deg/s. The speed of the ball was 6.00 deg/s.

Scenes were pregenerated and consisted of seven states describing the ball's and the players' positions. All players moved in straight lines from state to state. Each scene began with a pass from a goalkeeper and ended with the opposing team scoring a goal. The goalkeepers were stationary throughout the trial. An algorithm that simulated basic football rules calculated the transitions between these states. The football field consisted of an array of 120×81 possible positions. At the beginning (first state), all players were randomly positioned within a restricted area around the centreline on the floor plane that covered 50%. Each subsequent state (States 2–6) was determined by a valid ball position. A ball position was valid if there was only one player of the ball possessing team who was able to get to the ball within its predefined speed limits. A player was not allowed to pass back in the direction of its own goal. If any player was able to reach the ball along its passing path within the player's speed limits there was a probability of 10% to intercept the pass for each position that fulfilled this criteria. We defined for each state transition whether a pass interception was to take place. If the definition did not match the result, the generated state was discarded. All players (except the one catching the ball) moved in randomly chosen directions. In case of a pass interception all players (except the intercepting player) kept their movement directions as compared to no interception. Therefore, players' movements were comparable for these two state transitions (with vs. without pass interception) with one exception. If there was no pass-interception, only one player of the same team moved for the ball. If there was an interception, two players—one of the ball possessing team and one of the opposing team—moved for the ball. After the sixth state, the player in ball possession tried to score a goal. The ball was not allowed to be shot through the goalkeeper. If the goal shot was intercepted (by the same 10% rule already mentioned) or if the player was positioned farther than 25 units from the goal, the state was discarded and the scene was generated anew. This algorithm provided a maximum of random movement while allowing the definition of specific parameters.

Ball possession changed after the second or after the fourth pass. That allows the definition of two intervals: Interval 1 including Passes 2 and 3, and Interval 2 including Passes 4 and 5 (see Figure 2). Both start side (left or right goalkeeper) and colour of the team (yellow or blue) were counterbalanced. Intervals with and without change in ball possession differed in length. Intervals depicting a change in ball possession were slightly but

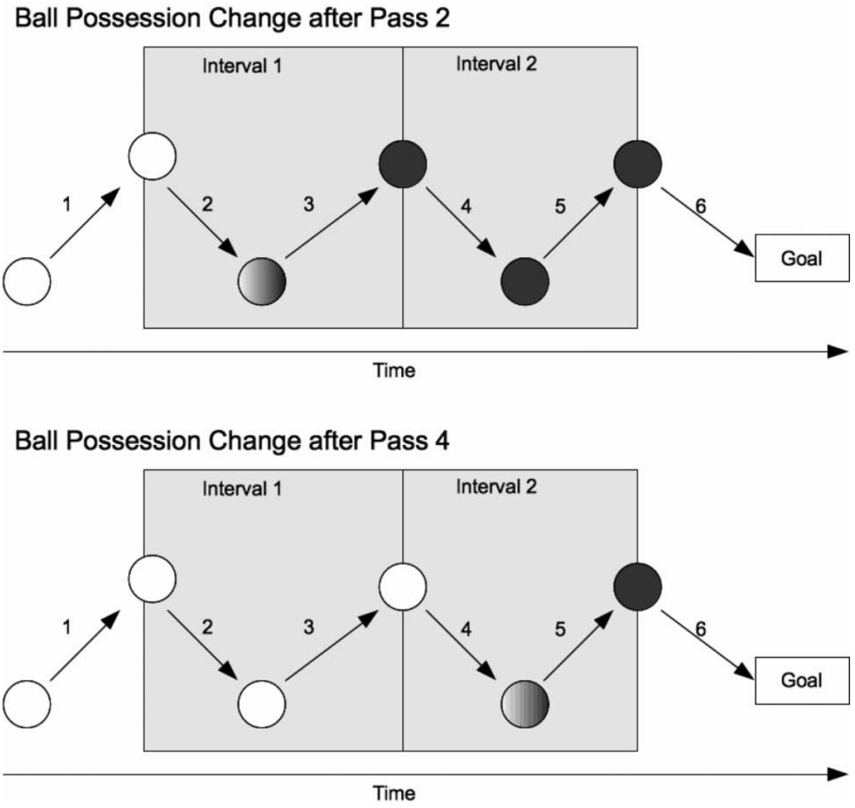

Figure 2. Schematic illustration of the football scenes. Ball possession (as indicated by white and black dots) changed either in the middle of the first or second interval.

significantly longer than intervals depicting no change in ball possession ($M = 3.54$ s, range: 3.39–3.69 s and $M = 3.16$ s, range: 3.01–3.27 s, respectively), $t(19) = 19.64$, $p < .001$.

