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A Goal Bias in Action: The Boundaries Adults Perceive in Events Align With Sites of Actor Intent

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We live in a dynamic world comprised of continuous events. Remembering our past and predicting future events, however, requires that we segment these ongoing streams of information in a consistent manner. How is this segmentation achieved? This research examines whether the boundaries adults perceive in events, such as the Olympic figure skating routine used in these studies, align with the beginnings (*sources*) and endings (*goals*) of human goal-directed actions. Study 1 showed that a group of experts, given an explicit task with unlimited time to rewatch the event, identified the same subevents as one another, but with greater agreement as to the timing of goals than sources. In Study 2, experts, novices familiarized with the figure skating sequence, and unfamiliarized novices performed an online event segmentation task, marking boundaries as the video progressed in real time. The online boundaries of all groups corresponded with the sources and goals offered by Study 1's experts, with greater alignment of goals than sources. Additionally, expertise, but not mere perceptual familiarity, boosted the alignment of sources and goals. Finally, Study 3, which presented novices with the video played in reverse, indicated, unexpectedly, that even when spatiotemporal cues were disrupted, viewers' perceived event boundaries still aligned with their perception of the actors' intended sources and goals. This research extends the goal bias to event segmentation, and suggests that our spontaneous sensitivity toward goals may allow us to transform even relatively complex and unfamiliar event streams into structured and meaningful representations.

Keywords: event segmentation, source-goal asymmetry, actions, experience, expertise

Events are continuous. Our perception of them is not. Making sense of experience demands that humans break down and assemble discrete units within the constant flux and flow of events. Indeed, remembering the past and predicting the future rely on this segmentation process (Elsner, Falck-Ytter, & Gredeback, 2012; Sargent et al., 2013). The modest literature investigating event segmentation demonstrates that people reliably parse experience at consistent boundaries (e.g., Zacks, Tversky, & Iyer, 2001a). However, the prior research does not clearly specify the nature of these boundaries, which is a necessary step toward understanding the mechanisms underlying event segmentation. This article begins to fill this void by investigating whether the boundaries adults perceive in continuous events align with the beginnings (*sources*) and endings (*goals*) of human goal-directed action sequences.

The vast majority of research on event segmentation comes from studies using an online event segmentation paradigm (e.g., Newtson, 1973; Sargent et al., 2013; Zacks, 2004; Zacks, Kumar, Abrams, & Mehta, 2009a; Zacks, Kurby, Eisenberg, & Haroutunian, 2011; Zacks, Speer, Vettel, & Jacoby, 2006; Zacks et al., 2001b, 2001a). Adults view an event display and are asked to press a button to denote natural boundaries. For example, the common event "doing the dishes" might be broken down into rinsing dishes by hand, loading the dishwasher, adding detergent, and running the dishwasher. Alternatively, dishwashing can be divided into smaller units (e.g., rinsing the glasses, rinsing the silverware, rinsing the plates, etc.). Adults independently converge on largely the *same* boundaries in a given event. This agreement emerges whether adults are invited to segment events into broad units or at a finer grain (Sargent et al., 2013; Zacks et al., 2001a). Further, people who deviate from group norms in their segmentation tend to have worse memory for the event than do those who align with the majority (Sargent et al., 2013; Zacks et al., 2006).

How do adults find these consistent boundaries? Event segmentation theory (EST), developed by Zacks, Speer, Swallow, Braver, and Reynolds (2007), posits that adults constantly and spontaneously generate predictions for upcoming action, based on the perceptual coherency of the event and guided by prior event experience. It is when event predictions fail that boundaries are perceived. For example, once soap is squeezed onto a sponge and a dirty dish is grasped, an observer of this event is likely to predict,

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successfully, that the dish will be washed. However, after the dish is cleaned, the event becomes less predictable. The actor may begin cleaning another dish, glassware, or utensil, or may turn to an activity unrelated to dishwashing. It is in these latter situations that EST posits the perception of event boundaries (Zacks, Speer, Swallow, Braver, & Reynolds, 2007). Consistent with this theory, studies show that action predictability is high within event boundaries but low across those boundaries (Reynolds, Zacks, & Braver, 2007; Zacks, Kurby, Eisenberg, & Haroutunian, 2011).

This mechanistic theory is intriguing, but is incomplete until we can more clearly characterize the information that observers perceive within event boundaries. Researchers have found that numerous physical feature changes correlate with perceived boundaries. Individuals tend to perceive boundaries when there are speed or directional changes of a moving entity (Hard, Tversky, & Lang, 2006; Maguire, Brumberg, Ennis, & Shipley, 2011), changes in body position (Newtson, Engquist, & Bois, 1977), changes in spatial location (Magliano, Miller, & Zwaan, 2001), and other movement changes (Zacks, 2004; Zacks et al., 2009a). However, in order to derive meaningful event units, individuals likely need to go beyond this spatiotemporal level of change. Do individuals' perceived event boundaries reflect more than just a summative assortment of movement and direction changes?

One prior study suggests this might be the case. Zacks, Speer, and Reynolds (2009b) compared the timing of participants' segment boundaries for an extended narrative film with the timing of "situational" changes in the film, determined separately by a pair of research assistants. Similar to the research on movement changes, this study found that many situational changes, including character changes, changes in the character's interaction with objects, changes in the interactions between characters, changes in causality, and changes in the character's goal, all correlate with perceived boundaries (Zacks et al., 2009b; see also Zacks, Speer, Swallow, & Maley, 2010).

While the research on spatiotemporal change focuses on microlevel analyses of human actions or movements, the research on situational change takes a broader approach, focusing on the changes typical of a narrative. In this way, research up until now has examined event segmentation correlates at a variety of levels, but not at the basic level of human action. Might there be something fundamental about the boundaries adults perceive in human action events?

Human action, and biological motion more generally, is intrinsically goal-directed, or directed toward some end. For example, we may run to acquire food, to complete a race, to improve our mood, or even just because we want to move in that particular way. Adults are keenly sensitive to the goal-directedness of human action, recognizing that an actor's movements are typically guided by the actor's intent to attain some objective (Elsner et al., 2012; Sartori, Becchio, & Castiello, 2011; Zacks, 2004). We assume that the goal of an action such as "reaching" is obtaining a particular object rather than extending the arm into the spatial location in which an object is situated (Hamilton & Grafton, 2006; Woodward, 1998) and we form distinct mappings between tools and their goals even when the means by which the actions are performed are spatiotemporally identical (Hernik & Csibra, 2015). Additionally, when an action is performed without an object or other relevant goal cues, we infer that the actor's goal is to complete the movement (Schachner & Carey, 2013). Thus, goals, which represent intentional action endpoints as perceived or assumed by observers, are prime candidates for the boundaries adults detect when parsing action events in real time.

