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BRIEF REPORTS

12-Month-Old Infants Represent Probable Endings of Motion Events

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This experiment investigated 12-month-old infants' ability to link an event's beginning to its probable ending. Following Csibra, Biro, Koos, and Gergely (2003), infants were habituated to a simple chasing event involving animated balls, and at test saw 2 possible endings: either 1 ball caught the other or failed to do so. Two controls were added to the previous work. First, the total amount of motion was controlled in the test endings; second, the endings were paired with a nonchasing beginning to ensure that behavior at test reflected representation of the event beginning itself. The results replicated Csibra et al.'s finding that infants look longer at the noncatching ending following the chasing beginning; moreover, infants showed no preference for either ending following the no-chasing beginning. This study supports the claim that infants can calculate the rational ending of a goal-directed motion event.

A critical aspect for making sense of events in the world is understanding the connection between the beginnings of events and their endings. Studies of infants' interpretations of events as goal directed (e.g., Woodward, 1998) or composed of causally related subevents (e.g., Leslie, 1984; Oakes & Cohen, 1990) bear on aspects of infants' representations of the connections between beginnings and end-

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ings of events. Indeed, in Csibra and Gergely's influential model of rational action (Csibra & Gergely, 1998; Gergely & Csibra, 2003), infants' ability to link the ending of an event to prior actions is a linchpin and helps serve as a base from which infants come to understand the role of intentions in determining outcomes.

Csibra and Gergely's model of infants' representations of rational action has three parts. They claim that infants represent goal-directed actions in terms of goals (Part 1) that are achieved via actions (Part 2), subject to the constraints of the environment (Part 3). The predictive power of the model comes from the principle of rationality according to which the actions taken to achieve goals satisfy a constraint of efficiency or least effort. Studies in support of this model (Csibra, Biro, Koos, & Gergely, 2003; Csibra, Gergely, Biro, Koos, & Brockbanck, 1999; Gergely, Nadasdy, Csibra, & Biro, 1995) have shown, for example, that infants expect actions to be rational with respect to the environment (i.e., infants expect a ball to jump to get over a barrier on the way to a goal, but their attention is drawn to an event in which a ball jumps needlessly in the absence of a barrier). They have also shown that infants infer the presence of an environmental constraint (e.g., a barrier) if shown an apparently irrational action (e.g., jumping when going behind an occluder; Csibra et al., 2003).

Moreover, infants appear able to calculate the goal of an event under some circumstances. Consider one of the experiments from Csibra et al. (2003, Experiment 1a). Infants were habituated to a large ball chasing a small ball. The small ball passed through a small gap in a barrier, and the large ball, unable to fit through the gap, moved around the barrier in pursuit. The infants were not shown what happened after the balls crossed to the other side of the barrier. At test, the other side of the barrier was revealed, and the small ball continued for a bit and then stopped. The large ball either caught up to the small ball (the catching outcome) or went past it and off the screen (the passing outcome). Infants looked longer at the passing outcome, suggesting that they represented the catching outcome as more natural or expected.

These data are consistent with the hypothesis that 12-month-old infants represent this event as goal directed and included a likely event ending as part of their representation. However, the conditions run so far leave open other explanations for the data. The preferred outcome in this study, the passing outcome, contained more total motion than did the catching outcome; infants may simply have looked longer at this outcome because it attracted more attention. More to the point conceptually, only a single event beginning was tested, so we cannot be sure whether infants' judgment about the event endings actually reflected knowledge about the connection between the beginning and ending of the event. Perhaps, rather, the passing event was simply intrinsically more interesting to the infants.

The study reported here aims to rectify these limitations. It provides a conceptual replication of Csibra et al.'s (2003) Experiment 1a, adding a control for the total amount of motion present in the test trials. In addition, to check for the possibility that infants' preference for one event ending over the other was independent of the event's beginning, a control condition was run in which the event's beginning was not chasing.