A total of 128 experimental trials were generated for each participant, 64 trials with ball possession change after the second pass and 64 trials with ball possession change after the fourth pass. Additionally, 22 practice trials were generated. The trials were presented in a randomized order.

Participants were instructed to segment at either a *fine* or *coarse* temporal grain. In the fine condition, participants were instructed to segment the dynamic scene into the “smallest units that were natural and meaningful” to them. In the coarse instruction condition, they were asked to segment the scenes into the “largest units that were natural and meaningful” to them. In the first session, half of the participants started with fine segmentation, the other half with coarse instruction. In the second session, each participant was instructed to segment the same dynamic scenes using the grain not tested in the first session. Participants were asked to press a yellow-marked button with their preferred hand on the keyboard when they perceived an event boundary.

Results and discussion

We calculated the mean number of event boundaries in each condition for every participant. The results are plotted in Figure 3. As can be seen in the figure, participants were substantially more likely to identify event boundaries during intervals in which a change in goal-directed action occurred.

We submitted these data to an ANCOVA with the within-subject factors *interval* (with change in ball possession, without change in ball possession) and *grain* (coarse, fine). Additionally, we included *interval length* as covariate because intervals with changes were slightly longer, and one would expect longer intervals to have more event boundaries, other things being equal. The increase in segmentation with changes in goal-directed action produced a significant main effect of interval, $F(1, 17) = 37.58$, $p < .001$, $\eta_p^2 = .69$. As expected, there was a significant effect of grain: When participants were instructed to segment into fine units they produced more event boundaries than when they segmented into coarse units, $F(1, 17) = 21.71$, $p < .001$, $\eta_p^2 = .56$. The interaction of these factors was not significant, $F(1, 17) < 1$,

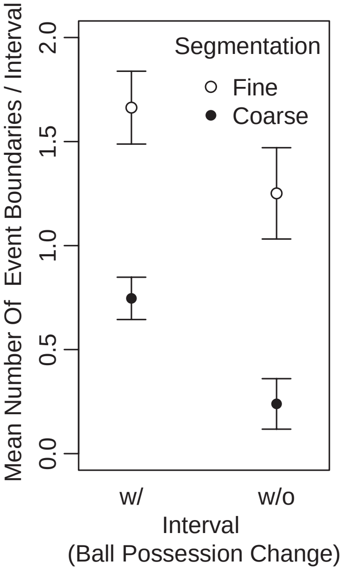

Figure 3. Mean number of event boundaries per interval in Experiment 1. Error bars indicate the *SEM*.

nor was there any significant influence of the covariate interval length. An additional analysis with *grain order* (fine segmentation first, coarse segmentation first) as an additional between-subjects variable showed no significant effects of the factor grain order. In sum, intervals in which there was a change in goal-directed behaviour were perceived as event boundaries. This difference was not accounted for by the fact that these intervals were slightly longer than those without changes in goal-directed behaviour.

The first analysis was based on intervals containing two passes. Given these relatively long intervals, it remains unclear when exactly participants perceived an event boundary. Therefore, we ran another analysis analysing participants' segmentation behaviour with respect to the time point of the actual change in ball possession (i.e., the time point the ball touched the player of the opposing team for the first time) and with respect to the corresponding pass in the interval with no change in ball possession. We time-locked participants' event-boundaries to these time points and calculated the temporal distance between each event boundary and the critical time point. The resulting data are plotted in Figure 4. We binned the data to 500 ms intervals.