Paired with goals are sources of actions, or the beginnings of goal-directed movements. Adults (and children) process the sources and goals of animate, intentional actions in a unique way, as compared with the sources and goals of inanimate, physical motion (Lakusta & Landau, 2012). When viewing an event such as a person hopping from a table (source) to a ladder (goal), and then, after a delay viewing the same event with a change in one of the two objects, individuals are much more likely to notice a change made to the goal (e.g., the person hops from the table to a *basket*) than a change made to the source (e.g., the person hops from a *chair* to the ladder). Action goals, like the ladder in this example, are encoded into memory more robustly than sources, controlling for which object is the source and which is the goal and controlling for movement dynamics between the source and goal (Lakusta & Landau, 2012; Papafragou, 2010). This is not the case for inanimate, physical events, such as a pen rolling from a camera to an eyeglass case; in these events, our ability to detect changes to the two objects is indistinguishable (Lakusta & Landau, 2012).

This goal bias in event memory may stem from a corresponding goal bias in event perception. Regier and Zheng (2007) compared the ability of adults to discriminate events with differing endpoints (e.g., placing a lid *on* a Tupperware container vs. placing a lid *in* the container) with their ability to discriminate events with differing starting points (e.g., taking the lid *off* a container vs. taking the lid *out of* the container). For each discrimination trial, the clips were played simultaneously and participants were asked to decide whether the two videos were the same or different; the task was made challenging by presenting the clips at six times the normal speed, and by requiring a response from participants within half a second (Regier & Zheng, 2007). Participants made significantly fewer errors when discriminating events with differing endpoints than events with differing starting points, suggesting an attentional bias toward action goals (Regier & Zheng, 2007). Given that sources and goals provide theoretical boundaries to human actions, and given the perceptual bias toward action goals, we expect that adults may spontaneously detect these sites of intent, particularly goals, as event boundaries.

Yet, there may be individual differences in the ability to detect action's sources and goals, just as there is variability in event segmentation patterns more generally (Sargent et al., 2013). An abundance of research suggests that having prior experience with a particular action goal enhances the person's ability to predict that goal when observing a similar action (Ambrosini et al., 2013; Kanakogi & Itakura, 2011; Möller, Zimmer, & Aschersleben, 2015; Sommerville, Woodward, & Needham, 2005). From a developmental perspective, there is a strong correspondence between young children's ability to perform an action and their ability to predict the goal of that action when it is performed by someone else (Ambrosini et al., 2013; Kanakogi & Itakura, 2011). Additionally, training studies suggest that even brief experiences can have an immediate effect on perception (Möller et al., 2015; Sommerville et al., 2005). For example, Möller and colleagues (2015) provided adult participants active experience with one of three tasks (block stacking, puzzles, or pursuit rotor task), and subsequently presented all participants with a video of an actor performing a task that just one of those groups had experienced (block stacking). Participants who had had *relevant* active experience, even just the short amount provided in this study, showed significantly more rapid gaze toward the actor's goals than participants in the other two groups (Möller et al., 2015). The demonstrated links between (a) prior action experience and goal prediction and (b) action prediction and event segmentation suggest a theoretical process whereby goals (and potentially sources) may be detected as event boundaries, partly as a function of prior action experience.

Although no studies to date have explored this theoretical process, the more general link between event experience and event segmentation, as posited by EST (Zacks et al., 2007) has been evaluated in two studies. Comparing the segmentation patterns of expert dancers and nondancers for a choreographed dance phrase, Bläsing (2015) found significant group differences, with experts marking fewer boundaries than novices. In post hoc interviews, experts reported using many segmentation criteria that the novices did not report (i.e., change of tempo/dynamics, feeling/imagery, change of energy or force, and movement impulse/accents), in addition to criteria reported by both experts and novices (i.e., change of movement type, stops/pauses, change in direction in space, change of main active body part, and change of height level). Experts' more complete awareness of boundary cues, as indicated by these interviews, may have helped them home in on the important sources and goals in the dance phrase while ignoring others.

Zacks, Tversky, and Iyer (2001a), in contrast, did not find support for the relation between expertise and event segmentation. The online segmentation task was used to compare how the following three groups of individuals parsed a saxophone assembly event: expert saxophone players, novices trained on saxophone assembly, and untrained novices. The authors assessed a quantitative measure of segmentation as well as a qualitative measure—examining the distribution of perceived boundary locations for the event—but found no group differences. The authors caution against overinterpreting this null finding, noting that "In retrospect, it seems likely that the unfamiliar event was simply not unfamiliar enough" (Zacks et al., 2001a, p. 44). Indeed, even without specific experience assembling a saxophone, novices' extensive experience with object assembly (e.g., assembling toys, furniture, etc.) was likely sufficient for identifying the sources and goals of the assembling actions working toward the finished saxophone product. Thus, unlike the dance study, which involved movement sources and goals largely unfamiliar to novices, this study may not have been a strong test of the effects of experience on event segmentation.

The ways in which adults parse complex, relatively unfamiliar events such as professional dance or sports may be particularly informative regarding the relevance of experience for detecting sources and goals as event boundaries. On the one hand, even without substantial domain-specific experience, novice adults are likely able to use their domain-general experience of action sources and goals and/or limited domain-specific experience to discover meaningful units in a continuous stream of human motion. On the other hand, however, having extensive domain-specific experience may mean that adults are more likely to find the *correct* boundaries—those which are marked most consistently across individuals—because of their access to more extensive mental representations of domain-specific actions. In the domain of figure skating, for example, Deakin and Allard (1991) showed that expert skaters were faster and more accurate than novice skaters at judging the similarity of two figure skating elements. Additionally, figure skating experts seem to have more precise mental representations of the time course of figure skating actions than novices, as evidenced by their greater accuracy judging the coherence of temporarily occluded figure skating elements, but not movement exercises (Diersch, Cross, Stadler, Schütz-Bosbach, & Rieger, 2012). These studies, and research on expertise more generally, implicate the importance of long-term memory retrieval structures (also referred to as "knowledge structures")—experts actively recruit their representations of complex domain-specific patterns (built up over time) as they process incoming information (Campitelli, 2015; Ericsson & Kintsch, 1995; Gobet & Simon, 1996). Thus, experience, in particular expertise, likely makes a difference for event segmentation. The present research was conducted not only to provide an additional test of whether experience matters for event segmentation, but to examine across experience groups the detection of particular boundaries—those that align with sources and goals, sites of actor intent.

In addition, if perceived event boundaries do align with sources and goals, it is necessary to determine how this alignment might dovetail with the bounty of microlevel spatial and temporal movement cues that have been found to correlate with perceived boundaries (Hard et al., 2006; Magliano et al., 2001; Maguire et al., 2011; Newtson et al., 1977; Zacks, 2004; Zacks et al., 2009a). Researchers have noted that physical changes naturally tend to co-occur with changes in intention in events (Baldwin & Baird, 2001). Thus, it is possible that the detection of sources and goals during event segmentation is dependent on the detection of spatiotemporal cues that converge on these sites of intent. The disruption of spatiotemporal cues would therefore be expected to reduce the alignment of perceived event boundaries with sources and goals.

