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Bound to remember: Infants show superior memory for objects presented at event boundaries

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Abstract

Following Event Segmentation Theory (EST) adult memory is enhanced at event boundaries (EB). The present study set out to explore this in infancy. Sixty-eight 21-month-olds watched a cartoon with one of two objects (counterbalanced) inserted for 3s either *at* EB or *between* EB. Ten minutes later they watched both objects (familiar and novel) in a 10s Visual Paired Comparison (VPC) test while being eye-tracked. Furthermore, they were asked to point to the previous object. Based on EST, we hypothesized that objects inserted *at* EB would be processed more fully, resulting in improved memory compared to objects inserted *between* EB. Only infants with objects at EB exhibited memory evidenced by a transient familiarity preference for the first 3s of the test. Only 18 infants completed the pointing test, but *all* infants presented with objects at EB (10/10) pointed to the correct (familiar) object, which was not the case for the infants presented with objects between EB (5/8).

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1. Introduction

Research on event segmentation in adults describes how we readily detect and parse what we perceive into smaller units or parts (e.g., Kurby & Zacks, 2008; Zacks, 2010). According to Event Segmentation Theory (EST) this ability is a basic mechanism in everyday perception making it easier to comprehend the otherwise complex environment that surrounds us, allowing us to make predictions about future actions. Several studies have shown that when a group of adults are asked to press a button within a continuous action whenever they identify breakpoints or meaningful boundaries they typically agree on the identification of these points (e.g., Kurby & Zacks, 2008; Newtson & Engquist, 1976). This has for instance been found when presenting adults with movies of everyday activities, such as someone doing the dishes or making a sandwich (for review see Kurby & Zacks, 2008).

Besides assisting in everyday perception of action streams, studies show that adults' event segmentation skills have consequences for later memory and learning of events (e.g., Swallow, Zacks, & Abrams, 2009; Zacks, Speer, Vettel, & Jacoby, 2006; Zacks & Swallow, 2007). More specifically, EST states that long-term memory is enhanced for information available at event boundaries (Kurby & Zacks, 2008; Zacks & Swallow, 2007). This prediction is based on the finding that event boundaries typically are identified at points of change (e.g., in goals or movements) when predictions about the future become less accurate, which leads to enhanced processing and hence more profound *encoding* of information present at event boundaries (Kurby & Zacks, 2008).

In a series of experiments Swallow, Zacks, and Abrams (2009) investigated the role of event boundaries for memory in a group of adults. The participants watched brief movie clips with different objects appearing during the clip. These objects either appeared while an event boundary occurred (Boundary object) or at a time when no boundaries occurred (Non-Boundary object). Shortly after, the participants' memory of the specific object was assessed and compared to another object in a recognition test. The results revealed that recognition accuracy was greater for Boundary objects than for Non-Boundary objects, suggesting that long-term memory may be superior for information present at event boundaries. Other studies support the general conclusion that event segmentation affects our memory, and that event boundaries or breakpoints are particularly important for what we remember (Newtson & Engquist, 1976; Schwan, Garsoffky, & Hesse, 2000).

Despite its origin in the adult domain, researchers have now started investigating the developmental origins of event segmentation skills. Studies on event segmentation in infancy have shown that infants' ability to segment events in many respects resemble event segmentation in adults. For instance, just like adults, even young infants distinguish between action sequences by using knowledge about objects and event categories (Hespos, Grossman,

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& Saylor, 2009, 2010). Like adults, infants seem to find disruptions of ongoing intentional actions more disturbing than disruptions placed when the action has ended (Baldwin, Baird, Saylor, & Clark, 2001; Pace, Carver, & Friend, 2013; Saylor, Baldwin, Baird, & LaBounty, 2007). Finally, resembling adults (Baldwin, Andersson, Saffran, & Meyer, 2008), infants seem capable of segmenting a continuous action sequence based solely on sequential predictability (Stahl, Romberg, Roseberry, Golinkoff, & Hirsh-Pasek, 2014). However, very few studies have examined event segmentation and its potential influence on memory in infancy or more specifically what event boundaries mean for infant memory across longer retention intervals. A recent exception is a study from our lab showing that inserting disturbances (i.e., occlusions in the shape of ellipses) during the encoding process affected 16- and 20-month-old infants' memory of a cartoon across a two-week retention interval differently depending on the temporal placement of the disturbances (Sonne, Kingo, & Krøjgaard, 2016a). This was the first study to show, that obstructing access to information either *at* or *between* event boundaries during encoding differentially affected memory across a two-week retention interval in infancy.