METHOD

Participants

In the chasing condition, 20 12-month-old infants were tested (*M* age = 12.01 months, range = 11.5–12.5 months); 11 were boys and 9 were girls. In the no-chasing control, 23 12-month-old infants were tested (*M* age = 12.00 months, range = 11.5–12.5 months); 12 were boys and 11 were girls. The data from an additional 17 infants were discarded because of experimenter error or equipment failure (3 infants), overall fussiness (i.e., infants failed to complete habituation or a counterbalanced set of test trials; 13 infants), and maternal interference (1 infant). Data from 2 additional infants were discarded because they were statistical outliers.[1] Infants were recruited through the database maintained by the New York University Infant Cognition Center and were given a token gift for their participation. Their parents were reimbursed for travel expenses.

Stimuli

The stimuli consisted of short animated movies created using Macromedia Director. Single event instances are described next; 12 event instances were strung together (separated by 1 sec interinstance intervals) in a continuous loop for each trial. The stimuli were presented on an 18 in. (45.7 cm) Macintosh computer screen using the Macromedia projector program.

Habituation. The screen's background was yellow with the upper half blacked out. Below the blacked-out portion was a gray barrier consisting of two lines separated by a small gap. In the chasing event beginning, a small red ball entered the display and moved on a roughly linear path straight through the gap in the barrier, disappearing into the blackness. Shortly after the red ball appeared, a larger blue ball entered the display and chased it. Moving slightly faster than the red ball, the blue ball swerved around the barrier and into the blackness (it was too large to fit through the gap in the barrier). The blue ball continued its movements for about 1 sec after the red ball had disappeared. The schematics of the chasing event are presented in Figure 1.

[1]The difference between these participants' looking times in the two test endings was more than 2.5 standard deviations from the mean difference. One outlier was from the chasing condition and one was from the no-chasing control condition.

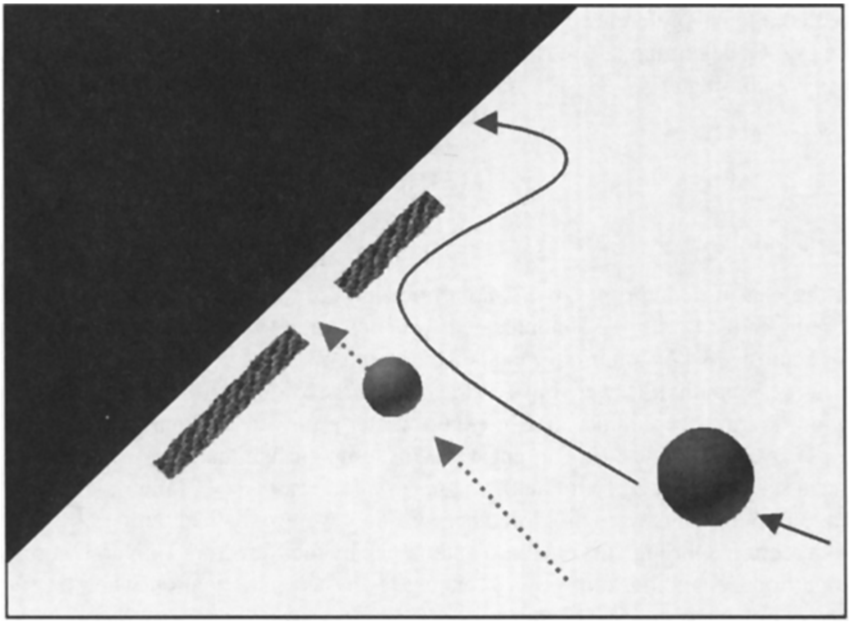

FIGURE 1 Schematic illustration of the chasing habituation event.

In the no-chasing control, the movements of the red ball were identical. The blue ball, however, no longer chased the red ball but instead entered from the upper right of the screen, dropped to the bottom of the screen, and bounced back up and around the barrier. A schematic drawing of the movie is shown in Figure 2.

