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Occlusions at event boundaries during encoding have a negative effect on infant memory

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Abstract

The present study investigated the importance of Event Boundaries for 16- and 20-month-olds' (*n*=80) memory for cartoons. The infants watched one out of two cartoons with ellipses inserted covering the screen for 3s either at Event Boundaries or at Non-Boundaries. After a two-week delay both cartoons (one familiar and one novel) were presented simultaneously without ellipses while eye-tracking the infants. According to recent evidence a familiarity preference was expected. However, following Event Segmentation Theory ellipses *at* Event Boundaries were expected to cause greater disturbance of the encoding and hence a weaker memory trace evidenced by reduced familiarity preference, relative to ellipses at Non-Boundaries. The results suggest that overall this was the case, documenting the importance of Boundaries for infant memory. Furthermore, planned analyses revealed that whereas the same pattern was found when looking at the 20-month-old infants, no significant difference was found between the two conditions in the youngest age-group.

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1. Introduction

When trying to understand how and what infants and young children remember from the first years of their lives, researchers have devoted considerable attention to mapping out and describing the development of episodic memory (e.g., Bauer, 2007; Howe, 2011). Surprisingly, whereas substantial interest has been devoted to the 'memory' part of the term 'episodic memory', very little is known regarding how people actually parse ongoing experiences into specific 'episodes' (Dahl, Sonne, Kingo, & Krøjgaard, 2013; Ezzyat, & Davachi, 2011). Consequently, we only have limited knowledge concerning the actual phenomenon we are asked to recall, namely the episode. This is thought-provoking, because being able to single out episodes seems to be a necessary pre-requisite to form episodic memories in the first place (Dahl et al., 2013). To fully understand the concept 'episodic memory', the basic question "what is an episode?" can hardly be discarded. In research primarily focusing on adults we have recently witnessed an increasing interest in this topic. Most notably, Jeffrey Zacks and colleagues have developed a theory of *event segmentation*, suggesting that people automatically seem to make sense of the ongoing flow of experience by segmenting it into identifiable chunks or parts (Kurby, & Zacks, 2008; Zacks, 2010).

Even though Zacks' theory also offers an account of how the development of event segmentation may take place (e.g., Kurby, & Zacks, 2008; Radvansky, & Zacks, 2014), the developmental part of the theory is less evolved. As recently stated by Radvansky and Zacks (2014, p. 189) "…we know approximately nothing about how infant segmentation develops into an adult-like capacity". Our objective was to contribute further to this theory by examining empirically whether some of the hitherto unexplored aspects of Zacks' theory of event segmentation would apply to infants. More specifically, the goal of the present study was to investigate whether event boundaries are as salient to infant memory, as studies on adults suggest they are (see e.g., Swallow, Zacks, & Abrams, 2009). Pursuing the possible origin of the relationship between event boundaries and memory is important for several reasons. First, as stated above very little is currently known about the development of the event segmentation ability we see in adults. The present study may contribute by bridging this gap in the event segmentation literature. Second, examining whether event boundaries are related to subsequent memory of events in infancy may contribute to our understanding regarding event memory development more broadly. We begin by outlining the theory on event segmentation as well as related research primarily focusing on adults.

1.1 Event Segmentation Theory

According to Event Segmentation Theory (EST) an event is defined as "a segment of time at a given location that is perceived by an observer to have a beginning and an end" (Zacks, & Tversky, 2001, p. 2). The ability to segment perception streams into identifiable and meaningful chunks assists us in dealing with an otherwise chaotic and dynamic world.

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Event segmentation is described as a core component of perception, and is thus considered an automatic and effortless part of everyday perception and comprehension (Kurby, & Zacks, 2008; Zacks & Swallow, 2007). Event segmentation facilitates transforming perceptual input into representations, allowing us to create predictions about future actions (Zacks, Kumar, Abrams, & Mehta, 2009; Zacks, Speer, Swallow, Braver, & Reynolds, 2007).

In order to segment perception streams people form *event models* (working memory representations, recently referred to as working models, see Radvansky, & Zacks, 2014) of the present perceptual information allowing us to comprehend "what is happening now?" and to distinguish this from what just happened (Kurby, & Zacks, 2008). As long as the event models reflect the current situation, they will remain relatively stable. This seems to be the case most of the time. While stable and valid, the event models will guide the perceptual processing and lead to accurate predictions. However, when prediction errors increase, the models need updating. This is assumed to lead to a transient increase in processing causing more robust encoding as well as increased focus on the information present at those times. The periods of time characterized by a transient increase in processing are also known as *Event Boundaries* (or breakpoints). Event Boundaries emerge at points of change, for instance if an agent shows a change in goals or intentions as well as in the context of physical changes, since this leads to an increased risk of prediction errors (Kurby, & Zacks, 2008; Zacks, 2010). The identification of Event Boundaries seems to be affected by both bottom-up processing as well as top-down influence of knowledge structures (Zacks, 2004).

Event segmentation has been found to affect a wide range of our abilities, such as our ability to learn from and remember events (e.g., Radvansky, 2012; Swallow, Zacks, & Abrams, 2009; Zacks, Speer, Vettel, & Jacoby, 2006; Zacks, & Swallow, 2007). Studies show that event segmentation plays a pivotal role in the encoding of events and that the increase in processing at Event Boundaries should lead to a more detailed encoding of information present at those times, and hence also to a better recall of items visible at boundaries (e.g., Newtson, & Engquist, 1976; Schwan, Garsoffky, & Hesse, 2000; Swallow et al., 2009; Zacks et al., 2006). Consequently, Kurby and Zacks (2008, p. 77) proposed that effective segmentation would facilitate subsequent memory of the activity. Moreover, as suggested by Zacks and Swallow (2007, p. 83) not only will identifying the 'right' events lead to superior memory and enhanced learning; identifying 'wrong' events may also lead to poorer memory and reduced learning. Information present at an Event Boundary is thus more likely to be captured into long-term memory (Radvansky, & Zacks, 2014).

1.2 Event Segmentation in Infancy

Just like episodic memory research originates from literature concerning adults, research on EST has so far primarily focused on adults. However, given that the methods typically employed in event segmentation studies primarily rely on parsing visual information, as for example by presenting participants with movie clips (e.g., Newtson, 1973), EST seems to be a promising platform for investigating segmentation in infancy as well. Although one cannot simply ask infants to identify boundaries by pressing a button, as is typically done in research with adults, one can still take advantage of the frequently

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employed visual stimuli and convert this to a task more suitable for infants. By use of looking time as an indicator of infants' understanding of events it is thus possible to avoid some of the inherent problems in using verbal instruction when doing infant research. Below we describe studies investigating event segmentation by means of looking time paradigms.