This article explores whether action sources and goals—sites of actor intent—are detected as a part of event segmentation. We examined this possibility using an Olympic figure skating routine, in which an international skating champion performed a series of fluid and complex action sequences. We first asked whether discrete source and goal states could be defined by experts for this complex event, in an explicit, untimed task (Study 1). Second, we asked whether these sources and goals might be detected as boundaries during adults' online parsing of the event (Study 2). We further assessed whether the online detection of action sources and goals could be attributed to experience and/or to perceptual familiarity (Study 2). Finally, we asked whether disrupting spatiotemporal cues in the figure skating event would reduce the alignment of adults' perceived boundaries with action sources and goals (Study 3). We hypothesized that experts would show agreement as to the sources and goals in an event, and that adults' perceived online boundaries would align with these sources and goals, with a bias toward goals. Additionally, we hypothesized that extensive experience, but not mere familiarity would contribute toward this alignment, and that this alignment pattern would be reduced by the disruption of spatiotemporal cues.

Study 1: Do Experts Agree on the Sources and Goals of a Figure Skating Routine in an Explicit, Untimed Event Segmentation Task?

Study 1 explored whether experts could consistently identify the sources and goals of actions within an event. We explicitly asked experts to name the action sequences they detected in a figure skating routine, and to mark the beginning (i.e., source) and ending (i.e., goal) of each sequence. Given that using language has been shown to improve the consistency of adults' event segmentation (Zacks et al., 2001a), we expected our task would produce reliable sources and goals across the figure skating experts. More specifically, we predicted experts would largely pick out and label the same action sequences, because there are particular sequences that receive emphasis both in the training and judging of figure skating routines. Additionally, given that adults' representations of events are biased toward goals (Lakusta & Landau, 2012; Papafragou, 2010), we predicted greater agreement among experts regarding goals compared with sources. This study was a first step toward revealing whether human action events have discrete and reliable sources and goals. If so, these sources and goals are potential candidates for the online boundaries adults perceive in events.

Method

Participants. Ten adult Olympic figure skating trainers (seven females, three males; mean age = 36.50 years; mean years coaching = 18 years), recruited from a U.S. figure skating training center, were included in analyses. One additional trainer was excluded due to technical error. Written informed consent was obtained from all participants prior to testing.

Materials and procedure. Participants were seated individually in front of a computer monitor and keyboard and, using VLC media player, were presented with a video. The video was a 172-s silent clip of Michelle Kwan, an international skating champion, performing her short program routine at the 1998 Olympics (the performance can be viewed on YouTube). In under 3 min, the short program consisted of eight required elements based on the International Skating Union regulations: three jumps, three spins, and two step/spiral sequences (in 2010 this was reduced to seven required elements; International Skating Union, 2010, 2014).

In a self-paced task, expert participants were asked to do two things each time they detected an action sequence in the figure skating routine: (a) to verbally name the action sequence, and (b) to pause the video and press a button to capture the precise video frame marking each sequence's beginning and ending. Experts had the opportunity to rewind and replay the video before settling on a video frame that in their judgment marked each action sequence's beginning and ending. Video frames marked as beginnings and endings were coded in milliseconds.

Results

Action sequence labeling. Across the expert participants, eight distinct figure skating action sequences were named. Of the eight sequences, six were commonly labeled by all 10 experts: triple flip, flying sit spin, double axel, triple Lutz double toe, spin combination, and layback spin; one was named by eight experts: spiral sequence; and one was named by five of the experts: circular footwork (see Table 1).

Temporal agreement. Agreement among participants regarding the timing of action sequences' sources and goals was determined by computing the temporal range within which each source and goal was identified by all experts. This temporal agreement was assessed across the subset of six action sequences marked by every expert and across all eight action sequences. Analysis of the six sequences marked by all the expert participants revealed significantly more variability in the identification of sources (M = 3.28 s, SE = 0.46 s) than goals (M = 1.85 s, SE = 0.13 s), $t(5)$ = 2.95, $p < .05$, d = 1.20. Similarly, the analysis with all eight action sequences showed more variability in the timing of sources (M = 3.84 s, SE = 0.95 s) than goals (M = 2.26 s, SE = 0.65 s), $t(7)$ = 3.65, $p < .01$, d = 1.30.

Discussion

The purpose of this study was to determine whether a group of experts with extensive domain-specific experience would reliably identify action sources and goals in a figure skating routine, in an explicit, untimed segmentation task. Figure skating experts were asked to name and mark the beginnings and endings of action sequences in the event. Experts independently labeled the same figure skating action sequences in the event, showing complete agreement as to the identity of six sequences and incomplete agreement as to the identity of two sequences. This finding suggests that experts divide up events in this domain in a largely consistent manner, at least when asked to produce verbal labels for event units. Further, as predicted, there was greater agreement among experts regarding goals relative to sources. This is consistent with the goal bias demonstrated by prior studies in attention and memory; thus, adults not only attend to and encode goals into memory more than sources (Lakusta & Landau, 2012; Papafragou, 2010; Regier & Zheng, 2007), but, at least expert adults, also have narrower, more definitive representations of goals relative to sources.

Table 1
Labeling and Temporal Agreement of Sources and Goals in Figure Skating Routine by Study 1 Experts

Figure skating action sequence	Experts identifying the sequence (out of 10)	Duration of sequence in seconds M (SE)	Source range across participants in seconds	Goal range across participants in seconds
Triple flip	10	3.3 (.28)	3.2	1.4
Flying sit spin (death drop)	10	9.8 (.33)	2.7	1.6
Double axel	10	2.6 (.38)	3.8	1.8
Triple Lutz double toe	10	4.6 (.70)	5.2	2.0
Spin combination	10	14.2 (.47)	2.9	2.1
Layback spin	10	8.9 (.32)	1.9	2.2
Spiral sequence	8	17.0 (.46)	1.2	2.4
Circular footwork	5	17.1 (2.35)	9.8	6.6

These results expose the possibility that source and goal sites of intent may be detected as wedges within events, dividing up the continuous flow into meaningful action units. However, the exploratory nature of Study 1 and its methods limit the conclusions that can be drawn. The experts were asked to verbally label event units, which may have amplified their sensitivity to sources and goals, thus reducing variability in the data. Further, these experts were given ample opportunity to rewind and review the event, which is not how events are typically experienced. Events are fleeting, and must be parsed instantaneously as they unfold. In addition, although experts with appreciable domain-specific experience showed agreement in this task, it was not known whether novices, lacking information about the specifics of figure skating routines, would perform with any degree of temporal agreement when asked to parse these events. For these reasons, a second study was conducted.

Study 2: Do Experts' and Novices' Perceived Event Boundaries Align With Sources and Goals?

