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Explanation-Based Learning in Infants
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Explanation-Based Learning in Infants

by

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Thesis

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Abstract

Applies an AI theory of learning, called explanation-based learning, to infant learning to explain one way in which infants learn about the physical world. Two experiments examined 12-month-old infants ability to observe an event and distinguish between relevant and irrelevant modifications of the event. In Experiment 1, infants saw a rod being pushed through a block with a hole in it. Then they saw two modifications- one possible, with a plastic rod very different in appearance from the original rod, but having the same diameter, and one impossible, with a fat rod that was identical to the original rod except that it was three times larger in diameter. The older 12-month-old infants looked reliably longer at the impossible than at the possible event, suggesting that they understood that for a rod to fit through a hole, the rod's diameter cannot be larger than the size of the hole. Experiment 2 was identical to Experiment 1 except that the infants were never shown the size of the hole in the block, as the infants in Experiment 1 were, and therefore both modifications to the event were possible. These infants looked reliably longer at the event with the plastic rod than at the event with the fat rod. Together, the results of Experiment 1 and Experiment 2 indicated that the infants, after observing an initial event, were able to make predictions for future events.

As adults, we live in a world about which we hold many beliefs. We have countless assumptions about how objects should behave in the world. This makes our environment very predictable. We know that if we put our coat in the closet, it will remain there until someone removes it. We know that if we drop a glass on a hard surface, it will probably break. Where do these beliefs come from, and how long have we had them? At what age do infants begin to share our knowledge about the physical properties of objects, and how do they acquire it? The present research addresses this question of infant learning.

Piaget's (1954) ideas about learning, or the specific development of infants' beliefs, have shaped the direction of research in the area of infant cognition since the early 1950's. He held that infants are born with absolutely no knowledge about the physical world. Recognizing that infants are very active, he asserted that it is through action that infants construct knowledge about objects. In other words, their actions are their "origins of intelligence." According to Piaget, infants from the time of birth begin to structure their world through interactions with the environment. This structuring evolves in a systematic way that is basically the same for all infants. Thus, all infants pass through the same stages of cognitive development. This development, resulting from action, is not surprisingly tied very closely

to sensorimotor development.

Until recent years, Piaget's constructivist theory of infant learning was widely accepted. However, in light of recent research which challenges Piaget's theory, it is now believed that infants have a much more sophisticated view of the physical world than was presumed.

One challenge has addressed Piaget's assertion that infants do not represent the existence of hidden objects until 9 months of age. Piaget based his conclusion on the fact that it is only at this age that infants begin to search for fully occluded objects. Today, many researchers use measures of infants' looking behavior instead of search tasks to investigate whether infants understand that objects continue to exist when hidden. Using measures of habituation of looking, Baillargeon (1987) found evidence of object permanence in some infants as young as 3.5-months-old. The 3.5- and 4.5-month-old infants in this study were habituated to a screen that rotated back and forth through a 180-degree arc in the manner of a drawbridge. Following habituation, a box was placed behind the screen and the infants saw two test events: a possible and an impossible event. In the possible event, the screen rotated until it reached the occluded box, stopped there, and then returned to its original position; in the impossible event, the screen rotated until it reached the occluded box and then continued as though the box was no

longer behind it. The screen rotated through the whole 180-degree arc before reversing direction and returning to its initial position, revealing the box standing intact in the same location as before. The 4.5-month-old infants, and the 3.5-month-old infants who were fast habituators, looked reliably longer at the impossible than at the possible test event. This suggests that they (a) believed that the box continued to exist after it was occluded by the screen; (b) understood that the screen could not rotate through the space occupied by the box; and hence (c) expected the screen to stop when it reached the box and were surprised that it failed to do so.

Infants' knowledge about adequate and inadequate support has also been examined by Baillargeon and Hanko-Summers (1990). In one experiment, infants between 7.5-months and 9.5-months of age were shown a small box that was centered between and supported by two larger boxes. Neither of these boxes alone provided adequate support for the small box. Prior to the experiment, the infants were shown that the small box was either attached to or separate from the left box. All infants were shown the same test event: the right box was moved to the right so that the small box was now supported only by the left box. The infants who saw the small box as separate from the left box looked reliably longer than the other infants at the test event, suggesting

that they realized that the left box alone did not provide adequate support for the small box, and were therefore surprised that the small box did not fall during the test event.