The few studies conducted on event segmentation or event processing in infancy generally show that infants are capable of segmenting events, indicating that they too are making sense of an otherwise complex perceptual stream by dividing it into smaller parts or events (e.g., Baldwin, Baird, Saylor, & Clark, 2001; Hespos, Grossman, & Saylor, 2009, 2010; Friend, & Pace, 2011; Pace, Carver, & Friend, 2013; Meyer, Baldwin, & Sage, 2011; Saylor, Baldwin, Baird, & LaBounty, 2007; Stahl, Romberg, Roseberry, Golinkoff, & Hirsh-Pasek, 2014). Two different lines of research have investigated event segmentation in infancy. Some researchers have examined how infants' understanding of objects and events may inform us about the development of event segmentation (e.g., Hespos, & Baillargeon, 2001; Hespos, Grossman, and Saylor, 2009; 2010). A different line of research has focused on how infants parse what may be considered the more intentional aspects of human behavior (e.g., goal directed behavior). In the following we briefly outline these two lines of research, one at a time.

Hespos, Grossman, and Saylor (2009, Exp. 1 and 2) found that infants as young as six months could readily detect familiar target actions operationalized as distinct physical events ('moving in and over' vs. 'moving on and under') in continuous action sequences, whereas the infants failed to discriminate between different transitions ('up and slide' vs. 'down and bounce') separating the target actions (Hespos, Grossman, & Saylor, 2009, Exp. 3). Note that in these experiments the action sequences and the transitions respectively were tested in separate experiments. In a sequel study Hespos, Grossman, and Saylor (2010) examined whether six- and eight-month-old infants would distinguish between target actions and transitions when actions and transitions appeared together in the same continuous action sequence. The results revealed that the infants in both age groups were sensitive to changes in target actions but not to changes in transitions. Taken together, these experiments show that even six-month-old infants seem to employ their knowledge about objects and event categories in order to distinguish between action sequences.

A different line of research has focused on how infants parse intentional aspects of human behavior. Several studies have shown that quite early, infants are proficient at detecting intentions and goals in human behavior (e.g., Woodward, Sommerville, & Guajardo, 2001). Despite the fact that we still do not have a complete answer as to how and why infants segment events, several studies have now demonstrated that infants are capable of segmenting action sequences and of processing events displaying intentional aspects of human behavior. For instance, Baldwin et al. (2001) presented a group of 10- to 11-month-olds with movies of everyday events showing a woman doing purposeful actions, such as picking up a towel from the ground and hanging it back on a rack. First, the infants were familiarized to the movie. Subsequently, the infants were divided into two different test conditions in which they were presented with two versions of the movie, each one with a still

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frame picture inserted. Half of the infants watched the *interrupting* test video in which the still-frame pause would interfere with the completion of the action, for example while bending down towards the towel, or right after having picked it up on the way to hang it on the rack. The other half watched the *completing* version, in which the still-frame pause was inserted directly *after* the completion of the intentional action. According to Baldwin et al. (2001) the fact that only the infants in the interrupting test video condition showed a renewed interest in the video after the familiarization phase, suggested that they were sensible to the structure inherent in the intentional action, thus illustrating event segmentation skills early in infancy. Saylor et al. (2007) have since replicated these findings, this time with no familiarization phase, indicating that infants are also capable of segmenting events in a more "on-line" fashion.

To summarize, infants clearly seem capable of segmenting events early in life. However, as stated by Radvansky and Zacks (2014) especially one part of event segmentation is still not fully understood, namely the role of event models in long-term memory retrieval in infancy, although it has been suggested that it "appears to respect the principles observed in adults" (Radvansky, & Zacks, 2014, p. 194). As a consequence there seems to be a lack of knowledge regarding exactly what role Event Boundaries may play for infants' memory of events and further if there are developmental changes in infants' ability to identify beginnings and endings of events. If Event Boundaries are as important to memory as suggested in the literature, and identifying 'wrong' events may have negative consequences for later memory (e.g., Swallow et al., 2009; Zacks, & Swallow, 2007), one would expect that a "disturbance" of information (e.g., by removing or occluding information) present *at* Event Boundaries should have a more detrimental effect on memory for the event relative to "disturbances" presented before or after Event Boundaries. We do not know, however, whether this applies to infants. Results from such studies would be important for at least two reasons. First, we would like to examine to what extent this aspect of EST applies to infants. This is crucial when attempting to understand how and when event segmentation comes into play as the infant develops. We thus need to study the phenomenon across different age groups. Typically, a given topic is not understood in its entirety unless the development of the phenomena is sketched out (Krøjgaard, 2005). Second, in a broader perspective, we want to know more about how event segmentation affects *memory* for events in infancy, since infants' parsing and memory of events constitutes a necessary (although not sufficient) element in the development of episodic memory (e.g., Dahl et al., 2013). Further knowledge on this matter would be beneficial when pursuing a more comprehensive understanding of episodic memory, as it would allow us to get a firmer grasp of how infants' event understanding may affect their episodic memory.

The aim of the present study was therefore not to examine how infants process and segment events as they occur in the present moment (since this has already been the target of investigation, e.g., Saylor et al., 2007); instead we wished to describe and investigate some of the parts of the segmentation skills that have not received much attention in the infant literature: More specifically, we wished to investigate the role of Event Boundaries and event segmentation in relation to subsequent memory of an event. This seems to be a promising

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way of moving the theory forward, and as mentioned by Radvansky and Zacks (2014, p. 190), they are "…unaware of studies that directly investigate this updating process in infants or children". To investigate this developmentally, a complete or direct translation of the methods used for studying event segmentation in adults is not possible. As already mentioned, the infants cannot simply press a button to indicate when a boundary occurs. The present study was thus an attempt to address these issues, but within a framework suitable for infants. As such the study is not using the exact same methods as in EST, however when possible a close alignment has been the aim. The focus is thus on whether the *theory* of event segmentation can be extended to include infants as well, but with use of slightly different methodologies.

2. The Present Study

In this study we wanted to investigate what (if any) significance Event Boundaries may have for 16- and 20-month-old infants' memory of events. In line with the studies on event segmentation and memory in adults (e.g., Swallow et al., 2009) and inspired by the study by Baldwin et al. (2001), we speculated that "disturbances" (in the shape of ellipses occluding the available information, inspired by Schwan & Garsoffky, 2004) in a cartoon displaying a simple narrative would have dissimilar consequences for the infants' memory of the cartoon depending on the temporal placement of these ellipses. We inserted the ellipses abruptly at different times (*at* Event Boundaries vs. *between* Event Boundaries) as an event unfolded. To increase the ecological validity, we chose to operationalize the disturbances as ellipses occluding the *ongoing* sequence rather than having the whole sequence simply "freeze" as in the study by Baldwin et al. (2001). Our reasoning was based on the assumption that whereas the former is often encountered in everyday life (e.g., watching a house while the visual access suddenly becomes obstructed due to a bus driving by), the latter is not.

