Research Report

TWELVE-MONTH-OLD INFANTS INTERPRET ACTION IN CONTEXT

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Abstract—*Two experiments assessed infants' understanding that actions that occur in sequence may be related to an overarching goal. Experiment 1 tested whether embedding an ambiguous action (touching the lid of a box) in a sequence that culminated with an action infants readily construe as goal-directed (grasping a toy inside the box) would alter infants' construal of the ambiguous action. Having seen the ambiguous action in this context, infants later construed this action in isolation as being directed at the toy within the box. Experiment 2 tested whether infants related the two actions on the basis of the temporal or the causal relation between them. When the causal relation was disrupted but the temporal relation was preserved, infants no longer related the two actions. These findings indicate that 12-month-old infants relate single actions to overarching goals and that they do so by construing goal-directed action in a causal framework.*

The propensity to see action as goal-directed is a powerful organizer in human cognition. Adults and children describe sequences of action in terms of the actor's goals (Heider, 1958; Lillard & Flavell, 1990; Trabasso, Stein, Rodkin, Munger, & Baugh, 1992), knowing the goal behind a series of events renders the series more easily remembered (Bransford & Johnson, 1972), and elements of a story that are relevant to the actor's goals are represented more strongly in memory than those that are not (Black & Bower, 1980). Underlying this organizational ability is the understanding that actions can often be interpreted as sequences deployed in service of an overarching goal (Schank & Abelson, 1977; Searle, 1983). For example, imagine a woman moving objects from one side of a crowded garage to the other. The goal behind her actions may not be obvious. Next, the woman wheels a lawn mower in from the driveway, fitting it into the newly cleared space. It now becomes apparent that the goal behind her earlier actions was to make a space for the lawn mower. As this example illustrates, the ability to relate actions to overarching goals is particularly useful when dealing with actions that are difficult to interpret on their own. In the current studies, we investigated the early development of the ability to relate actions in sequence and to use this relation to infer the goal of an ambiguous action.

Recently, researchers have begun to explore infants' understanding of action. Their findings indicate that infants can use certain perceptual cues to break a continuous stream of behavior into action-sized units (Baldwin & Baird, 1999; Sharon & Wynn, 1998; Wynn, 1996). Moreover, babies understand human actions not simply as a series of motions through space, but rather, as directed toward goals. Fourteen- to 24-month-olds draw on behavioral cues such as jerkiness of motion and vocal expressions of dismay to determine whether a novel action is intentional (Carpenter, Akhtar, & Tomasello, 1998; Tomasello & Barton, 1994), and, given contextual and behavioral cues, 18-month-olds can infer the goal of a novel action that is not completed (Meltzoff, 1995).

The roots of this ability extend earlier into infancy. Before they are a year old, infants interpret one familiar action, grasping, as goal-directed. In a previous study (Woodward, 1998), we used the visual habituation paradigm to investigate 6- and 9-month-old infants' representations of an event in which an actor moved her arm through a distinctive path in order to grasp one of two toys that sat side by side on a small stage. This event could be described in at least two ways: in terms of the motion of the actor's arm through space or in terms of the relation between the actor and the object that was her goal. The question was which of these features infants would weight more heavily in their representations of the event. This question was addressed by switching the positions of the toys following habituation to one event and then showing infants test events in which either the path of motion taken by the actor's arm or the object that was grasped had changed. Infants showed a greater novelty response (as indicated by longer looking) to the change in goal object than to the change in path. That is, when babies saw a person grasp an object, they paid special attention to the relation between the actor and the object. Moreover, infants differentiated between people and inanimate objects on this dimension. Infants who saw inanimate objects such as rods and mechanical claws move toward and touch or grasp the toy did not show this pattern. If anything, infants in these conditions tended to look longer when the path of motion was new. Follow-up analyses revealed that these results were not a by-product of infants' interest in hands versus rods or claws. Infants in all conditions had their attention drawn to the toy that was grasped or touched, but infants who saw a person grasp the toy differed from those who saw an inanimate claw in the features they weighted most heavily in their representation of the event.