Note that whereas the previous study from our lab showed that disturbances of the encoding process by *removal* or *occlusion* of boundary information had negative consequences for later memory (Sonne et al., 2016a), we do not know whether increased processing occurs at event boundaries in infancy or whether enhanced memory is to be found for information *present* at these points in time for infants. Based on EST and studies within this framework focusing on adults (e.g., Swallow, Zacks, & Abrams, 2009) this would indeed be the prediction, but no one has investigated whether it would also hold for infants. Investigating whether enhanced memory is found for information present at boundaries is important for several reasons. First of all it would add to our knowledge regarding the development of event segmentation skills in general, and so far no studies have directly investigated this part of event segmentation in infancy. Second, it would increase our knowledge regarding the importance of event boundaries for later memory. Third, identifying points in time of central importance to memory could potentially have practical consequences for how information is presented in learning contexts. The present study set out to examine exactly this.

2. The Present Study

In the present study we presented a group of 21-month-old infants with a cartoon about a crab with one of two event-related objects (a bucket or a spade) inserted for 3s at different time points in the cartoon (either directly at an event boundary *or* at a time when no event boundary was present). Please note that this part of the study was inspired by, and employed similar stimulus material, as the recent study from our lab (Sonne et al., 2016a). After 10 minutes retention we tested the infants' memory of the objects in a visual-paired comparison (VPC) test lasting 10s. The VPC paradigm is among the most widely used procedures for assessing infant memory (Hayne, 2004). In the VPC test one object was then now familiar

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whereas the other was completely new. Employing eye-tracking technology we recorded the infants' looking time to the two objects in this final test. Furthermore, after this we added a prompted pointing test, where the infants were asked to point to the object they had previously seen. Given the age of the infants and based on previous experience from our lab we did not expect all of the infants to be able to understand this task. We however still found it to be worth pursuing the combination of a more implicit visual test as well as a prompted test in order to see whether the same pattern of results would appear when employing different tests.

Based on EST and the previous study from our lab, we expected that memory for objects presented at the event boundary would be superior due to enhanced processing compared to memory for objects presented at a Non-Boundary point in time. Hence, we expected to see more pronounced memory for the objects presented at event boundaries, indicated by prolonged looking time at, and more incidents of pointing to, the correct object. Although the traditional view has been, that only a novelty preference was indicative of memory (for a review, see Richmond, Colombo, & Hayne, 2007), several studies using the VPC paradigm have argued that *both* a novelty *and* a familiarity preference can be interpreted as memory (e.g., Bahrick & Pickens, 1995; Kingo & Krøjgaard, 2015; Richmond, Colombo, & Hayne, 2007; Roder, Bushnell, & Sasseville, 2000; Sonne et al., 2016a; see also Hayne, 2004). In the present study a familiarity preference however was expected based on previous studies from our lab using similar stimuli as well as participants in the same age range (i.e., 18-20 months of age, Kingo & Krøjgaard, 2015; Sonne et al., 2016a). Although general event segmentation skills have been investigated in much younger age-groups (e.g., 6 months, Hespos, Grossman, & Saylor, 2009), 21-month-old infants were chosen because previous studies from our lab have shown that the stimulus material used was suitable for infants in this age range (Kingo & Krøjgaard, 2015; Sonne et al., 2016a). Furthermore, we thought that investigating an age group close to the one used in the recent study from our lab, would help us identify whether in fact *enhanced* memory, and not only disturbance of memory, at event boundaries can be found using similar stimuli.

3. Method

3.1 Participants

Sixty-eight healthy and full-term infants aged 21 months (M_{age}= 20.79 months, SD = .42, 35 girls) participated. All of the infants were recruited from birth registries from the National Board of Health and had an Apgar score of at least seven. The infants were predominantly Scandinavian Caucasian, living in the area of BLINDED in families with middle to a higher SES. Nine additional infants were tested, but excluded from the analysis: Three infants were excluded due to missing looking time data, one due to a technical failure,

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and five were excluded due to fussiness. All of the infants received a small teddy for participating.