Despite the fact that previous studies on event segmentation skills in infancy have been done with younger infants (e.g., 6 months, Hespos, Grossman, & Saylor, 2009), due to our primary interest in memory and Event Boundaries, we decided to focus on even older infants (16- and 20-month-old infants). Furthermore, a previous study from our lab showed that infants in the approximate same age (18 months) remembered very similar stimulus material after a retention interval of two weeks (BLINDED). Finally, we wished to investigate the developmental course of these skills, which led us to investigate two age groups within the period of infancy characterized by a great degree of developmental change (for a review see e.g., Hayne, 2004).

In order to investigate the possible effect of the ellipses we employed the Visual Paired-Comparison (VPC) task, which is frequently used to assess preverbal infants' visual recognition memory. In a typical VPC task the infant is first presented and familiarized with a visual stimulus. Then following a delay, the infant's visual preference is assessed by simultaneously showing the infant a novel as well as the familiar stimulus (e.g., Hayne, 2004).

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At the first visit to our lab the infants were presented with one of two cartoons – one involving a crab and the other a snowman (see Fig. 1). Each of the cartoons was presented in one of two versions both with disturbances inserted covering most of the information available on the screen for 3 seconds. In one version the ellipses were inserted covering for information *directly at* an Event Boundary (Boundary condition); in the other version they were inserted at a time with *no* Event Boundary present (Non-Boundary condition) (see Fig. 1). After a retention interval of two weeks both cartoons (one familiar and one novel) were presented simultaneously two times in a row, but this time *without* ellipses inserted. Using eye-tracking technology we assessed the infants' looking time at the two cartoons in this final test.

Memory in the VPC paradigm has primarily been inferred if the infant predominantly is paying attention to the novel stimulus, i.e., illustrating a novelty preference (Barr, Walker, Gross, & Hayne, 2014; Morgan, & Hayne, 2011; Richmond, Colombo, & Hayne, 2007). However, research now suggests that memory can be expressed as a novelty preference as well as a familiarity preference depending on a range of factors (e.g., age, retention interval, degree of familiarization, Bahrick, & Pickens, 1995; Richmond et al., 2007). In short: Provided that the chosen stimuli are comparable in complexity, any *systematic* preference at test can be attributed to memory. In accordance with the results from a previous study from our lab presenting a group of 18-month-olds with the exact same stimulus material (except for the inclusion of ellipses) using the same retention interval (BLINDED), and following the four-phase attention function suggested by Bahrick and colleagues (e.g., Bahrick, & Pickens, 1995; Bahrick, Hernandez-Reif, & Pickens, 1997) describing that longer retention intervals typically lead to familiarity preferences (if any), we hypothesized that the infants as a group would show a familiarity preference. However, based on the previously mentioned studies showing that Event Boundaries have a privileged status in memory (e.g., Swallow et al., 2009), we also expected that this familiarity preference would be weaker for the infants in the Boundary condition compared to the infants in the Non-Boundary condition.

3. Method

3.1 Participants

Forty healthy and full-term 16-month-olds (M_{age}= 16.22 months, *SD* = .12, 20 girls) and forty 20-month-olds (M_{age}= 20.19 months, *SD* = .15, 23 girls) were recruited from a birth register from the National Board of Health. All of the infants lived in BLINDED or the near surroundings, and they all had an Apgar score of at least seven. The infants were predominantly Scandinavian Caucasian, living in families with middle to a higher SES. Twelve additional infants were excluded from the analysis: Eight infants were excluded because their total sampled looking-time to the stimuli during the test was more than two standard deviations below the overall group mean, three were excluded due to fussiness, and one due to technical failure. All of the infants received a teddy for participating.

3.2 Materials

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The infants were presented with two custom-made cartoons, each illustrating a simple narrative lasting 30 seconds. The exact same cartoons have been used in another format in a different memory study from our lab (BLINDED). Cartoons were chosen over real-world video as stimulus material to increase the degree of control and to reduce the complexity of the material. Furthermore, we decided to use two cartoons in order to test whether the results would extend to both cartoons. The snowman cartoon depicted a snowman in a winter landscape. The snowman entered the scene and noticed a black hat lying on the ground. The snowman then started jumping up and down making the hat bounce higher and higher into the air. The hat finally landed on top of the snowman's head making the snowman smile. After this the snowman exited the scene towards the opposite side of the screen. The other cartoon was about a crab on a beach. The crab entered the scene and found a ball lying on the ground. The crab then started playing with the ball, until one of the claws punctured it causing it to deflate and fall back to the ground. After this, the crab exited the scene towards the opposite side of the screen. Both cartoons were without audio track to avoid interference, when they at the second visit would be displayed simultaneously.

Each cartoon came in three different versions: two versions with ellipses inserted (occlusion versions) and one version without occlusions. At the first session (the familiarization phase), the infants were presented with one of the two versions with ellipse-shaped occluders inserted abruptly at the specified points in time depending on condition. These ellipses covered almost all of the information on the screen for three consecutive seconds leaving only the corners of the cartoon visible. We placed the ellipses *either* directly *at* an Event Boundary (Boundary condition) *or* exactly 12 seconds *before* the occurrence of an Event Boundary (Non-Boundary condition) (Event Boundaries had been identified by a group of adults prior to the experiment – see below). In the snowman cartoon the Non-Boundary ellipse was placed while the snowman was looking at the hat lying on the ground and the Boundary ellipse was placed exactly when the hat landed on the snowman's head, and in the crab cartoon the Non-Boundary ellipse was placed just when the crab started playing with the ball and the Boundary ellipse was placed when the claws punctured the ball. All of the ellipses were followed by further action in each cartoon (see Fig. 1).

At the second session (the test) we presented the infants with the no-occlusion versions. This time both cartoons were presented simultaneously, meaning that the infants watched the same (although this time without ellipses) cartoon they were presented with at the first visit as well as the other (novel) cartoon.