The habituation movie lasted 6 sec; the balls were in motion during the first 5 sec and the last second showed the static background alone. During the inter-instance second, the barrier was removed, showing a screen that was half yellow and half black.

To ensure that the two habituation movies were genuinely different, we calculated two objective measures of the movies themselves: path overlap and a catch-up function. Path overlap was a measure of how closely the blue chaser ball followed in the footsteps of the red chasee ball. The red ball's path was laid on the display screen in the form of a line corresponding to the locations that the center of the ball had traversed. A movie frame was scored as containing an overlap if within it any portion of the blue ball overlapped with the path line of the red ball. The paths of the two balls overlapped on 33% of possible frames for the chasing movie and for 0% of the frames for the no-chasing movie. That is, during the chasing movie, the blue ball followed a path fairly similar to the red ball's (as one would expect from a chasing event); in the no-chasing movie, by contrast, the paths of the

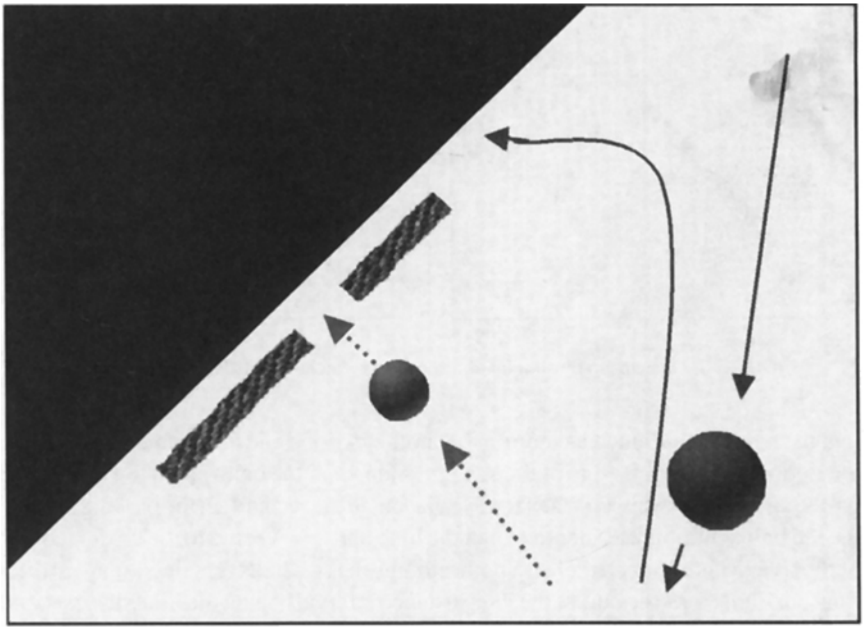

FIGURE 2 Schematic illustration of no-chasing habituation event.

two balls used completely nonoverlapping portions of the display. The catch-up function assessed the extent to which the distance between the two balls got linearly smaller (as one would expect from a successful chasing event). The distance between the two balls at their closest points was measured every fifth frame of the movie (the movie ran at 30 frames per sec) as the movie was shown on a 10 in. (25.4 cm) computer screen. The catch-up function was measured by plotting these distances and calculating the slope of the line that best fit the data. The best fit for the chasing movie was linear (R^2 = .99) with a slope of $-9.86x$. That is, with time the blue ball was steadily closing in on the red ball. The best fit for the no-chasing movie was quadratic (R^2 = .98) with a slope of $2.5x^2 - 29x$ (a linear fit of the data had R^2 = .78). That is, although the large ball got closer to the small ball as it dropped into the frame, it then reversed this function and began to get systematically farther from the small ball as the small ball went through the gap. This is not the function consistent with trying successfully to catch.