In sum, infants give special weight to goal-related information in their representations of events in which a person acts. When dealing with single actions, then, infants' understanding of human behavior shares a critical feature with mature understandings. If infants were limited to construing only single actions as goal-directed, however, their understanding of human behavior would be fragmentary at best. For example, watching someone go to the kitchen to get a glass of milk, an infant limited in this way might construe some of the subunits as goal-directed (grasping the refrigerator door handle, grasping the milk carton, grasping a glass, etc.), but miss the fact that these units are parts of a higher-order plan. Moreover, the goals behind many aspects of the event (e.g., opening the milk carton, sniffing its contents, and pouring the milk into the glass) would remain uninterpretable.

These considerations raise the question of whether infants can interpret longer sequences of actions in terms of overarching goals. The current studies investigated this question for 12-month-old infants. We adapted the methodology developed by Woodward (1998) to ask whether infants' construal of a particular action is influenced by

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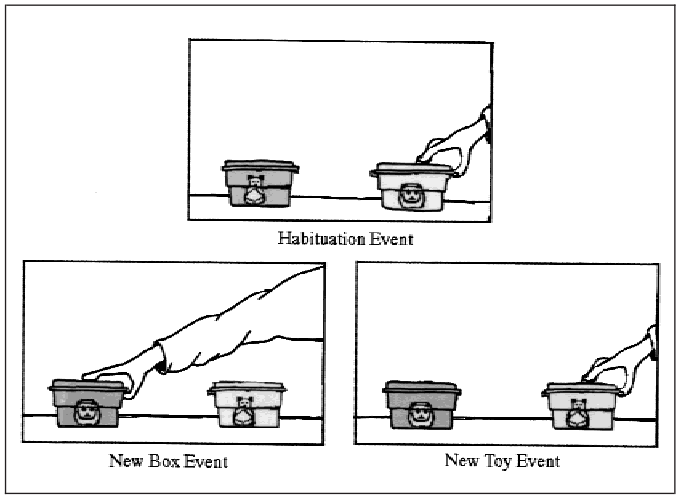

Fig. 1. Sample events for the single-action condition.

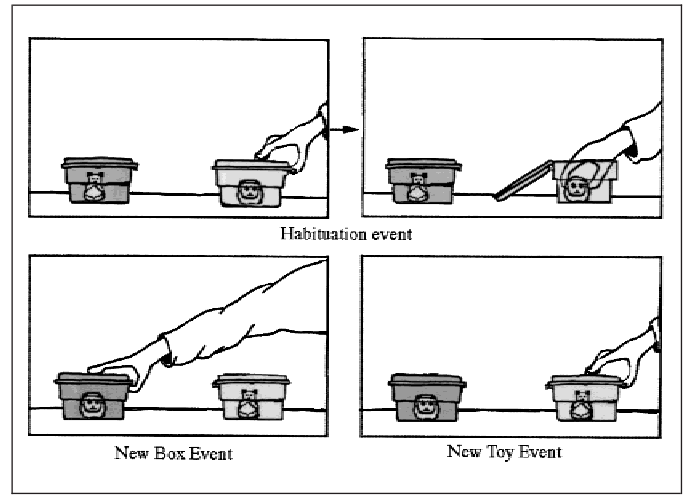

Fig. 2. Sample events for the embedded-action condition.

the actions that accompany it. We began with an action that was not interpretable as goal-directed by 12-month-olds, and then introduced it in a sequence that culminated in an action that infants readily interpret as goal-directed, namely, grasping. The question was whether this embedding would lead babies to interpret the ambiguous action as being directed toward a particular goal.