Following the procedure from Baldwin et al. (2001), the two possible temporal placements of the Boundary ellipses were based on reports from a group of adults (n=15). After viewing the cartoons twice on a PC or a lap top, the adults were asked to indicate which point in time they thought would be most important in the cartoon (e.g., a turning point or point of change). They were told that they might identify more than one time-point; however they had to choose the one they thought would be the most important. By carefully watching the screen the adults thus read the exact number of seconds that the cartoon had been playing

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for, when they identified the event boundary and reported this number to the experimenter. This point in time was then referred to as an Event Boundary.

As is evident from this instruction it is not completely identical to Zacks' typical way of asking participant to segment events (see e.g., Zacks & Swallow, 2007). The wording of the instructions was however made to more closely fit the situation of the infants-to-be-tested. To avoid confusing the infants, we were only interested in having one Boundary and one Non-Boundary, and the wordings were thus chosen to secure that the participants would choose coarse-grained Boundaries and to make sure that only *the* most prominent Boundaries were chosen. While acknowledging that several types of Boundaries exist (e.g., coarse/fine-grained or in relation to physical changes or conceptual changes, see Kurby & Zacks, 2008), our focus on the more coarse-grained Boundaries was based on the fact that no previous studies directly have investigated Event Boundaries in infant memory, and we thus wanted to investigate this first by the use of coarse-grained Boundaries, since disturbing information at more coarse-grained Boundaries were deemed to have the largest consequences for the flow of the event.

Based on the answers from the adults, we picked the most frequently mentioned Event Boundaries: In the snowman cartoon 9 out of 15 adults agreed on the same Boundary, and in the crab cartoon 11 out of 15 adults chose the same Boundary (As opposed to 4 out of 15, and 2 out of 15 for the second most frequently mentioned Boundaries for the two cartoons, respectively). In order not to coincide with other less frequently mentioned Event Boundaries, we decided to place the Non-Boundary ellipses exactly 12 seconds earlier than the chosen Event Boundaries in both cartoons. For both cartoons this was thus at a time when nothing crucial happened according to the adults' assessment.

Furthermore, as a way of assessing potential differences between the infants in the two conditions, we asked the infants' parents to fill out a standardized BLINDED version of the MacArthur-Bates Communicative Development Inventory. All infants would be given the age-appropriate version ("Words and Gesticulations" for the 16-month-olds and "Words and Sentences" for the 20-month-olds). Both of these versions include a measure of productive vocabulary. The parents received this questionnaire on their first visit to the laboratory, and they were asked to return it when coming back for the final visit.

3.3 Eye-Tracking Setup

A Tobii X120 eye-tracker was used to record the infants' fixations at 120 Hz (with 0.5° accuracy) on a 30" LCD widescreen. The total visual angle of the screen was 40 (width) x 25 (height)°, while the visual angle of the stimuli area was 33 (width) x 16.5 (height)°. The eyes of the infants were approximately 70 centimeters from the eye-tracker and at level with the center of the screen. At both visits the infants were seated in a car seat on top of an adjustable chair to match the settings of the eye-tracker.

The Tobii Fixation Filter (default) was used. This filter detects quick changes in the gaze point signal using sliding averaging and can thus distinguish between fixations and saccades. Interpolation of samples was used when data samples were missing e.g., during a

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blink. Before each demonstration and the actual data collection a 5-point calibration was conducted using Tobii Studio calibration for infants. The stimulus material was presented by use of E-prime software.

In order to extract data from the eye-tracker Areas of Interests (AOIs) had to be defined. Since we were interested in the infants' general looking time to the two cartoons respectively, two simple AOIs were created: one for each cartoon. Each AOI was equivalent in size to the size of the cartoon.

3.4 Design and Procedure

The infants were randomly assigned to two conditions: half of the infants were in the Boundary condition and the other half in the Non-Boundary condition. The infants in the Boundary condition (n = 40) watched the version of the cartoons with ellipses inserted covering the information *at* the Event Boundary. The infants in the Non-Boundary (n = 40) condition watched the version with ellipses inserted *between* Event Boundaries.

At the first session (the familiarization phase), the infants watched one of the two cartoons (the crab *or* the snowman cartoon). Half of the infants watched the crab cartoon; the other half watched the snowman cartoon. The cartoons were presented in a fixed familiarization sequence consisting of four consecutive presentations in a loop for a total of 120s. The four presentations were only separated by a minor fading (to black) period. This was done for two reasons: First, we wanted to make sure that the infants had ample opportunity of encoding the cartoon. Second, presenting the stimuli in a cyclic format allowed the Boundaries and the Non-Boundaries to appear both before *and* after each other to control for the potential risk that the fixed temporal order of Non-Boundaries followed by Boundaries within each distinct viewing would affect the results. Based on (BLINDED) it was not deemed necessary to eye-track the infants during encoding, but to ensure that they did watch the cartoons, the infants had to pay attention to at least the first two of the four presentations to participate in the memory test. This was ensured by carefully watching the infants' behavior on a monitor in the control room, and if they did not pay attention they were excluded due to fussiness (see 3.1).

Two weeks later (M = 14.03 days, SD = .73 days) the infants returned to the lab for the second and final session (the test). At the second session both of the cartoons were presented simultaneously side by side for two consecutive times for a total of 60 seconds (with no occluders inserted). The left-right orientation of the cartoons was counterbalanced. During the presentation at the second session the infants' fixations on the screen were eye-tracked.

4. Results

Of central interest was whether the infants were capable of remembering the cartoon they had seen the first time they were here, and if so, whether their memory had been affected by the condition they were in. Following the standard procedure in VPC studies the primary dependent measure was the proportion of time spent looking at the *novel* stimulus during test. This was calculated as a proportional novelty-preference score by dividing the total looking-

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time to the novel cartoon with the total looking-time at both cartoons, thus producing a novelty-preference score between 0 and 1 (e.g., Kingo, Staugaard, & Krøjgaard, 2014; Richmond et al., 2007).

As a preliminary control we examined if there were any differences in the CDI results from the infants in the two conditions: no such differences were found and any potential differences between the two conditions can thus not be explained by a difference in vocabulary, $t(78)= -.398$, $p = .69$, $r = .05$ ($M_{\text{Boundary}} = 66.80$, $SD = 66.69$; $M_{\text{Non-Boundary}} = 74.30$, $SD = 98.90$). Furthermore, no significant correlations were found for the CDI scores and the proportional looking to the novel cartoon. Additionally, as expected we found that there was a significant development of the infants language production with age (16 months: $M =32.55$, $SD =40.4$; 20 months: $M =108.55$, $SD =98.3$, $t[78] = 4.52$, $p < .001$, $r =.46$).

First, we investigated whether the infants would remember the cartoon they had seen at their first visit, and whether we would find an overall effect of condition when focusing on all of the infants as a group. Second, we ran planned analyses for each age group separately in order to investigate further possible developmental differences between the 16-month-olds and the 20-month-olds. Third, we investigated what happened over time regarding proportional looking across the two iterations.