Study 2 had two purposes. First, it asked whether the results from Study 1 could be replicated in an online segmentation paradigm like those that have been used by Zacks and colleagues (e.g., Zacks et al., 2001a). Experts were thus asked to mark the boundaries they perceived spontaneously in the event, without labeling the action sequences and without the opportunity to rewind and replay the video. Would these boundaries, perceived by experts while parsing the event in real time, align with source and goal sites of intent? Thus, we tested a new set of figure skating experts and compared their online detection of event boundaries with the sources and goals defined by the experts from Study 1. We expected that the online boundaries of Study 2 experts would align with the sources and goals identified by Study 1 experts, with a similar bias toward goals.

Second, Study 2 asked whether expansive domain-specific experience, as that of experts, is necessary for detecting sources and goals during event parsing, or whether the experiences of novices (i.e., domain-general and limited domain-specific experience) and/or perceptual familiarity may also contribute. We tested two additional groups in the online segmentation task: novice adults who were relatively unfamiliar with figure skating events, including the Kwan routine, and "familiarized" novices, who first viewed the full Kwan video and then completed the same segmentation task upon their second viewing. While lacking the comprehensive domain-specific experience of experts, both novice groups possessed domain-general experience of beginnings and endings of human goal-directed action as well as limited domain-specific experience of figure skating sources and goals. Thus, we predicted that novices' perceived online boundaries would align with the sources and goals identified by Study 1 experts, with a similar goal bias. We further expected that Study 2 experts' perceived boundaries would show greater alignment with sources and goals than novices' boundaries, due to their sizable domain-specific experience. Familiarity was provided to one group of novices to give them an opportunity to view the entire event first and to become familiar with its components, in order to determine whether perceptual familiarity is a factor in the detection of sources and goals.

Method

Participants. Twenty-five adult professional figure skaters or figure skating trainers (17 females, eight males; mean age = 26.29 years), recruited from the same U.S. figure skating training center as Study 1 but who had not participated in that study, comprised one group. In addition, 46 adult novices, who were not professional figure skaters or trainers by self-report, were randomly assigned into two distinct groups: 23 familiarized novices who saw the tape once before testing (21 females, two males; mean age = 35.61 years) and 23 unfamiliarized novices who were tested on their first encounter with the routine (22 females, one male; mean age = 36.48 years). One additional expert and five additional novices were excluded due to lack of cooperation with task instructions. The novice sample was female biased because recruitment occurred within a developmental psychology laboratory—parents (mostly female) were recruited to participate while their children participated in other studies. However, no prior event segmentation studies have given any evidence of gender differences, and there was no reason to expect any such differences in this study. All participants provided written informed consent prior to testing.

Following participation in the experiment, novices completed a brief questionnaire to capture the breadth of their figure skating experiences as novices in this domain. In particular, novices were asked to report the frequency of their visual and physical experience with figure skating from the following options: *never, a few times ever, once a year, several times each year, or at least monthly*. The majority of the novices reported watching figure skating once a year (43.14%), a few times ever (37.25%), or several times each year (17.65%); one novice reported never having watched figure skating (1.96%), and none of the novices reported watching figure skating at least monthly. In addition, most novices reported never having figure skated (54.90%) or having skated a few times ever (29.41%); a smaller subset skated once a year (11.77%) or several times each year (3.92%), and none of the novices reported skating at least monthly.

Materials and procedure. Participants were tested individually, seated in front of a computer monitor and keyboard. An online event segmentation task (Zacks et al., 2001a) was administered with the same figure skating video as in Study 1. Participants were told to mark off the behavior of the skater into the "largest units that seem natural and meaningful to you" and to record their unit assessments by "pressing the space bar when, in your judgment, one unit ends and a different one begins" (Zacks et al., 2001a). Participants were not given practice trials, but were provided with the following example prior to engaging in the experiment: "One could turn around, walk over, push the door closed, turn around, and walk back. Each of these actions could be seen as a discrete event, or they might be classified into one larger unit, such as *closing the door*." In contrast to Study 1, the video continued to play to the end independent of participants' key presses marking event boundaries. Participants segmented the video in real time and did not have an opportunity to review or modify their responses after this segmentation. Stimulus presentation and collection of behavioral responses were conducted using E-prime (Psychology Software Tools, Sharpsburg, PA).

Participants' key-pressing records were divided into 1-s bins, consistent with prior studies of event segmentation (e.g., Zacks et al., 2001a). The ranges of sources and goals determined by the expert trainers from Study 1 were rounded up to the next whole second for comparison with these key-pressing records.

Results

Online detection of sources and goals.

Expert agreement. The online boundaries of Study 2 experts were compared with the aggregate boundaries of the expert group in the previous study, that is, the range of source and goal timings across the Study 1 experts. On average, Study 2 experts' online boundaries aligned with 3.92 (SE = .42) of the six sources commonly noted by the Study 1 experts, and 5.56 (SE = .15) of the six goals commonly identified by the Study 1 experts (see Figure 1). Additionally, in Study 1, these six sources and goals represented 83.75% of the total sources and goals that the experts identified, and in Study 2 these same six sources and goals represented 68.76% of experts' online key presses.

To confirm that Study 2 experts' selection of sources and goals was meaningful and could not be attributed to chance, chi-square analyses were conducted. The observed number of source and goal boundaries marked by Study 2 experts were compared to values expected by chance. Chance values were determined based on Study 2 participants' total number of key clicks as well as the fraction of the 172-s video devoted to sources and goals (.28) and the fraction not classified as sources or goals (.72), as defined by Study 1 experts. For the selection of sources and goals to be greater than chance, significantly more than 28.49% of Study 2 experts' key clicks needed to be characterized as sources or goals. Study 2 experts' boundaries aligned with the sources and goals identified by Study 1 experts at greater than chance levels, $\chi^2(1) = 296.76$, $p < .0001$, $\phi = 3.45$ (see Figures 1 and 2).

Group analyses. The online boundaries of experts, familiarized novices, and unfamiliarized novices were compared to the range of source and goal timings defined by Study 1 experts. A

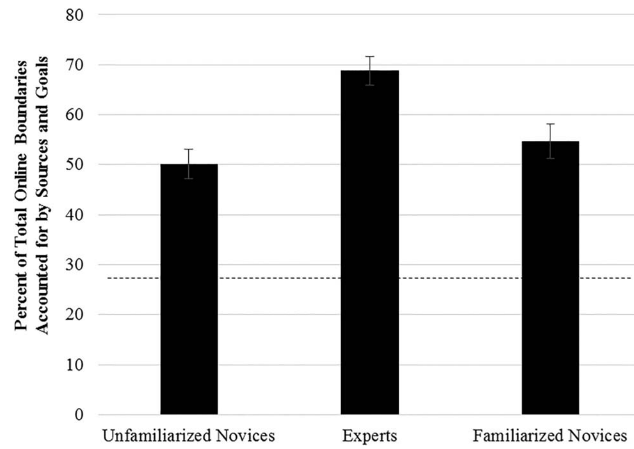

Figure 2. Percent of online event boundaries, detected by unfamiliarized novices, experts, and familiarized novices in Study 2 that align with the sources and goals defined by Study 1 experts. The dotted line represents the percent of the 172-s video containing sources and goals, or chance (28.49%) and the error bars represent ±1 standard error.