Test trials. For the test trials, the black half of the display was now also yellow and participants could see how the motion of the balls continued in that half of the screen. The test trial events began with the same motion patterns as seen in habituation, but they lasted 1 sec longer as the balls' motion continued. In the catching end-

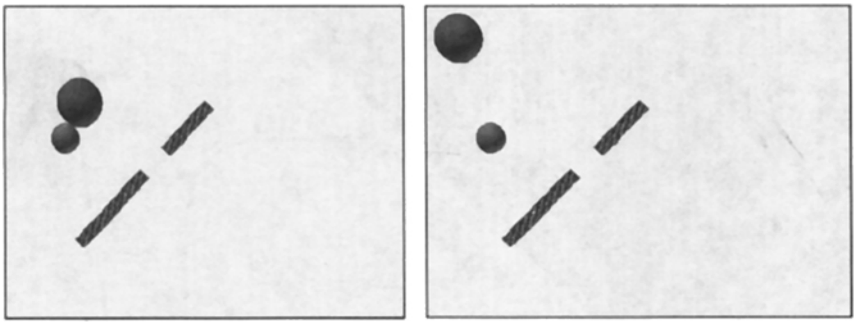

FIGURE 3 Schematic illustration of test endings: catching (left) and passing (right).

ing, the red ball continued its motion for another second and then came to a stop near the midpoint of the left edge of the screen. Then, the blue ball veered toward the red ball's position and stopped when it was adjacent to the red ball. In the passing ending, the red ball's motion was identical, but the blue ball now veered to the top left corner of the screen and stopped there. In both endings the two balls remained static in their final positions for 1 sec before the interinstance interval began; the final static second of these test trials was identical across habituation conditions and is shown in Figure 3. The test trial movies each lasted 7 sec; the balls reached their final positions at 6 sec and then remained there for 1 sec. During the interinstance second, the balls and the barrier were removed, showing a blank yellow screen.

Procedure and Coding

Infants were seated on a parent's lap approximately 3 ft. (0.9 m) away from the monitor. Parents were instructed to keep their babies on their laps (sitting or standing) but were told, and explicitly reminded, not to direct their child's attention in any fashion. A trial consisted of showing infants the habituation loop until they looked away from it for 2 consecutive sec (after having looked at it for at least 0.5 sec). If the infant did not look away, the trial was terminated when the loop ended (after 84 sec). There was an approximately 5-sec pause between trials, resulting from the time it took to stop and restart the movie. Infants continued to receive habituation trials until either (a) their looking times on 3 consecutive trials added to less than half the summed looking time from the first 3 habituation trials, or (b) they had seen 12 habituation trials. Infants were then presented with two pairs of test trials alternating between catching and passing trials. The order of presentation was counterbalanced across participants.

The presentation of the trials was controlled by an experimenter hidden in the same room as the infant. The infant's looking was monitored by a second experimenter in an adjoining room with access to the output of a camera placed next to the stimuli display. Looking times were recorded and the habituation criterion was calculated using the Xhab program (Pinto, 1995). The coding experimenter was completely blind to which test condition was being presented; the two experimenters communicated the beginning and end of trials through signals on a light box.

Pilot testing revealed that a large number of infants met the look-away criterion for ending a trial during the first 6 sec of the test trials. The data from such infants were useless, as these infants had not yet seen the ending of the event and so their behavior could not reflect a preference for one ending over the other. To avoid the high numbers of infants who had to be discarded for failing to dishabituate in this manner, the first 6 sec of the test trials was not counted. Infants were simply not allowed to end a test trial until the ending had appeared on the screen. Thus, an infant who in fact did look straight through for the first 10 sec of a test trial (and then looked away for 2 sec) would be coded as having a 4-sec looking time on that trial. Or, an infant who looked at the beginning of the test trial for 2 sec, then away for 6 sec, then back at the screen for 10 sec, would be coded as having a 10-sec looking time. If an infant did not look straight through the first 6 sec and then return to look at the trial for less than 7 sec, it is possible that the child's look did not include the event's ending (the infant could see just an interinstance interval plus the 6-sec run-up to the ending). When this occurred, the timing of the look was cross-checked with the movie to ensure that the infant's look did include the event's ending; when it did not, the data were excluded.