We compared segmentation behaviour in the 500 ms interval following the pass interception with the two adjacent 500 ms intervals using paired *t*-tests. A family-wise correction with $\alpha = .025$ was used to correct for two multiple comparisons. When ball possession changed we observed a significantly higher amount of segmentation responses in the 500 ms following this critical event for both fine (proportion segmented: $M = 0.60$, $SEM = 0.06$) and coarse (proportion segmented: $M = 0.38$, $SEM = 0.07$) segmentations than in the corresponding adjacent intervals, smallest $t(19) = 3.72$, $p = .001$. When there was a pass reception without change in ball possession, the amount of segmentation responses was generally lower. We observed an increase in fine event boundaries in the 500 ms after the pass reception (proportion segmented: $M = 0.37$, $SEM = 0.08$), smallest $t(19) = 3.06$, $p = .006$, but not in coarse event boundaries (proportion segmented: $M = 0.04$, $SEM = 0.02$), largest $t(19) = 2.14$, $p = .046$. In sum, whereas pass receptions were generally related with the perception of *fine event boundaries*, *coarse event boundaries* were only perceived if there was an actual change in the goal-directed action (i.e., due to pass interceptions).

EXPERIMENT 2

In Experiment 1, we found that a change in the goal-directed action, namely a change in ball possession, was perceived as a coarse event boundary. In Experiment 2, we asked whether these event boundaries affected visual attention. The participants' task was to detect a probe dot that could appear in one of the players' heads. To ensure that participants focus on the football play we asked them to judge the quality of the football play while keeping

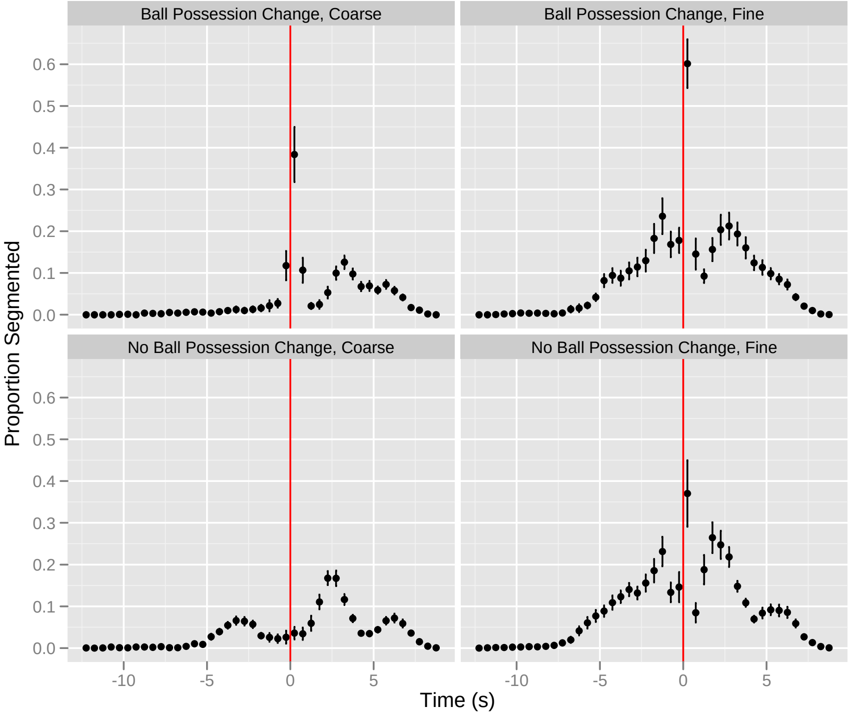

Figure 4. Proportion of trials segmented in relation to the ball possession change (0 s, upper row) and in relation to a regular pass reception by a teammate (0 s, lower row). The segmentation data are binned to 500 ms intervals. Error bars indicate the *SEM*. To view this figure in colour, please see the online issue of the Journal.

track of four players and performing the probe detection task. Thus, if event boundaries affect visual attention, probe detection performance should be different if probes are presented in close temporal relation with an event boundary. Event boundaries may improve or impair probe detection performance. If event boundaries open an attentional gate facilitating processing of a secondary task (Swallow & Jiang, 2010), we would expect improved probe detection performance at event boundaries. On the other hand, if event boundaries trigger reorientation processes needing additional attentional resources (which are limited), we would expect probe detection performance to be lower at event boundaries (Tombu & Seiffert, 2008).

Method

Participants. Twenty new participants (18 female; 20–32 years) from the same population as those of Experiment 1 were recruited. The experiment lasted approximately 60 minutes. All participants reported normal or corrected to normal vision. They received course credit or compensation for their participation. The data of three participants did not enter the reported analyses. Two participants were excluded, because their tracking performance was more than 2 *SD* below the average. One participant was excluded, as he reported not doing the task.