3 × 2 mixed-design analyses of variance (ANOVA) was conducted to examine the number of sources and goals (i.e., of the six from Study 1) that were detected as boundaries by the three groups. Group (expert, familiarized novice, unfamiliarized novice) was entered as the between-subjects factor and Site of Intent (source, goal) as the within-subjects factor. A significant effect of site of intent, $F(1, 68) = 69.66$, $p < .001$, $\eta^2_{partial} = .51$, revealed that across all three groups, significantly more goals (M = 4.94, SE = .18) were detected as boundaries than sources (M = 3.03, SE = .25; Figures 1, 3). The effect of group was also significant, $F(1, 2) = 4.97$, $p < .05$, $\eta^2_{partial} = .13$. Between-subjects contrasts indicated no differences between familiarized novices and unfamiliarized novices, $t(68) = .05$, ns. However, experts detected significantly more sources and goals (M = 9.48, SE = .49) than

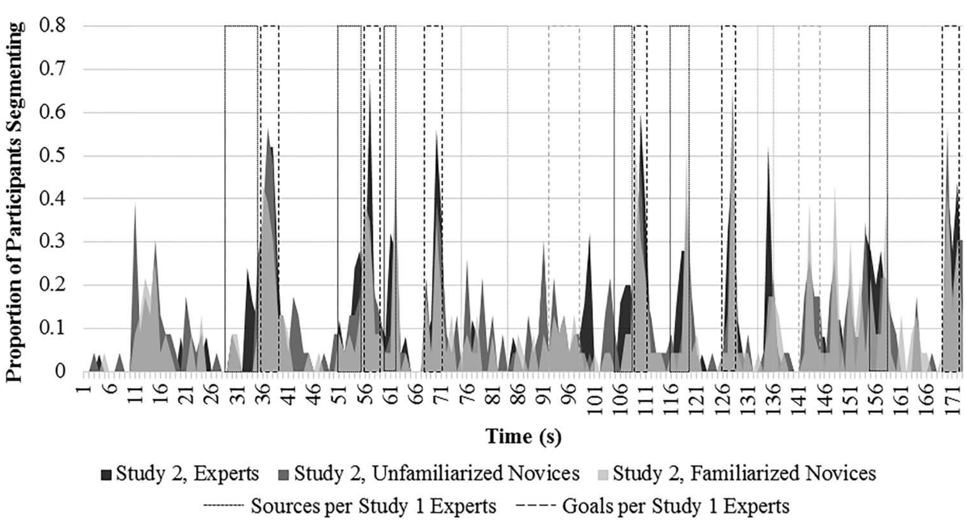

Figure 1. Timeline of the figure skating routine comparing the sources and goals explicitly identified by Study 1 experts and the proportion of participants in Study 2 who identified an event boundary during each 1-s interval.

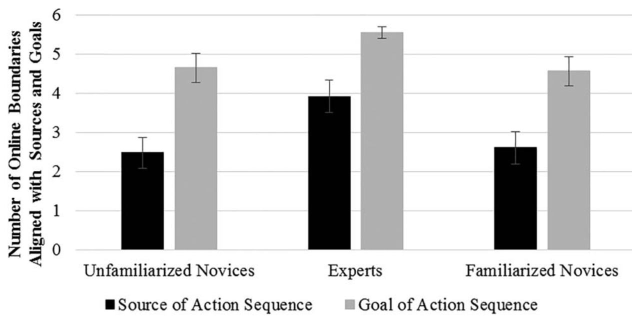

Figure 3. Number of online event boundaries, detected by unfamiliarized novices, experts, and familiarized novices in Study 2 that align with the sources and goals defined by Study 1 experts. Error bars represent ±1 standard error.

familiarized novices ($M = 7.17$, $SE = .71$), $t(68) = 2.69$, $p < .01$, $\eta^2_{partial} = .14$, and unfamiliarized novices ($M = 7.13$, $SE = .63$), $t(68) = 2.74$, $p < .01$, $\eta^2_{partial} = .16$ (see Figures 1 and 3).

A second 3 (Group) × 2 (Site of Intent) ANOVA was conducted to compare the percent of each group's online event boundaries that were accounted for by clicks occurring at sources and goals. The effect of site of intent was significant, $F(1, 68) = 61.93$, $p < .001$, $\eta^2_{partial} = .48$, with goals representing a higher percentage of individuals' online boundaries ($M = 39.50\%$, $SE = 1.84$) than sources ($M = 18.64\%$, $SE = 1.50$; Figures 1, 2). There was also a significant main effect of group, $F(1, 2) = 9.44$, $p < .001$, $\eta^2_{partial} = .22$. Again, between-subjects contrasts indicated no differences between familiarized novices and unfamiliarized novices, $t(68) = .33$, *ns*. However, sources and goals represented a significantly higher percentage of experts' online event boundaries ($M = 68.76\%$, $SE = 3.13$) than familiarized novices' ($M = 54.64\%$, $SE = 2.99$), $t(68) = 3.14$, $p < .01$, $\eta^2_{partial} = .19$, and unfamiliarized novices' ($M = 50.11\%$, $SE = 3.48$), $t(68) = 4.14$, $p < .01$, $\eta^2_{partial} = .26$ (see Figures 1 and 2).

To confirm that, similar to experts, familiarized and unfamiliarized novices detected sources and goals at greater than chance levels, chi-square analyses were conducted (see previous section for description of method). For both groups, online event boundaries aligned with the sources and goals defined by Study 1 experts at greater than chance levels: familiarized novices, $\chi^2(1) = 128.46$, $p < .0001$, $\phi = 2.36$, and unfamiliarized novices, $\chi^2(1) = 87.26$, $p < .0001$, $\phi = 1.95$ (see Figure 2).

Discussion

Study 2 was conducted with two objectives. First, we asked whether experts would detect action sources and goals when parsing a complex figure skating event online, without having the opportunity to rewind the video or describe what they see in words. Indeed, Study 2 experts' online event boundaries aligned with the sources and goals defined by Study 1 experts at rates significantly greater than chance, and showed a similar bias toward goals.

Our second objective was to determine the contributions of domain-specific expertise and perceptual familiarity to the detection of sources and goals in this complex event. Experts' online boundaries aligned more with sources and goals than both the familiarized and unfamiliarized novices' boundaries, with no differences between the two novice groups; however, all groups, expert and novice alike, showed a similar goal bias pattern, with more boundaries aligning with goals than sources. These results provide evidence for the effects of expertise but not perceptual familiarity on event segmentation. Experts' greater detection of sources and goals is attributed to their additional, extensive domain-specific experience. In addition, these findings indicate a common pattern of source-goal asymmetry across groups, which is not dependent on extensive domain-specific experience.

This study is the first to show that two fundamental sites of human intention in action are reliably detected as boundaries in ongoing events. Sources and goals, which had previously only been studied in the context of isolated action units (e.g., Lakusta & Landau, 2012), may also be important for isolating action units from a larger event flow.