Considering yet another aspect of object behavior, Spelke and Kestenbaum (1986) presented evidence suggesting that infants at 4 months of age have some understanding of spatiotemporal continuity. That is, they expect objects to move continuously through space and over time.

Is it possible, then, to say that young infants have no concept or knowledge of objects? Most research today suggests it is not. The physical world perceived by the infant appears to be much more sophisticated than was believed by Piaget.

Given that infants demonstrate knowledge of physical properties well before they manipulate objects, the question becomes one of how they acquire this knowledge. Where does this knowledge come from?

Spelke (in press) asserts that infants are born with a very rich, sophisticated conception of the physical world which guides their behavior. According to this view, infants are born with an innate understanding of objects and of some of their physical and spatial properties. Spelke draws support for this position from recent research, as was mentioned earlier, which suggests that Piaget's theory is not

completely accurate in specifying the knowledge infants hold at certain ages. Infants, according to Spelke, are endowed with an initial object concept. More specifically, infants enter the world with a concept of objects as "cohesive, bounded, substantial, and spatiotemporally continuous." The object concept "is present, albeit in impoverished form, near the beginning of life....[and] reveals itself through the way infants organize and make sense of the world they perceive" (Spelke, in press). This object concept, contrary to Piaget's theory, does not depend on the development of sensorimotor activity.

Alternatively, Baillargeon (1987) has proposed that perhaps infants are born with powerful learning mechanisms which allows them to learn in a variety of ways through observing the world around them. These ways could include analogy-based learning and similarity-based learning, as well as the type of learning specifically addressed in the present research which is called explanation-based learning. Explanation-based learning (EBL) is a term borrowed from the field of artificial intelligence (AI) (DeJong, in preparation). It has not previously been applied to infant learning. This could be partially due to the fact that EBL is a relatively young concept in the realm of artificial intelligence itself, and is the object of much research in the field. It can be viewed as a type of "learning from

observation" which allows a system to analyze a few specific episodes, build explanations, and through this obtain general knowledge. Background knowledge is very important in this process. In AI, the important feature of this model is the way in which the system uses an explanation built from a few examples: through understanding how or why the specific examples work, it then generalizes that specific information to other problems with similar properties (e.g. it goes from specific to general knowledge). This differentiates it from, for example, similarity-based learning which requires the consideration of many examples and very little background knowledge (i.e. applies general knowledge gained from many examples to address a specific problem). In EBL, by using only a few examples, the system "defines the boundaries of a concept" in what we call an explanation. This concept definition, or explanation, is determined by speculation guided by background knowledge of why the example worked, not by similarities and differences between the present example and previous instances, as is the case in similarity-based learning. Then the system can use the explanation it has built by generalizing it to solve other similar problems (DeJong, in press).

When applied to infant learning, the concept remains much the same. The theory asserts that when infants observe an event in the physical world (e.g. a green, wooden stick

pushing a red ball, causing it to roll) they build some type of explanation for it, using their background knowledge. This explanation may or may not be correct. A correct explanation would be one in which the infant identifies the properties of the event or objects which are important or relevant to the specific task at hand (e.g. the stick impacting the ball). If infants build correct explanations for events which they observe, then they should be able to generalize this information and make correct predictions about how the objects should behave in future events. In particular, they should be able to differentiate between a relevant modification (e.g. the stick being pushed, but stopping a few inches before hitting the ball) and an irrelevant modification (e.g. changing the color or texture of the stick) of the event. If one of the objects is transformed in a way that should disrupt the event shown to the infant (e.g. the stick not touching the ball), then the infant who has built a correct explanation for this event should predict this disruption. If this disruption does not occur, the infant will probably be surprised.