The data from every infant were coded offline by two coders to ensure reliability and to ensure the correct application of the 6-sec rule for the test trials. Coders were blind to the order of the test trials. Across all trials, the two coders agreed, on average, 93% of the time about when the baby was looking at the display.

RESULTS

The overall pattern of habituation and dishabituation at the test phase attests to the successful implementation of the habituation paradigm. Infants' looking times decreased across the habituation phase but recovered their interest in looking for the test trial phase. The habituation curve along with the mean looking time for the first test trial (collapsed across test trial type) is graphed in Figure 4. The mean number of trials needed for habituation was 7.05 for the chasing movie and 7.10 for the no-chasing movie. There was significant recovery (dishabituation) between the last habituation trial and the first test trial (collapsing across test trial type), as shown by a two-tailed paired t test conducted over the mean looking times for those two trials: chasing movie, $t(19) = 3.59$, $p < .002$; no-chasing movie, $t(19) = 2.24$, $p < .04$.

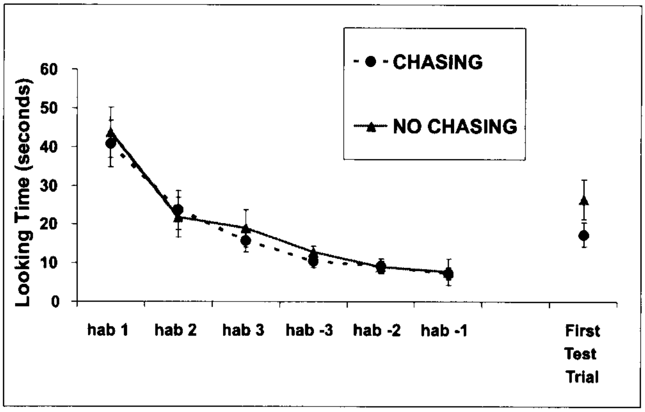

FIGURE 4 Mean habituation times for both event beginnings.

Analysis of infants' looking during the test trials following the chasing movie replicated the Csibra et al. (2003) result: Infants looked longer at the passing test trials than at the catching test trials. An analysis of variance (ANOVA) was conducted on these looking times, with ending order of presentation (catching first vs. passing first) as the between-subjects variable and test pair (first pair vs. second pair) and ending type (catching vs. passing) as within-subjects variables. This analysis revealed a main effect of test pair, $F(1, 18) = 4.36, p < .02$, which reflects a significant decrease in infants' looking from the first pair of test trials ($M = 17.3$ sec) to the second pair of test trials ($M = 8.3$ sec). The crucial effect concerns ending type: Did infants look longer at the passing ending? Given that this experiment was a replication and we had a directional prediction for the effect, we adopted a one-tailed criterion for significance. We found a main effect of ending type, $F(1, 18) = 3.72, p = .035$, one-tailed; infants did look longer at the passing ending ($M = 14.59$ sec) than at the catching ending ($M = 11.03$ sec). At the participant level, 15 of the 20 participants contributed to this effect ($p < .05$, Wilcoxon signed rank test, two-tailed). There was no effect of ending order and no significant interactions among the variables. Figure 5 shows the mean difference in looking to the two kinds of test trials.

By contrast, infants who watched the no-chasing movie showed no preference for either test ending. An ANOVA was conducted on the looking times, with ending order of presentation (catching first vs. passing first) as the between-subjects variable and test pair (first pair vs. second pair) and ending type (catching vs. passing) as within-subjects variables. This analysis revealed no main effects. Most important, there was no main effect for ending type: Infants looked at both catching and passing endings equally (see Figure 5). At the participant level, 12 of the 23