As expected we found that the infants overall (both age groups combined) did remember the cartoon they had previously seen, illustrated by a strong familiarity preference when comparing the proportional looking to the novel ($M = .30$, $SD = .17$) to chance level (.5), $t(79) = -11,07$, $p <.001$, $r = .80$. To disentangle which factors affected the proportional looking we then ran a univariate ANOVA with Age Group (16-month-olds vs. 20-month-olds) and Condition (Boundary vs. Non-Boundary), Gender (boy vs. girl), and Target Movie (Crab vs. Snowman) as between-subjects factors and with the proportional looking to the novel cartoon as dependent variable. This analysis presented us with a main effect of Condition, $F(1,64) = 6.90$, $p =.011$, $\eta^2_P = .097$ ($M_{\text{Boundary}} = .34$, $SD= .16$; $M_{\text{Non-Boundary}} = .25$, $SD = .16$). The results show that the familiarity preference was significantly stronger for the infants in the Non-Boundary condition relative to the infants in the Boundary condition. This suggests that disturbances located at Boundaries during encoding were significantly more detrimental to the infants' ability to remember the cartoons across the two-week retention interval, than if the disturbances were located at Non-Boundaries.

The analysis also revealed an interaction between Age Group and Target Cartoon, $F(1,64) = 4.07$, $p =.048$, $\eta^2_P = .060$ ($M_{\text{Snowman16 months}} = .35$, $SD= .21$; $M_{\text{Crab16months}} = .28$, $SD = .14$; $M_{\text{Snowman20months}} = .24$, $SD = .15$; $M_{\text{Crab20months}} = .31$, $SD = .14$). This analysis suggests that the youngest age group is paying more attention to the snowman cartoon, whereas their older peers were more inclined to look at the crab cartoon. Since the current design is balanced with regard to the cartoons, this finding was not considered important relative to overall aim of the study. All other interaction analyses resulted in p's > .16. As a consequence the subsequent analyses were collapsed across gender.

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Based on the fact that we were interested in the developmental course of event segmentation skills we wished to investigate closer how each age group performed in the VPC test. Preliminary analysis revealed no significant differences in looking time during the test when comparing the two age groups (p=.53). When only considering the 16-month-olds they as expected showed sign of remembering the cartoon they had seen at their first visit, i.e., there was a clear preference for the familiar cartoon: the proportional looking to the novel (M =.31, SD = .18) was below chance level (.5), t(39)= -6.63 p <.001, r =.73. The main interest was, however, whether this familiarity preference would be affected by the Condition (Boundary vs, Non-Boundary) the 16-month-olds were in. To test this we ran a t-test for the proportional looking to the novel in the Boundary condition (M = .34, SD = .18) and compared this to the proportional looking to the novel in the Non-Boundary condition (M = .29, SD = .18), $t(38)$= .76, p =.45, r =.12. Although the looking time towards the novel cartoon in the Non-Boundary condition was numerically smaller than the looking time towards the novel cartoon in the Boundary condition, the difference was not significant, hence barely suggesting a tendency for the infants to be affected by the condition they were in (see Fig. 2).

When only focusing on the 20-month-olds we also found that they looked more at the cartoon they had already seen, thus showing a clear familiarity preference: we compared the proportional looking to the novel (M = .28, SD = .15) to chance level (.5), t(39) = -9,28, p <.001, r = .83. To investigate whether this would be affected by the Condition, we compared the proportional looking to the novel in the Boundary condition (M = .35, SD = .15) in a t-test to the proportional looking to the novel in the Non-Boundary condition (M = .21, SD = .12), t(38) = 3.33, p = .002, r =.47. This analysis reveals that for the 20-month-old infants there was a significant difference between the two conditions: the infants in the Boundary condition had a significantly smaller familiarity preference compared to the infants in the Non-Boundary condition, thus following our predictions (see Fig. 2).

Given that the infants at test were presented with two iterations of the cartoons, we wanted to see what happened with their preference over time. A mixed-model repeated measures ANOVA with Age Group (16-month-olds vs. 20-month-olds) and Condition (Boundary vs. Non-Boundary) as between-subjects factors and Iteration (1st vs. 2nd iteration) as within-subjects factor and with the proportional looking to the novel cartoon as dependent variable, revealed an interaction between condition and iteration, F(1, 76)= 5.4, p=.02 η^2_P =.07. Looking at the graph in Figure 3 it is evident that the difference between the two conditions is more pronounced during the first iteration compared to the second iteration. The familiarity preference in the Boundary condition increases from the first to the second iteration (see Fig. 3). No other effects were found.

To summarize, the results showed that the infants were indeed capable of remembering the cartoon presented to them two weeks earlier as evidenced by a familiarity preference. This finding is in accordance with the typical pattern seen in infant memory research, namely that infants around this particular age-span are capable of remembering over briefer and longer delays (for reviews see e.g., Bauer, 2007; Hayne, 2004; Kingo & Krøjgaard, 2015).

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Our main interest was to investigate whether this anticipated familiarity preference would be affected by the condition the infants were in. As predicted we found an overall effect of Condition on the infants' proportional looking to the novel stimuli. Disturbances located *at* Event Boundaries seemingly made it more difficult for the infants to remember the original event across the two-week retention interval compared to when the disturbances were located at Non-Boundaries. Despite the same duration of occlusion, the ellipses covering for Boundary information thus significantly reduced the familiarity preference when compared to ellipses covering for Non-Boundary information across two different cartoons. Planned analysis furthermore showed that only in the group of 20-month-olds was a significant difference between the two conditions to be found. This will be commented upon in the discussion.

5. Discussion

As adults we continuously parse the ongoing perceptual stream of experience into meaningful chunks or segments (Kurby & Zacks, 2008; Zacks & Swallow, 2007). This ability has been found to be crucial for us to make sense of our surroundings, to remember and to learn from episodes, as well as for our ability to predict the near future (e.g., Swallow et al., 2009; Zacks et al., 2006; Zacks & Swallow, 2007). A relatively new theory, EST, has been developed describing this ability in adults. However, as stated by Radvansky and Zacks (2014) we do not yet have a complete outline of how the ability to segment events develops through the ontogenesis and as such a lot of unanswered questions remain, especially regarding how this ability relates to memory in infancy. The present study was one of the first attempts to remedy this gap in the literature.