Apparatus, stimuli, and procedure. All apparatus and stimuli and the number of trials were identical to those in Experiment 1 with the following exceptions: Each trial began with the static presentation of the first frame of the scene for 1000 ms. Four players (two players from each team) were designated as targets by flashing their heads on and off in red colour four times in 200 ms intervals and remaining red for another 2000 ms. Thereafter, they began to move.

Attentional probes were presented in half of the trials and took the form of red dots (RGB = [255, 0, 0], 0.19–0.26 degrees of visual angle in diameter) appearing for 120 ms in the head of one randomly chosen player. Only one probe was presented per trial, on the head of a target or a distractor player (counterbalanced). Probe onset was immediately after either the second or fourth pass at the moment the ball first touched the receiving player. The dynamic scenes were similar to Experiment 1. That is, a change of ball possession, intended to produce an event boundary, also occurred after either the second or fourth pass. The timing of the probe was fully crossed with the timing of the putative event boundary. Thus, on half of the trials the probes appeared at an event boundary, and on the other half they appeared during an ongoing event. Note that in the case of changes in ball possession, probes were presented at the critical time interval identified to elicit (coarse) event boundaries in Experiment 1. Two spatial parameters that could potentially influence probe detection performance were controlled so as to be matched across probes occurring during event boundary and no-event boundary intervals: The distance between probe dot and the mean position of the target players, $t(16) = 0.45$, $p = .660$; and the mean distance between all players (i.e., the degree of visual crowding), $t(16) = 1.05$, $p = .310$.

Participants were given three tasks: (1) To ensure that participants focus on the football game we asked them to judge the quality of the teams' performances and to report the better team at the end of each trial. The instruction was as follows: "You will be asked to judge which team (the yellow one or the blue one) played better. This does not necessarily need to be the team that scored", (2) to watch out for probe dots and to report the detection of a probe at the end of each trial, and (3) to keep track of each of the four target players for the duration of the football scene. The scene ended after either the yellow or the blue team scored. Thereafter, all players and the ball stopped moving and participants used the mouse to mark the four players they judged to be the targets. Marked players' heads appeared in red. Afterwards, participants reported by mouse click whether they noticed a dot appear in one of the players' heads. Then, participants judged—by mouse click—whether the blue or the yellow team was the better one. Finally, they received feedback about their tracking performance. The next trial began after participants pressed the spacebar.

Results and discussion

The mean proportion of correct tracked target players was high (86.7%) and commensurate with previous studies on the combination of MOT with probe detection (e.g., Pylyshyn, 2006) indicating that the football scenes resemble classic MOT scenes in its basic features. In addition, participants had low false alarm rates (trials in which participants falsely indicated that they saw a probe dot), averaging only six trials over the course of 128 trials (4.48%). Hence, we can exclude the possibility that some participants just guessed with regard to the probe detection task.

For the further analyses, we excluded trials based on two selection criteria. First, we excluded all trials in which participants rated the nonscoring team as being the better one (272 of the 1088 trials including a probe). This reduced the contribution of guessing about the team-rating task. Second, as we were interested in the influence of event boundaries on visual attention that was measured by probe detection performance on target and distractor players, we had to be sure that no target was lost. This ensures that visual attention is related with the targets. Hence, we excluded trials in which participants were not able to correctly track all four targets (438 trials). In 94 trials, participants neither answered the scoring team as being the better one nor correctly tracked all four targets. Based on these two criteria, 56.6% of the trials (616 of the 1088 trials including a probe) were excluded. The amount of excluded trials did not differ among experimental conditions, $\chi^2(3, N = 616) = 1.21$, $p = .751$ (the data were pooled across participants for this analysis).

We calculated mean probe detection performance for each participant (see Figure 5) and submitted these data to an ANOVA including the within-subject factors *probe location* (target, distractor) and *interval* (interval including an event boundary, intervals without an event boundary). Probe detection was significantly higher for probes on targets compared to distractor probes, $F(1, 16) = 30.91$, $p < .001$, $\eta_p^2 = .66$, replicating previous findings (e.g., Pylyshyn, 2006). Further, probe detection was significantly lower in intervals containing an event boundary compared to probes in intervals without event boundary, $F(1, 16) = 9.03$, $p = .008$, $\eta_p^2 = .36$. Thus, event boundaries influence visual attention eventually leading to impaired probe detection performance. The interaction of these factors was not significant, $F(1, 16) < 1$.