Babies saw a toy that was inside a closed, clear plastic box. An actor reached in and laid her hand on top of the box, hooking her thumb under the edge of the lid. We reasoned that this action might be ambiguous to infants. It could be directed at the box or at the toy inside the box. We tested this possibility in the *single-action condition* by habituating infants to the first event and then showing them test events in which the actor completed the same action on either a new box or the same box, which now contained a new toy. We reasoned that if infants construed the reach as directed toward the box, they would show a stronger novelty response (i.e., look longer) to the change in box. If they construed the reach as directed toward the toy, they would show a greater novelty response to the change in toy. In the *embedded-action condition*, the ambiguous action was followed by the actor opening the box and grasping the toy inside. After habituation, infants saw the same test events as in the single-action condition. The question was whether this embedding would lead infants to interpret the touch to the box lid as being directed toward the toy inside the box. If so, then infants in this condition would be predicted to look longer when the relation between the actor and the toy had changed than when the relation between the actor and the box had changed.

EXPERIMENT 1

Participants

Forty full-term infants participated in Experiment 1 (mean age = 11 months, 22 days; range: 10 months, 21 days to 12 months, 26 days). Ten additional infants began testing but were excluded from the final sample because of experimental error ($n = 8$) or failing to complete all of the test trials as a result of distress ($n = 2$). Twenty infants were tested in the single-action condition, and 20 were tested in the embedded-action condition. There were 12 boys and 8 girls in the single-action condition (mean age = 11 months, 21 days) and 10 boys and 10 girls in the embedded-action condition (mean age = 11 months, 23 days).

Procedure

Infants saw the experimental events presented on a small stage at a distance of 30 in. Sitting side by side on the stage were two tinted clear plastic boxes (one purple and one blue), each of which contained a small toy (a bear or a tiger). At the start of each trial, an actor reached in through a curtain at the side of the stage to lay her hand on top of one of the boxes, hooking her thumb under the edge of the lid. Only the actor's arm, clothed in a magenta sleeve, and her bare hand were visible to the infant. In the single-action condition, and during the test trials in both conditions, the event ended at this point (see Fig. 1). In the habituation phase of the embedded-action condition, after the actor touched the lid, she opened the box, reached inside, and grasped the toy (see Fig. 2). In each condition, the action was performed once per trial. The actor remained still, with her hand on the box or grasping the toy, until the trial ended. A screen was raised from below the stage to hide it from view between trials. The actor retracted her hand (and closed the box if necessary) once the screen was in place. Then the screen was lowered and the next trial began. The infant's looking was timed beginning when the actor's hand had stopped moving and ending when the infant looked away for 2 s. Infants' looking was coded on-line over video by an observer who could not see the experimental events and was not informed of the condition to which the infant had been assigned.[1]

1. To assess reliability, we asked a second observer to code each infant from videotape. The two observers were counted as agreeing if they identified the same endpoint for a trial. On this criterion, the coders agreed for 88% of test trials in the single-action condition and 84% in the embedded-action condition. Disagreements were categorized according to whether the video coder judged that the trial had ended too soon or too late. These disagreements were randomly distributed across trial types for each condition (Fisher's exact tests: $p > .99$ for the single-action condition, $p = .52$ for the embedded-action condition).

Table 1. *Median total looking time during the last three habituation trials and the three test trials of each type*

Condition	Last 3 habituation trials	Test trials	
		New toy	New box
Experiment 1			
Single-action	7.7 (2.9)	13.9 (6.0)	15.1 (7.5)
Embedded-action	8.5 (3.8)	21.5 (6.6)*	15.5 (5.5)
Experiment 2			
Toy-out-of-box	9.4 (2.7)	14.5 (5.3)	20.0 (4.5)

Note. Median absolute deviations are given in parentheses.
*Different from comparison test event, $p < .05$.