The results from the present study show that overall (both age groups combined) the temporal placement of ellipses in our cartoons *does* seem to be of substantial importance in infancy: Ellipses inserted *at* Event Boundaries during encoding seem to interfere significantly more with memory of the cartoons across a two-week retention interval compared to ellipses inserted at a Non-Boundary point in time as evidenced by a weaker familiarity preference in the Boundary condition. When looking at the two age groups separately only the results from the 20-month-olds reached significance, whereas there was no significant difference between the two conditions in the 16-month-olds.

Based on these results, it thus seems safe to say that infant memory is also dependent on key time points in the flow of an event. Despite the use of slightly different methods when compared to event segmentation tasks developed for adults, we see the same pattern: event boundaries are important for memory of events. In the future, studies investigating whether this effect can be found for different types of events (e.g., more fine-grained events) would be of interest. This study is however the first of its kind to illustrate the importance of boundaries in infant memory.

The finding that the effect of condition seemed to be more pronounced in the 20-month-old infants could imply that memory earlier in infancy is not as dependent on information at Event Boundaries as expected. However, when looking at the ANOVA we

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found no effect of age in relation to condition. The present results thus cannot be taken as evidence of a true developmental change. Based on this we favor an alternative interpretation suggesting that the 16-month-olds may simply have had a somewhat harder time following and/or understanding the storyline in the cartoons potentially minimizing a possible effect of the ellipses. Essentially, several aspects of child development, considered important to understand dynamic movie sequences, may be less evolved in 16-month-old infants relative to their older peers, such as vocabulary (as was also supported in this study by the results from the CDIs) (e.g., Bauer & Wewerka, 1995; Kingo & Krøjgaard, 2015; McGuigan & Salmon, 2004), their understanding of agency and self-recognition as well as their capability to engage in pretend play (e.g., Nielsen & Dissanayake, 2004). It is therefore plausible that the 16-month-olds in this study had been affected by a limited development hereof, and that this may have had consequences for their understanding of the cartoons (e.g., by a limited understanding of intentions, narrative structure, and actions). A weaker understanding of the storyline inherent in the cartoons could then potentially lead to the development of weaker or at least different event models of the perception stream, which in turn could imply that the temporal placement of the disturbances, decided by a group of adults, would not have the planned disturbing effect for these infants. The present study however, only leads us to speculate about this, and clearly warrants further examination.

Despite the importance of our findings some limitations do stand out and several aspects remain to be examined. First, although we have shown that *disturbances* at Boundaries make a difference in infants' memory, a more direct test of the privileged status of Boundary information in infancy, would be a demonstration of superior *memory* for information presented *at* Boundaries similar to what has been shown in adult participants (Swallow et al., 2009). An obvious extension of the present study would therefore be to examine whether infants would also remember information displayed *at* Boundaries better than information displayed at other points in time. A recent study from our lab employing a different version of the crab cartoon from the present study, indeed set out to explore this (BLINDED, subm.). To investigate whether the infants exhibited increased memory for information present at Boundaries, we presented them with objects (a bucket or a spade) in the cartoon. The results revealed that *only* the infants, who were presented with objects at an Event Boundary exhibited memory (evidenced as a transient familiarity preference present in the first 3s) for the object in a visual-paired comparison task 10 minutes after the original encoding. Infants presented with objects at Non-Boundaries on the other hand did not show sign of memory. Furthermore, the infants were asked to point to the previously seen object, and only the infants in the Boundary condition performed better than chance. The results from the present study combined with the results obtained in this recent study provide converging evidence suggesting that even for infants the encoding of memory seems to be especially sensitive to information present or disturbed at event boundaries – just as it has been shown with adults (Swallow et al., 2009). To clarify the development of event segmentation, it would clearly be of interest to investigate the significance of boundaries for infant memory in even younger infants. Finally, it would be interesting to see if the results besides replicating across two cartoons would also replicate to other stimulus material including more naturalistic events.

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In spite of the limitations, we find this study to be a significant step towards a more elaborated understanding of the development of episodic memory as well as event segmentation in infancy. It is thought provoking that the episodic part of episodic memory hitherto has received so little attention – even when focusing on adult research. Although clearly important, we know close to nothing about how the understanding of an episode develops through the ontogenesis and how this affects the extent and content of episodic memory. This could potentially be of importance in the research field of event memory (e.g., Bauer, 2007). By testing infants’ understanding of an event more directly, for instance the event of watching or imitating a sequence of actions in an imitation task, it would be possible to see whether their understanding of this event would be of importance for their performance.

The present results suggest that the understanding of event structure plays an important role for memory already in infancy. By meticulously testing to what extent EST may apply to infants and younger children and how it may affect their memory we may be able to bridge at least some of the important gaps in the research literature. We believe that the present study provides one of the first contributions in this regard.

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References

Bahrick, L. E., & Pickens, J. N. (1995). Infant memory for object motion across a period of three months: Implications for a four-phase attention function. *Journal of Experimental Child Psychology*, *59*, 343-371. http://dx.doi.org/10.1006/jecp.1995.1017

Bahrick, L. E., Hernandez-Reif, M., & Pickens, J. N. (1997). The Effect of Retrieval Cues on Visual Preferences and Memory in Infancy: Evidence for a Four-Phase Attention Function. *Journal of Experimental Child Psychology, 67*, 1-20. doi: 10.1006/jecp.1997.2399

Baldwin, D. A., Baird, J. A., Saylor, M. M., & Clark, M. A. (2001). Infants parse dynamic action. *Child Development, 72*, 708-717.

Barr, R., Walker, J., Gross, J., & Hayne, H. (2014). Age-Related Changes in Spreading Activation During Infancy. *Child Development, 85*, 549-563. doi: 10.1111/cdev.12163

Bauer, P. J. (2007). Remembering the times of our lives: Memory in Infancy and Beyond. Mahwah, NJ: Laurence Erlbaum Associates, Inc.

Bauer, P. J., & Wewerka, S. S. (1995). One- to two-year-olds' recall of events: The more expressed, the more impressed. *Journal of Experimental Child Psychology, 59*, 475-496.

Dahl, J.J., Sonne, T., Kingo. O.S., & Krøjgaard, P. (2013). On the development of episodic memory: two basic questions. *Nordic Psychology, 65*, 189-207. doi: 10.1080/19012276.2013.807661

Ezzyat, Y., & Davachi, L. (2011). What constitutes an episode in episodic memory? *Psychological Science, 22*, 243-252. doi: 10.1177/0956797610393742

Friend, M., & Pace, A. (2011). Beyond Event Segmentation: Spatial- and Social-Cognitive Processes in Verb-to-Action Mapping. *Developmental Psychology, 47*, 867-876.