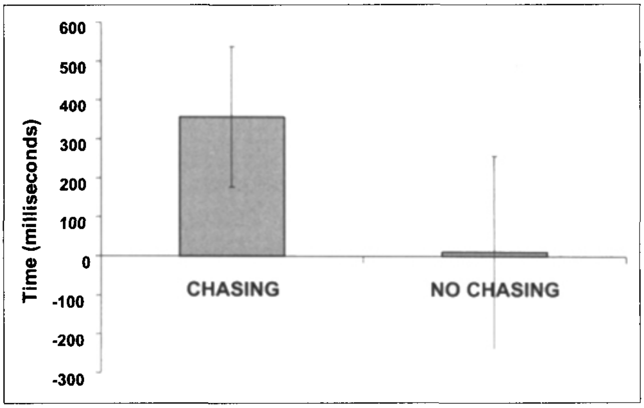

FIGURE 5 Mean difference in looking at test for both event beginnings.

participants looked longer at the passing ending (*ns*). There was only one significant interaction, Ending Order × Test Pair, $F(1, 18) = 16.53$, $p < .001$, resulting from overall higher looking times in the first test pair to both ending types when the passing ending was presented first but no differences between the ending orders in the second test pair. As far as we know, no interpretation of our experiment predicts such an interaction and we have nothing further to say about it. Inspection of the data revealed that what is happening in this experiment is that infants look longer at whatever kind of ending they see first: 19 of 20 participants showed this pattern.

Finally, an ANOVA was conducted on test trial looking times, with event beginning (chasing vs. no-chasing) as a between-subjects variable and event ending (catching vs. passing) as a within-subjects variable. There were no main effects and no interactions present in this analysis. Thus, although infants differentiated the catching and passing outcomes in the chasing condition, and failed to do so in the no-chasing condition (Figure 5), the difference between the two conditions was not statistically reliable, presumably due to the huge variance in looking times on the test trials of the no-chasing condition.

DISCUSSION

The experiments conducted here investigated 12-month-old infants' ability to calculate a probable representation of an event's ending based on seeing its beginning. The results of the experiments provide support in favor of the position that infants at this age can include information about a probable event ending in their representation of a motion event. Infants prefer to look at the unexpected ending of passing following a chasing event (a replication of Csibra et al., 2003) even when the total amount of motion in the two endings is equated. Moreover infants have no preference for either test ending following a no-chasing event, suggesting that they do not expect all motion events to end with a catching conclusion. These results, however, also suggest the capacity to calculate the ending of an event is fragile. The difference between the two types of test trials (passing and catching) following the chasing movie was significant only on a one-tailed test, and there was no statistical interaction between the test trial type (passing and catching) and the event beginning type (chasing and no-chasing).

Nevertheless, these results provide general support for the tripartite model of rational action proposed by Gergely, Csibra, and colleagues (Csibra & Gergely, 1998; Gergely & Csibra, 2003). Moreover the fact that infants behaved differently in the chasing and no-chasing conditions raised a question not explicitly addressed in Csibra and Gergeley's work: How do infants know when the model should be applied? Gergeley and Csibra suggested that goal attribution is triggered by equifinality (the same outcome is observed repeatedly) and by equipotentiality (different means or paths are taken to achieve the same end). However, these cues are only available when the infant sees the outcome and thus not in cases such as this one in which the infant must infer the ending of an event from its beginning.

Objective measurements revealed two differences between the two movies: degree of overlap of paths and the shape of the function relating the distance between the two objects over time. In an unpublished exploration of the relative importance of these two factors, we created a movie in which the path overlap was even higher (82% as compared to 33% of the chasing condition reported here; the red ball moved back and forth across the stage during the beginning event and the blue ball followed after it closely) but in which the gap between the two remained fairly constant. Adults viewed this "extended chasing" scenario as involving intentional chasing by the blue ball, but chasing in the sense of following, not in the sense of trying to catch. Infants did not differentiate the two endings. This suggests that path overlap is not sufficient to engage the mechanism that leads infants to predict catching in these events. Clearly, much more work is required to establish the bases on which infants predict endings from beginnings of events.

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