The effect of experience documented here is consistent with a prior finding indicating that dance experience influences how a complex dance sequence is parsed (Bläsing, 2015). However, a separate study found no effect of experience on the segmentation of a saxophone assembly event (Zacks et al., 2001a). This disparity may be explained by the fact that these are very different types of events. In contrast to dance and figure skating sequences, a saxophone assembly event could be parsed by experts and novices alike using domain-general knowledge of object assembly, such as finding couplings for small pieces into slightly larger pieces. Adults' everyday experiences likely include this general type of event as when a chair or table is assembled. Here, we selected an event, similar to professional dance, for which novices lack appropriate experiences. While the study of dance segmentation focused on the gross number of boundaries perceived by experts and novices, our study examined the alignment of experts' and novices' boundaries with the sources and goals of the actor. Indeed, we found effects of domain-specific experience on the alignment of perceived boundaries with sites of actor intent.

Why does expertise increase alignment of perceived boundaries with sources and goals? Individuals with expertise in a particular domain (e.g., figure skating, chess) acquire knowledge structures in long-term memory that actively facilitate the processing of incoming domain-specific information (Campitelli, 2015; Ericsson & Kintsch, 1995; Gobet & Simon, 1996). In the domain of figure skating, experts, relative to novices, have an enhanced ability to identify elements accurately and rapidly (Deakin & Allard, 1991), and to predict the precise time course of each element (Diersch et al., 2012). Experts' perceived event boundaries likely aligned with sources and goals more than novices' did because the acquired knowledge structures of experts made them better able to identify the important action sequences in the skating routine and better able to predict those sequences' sources and goals.

Although no differences were found between the unfamiliarized novices and novices receiving a brief perceptual familiarization with the event, it is possible that providing novices with greater familiarity (i.e., several views of the video) would have increased their detection of sources and goals. In the General Discussion section we will consider whether certain types of experience may contribute to the acquisition of relevant knowledge structures and enhanced detection of sources and goals during event parsing. We now turn to the question of what caused participants, in particular novices, to mark these sites of intention as boundaries.

As spatiotemporal change typically accompanies changes in intention (Baldwin & Baird, 2001), a potent possibility based on prior research is that source and goal detection is explained by perceptual/visual sensitivity to a probabilistic combination of spatiotemporal movement features (Zacks, 2004; Zacks et al., 2009a). For goals, for example, participants may have detected the blade hitting the ice and the extension of the arms and leg when jumps were landed. Participants may also have detected changes in speed and torque at or in anticipation of sources and goals. To test whether the alignment of novices' perceived boundaries with sources and goals would be influenced by the disruption of spatiotemporal cues, Study 3 was conducted.

Study 3: How is the Detection of Sources and Goals During Online Event Segmentation Affected by Spatiotemporal Disruption?

In Study 3 we examined how the alignment of perceived boundaries with sites of actor intent was impacted when spatiotemporal cues were disrupted in the event. To address this question, we asked an additional group of novices to segment the event stream as it played in reverse. Figure skating events are comprised of continuous human movements; therefore, when the forward sequence was played in reverse, there were two primary consequences. First, the source of the forward sequence became the goal in the reverse sequence, and the goal of the forward sequence became the source. Second, many spatiotemporal features of the sequence were disrupted. Not only did the spatial features characterizing the goal in the forward event characterize the source in the reverse event, but the movements of the skater in the reverse event were also poorer predictors of subsequent movements than in the forward event (e.g., set-up for a jump sequence). If the detection of sources and goals is dependent on the convergence and predictability of physical event characteristics, as hypothesized based on prior research demonstrating strong relations between perceived boundaries and spatiotemporal change (Hard et al., 2006; Magliano et al., 2001; Maguire et al., 2011; Newtson et al., 1977; Zacks, 2004; Zacks et al., 2009a), then the alignment of participants' event boundaries with sources and goals would be diminished, and the goal bias pattern would disappear. Study 3 examined this possibility by comparing the segmentation patterns of the novices viewing the reverse video with those of the unfamiliarized novices from Study 2.

Method

Participants. Twenty-four novices (16 females, eight males; mean age = 35.78 years), who were not professional figure skaters or trainers by self-report, were recruited to view the event sequence in reverse for comparison with the 23 unfamiliarized novices from Study 2. Three additional novices were excluded due to lack of cooperation with task instructions. All participants provided written informed consent prior to testing.

Following participation in the experiment, novices completed the same questionnaire as did Study 2 novices, reporting on their recreational experiences with figure skating. Most novices reported watching figure skating a few times ever (44.45%), several times each year (29.63%), or once a year (22.22%); one novice reported never having watched figure skating (3.70%), and none of the novices reported watching figure skating at least monthly. Additionally, the majority reported never having figure skated (62.96%); a smaller subset reported skating a few times ever (18.52%), once a year (11.11%), or at least monthly (7.41%), and none of the novices reported skating several times each year.

Materials and procedure. Video editing software (Final Cut Pro, Apple, Cupertino, CA) was used to reverse the figure skating video from Studies 1 and 2, such that the video began at 172 s of the original video and ended at the original video's beginning. Participants in the reverse novice condition were tested using this reverse video and the exact same procedure as was used with the unfamiliarized novices in Study 2. Participants were tested individually using the online segmentation paradigm (Zacks et al., 2001a), and as in Study 2, the video continued to play throughout participants' marking of event boundaries. Presentation of the video and collection of behavioral responses were performed using E-prime (Psychology Software Tools, Sharpsburg, PA). During debriefing, participants were informed that the figure skating video had been played in reverse. Most participants expressed surprise at this information, or commented that they only guessed something was off about the video during the last few seconds, when the camera angle shifted abruptly.

Participants' key-pressing records were divided into 1-s bins for comparison with the sources and goals identified by Study 1 experts. Video frames comprising sources in the forward event were characterized as goals in the reverse event, and the frames comprising goals in the forward event were characterized as sources in the reverse event. However, simply redefining source ranges as goal ranges and vice versa would increase the likelihood of marking a goal range in the reverse event and decrease the likelihood of marking a source range (i.e., because of the larger source range and smaller goal range in the forward event). To control for this, we normalized range sizes for better comparability between the two novice groups. Areas of comparable length were defined around the middle of each range, creating 3-s windows for each source and goal identified by the Study 1 experts. The alignment of these normalized sources and goals with the boundaries marked by novices viewing the reverse video and novices viewing the forward video were compared.

Results

Similar to Study 2, mixed-design analyses of variance (ANOVAs) were conducted with group (novice, reverse novice) as the between-subjects factor and site of intent (source, goal) as the within-subjects factor. First, a 2 (Group) × 2 (Site of Intent) ANOVA compared the number of sources and goals detected as boundaries by novices and reverse novices. A significant effect of site of intent, $F(1, 45) = 62.42$, $p < .001$, $\eta^2_{partial} = .58$, revealed that across both groups, significantly more goals ($M = 4.64$, $SE = .23$) were marked as boundaries than sources ($M = 2.38$, $SE = .21$; Figure 4). There was no effect of group, $F(1, 1) = 0.89$ and no interaction effect, $F(1, 45) = .10$, both *ns*.