Infants were shown the same event on each trial during habituation. The habituation phase ended when the infant's looking had decreased by 50% over a 3-trial window, or when 14 trials had been completed. Following habituation, the positions of the toys were switched, and infants were given 1 trial in which the actor did not reach into the stage area to familiarize them with the new locations. Then, infants in both conditions saw the same two test events in alternation for a total of 6 trials: On *new-toy* trials, the actor reached in and touched the top of the box she had touched during habituation, which now contained a different toy; on *new-box* trials, the actor touched the top of the other box, which contained the same toy as the one contained in the box she had touched during habituation. This event also involved a new path of motion for the actor's arm. The side of the reach during habituation and the order of test trials were counterbalanced within each condition.

Results and Discussion

Table 1 summarizes infants' looking times for the habituation and test trials in each condition. To reduce positive skew, we subjected the looking-time scores to a log transformation before parametric tests were conducted. Our first analyses confirmed that infants in the two conditions showed comparable levels of attention in the habituation phase. Looking times on the last three habituation trials did not differ as a function of condition ($t < 1$). Infants' rate of habituation did not differ as a function of condition. Infants in the single-action condition averaged 10.1 habituation trials, and infants in the embedded-action condition averaged 9.4 habituation trials ($t < 1$).[2]

We next explored infants' responses to the two test events. Preliminary analyses revealed no reliable effects of the side of the habituation reach or the test trial given first. Therefore, subsequent analyses were collapsed across these dimensions. An analysis of variance (ANOVA) conducted on the looking times for each trial type with condition (single-action vs. embedded-action) as the between-subjects variable and trial type (new-box vs. new-toy events) as the within-subjects factor yielded a condition-by-trial-type interaction, $F(1, 38) = 4.79$, $p < .05$, and no other reliable effects. Planned comparisons revealed that infants in the single-action condition did not differ in their looking times on the two kinds of test trials, $t(19) = 0.78$, $p = .44$. Thus, infants in this condition did not clearly interpret the touch as directed at either the toy or the box. In contrast, infants in the embedded-action condition looked longer on new-toy trials than on new-box trials, $t(19) = 2.58$, $p < .05$. That is, infants looked longer when the actor's hand was in relation to a new toy, even though in this event the hand followed the same path of motion and rested on the same box as during the habituation trials. Thus, embedding the touch in a sequence culminating in a grasp of the toy within the box affected infants' interpretations of the touch.

In a follow-up analysis, we tested the possibility that infants in the single-action condition failed to differentiate between the new-toy and new-box events because of a lack of overall attention. One piece of evidence against this possibility is the absence of a main effect of condition during the test phase, which suggests that infants in the two conditions were equally attentive. We also approached this question by analyzing infants' recovery from habituation. Infants' total looking time on the last three habituation trials was compared with their total looking times on the three new-box events and the three new-toy events. These analyses revealed that infants in both conditions recovered attention on both types of test trials: single-action condition, new-toy trials, $t(19) = 3.53$, $p < .005$; single-action condition, new-box trials, $t(19) = 4.10$, $p < .001$; embedded-action condition, new-toy trials, $t(19) = 7.07$, $p < .0001$; embedded-action condition, new-box trials, $t(19) = 4.65$, $p < .001$. Thus, inattention does not account for the findings in the single-action condition.

The results of the first experiment indicate that infants attended to the sequence of actions, and used a familiar action in the sequence (grasping) to interpret a novel action (the touch to the box lid). This raises the question of how infants related the two actions. Recent evidence indicates that 8-month-old infants are adept at extracting the conditional probabilities of occurrence of sequential stimuli (Saffran, Aslin, & Newport, 1996). It is possible that infants use this ability when interpreting action, relating any two actions that occur in sequence. If so, infants would, of course, differ dramatically from mature reasoners. Adults do not assume that any two actions in sequence are in service of a single overarching goal. At a picnic, an adult who sees someone swat at a mosquito and then reach for another helping of potato salad would not assume that the swat and the reach were related to the same goal.