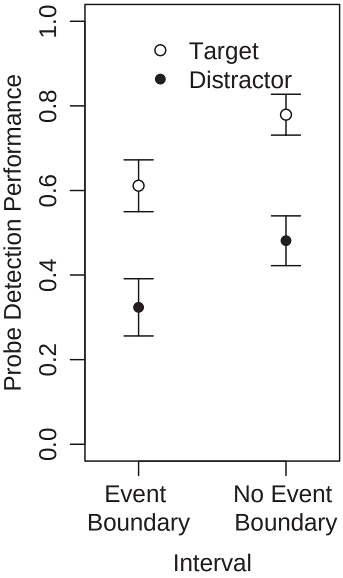

Figure 5. Mean probe detection performance scores of Experiment 2. Error bars indicate the *SEM*.

Time course. Is the effect of event boundaries on attention temporally selective? Each trial consisted of one interval with and one interval without an event boundary. Because the serial order of these intervals was counterbalanced we were able to compare probe detection performance in intervals that included event boundaries to both intervals that preceded a boundary and intervals that followed a boundary. Because there was no interaction of the probe location and event boundary factors in the previous analyses, we collapsed the data over probe location—probes on targets and probes on distractors.

As can be seen in Figure 6, the effect of event boundaries on probe detection was selective to the interval containing the boundary. A repeated measures ANOVA found this differences to be significant, $F(2, 32) = 3.79$, $p = .033$, $\eta_p^2 = .19$. Follow-up two-tailed paired t-tests showed that probe detection performance in the interval with the event boundary was significantly lower than in the interval before the event boundary, $t(16) = 2.80$, $p = .013$, and in the interval after the event boundary, $t(16) = 2.64$, $p = .018$. Probe detection performance in intervals before and after event boundaries was comparable, $t(16) = 0.35$, $p = .731$. (It is important to note that we selected only the trials with perfect tracking performance for this analysis. In further research it could be worth looking at eye movements enabling a closer look at specific processes at event boundaries.)

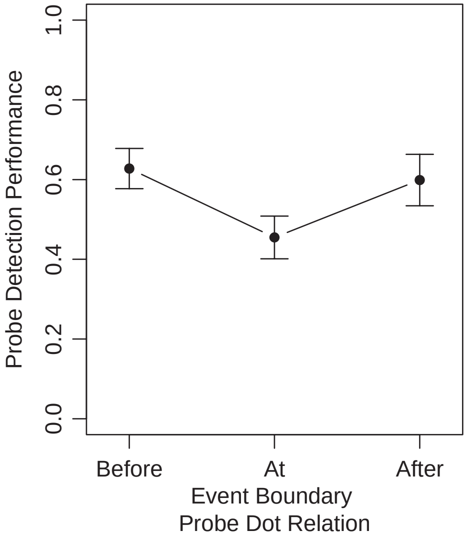

Figure 6. Probe detection performance in relation to the event boundary. Error bars indicate *SEM*.

In short, changes in ball possession, which in Experiment 1 were shown to produce the perception of an event boundary, here produced lapses in detection of a visual probe. Probe detection performance recovered during the interval following an event boundary. This suggests that the processes engaged in processing the action of the football game during the event boundary produce a transient decrement in processes available to detect the visual target.

GENERAL DISCUSSION

In two experiments we asked participants to segment short animated football scenes into meaningful events (Experiment 1) and to do a probe detection task while watching and tracking several football players (Experiment 2). Changes in ball possession were perceived as coarse event boundaries and—compared to intervals depicting no change in ball possession—impaired probe detection performance. The results show that changes in goal-directed actions influence attention processes.

Relation to Event Segmentation Theory

According to Event Segmentation Theory (EST), perceptual processing is guided by working memory representations, *event models*, that maintain a stable representation throughout a perceptual event (Zacks et al., 2007).

In our case, such an event model could hold information such as the teams' shirt colours, which team is on offence, and which goal each team is aiming for. Event models help observers to make predictions about future states of the event, thus facilitating memory processes. In the football example, one likely prediction is that the next pass will go to one of the players of the offensive team. EST proposes that event models are updated when prediction errors suddenly increase. For example, if there is an unexpected pass interception the prediction derived from active event model does not match the perceptions. In response, the event model is updated based on current sensory input; this is a resource demanding process. The current data are consistent with this account. However, an important limitation is that all of the scenes included pass interceptions that were shown to produce event boundaries. Thus, participants may have adapted to these changes. A further test of the theory might be to have both scenes with and scenes without event boundaries.