3.2 Materials, Design and Procedure

The present study consisted of two phases: In the *encoding phase*, the infants were presented with a fixed number of four familiarization trials each involving a 30s custom-made cartoon about a crab, and then after approximately 10 minutes they were presented with the VPC test in the *testing phase*.

The same cartoon had been used in different formats in two previous studies from our lab (Kingo & Krøjgaard, 2015; Sonne et al., 2016a). In the cartoon the crab entered a beach 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 on the ground. Following this, the crab left the scene. In order to test whether memory was superior for information presented at event boundaries, we inserted event-related objects (a bucket or a spade) abruptly for 3s at different time points in the cartoon. The objects were thus chosen to fit the overall story, but we also ensured that they were equivalent with regard to size. We placed the objects *either* directly *at* an event boundary (Boundary condition) *or* exactly 12s *before* the occurrence of an event boundary (Non-Boundary condition) (see Fig.1). Note that although the objects appeared right next to the main character (the crab), they were not central to the story-line of the event.

The temporal placement of the objects was exactly the same as the temporal placement of the disturbances (i.e., ellipses) in our previous study which were based on the decision of a group of adults (see Sonne et al., 2016a). In the previous study a group of adults (*n*=15) were asked to indicate the point in time they thought would be most important for the cartoon (e.g., a turning point or a point of change) and this was referred to as the Boundary point in time[1]. The adults simply watched the cartoon twice on a lap top or a PC and then were asked to write down in seconds which point in time they thought was most important. The Non-Boundary point in time was placed exactly 12s before the event boundary making sure that it did not coincide with other less frequently mentioned event boundaries. In the Boundary condition the objects were inserted when the claws punctured the ball, and in the Non-Boundary condition the objects were inserted just as the crab started playing with the ball

[1] Please note that this instruction differs from the original instruction developed by Jeffrey Zacks. The change in instruction was motivated by the fact that our experimental group consists of infants and as such we wished to make the instructions fit the test used for the infants. Therefore, we only wanted to have a single event boundary in the cartoon to keep it simple for the infants (see also Sonne et al., 2016). A later validation was made which more directly followed the instructions used by Zacks, asking 15 new adults to identify when one meaningful unit of activity ends and another unit begins. In this case all of the adults identified the original event boundary as one of their boundaries, and when asked to choose *the* most meaningful unit of activity out of all of their identified segments, 14 out of 15 identified the original boundary supporting our initial identification of boundaries.

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(see Fig. 1). Please note that both the Boundary and the Non-Boundary objects were preceded and followed by movement of the crab.

Thus, the infants were randomly assigned to four different versions of the cartoon: a Non-Boundary (*n*= 17) and a Boundary version (*n*= 17) with the bucket inserted and a Non-Boundary (*n*= 17) and a Boundary version (*n*= 17) with the spade inserted.

First, the infants watched one of the four versions of the cartoon depending on the condition as well as what object they were presented with. The infants were presented with the same cartoon four times in a row for a total of 120s to ensure encoding. The four demonstrations were presented in a loop, only separated by a minor fading in and out period. Using four consecutive presentations served two purposes: the first was to make sure that the infants had ample opportunity to encode the sequence, and the second was that the cyclic format allowed the Boundaries and the Non-Boundaries to appear both before and after one another as a control for a possible order effect. Using a fixed number of encoding trials is common in the VPC paradigm (e.g., Hayne, 2004), and based on previous looking time studies employing a fixed number of encoding/familiarization trials (e.g., Krøjgaard, 2000; Morgan & Hayne, 2006, 2011), this procedure was deemed sufficient. The 120s encoding has been further validated in a previous study from our lab showing that even younger infants are capable of remembering an almost identical cartoon across a delay of two weeks after a fixed familiarization trial of 120s (Kingo & Krøjgaard, 2015). Following the procedure used in Kingo and Krøjgaard (2015) it was not considered necessary to monitor looking time during encoding explicitly, but in order to ensure encoding, infants had to pay attention to at least the first two of the four presentations in order to proceed to the memory test. The experimenter monitored this by carefully watching the infant through a monitor in the control room.