A second 2 (Group) × 2 (Site of Intent) ANOVA was conducted on the percent of boundaries individuals identified with their button presses that landed on sources and goals. The effect of site of intent was significant, $F(1, 45) = 53.47$, $p < .001$, $\eta^2_{partial} = .54$, with goals representing a higher percentage of individuals' online boundaries ($M = 33.88\%$, $SE = 2.18$) than sources ($M = 14.11\%$, *SE* = 1.05; Figure 5). There was no effect of group, $F(1, 1) = 0.19$ and no interaction effect, $F(1, 45) = 1.15$, both *ns*.

To confirm that the alignment of reverse novices' boundaries with sources and goals was greater than would be expected by chance, chi-square analyses were conducted. Chance values were determined based on reverse novices' total number of key clicks as well as the fraction of the 172-s video devoted to the normalized sources and goals (.21) and the fraction not classified as sources or goals (.79), as defined by Study 1 experts. The boundaries of novices viewing the reverse event aligned with sources and goals at greater than chance levels, $\chi^2(1) = 148.55$, $p < .0001$, $\phi = 2.49$ (see Figure 5).

Discussion

Study 3 asked whether the detection of sources and goals during online event parsing would be diminished by spatiotemporal disruption. Based on the preponderance of evidence linking perceived event boundaries to spatiotemporal cues (Hard et al., 2006; Magliano et al., 2001; Maguire et al., 2011; Newtson et al., 1977; Zacks, 2004; Zacks et al., 2009a), we had hypothesized that the alignment of perceived boundaries with sources and goals would be eliminated or reduced when the event was played in reverse. Unexpectedly, novices viewing the event in reverse marked boundaries that aligned with source and goal sites of intent, with a bias toward goals, similar to novices viewing the forward event. No between-groups differences were found. This null finding suggests that whatever information was used by novices to detect sources and goals in the figure skating event was not altered by playing the event in reverse.

A figure skating action, similar to most intentional actions, is a cohesive movement pattern defined by a basic-level goal, such as a jump or spin. The action's movement pattern is distinguished from the motions prior to and following the action. Therefore, especially given a lack of extensive domain-specific experience, novices may have been inclined to base their event boundary judgments on their perception of the beginnings and endings of cohesive movements, rather than spatiotemporal cues more generally. Indeed, many of the participants' comments after parsing the reverse event revealed they had not even noticed the event was reversed. Participants seemed to perceive the event, despite its spatiotemporal oddities, as typical, goal-directed human activity.

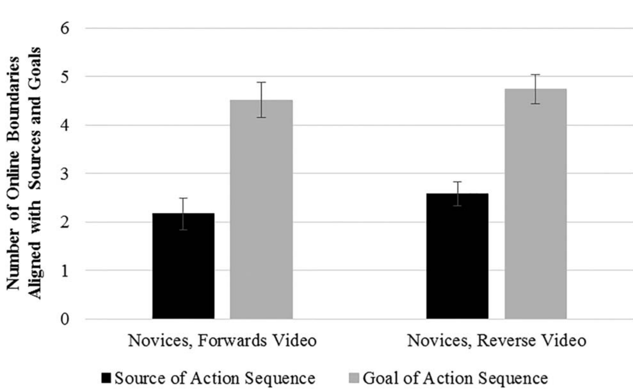

Figure 4. Number of online event boundaries, detected by novices viewing the forward video in Study 2 and novices viewing the reverse video in Study 3 that align with the sources and goals defined by Study 1 experts. Error bars represent ±1 standard error.

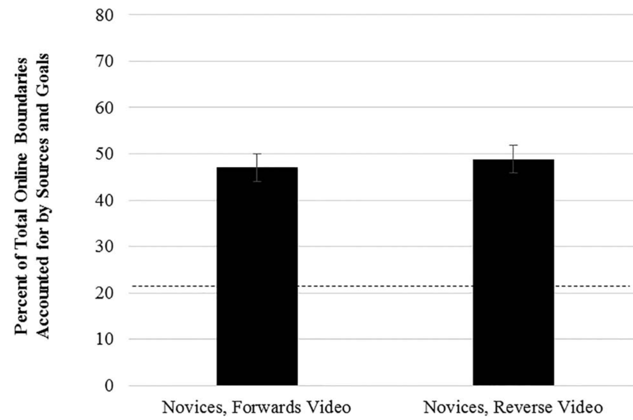

Figure 5. Percent of online event boundaries, detected by novices viewing the forward video in Study 2 and novices viewing the reverse video in Study 3 that align with the sources and goals defined by Study 1 experts. The dotted line represents the percent of the 172-s video containing normalized 3-s sources and goals, or chance (20.85%) and the error bars represent ±1 standard error.

Although unexpected, this finding does not diminish the importance of spatiotemporal cues in event segmentation for two reasons. First, one particular spatiotemporal cue remained—the cohesion of movements within goal-directed actions—and this may be the most critical spatiotemporal cue for segmentation of an event like figure skating. Second, novices, unlike experts, may have difficulty using spatiotemporal cues other than movement cohesion in a predictive way. Novices' source/goal detection in events may occur primarily at the level of movement cohesion; experts' source/goal detection may occur at a more fine-grained level of spatiotemporal change.

It may be that in typical goal-directed action events, movement cohesion and other spatiotemporal cues as well as actor intent all generally converge on the same event boundaries. However, the cognitive processes that lead to this convergence seem to be somewhat distinct. These findings reveal an event segmentation process that is not focused on spatiotemporal cues broadly, but that is sensitive to the actor's intended sources and goals (perhaps via the detection of movement cohesion). Additionally, in prior studies, when situational information was removed from an event, adults shifted to basing their segmentation more heavily on movement cues (Zacks, 2004; Zacks et al., 2009a). Taken together, this suggests that situational cues and lower-level spatiotemporal cues may work together to support event parsing, with one or the other dominating depending on the available information and the prior experiences of the individual.

General Discussion

Results from these studies demonstrate that the boundaries individuals perceive in human action events align with the sources and goals of the actor's goal-directed movements. Study 1 asked whether there are definable sources and goals in a complex event which can be identified by experts in an explicit, untimed task. Results indicate strong consensus among a group of experts as to the component action sequences within the figure skating event and those sequences' sources and goals. In addition, experts collectively demonstrated a narrower temporal definition of goals relative to sources. Study 2 asked (a) whether these sources and goals would account for the boundaries adults detect as the event unfolds in real time, and (b) whether experience and/or perceptual familiarity are factors in the alignment of online boundaries with sources and goals. We found that sources and goals aligned with online boundaries at greater than chance levels, for experts and novices alike, with both groups detecting more goals than sources. Prior familiarization of novices with the event had no detectable effect on the pattern of perceived boundaries, but experts' boundaries aligned with sources and goals more than both novice groups' boundaries. These results provide evidence for effects of domain-specific expertise, but not familiarity—or at least limited familiarity. Finally, Study 3 tested whether disrupting spatiotemporal movement information by playing the video in reverse would alter the observed goal bias pattern. The boundaries that novices marked when watching the event stream in reverse aligned with the new sources and goals in precisely the same manner as Study 2 novices' boundaries aligned with the original sources and goals, suggesting a sensitivity to cohesive goal-directed movements rather than sensitivity to spatiotemporal cues more broadly.