Hayne, H. (2004). Infant memory development: Implications for childhood amnesia. *Developmental Review, 24*, 33-73. http://dx.doi.org/10.1016/j.dr.2003.09.007

Hespos, S. J., & Baillargeon, R. (2001). Infant's knowledge about occlusion and containment events: A surprising discrepancy. *Psychological Science, 12*, 141-147.

Hespos, S. J., Grossman, S. R., & Saylor, M. M. (2009). Infants' Ability to Parse Continuous Actions. *Developmental Psychology, 45*, 575-585. doi: 10.1037/a0014145.

Hespos, S. J., Grossman, S. R., & Saylor, M. M. (2010). Infants' ability to parse continuous actions: Further evidence. *Neural Networks, 23*, 1026-1032. doi:10.1016/j.neunet.2010.07.010

Howe, M.L. (2011). *The nature of early memory: An adaptive theory of the genesis and development of memory*. Oxford University Press, N.Y.

Kingo, O.S., & Krøjgaard, P. (2015). Eighteen-month-olds' memory for short movies of simple stories. *Scandinavian Journal of Psychology, 56*, 151-156.

Notice: This is the author's version of a work that was accepted for publication in *Consciousness and Cognition*. A definitive version was subsequently published in *Consciousness and Cognition*, *41*, 72-82. DOI: 10.1016/j.concog.2016.02.006

Kingo, O.S., Staugaard, S.R., & Krøjgaard, P. (2014). Three-year-olds' memory for a person met only once at the age of 12 months: Very long-term memory revealed by a late-manifesting novelty preference. *Consciousness and Cognition, 24,* 49-56. doi: 10.1016/j.concog.2013.12.011

Krøjgaard, P. (2005). Spædbarnsforskningens relevans for almenpsykologien [The releveance of infant research in relation to general psychology. (Target article with open peer commentaries)]. *Bulletin fra Antropologisk Psykologi, 15,* 2-27.

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

McGuigan, F., & Salmon, K. (2004). The Time to Talk: The Influence of the Timing of Adult-Child Talk on Children's Event Memory. *Child Development*, *75,* 669-686.

Meyer, M., Baldwin, D. A., & Sage, K. (2011). Assessing Young Children's Hierarchical Action Segmentation. *In Proc. of the 33rd Annual Conference of the Cognitive Science Society*, 3156-3161.

Morgan, K., & Hayne, H. (2011). Age-related changes in visual recognition memory during infancy and early childhood. *Developmental Psychobiology, 53*, 157–165. doi: 10.1002/dev.20503

Newtson, D. (1973). Attribution and the unit of perception of ongoing behavior. *Journal of Personality and Social Psychology, 28,* 28–38.

Newtson, D., & Engquist, G. (1976). The perceptual organization of ongoing behavior. *Journal of Experimental Social Psychology, 12,* 436–450.

Nielsen, M. & Dissanayake, C. (2004). Pretend play, mirror self-recognition and imitation: a longitudinal investigation through the second year. *Infant Behavior and Development, 27,* 342-365. doi:10.1016/j.infbeh.2003.12.006

Pace, A., Carver, L. J., Friend, M. (2013). Event-related potentials to intact and disrupted actions in children and adults. *Journal of Experimental Child Psychology*, *116,* 453-470. doi: 10.1016/j.jecp.2012.10.013

Radvansky, G. A. (2012). Across the Event Horizon. *Current Directions in Psychological Science, 21*,269-272. doi: 10.1177/0963721412451274.

Radvansky, G. A. & Zacks, J. M. (2014). *Event Cognition.* Oxford University Press.

Richmond, J., Colombo, M., & Hayne, H. (2007). Interpreting visual preferences in the visual paired-comparison task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 823–831. doi: 10.1037/0278-7393.33.5.823

Saylor, M.M., Baldwin, D.A., Baird, J.A., & LaBounty, J. (2007). Infants' on-line segmentation of dynamic human action. *Journal of Cognition and Development, 8,* 113-128. doi: 10.1080/15248370709336996

Notice: This is the author's version of a work that was accepted for publication in *Consciousness and Cognition*. A definitive version was subsequently published in *Consciousness and Cognition*, *41*, 72-82. DOI: 10.1016/j.concog.2016.02.006

Schwan, S., & Garsoffky, B. (2004). The Cognitive Representation of Filmic Event Summaries. *Applied Cognitive Psychology, 18*, 37-55. doi: 10.1002/acp.940

Schwan, S., Garsoffky, B., & Hesse, F. W. (2000). Do film cuts facilitate the perceptual and cognitive organization of activity sequences? *Memory & Cognition, 28*, 214–223.

Stahl, A. E., Romberg, A. R., Roseberry, S., Michnick Golinkoff, R., & Hirsh-Pasek, K. (2014). Infants Segment Continuous Events Using Transitional Probabilities. *Child Development, 85*, 1821-1826. doi: 10.1111/cdev.12247

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

Woodward, A. L., Sommerville, J. A., & Guajardo, J. J. (2001). How infants make sense of intentional action. In B. Malle, L. Moses & D. Baldwin (Eds.) *Intentions and intentionality: Foundations of Social Cognition* (pp.149-169). Cambridge, MA: MIT Press.

Zacks, J. M. (2004). Using movement and intentions to understand simple events. *Cognitive Science, 28,* 979-1008. doi:10.1016/j.cogsci.2004.06.003

Zacks, J. M. (2010). How we organize our experience into events. *Psychological Science Agenda*, *24.*

Zacks, J. M., Kumar, S., Abrams, R., & Mehta, R. (2009). Using movement and intentions to understand human activity. *Cognition*, *112,* 201-216. doi:10.1016/j.cognition.2009.03.007

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

Zacks, J. M., Speer, N. K., Vettel, M.J., & Jacoby, L. L. (2006). Event Understanding and Memory in Healthy Aging and Dementia of the Alzheimer Type. *Psychology and Aging, 21*, 466-482. doi: 10.1037/0882-7974.21.3.466

Zacks, J. M., & Swallow, K. M. (2007). Event segmentation*. Current Directions in Psychological Science, 16*, 80-84.

Zacks., J. M., & Tversky, B. (2001). Event structure in perception and conception. *Psychological Bulletin, 127*, 3-21.