Ten minutes later (during which the infants participated in another non-related experiment not reported here) in the memory *testing phase* both possible objects (novel and familiar) were presented simultaneously side by side (left-right counterbalanced) for 10s. This was done in the same setting as in the *encoding phase*. During the memory test, the infants' fixations on the screen were eye-tracked. Immediately after the memory test, the experimenter entered the room and explicitly prompted the infants to point to the object he or she had previously seen by saying: "You have just seen a cartoon with a crab, do you remember? One of the things on the screen appeared right next to the crab. Can you point to the object that appeared right next to the crab? Was it this one or that one?" (while always pointing to the left object first, hence counterbalancing which object was pointed to first, as the presentation of the objects was again left-right counterbalanced). If the infant did not respond, the question was repeated one more time. If by then no answers had been given, the test was stopped.

The parents were present during the whole session, but had been instructed not to interfere during the different tasks. Furthermore, the parents of the infants were asked to fill out a standardized BLINDED version of the MacArthur-Bates Communicative Development

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Inventory. This was done in order to be able to control for potential differences in relation to productive vocabulary in the two conditions.

3.3 Eye-Tracking Setup and Data Reduction

A Tobii X120 eye-tracker was used to record 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 distance between the infants’ eyes and the eye-tracker was approximately 70 cm. 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 an eye blink). Before the actual data collection, a 5-point calibration was conducted using Tobii Studio calibration for infants. The stimulus material was presented via E-prime software.

In order to extract data, Areas of Interests (AOIs) were defined. Since we were interested in the infants’ general looking time to the two objects respectively, two simple AOIs were created equivalent in size: one for each object. The size of the AOIs in visual degrees was (W x H) 14,4° x 13.25°. The space between the two AOIs was 2°, and the sizes of the actual objects covered by the AOIs ranged from 6,51°- 8,37° (W) and 4,96° - 11.47° (H). Fixation time was assessed within each of these AOIs.

4. Results

Since more than 50 percent of the infants did not look at all in the final second of the total 10s the VPS task lasted, we decided to run all of the analyses based on the first nine seconds and divided these into three 3-second blocks allowing us to investigate what happened over time. Preliminary analyses revealed that no gender differences in the novelty-preference scores were to be found in overall looking time for the nine seconds ($M_{\text{prop\_female}}$ = .48, *SD* = .18; $M_{\text{prop\_male}}$ = .54, *SD* = .19), $t(66) = -1.27$, $p = .21$, $r = .15$. Based on this, data from the two genders were collapsed in the following analyses. As a control we also investigated whether there would be a difference in the productive language scores from the two conditions, but no such differences were found (M_{Boundary} = 135.78, *SD* = 107.48; $M_{\text{Non-Boundary}}$ = 132.76, *SD* = 92.39), *t*(64[2])= .12, $p = .90$, $r = .015$.

A paired sampled t-test revealed that the infants looked longer at the first 3-second block ($M_{0\text{-}3s}$ = 2.11, *SD* = .67) compared to the second 3-second block ($M_{3\text{-}6s}$ = 1.62, *SD* = .93), $t(67) = 5.00$, $p < .001$, $r = .52$. Similarly, a paired sampled t-test revealed that the infants looked longer at the second 3-second block ($M_{3\text{-}6s}$ = 1.62, *SD* = .93) compared to the final 3-second block ($M_{6\text{-}9s}$ = 1.19, *SD* = .94), $t(67) = 3.80$, $p < .001$, $r = .42$.

[2] Note that we did not receive CDI’s from two infants; therefore data from these two infants were missing.

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Our main interests were to examine whether the infants could remember the object they had been presented with during the presentation of the cartoon and whether their memory would be affected by the condition they were in. The dependent measure was the proportion of looking time at the novel object during test and was calculated as a proportional novelty-preference score by dividing the total looking time to the novel object with the total looking time at both objects, thus producing a novelty-preference score between 0 and 1 (e.g., Kingo, Staugaard, & Krøjgaard, 2014; Richmond, Colombo, & Hayne, 2007).