This set of studies, similar to prior studies of event segmentation (e.g., Zacks et al., 2001a) reveals remarkable consistency between individuals in the way they parse events. Prior research has found correlations between innumerable bottom-up perceptual cues (e.g., speed, body position, etc.) and perceived event boundaries (Hard et al., 2006; Magliano et al., 2001; Maguire et al., 2011; Newtson et al., 1977; Zacks, 2004; Zacks et al., 2009a), yet it is difficult to explain how these varied cues, in the absence of a unifying factor, produce such consistent boundaries. Evidence from the current studies suggests that the interindividual consistency found in event segmentation may come in part from adults' identification of the source-goal intentional structure of events.

How do these findings fit into Zacks et al.'s (2007) event segmentation theory? According to EST, event segmentation is a product of adults' event predictions, which occur constantly and spontaneously (Zacks et al., 2007). Indeed, previous research indicates that prediction failures during event processing may be at the root of the way boundaries are perceived during online segmentation (Zacks et al., 2011). Changes in physical features in the event have been shown to contribute to these vacillations in predictability (e.g., Zacks et al., 2009a). However, based on the research presented here, event predictions may also be heavily influenced by expectations regarding goal-directed activity.

Goal-directed expectations and sensitivity to intentions in action may be shaped by two key knowledge structures: (a) action representations from prior experience, and (b) language relevant to the event. First, mental representations of body movements, acquired through prior sensorimotor experience, likely contribute to these expectations. Adults exhibit body-part-specific activation in the premotor cortex when observing others' actions (Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006; Wheaton, Thompson, Syngeniotis, Abbott, & Puce, 2004) and the magnitude of this activation is a function of prior experience (Calvo-Merino, Glaser, Grezes, Passingham, & Haggard, 2005). The fine-tuning of motor representations through action experience, as with professional sports, functions to improve the prediction of goals based on observed movement patterns (e.g., predicting the success of free throws when observing a basketball player making a shot; Abreu et al., 2012; Aglioti, Cesari, Romani, & Urgesi, 2008). Thus, domain-general experience with a wide variety of goal-directed actions of the human body as well as domain-specific (i.e., figure skating) experience, however limited, may have enabled the adult novices in this study to detect boundaries that align with the skater's sources and goals. Extensive domain-specific experience may have fine-tuned the experts' embodied action representations, leading to their superior detection of source and goal boundaries. In contrast, the brief familiarization provided to novices likely did not constitute sufficient experience for altering their sensorimotor representations and improving their segmentation of the figure skating event.

A second knowledge structure that may contribute to goal-directed expectations is the language one uses to describe the event. Zacks et al. (2001a) demonstrated that eliciting language during online event parsing improved the consistency of event segmentation across participants. Although our online segmentation task in Studies 2 and 3 did not explicitly elicit language, linguistic representations have been shown to influence event processing even without being overtly activated (Athanasopoulos et al., 2015; Choi & Hattrup, 2012; McDonough, Choi, & Mandler, 2003). Thus, it is possible that linguistic representations, which are known to be biased toward goals for a broad range of events (Lakusta & Landau, 2005, 2012), contributed to goal-directed expectations. The use of language for parsing the figure skating routine would have been helpful to novices, who have words such as "jump" and "spin," and would have been even more helpful to experts, who have a highly detailed vocabulary describing not only each cohesive figure skating action, but also the varied movement patterns contained within each action (presumably helpful for predicting the goal) and the movement patterns leading up to the action (presumably helpful for anticipating the source).

In addition to improving sensitivity to goal-directed movement patterns, sensorimotor experience and language may also improve experts' sensitivity to spatiotemporal cues more generally. By analogy to findings in the chess expertise literature, expertise in figure skating may enable rapid and exclusive attention to relevant visual features, as compared with novices who also attend to irrelevant features (Bilalic, Langner, Erb, & Grodd, 2010).

Importantly, however, despite novices' limited sensorimotor experience and minimal knowledge of language specific to figure skating, they were sensitive to the goal-directed movement patterns in the figure skating event and were able to parse the event in a meaningful and consistent manner. This finding may have implications for how the ability to segment events begins to develop during infancy. The experience of novice adults parsing a complex figure skating event simulates, to a certain degree, the experience of infants observing the novel events in their world. Given infants' sensitivity to the goal-directedness of biological action by 6 months (Baldwin, Baird, Saylor, & Clark, 2001; Cannon & Woodward, 2012; Schlottmann & Ray, 2010) and their biased encoding of goals over sources in simple motion events by 12 months (Lakusta & Carey, 2014; Lakusta & DiFabrizio, in press; Lakusta, Wagner, O'Hearn, & Landau, 2007), infants may also detect source and goal boundaries in action events. Indeed, ongoing research in our laboratory suggests that 10- to 14-month-old infants are sensitive to boundaries aligning with goal completion, even in the complex and novel event of figure skating (Levine, Hirsh-Pasek, & Golinkoff, 2013; Pace et al., 2014).

One limitation of the current studies is that we did not examine direct effects of adults' sensitivity to goal-directedness and their sensitivity to spatiotemporal features simultaneously. As noted by prior research, conceptual and perceptual features of events tend to co-occur, and are therefore extremely difficult to tease apart (Baldwin & Baird, 2001; Zacks et al., 2009a). Despite our attempts to compare segmentation patterns between the forward and reverse events, it remains difficult to separate influences of top-down and bottom-up processes. These influences likely work in concert with one another during observation of a typical, forward event, but further research is needed to clarify how these processes are integrated with one another.

Future research should also replicate our findings using events that are less constrained than a figure skating routine. It is possible that adults' general knowledge of how skating performances are judged, such as the importance of a good landing for a jump sequence, influenced the goal bias pattern identified in this study. However, our ongoing studies with infants, who lack these preconceived notions, suggest this is not the case (Levine et al., 2013; Pace et al., 2014).

In conclusion, the present results indicate that sites of intent in human action, specifically goals and to a lesser extent sources, are spontaneously detected as boundaries during adults' online parsing of an event stream. The ability to detect these boundaries is impacted by experience, but not by mere and limited perceptual familiarity. Moreover, the ability of novices to parse this event seems to depend on their sensitivity to movement patterns that are typical of goal-directed activity, rather than their sensitivity to spatiotemporal cues more broadly. Humans' biased attention toward goals presents as a potentially powerful mechanism for making sense of even complex, relatively unfamiliar events.

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