To inform inferences about how actions are related, adults draw on

2. Seven infants in the single-action condition and 2 in the embedded-action condition completed 14 habituation trials without meeting the habituation criterion. When these infants were excluded from the analyses, the interpretation of the results was unchanged.

knowledge about the causal constraints in a situation (Schank & Abelson, 1977; Searle, 1983). The example we began with illustrates this process. If the woman working in her garage had cleared a space the size of a shoe box, an adult would not consider the possibility that her goal in doing so was to move the lawn mower inside. The physical constraints in the events in Experiment 1 could have led infants to relate the box touch to the grasp of the toy because in order to gain access to the toy, the actor had to first remove the box lid. Thus, touching the box lid was causally related to freeing access to the toy. Prior research indicates that infants under 1 year of age understand the physical constraints imposed by containment. Baillargeon, Graber, DeVos, and Black (1990) found that 5 1/2-month-old infants did not expect a person to be able to retrieve a toy that was covered by a container if the container was not first removed. Did infants use this knowledge in interpreting the goals of the actor in Experiment 1? We conducted a second experiment to address this question. The procedure was identical to that of the embedded-action condition in Experiment 1 with one important difference: The toys sat outside and in front of the boxes. Thus, touching the lid and grasping the toy were no longer causally related, although they occurred in the same temporal sequence as in Experiment 1.

EXPERIMENT 2

Participants

Twenty full-term infants (8 boys and 12 girls) participated in Experiment 2 (mean age = 12 months, 0 days; range: 10 months, 24 days to 13 months, 12 days). Three additional infants began testing but were excluded from the final sample because of experimental error ($n = 1$) or because they moved off camera during test trials ($n = 2$).

Procedure

The design and procedure were the same as those in the embedded-action condition in Experiment 1 except that each toy sat outside and in front of one of the boxes.[3] The toy was centered with respect to the front of the box, with its back surface 2 in. from the front of the box.

Results and Discussion

Table 1 summarizes infants' looking times for the habituation and test trials. Infants in Experiment 2 averaged 8.9 habituation trials. To reduce positive skew, we subjected the looking-time scores to a log transformation before parametric tests were conducted. We first explored infants' responses to the two test events. Because preliminary analyses revealed no reliable effects of the side of the habituation reach or the test trial given first, subsequent analyses were collapsed across these dimensions. Planned comparisons revealed a nonsignificant trend for infants to look longer on new-box trials than on new-toy trials, $t(19) = 1.67$, $p = .11$.[4] Therefore, seeing the grasp and touch events in temporal sequence did not lead infants to interpret the touch as directed toward the toy.

In a second analysis, we compared the data from this study with the data from infants in the embedded-action condition in Experiment 1. An ANOVA conducted on the looking times for each trial type with condition (embedded-action vs. toy-out-of-box) as the between-subjects factor and trial type (new-box event vs. new-toy event) as the within-subjects factor revealed a trial-type-by-condition interaction, $F(1, 38) = 9.25$, $p < .005$, and no other reliable effects, confirming that infants responded differently to the sequence of events when the toy was inside the box as opposed to being outside of it.

Finally, we analyzed recovery from habituation to test the possibility that infants were inattentive on test trials. Comparisons between the final three habituation trials and the three test trials of each type revealed that infants recovered attention reliably for both new-toy and new-box trials, $t(19) = 2.39$, $p < .05$, and $t(19) = 3.28$, $p < .005$, respectively.

GENERAL DISCUSSION

We began with an ambiguous action—when the actor touched the top of the box in the single-action condition in Experiment 1, 12-month-olds did not clearly interpret the touch as directed at either the box or the toy within it. After seeing the touch followed by the actor opening the box and grasping the toy, infants interpreted the touch as directed at the toy: During test trials, when the actor touched the box but did not open it, babies responded to a change in the relation between the actor and the toy. That is, 12-month-olds interpreted the first action, touching the box lid, on the basis of the action that occurred afterward, grasping the toy. The findings of Experiment 2 indicate that infants drew on the causal constraints in the situation in making the link between the two actions. When the two actions occurred in the same temporal sequence, but the causal relation between them was disrupted, infants did not link the two actions. These findings suggest that these 12-month-old infants interpreted action in context in two senses: They used both the other actions performed by the actor and the causal constraints in the situation to interpret an ambiguous action.