We found no general preference or sign of memory when focusing on the nine seconds in total, neither when focusing on all of the infants nor when focusing on each of the two conditions (all *p*'s > .14). Based on the fact that (1) the infants looked reliably longer at the first 3-second block compared to the second and third 3-second blocks (see above) and that (2) no missing data were to be found for the first 3-second block compared to 6 missing for the second 3-second block and 15 missing in the final block, and (3) some studies have found that infants show a brief and transient initial preference (e.g., Richmond & Nelson, 2009), we decided to focus on the first 3 seconds of the VPC test.

In the first three seconds we did not find a general preference when focusing on all of the infants (p = .41). However, we found a significant familiarity preference for all of the infants in the Boundary condition: the proportional looking to the novel object (M =.42, SD = .21) was significantly different from chance level (.5), $t(33) = -2.31$, p =.03, r =.37. This was not the case for the infants in the Non-Boundary condition and the proportional looking to the novel object (M =.54, SD = .20) was not significantly different from chance level (.5), $t(33)$ = 1.23, p =.23, r = .21. Moreover, we found a significant difference between the two conditions in the first 3-second block: A *t*-test comparing the proportional looking to the novel object in the Boundary condition (M = .42, SD = .21) to the proportional looking to the novel object in the Non-Boundary condition (M = .54, SD = .20) was significant, $t(66) = -2.53$, p =.014, r =.30 (see Figure 2).

Finally, we wanted to investigate how well the infants performed in the Pointing Test. Only 18 infants in total (out of the 56[3]) followed the instruction and pointed to any object during this test. No differences in CDI scores were to be found for the 18 infants who did point in the test (including correctly pointing to the object, or failing to point to the previously seen object) and the rest of the infants who weren't capable of pointing when asked to do so. Therefore, the following analyses are only based on this sub-group of the infants. Binomial tests of the correct answers revealed that only the infants in the Boundary condition pointed to the correct object above chance level (binomial test against 0.5), p = .002, whereas this was not the case for the infants in the Non-Boundary condition (p = .73). In the Boundary condition 10 infants participated and all of them (100 %) answered correctly, whereas only 5

[3] The pointing test was not administered to the first 12 participating infants. As a consequence we only have data on the pointing test from 56 of the 68 participating infants. Note that this difference in procedure had no influence on the looking time measures, as the pointing test was always done *after* the VPC test.

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out of the 8 (62.5 %) infants in the Non-Boundary condition responded correctly. These results were partly supported by a Fisher's exact test revealing a marginally significant difference between the two conditions, with better pointing in the boundary condition, p=.069. Although it evidently was a difficult task for the infants to point, the results from the pointing test supports and underscores the results from the VPC test.

5. Discussion

Event Segmentation Theory has provided evidence that adult memory is affected by how we segment events and that event boundaries are of major importance to our long-term memory (e.g., Kurby & Zacks, 2008; Swallow, Zacks, & Abrams, 2009). To the best of our knowledge the present study is the first to show that also infants can have enhanced memory for information presented at an event boundary. More specifically, the results from the present study revealed that the infants in the Boundary condition showed enhanced memory for a previously seen object evidenced by a transient familiarity preference in the first 3-second block when compared to the infants in the Non-Boundary condition. These results are important for our understanding of the development of event segmentation skills in general, but also more specifically of great importance for our understanding of event boundaries in relation to memory in infancy. The results suggest, that the enhanced encoding of information available *at* event boundaries relative to *between* event boundaries - which until recently has only been shown in adults (Kurby & Zacks, 2008; Zacks & Swallow, 2007) - may hold for infants as well. Thus, enhanced encoding at event boundaries may occur early in development. Knowledge about the relation between an infants' understanding of an event as it unfolds and later memory for this event is beyond doubt important when studying developmental aspects of memory (e.g. childhood amnesia, Bauer, 2007). For instance, in order to remember a given episode experienced early in life, one has to be able to demarcate the specific incidence in question. Developmental research on event segmentation may help to shed light on when the ability to segment events develop during the ontogenesis.