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Figure 1

Figure 1: A graphic representation of the story line illustrated by six static pictures from the two cartoons, including pictures of the Boundary and Non-Boundary points in time

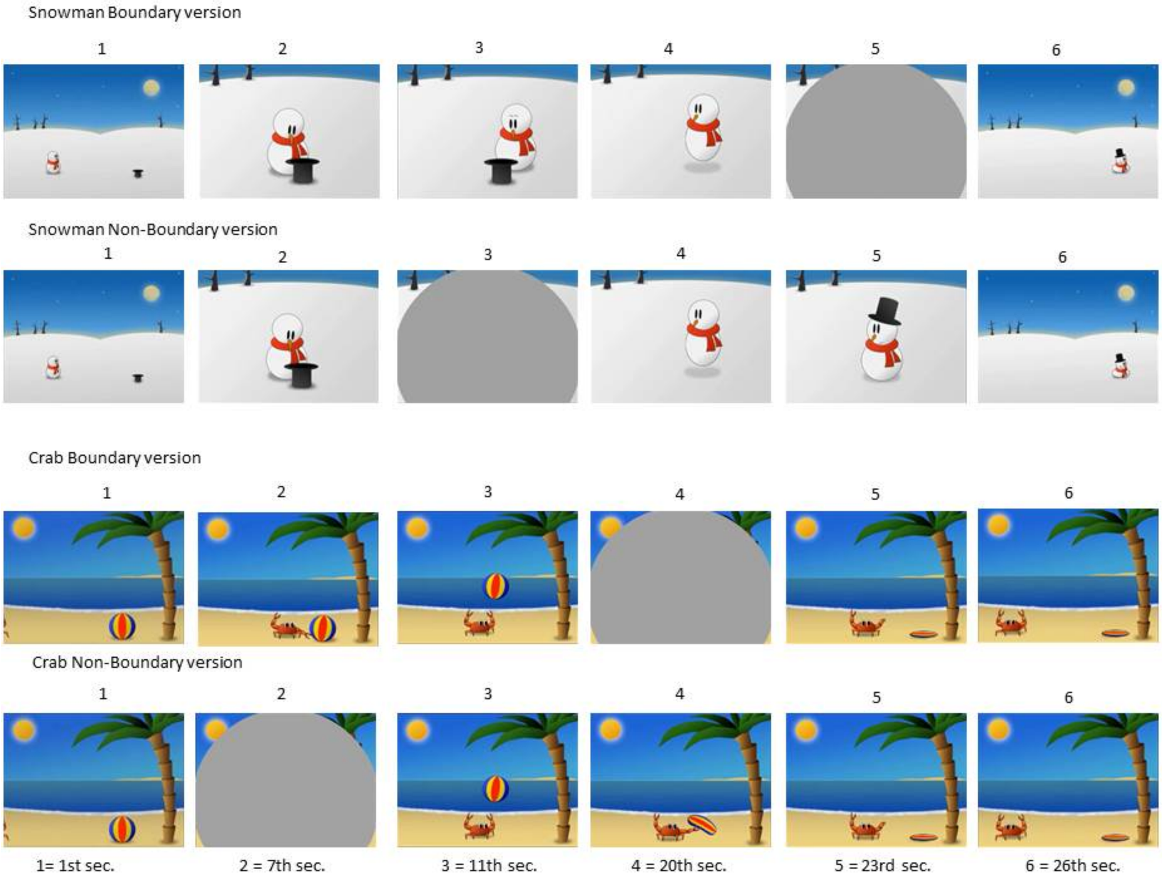

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Figure 2

Figure 2: A graphic representation of the proportional looking to the novel across conditions for both age groups. The dotted line represents chance level (0.5).

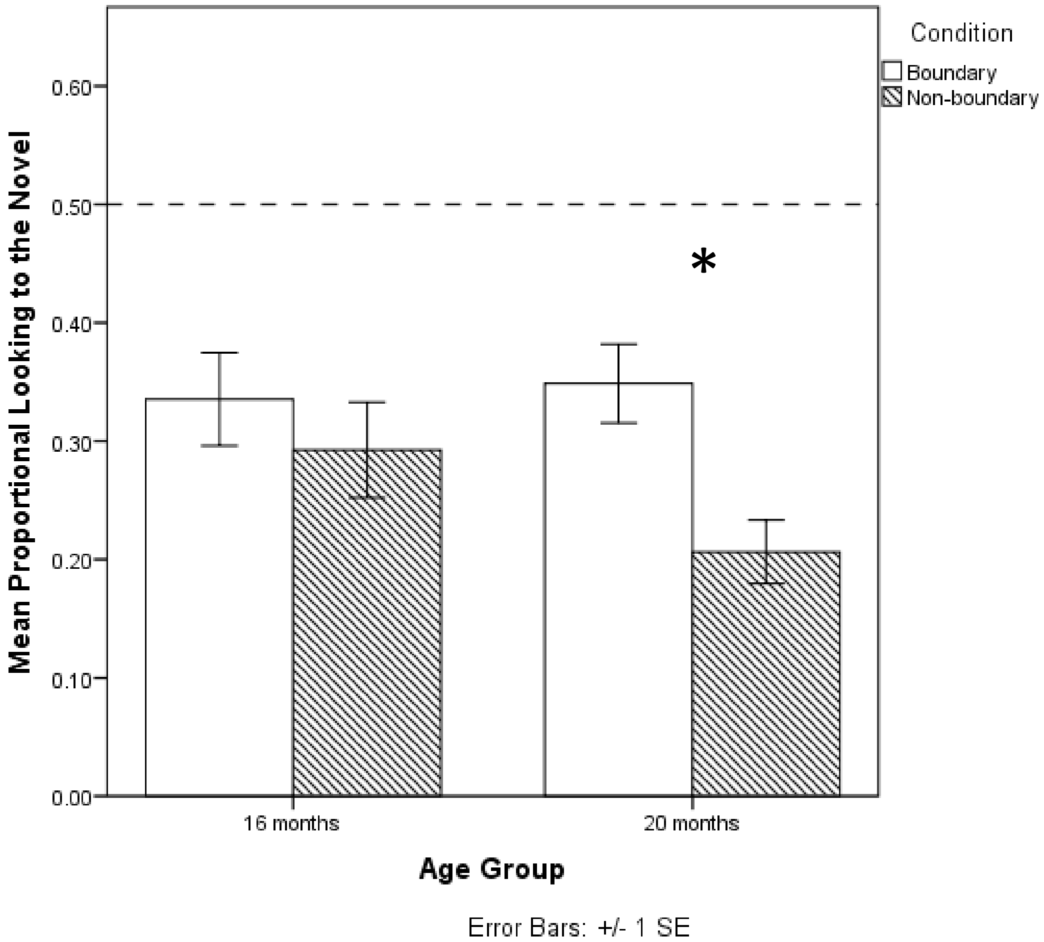

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Figure 3

Figure 3: A graph of proportional looking to the novel cartoon across both iterations in the test-phase. Error bars +/- 1 SE.