The ability to link actions that occur together provides infants with a powerful tool for making sense of human behavior. This ability would enable infants to form coherent representations of action sequences at the level of "getting a drink of milk" rather than at the level of "grasping the milk carton." In so doing, infants must represent goals as in some way separable from the particular actions that they drive. It is possible that younger infants initially conceive of goals as inherent in particular actions. Our findings indicate that by 12 months, infants are on the path to understanding a critical aspect of intentional action, namely, that goals exist independent of particular actions.

In addition, our findings suggest that the ability to relate actions in sequence enriches infants' understanding of particular actions. Through seeing actions such as touching the lid of a box, twisting the top to a jar, or pulling open the drawstrings of a bag in sequences that culminate in the actor obtaining the object within the container, infants may come to construe these actions as directed at particular kinds of goals.

Seeking connections between actions that co-occur is useful, but linking any two actions that occur in sequence would be a hazardous move, leading to potentially faulty inferences about goal structure. By

3. Reliability for this study, assessed as in Study 1, was 93%. The direction of disagreements was randomly distributed across trial types (Fisher's exact test: $p > .99$).

4. Three infants completed 14 habituation trials without meeting the habituation criterion. When these infants were excluded from the analysis, the preference for the new-box test event was somewhat stronger, $t(16) = 1.94$, $p = .07$.

using causal relations as a basis for linking actions in sequence, babies in the current studies avoided this error. More generally, seeking causal relations between events has been argued to play a central role in conceptual development, leading to rich, theory-like knowledge structures (Carey, 1985; Gopnik & Meltzoff, 1997; Keil, 1992). Our findings indicate that by 12 months of age, infants construe goal-directed action in a causal framework. This early reasoning could contribute to the development of a theory of mind or theory of action.

One potential limit on infants' ability to relate actions in sequence is the complexity of causal relations they can consider. As part of reasoning that the actor did Y in order to get X, infants seem to have understood that in order for X to happen, Y had to happen first. Thus, one prerequisite for the ability to relate actions in sequence may be the attainment of means-end reasoning. There is debate in the literature about when this occurs. Some researchers place this achievement at around 12 months, based on infants' ability to solve problems such as removing a barrier to obtain a toy (Diamond, 1991; Piaget, 1952/1974). However, Baillargeon et al. (1990) reported that when infants observe actions rather than acting themselves, they understand means-end sequences well before this, at 5 1/2 months. Given this finding, and the fact that infants as young as 6 months construe grasping as goal-directed, infants under 12 months may be able to interpret the goal of an action on the basis of sequences like the ones used in the current studies. Further research is required to investigate this possibility.

In addition, infants' ability to relate actions in sequence would be limited by the kinds of causal constraints that they can consider. In understanding action, adults consider not only the physical constraints present in a situation, but also the psychological constraints (e.g., what a person knows) and social constraints (e.g., conventionally appropriate behaviors). To the extent that infants lack knowledge about these constraints, their ability to construe actions in context will be limited. In addition, it is not clear whether, like adults, infants can think ahead to possible actions. Seeing a lawn mower sitting in the driveway would suggest why someone would be clearing a space in the garage, just as seeing an actor with her hand on the lid of a box would suggest that she was interested in obtaining the toy inside. Twelve-month-old infants did not seem to make this inference in the current studies. When babies saw the actor repeatedly rest her hand on the box in the single-action condition in Experiment 1, they did not interpret this action as directed at the toy. It is possible that given additional behavioral cues (e.g., if the actor were shown to be looking into the box and smiling) or contextual information (e.g., if they were allowed to play with the boxes and toys before the study), babies might have made this inference. Nevertheless, in the absence of these potentially helpful cues, infants were able to interpret an ambiguous action on the basis of the behavioral and physical context.

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