Further converging evidence was obtained from the pointing test where *all* of the 10 infants in the Boundary condition, who also participated in the pointing test, pointed to the familiar object, whereas the proportion of infants in the Boundary condition who pointed (five out of eight) did not differ from chance. Although only 18 out of the 56 infants who were asked to point to the target object actually followed the instructions and pointed, the results from those who did participate in the test were clear, systematic, and significant (and was also supported by a marginally significant Fisher's exact test). Thus, even with severely restricted statistical power, the results from the obtained in the pointing test were clear *and* in accordance with the results obtained from the VPC task. Few studies employ both explicitly prompted tasks as well as implicit memory tasks, and taken together the results from the two tasks converge and seem to underscore the finding that event boundaries are truly salient for memory. The results from the present study thus highlight that the combination of explicit

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and implicit memory tasks seem to be worth pursuing in future studies potentially providing a more comprehensive understanding of the results.

One potential concern about this study might be that the Non-Boundary objects were invariably temporally placed *before* the occurrence of a boundary. Note however, that this is only the case when considering a single cartoon in isolation. During the encoding phase the infants were presented with a cyclic flow of the cartoon for a total of four consecutive presentations. In this way the boundaries appeared both before and after a non-boundary, only separated by a minor fading out. Thus, whereas Non-Boundary and Boundary objects appeared in a fixed order when considering each encoding film separately, this was not the case when considering the encoding sequence employing four consecutive presentations as a whole.[4]

Another concern could be that eye tracking data were not recording from the encoding trials. Although we acknowledge that eye tracking data from the encoding trials might have qualified the analyses, we do not consider this limitation crucial. First, whereas eye tracking data were not recorded during the encoding trials, the infants looking behavior *was* carefully monitored as infants had to pay attention to at least two of the four encoding trials (cf. the procedure section). Note that an additional five infants were excluded due to fussiness, showing that minimum requirements regarding the infants' attention during encoding were indeed employed. Second, as previously stated, using a fixed number of encoding trials is a standard procedure in the VPC paradigm (e.g., Hayne, 2004), and has also been used in other looking time paradigms (e.g., Krøjgaard, 2000; Morgan & Hayne, 2006, 2011). Last, but not least, the same procedure employing a fixed number of encoding trials has been used in two previous studies using very similar (although not completely identical) stimulus material and with infants within the same age range (Kingo & Krøjgaard, 2015; Sonne et al., 2016a). Thus, since looking time was indeed monitored using a well-proven procedure, we do not find it likely that actually recording the looking time during encoding would have changed the overall results.

Could the results be accounted for *without* referring to EST, for instance by potential low-level stimuli differences between the Boundary and the Non-Boundary conditions, that may have made it more or less likely to visually process the critical object during encoding? Although we cannot rule out this possibility entirely, we find it unlikely: The two visual contexts in the Boundary and the Non-Boundary condition respectively were very similar (i.e., same overall scene with the same entities in the same visual perspective). Thus, the only

[4] Along the same lines one might speculate whether the fading out *between* each of the four cartoon presentations constituted event boundaries too. They probably did, but these potential event boundaries were at least 7s away from the nearest boundary (or non-boundary) were the objects to remember were inserted in the study. Thus, although we acknowledge that the fading out between the four cartoon presentations may be event boundaries, we have no reason to believe that these 'boundaries' could have affected the results. Note further, that the presence of boundaries in the form of fading out between movie presentations was exactly the same for all participants *across* conditions, and therefore we do not find it likely that they could have influenced the obtained results.

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salient low-level stimulus differences would be the target objects, but these were counterbalanced across subjects and conditions. Hence, although possible in principle we find it unlikely that the obtained results could be due to low-level visual differences in the available stimulus material between the conditions during encoding. In our view, the crucial difference between the Boundary and the Non-Boundary condition lies in the *dynamics* and configuration of agents and objects. This all falls into the domain of the event structure which is the very structure for which EST makes hypotheses.

The results from the present study extend the findings from a previous study from our lab showing that the disturbance of boundary information has negative consequences for memory in 20-month-old infants (Sonne et al., 2016a). The results from the present study add to this knowledge by more directly showing enhanced memory for information present at event boundaries, which is following the results from studies on event boundaries in adult participants (e.g., Kurby & Zacks, 2008; Swallow, Zacks, & Abrams, 2009). Taken together the two studies from our lab indicate that event boundaries are important for infant memory by showing, that (1) the removal or disturbance of information at event boundaries has negative consequences for later memory of a cartoon, and (2) that enhanced memory has been found for information present at event boundary information. As such, the studies combined show that event segmentation affects memory of whole cartoons as well as memory of smaller features (i.e., objects) included in an event flow.