In the current study, we examined segmentation and perceptual processing with meaningful dynamic scenes. However, several studies showed that changes of low-level features (e.g., abrupt direction changes of moving dots) also influence segmentation behaviour (Hard et al., 2006; Zacks, 2004; Zacks et al., 2009). Thus, low-level features play an important role in the segmentation and perceptual processing of dynamic scenes. In the football scenes of the current study, participants perceived event boundaries in intervals depicting a change in ball possession that triggered a counterattack. We controlled for many low-level features—most importantly, whether the global direction of the scene had changed at the time of the probe dot. However, event boundaries correlate with changes in some low-level features (e.g., the colour of the ball possessing player, the directional momentum of the ball). Future studies should continue to tease apart the relations between changes in low-level visual features, event segmentation, and the regulation of attention over time in natural scenes.

Relation to studies examining visual attention in dynamic scenes

The results of this study clearly relate to multiple-object tracking. Previously, it had been shown that increased crowding and/or increased object speed impair secondary task performance (Tombu & Seiffert, 2008). In our study, crowding and speed parameters were comparable across intervals with and without change in ball possession. Further, these intervals did not differ with respect to the mean distance between probe dot and the target players. Yet, we showed that changes in goal-directed actions modulate visual attention over time. Hence, it was not the spatiotemporal movement pattern but the perceived event boundaries that led to lower probe detection performance in intervals depicting the event boundary. This suggests a role for top-down deployment of visual attention in MOT.

In MOT, the start positions and movement directions of the objects are usually chosen at random. Only more recently has there been accumulating evidence that motion information on the level of individual objects is used in multiple-object tracking (Horowitz & Kuzmova, 2010; Iordanescu et al., 2009; St. Clair, Huff, & Seiffert, 2010). Further, sudden and unexpected changes in object movement capture attention (Pratt, Radulescu, Guo, & Abrams, 2010). In our stimuli, the football players were positioned randomly and—except for the ball-carrying player—all players were moving in randomly chosen directions (most of the time). The special feature in our stimuli, however, was the ball that was neither a target nor a distractor but added a global direction to the stimuli. The current results show that not only changes on the level of individual objects but also changes in the global, scene-based level affect attentional processing.

Relation to RSVP effects

RSVP is a paradigm that allows for the examination of dynamic visual attention over time. Researchers have investigated the temporal dynamics of attention in RSVP by varying parameters including presentation duration per image, stimuli (e.g., letters, faces, images with superimposed squares) and task (e.g., search for one or two targets). When the second target is presented within a critical interval of approximately 200–500 ms it is less likely detected; this is the attentional blink (Chun & Potter, 1995; Raymond et al., 1992). Similarly, an unexpected stimulus in RSVP impairs target detection for up to two presentations; this is surprise-induced blindness (Asplund, Todd, Snyder, Gilbert, & Marois, 2010). Finally, detecting a target in a long stream of distractor objects facilitates processing of an unrelated concurrent secondary task; this is the attentional boost effect (Swallow & Jiang, 2010). At first glance, the task used by Swallow and Jiang (2010) to demonstrate the attentional boost effect seems quite similar to the task in Experiment 2, but in Experiment 2 we observed a decrement in performance rather than facilitation. However, there are substantial differences between the two paradigms. First, the participants in the attentional boost effect experiments were instructed to make a response when they saw the target object. In Experiment 2 of this study no response was required. One possibility is that the orienting response underlying the attentional boost effect is closely tied to planning a physical action response. Second, the stimuli in the attentional boost effect experiments were geometric figures on photographs that were shown for several hundred milliseconds. We used animated football clips that lasted several seconds with the visual probes being presented at a location different to that of the indicator of the event boundary (the ball). Thus, in addition to different durations, differences in the spatial layout of the stimuli might be responsible for different effects.

CONCLUSION

Changes in goal-directed behaviour are important not only in sports but also in everyday interactions. Here, we examined changes in goal-directed action in scenes that were rich and dynamic while controlling a number of extraneous visual and spatial features. We found that such changes led to the perception of a meaningful boundary between events during online viewing. Further, we found that changes in goal-directed action modulated attention over time. These results suggest that when there is a change in action, perceivers reorient to the perceptual world, forming a new representation of what is happening now.

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Manuscript received October 2011
Manuscript accepted June 2012
First published online July 2012