EST was developed in the adult domain and until recently very little was known concerning which aspects of EST would also be true for infants. Knowing that boundary information plays an important role for infants' event memory as well as for adults is an important step in identifying the developmental steps necessary for reaching full-blown event segmentation ability. After having demonstrated the importance of event boundaries for infant memory, an obvious next step would be to further investigate the mechanisms behind this effect. For instance by focusing on what is happening during the encoding of an event, perhaps with a special focus on the boundaries. In order to investigate whether increased processing occurs during event boundaries one would have to look beyond raw looking time data, given the fact that the relationship between processing and looking time during encoding may not necessarily be linear (e.g., Óturai, Kolling, & Knopf, 2013; Sonne, Kingo, & Krøjgaard, 2016b). In addition, future studies should investigate whether these results would replicate using more daily-life stimuli.

Taken together, we believe that the results from the present study are an important first step when examining to what extent the importance of event boundaries for adult memory as described by EST holds in the infancy domain. Future research pursuing such questions further would not only investigate the breadth of EST, but would also contribute by specifying the developmental path of event segmentation skills as they evolve during development.

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Figure Captions

Figure 1: A graphic representation of the story line illustrated by six static pictures from the cartoon, including pictures from the Boundary (#4) and Non-Boundary (# 2) points in time indicated by the dotted frames. The top line of the static pictures represents an outline of the Boundary version with the bucket, whereas the lower line of the static pictures represents the Non-Boundary version with the spade. Each object was used for both conditions (balanced across infants). Note that during encoding each 30s cartoon was presented four times consecutively.

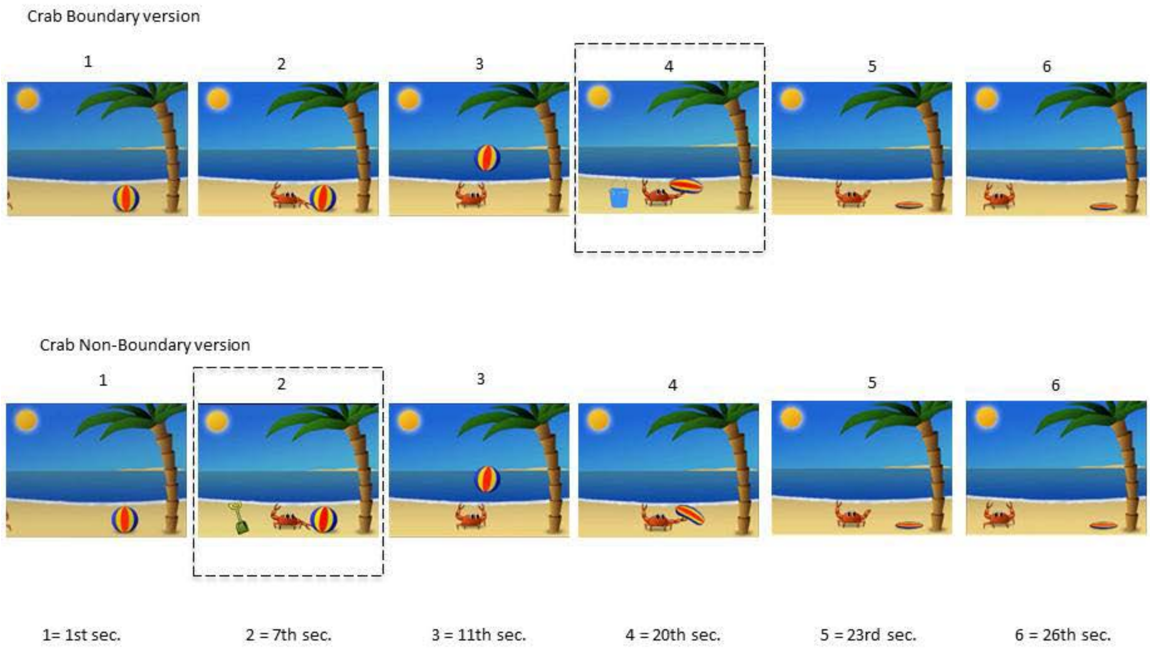

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Figure 2: A graph illustrating proportional looking to the novel object over time across the 9 seconds.