A concrete example and evidence for this type of learning in children can be drawn from a study devised by Baillargeon, Gelman, and Meck (in preparation) to test causal reasoning in 3- and 4-year olds. The children were shown a causal event as follows: a rod was pushed through a post and

hit the first of 5 standing blocks; each block fell on the block next to it in a domino-like fashion and the fifth block fell on a small lever, causing a toy rabbit to jump into a small bed. The children were then asked about relevant and irrelevant modifications to the sequence, but the sequence was not performed for them using the modifications. An example of a relevant modification was showing them a rod too short to reach the first block. An example of an irrelevant modification was using a rod that was a different color. When asked to predict whether these modifications would affect the outcome, the rabbit falling, all the children were reliably able to predict which modifications were relevant and which were irrelevant. These findings provide a good illustration and lend excellent support to the theory of explanation-based learning. The children in the experiment observed an event, a causal sequence. They were subsequently able to make correct predictions about modifications of the sequence, indicating that they had built a correct cognitive explanation of the event. They were able to use the specific information they observed, identify relevant variables, and generalize these explanations to novel situations, all the components of EBL. Does this type of learning exist in infants as well?

Experiment 1

In the present experiment, 12-month-old infants were first habituated to an event in which a wooden rod was pushed through a wooden block with a hole running through it; the rod had the same diameter as the hole in the block. Following this habituation phase, the infants were shown 2 modifications of the original event, in which different rods were used. In one modification, the new rod was almost identical to rod in the original event (e.g. same color, length, texture) but its diameter was three times larger than the diameter of the original rod, making it much too large to fit through hole in the block. However, during this event, the new rod "magically" fits through the block. In the other modification, the new rod is very different in appearance from the original rod; it is longer and made of clear plastic. However, the relevant variable, the diameter, is the same as that of the original rod. This experiment was designed to test the explanation-based learning theory. According to the theory, the infants would build an explanation for the original event during the habituation phase, and would then be able to generalize this knowledge to make predictions about the subsequent modifications to the event. Our predictions are as follows: if the infants built a correct explanation for the original event (e.g. one in which they identified the rod diameter as the relevant

variable), then they would (a) expect the event to be disrupted when the fat rod was used, but not when the plastic rod was used, and (b) indicate surprise when the fat rod does not disrupt the event by looking longer at this event than at the event using the plastic rod.

Method

Subjects

Subjects were 32 full-term infants ranging in age from 11 months, 28 days, to 13 months, 3 days (M= 12 months, 19 days). Four additional infants were eliminated from the experiment: 1 because of procedural error, 2 because of fussiness, and 1 because of equipment failure. The infants' names were obtained from the birth announcements in a local newspaper. Parents were contacted by letters and follow-up phone calls. They were offered reimbursement for their travel expenses but were not compensated for their participation.

Apparatus

The apparatus consisted of a large wooden box, resembling a puppet theater, which was 182 cm high, 103 cm wide, and 61 cm deep. The infants faced a large opening 33 cm high and 93 cm wide in the front wall of the apparatus. The floor of the apparatus was pale blue; the back wall was white decorated with pastel colors; the sides were white decorated with thin primary color stripes.

The objects used in the events included a metal stand, two rectangular wooden blocks, two wooden rods, and a plastic rod.

The metal stand consisted of a horizontal metal square, 7.5 x 7.5 cm with a 5 x 5 cm hole at its center, made of a flat sheet of metal. From the middle of the left and right sides of the square protruded a 1.75 cm screw. Beneath the square was attached a 3 cm skirt made of green material. This metal square was affixed at the top of a vertical metal rectangle 15.5 cm high, 7.5 cm wide, and .01 cm thick. The vertical metal rectangle was covered with bright red contact paper. This entire fixture was mounted on another piece of flat metal which lay on the ground and was hidden by the stand, and a weight was placed on this piece of metal to hold the stand firmly in place.

The two rectangular wooden blocks were identical in every aspect except for the size of the hole in each block. The blocks were 7.5 cm wide, 7.5 cm deep, and 12.5 cm high. They were painted bright yellow with a thin hot-pink stripe around the top and bottom. Each block also had a hole running through the longest dimension. In one block, the hole was 1.3 cm wide, and was outlined by a thin stripe of green paint; in the other block, the hole was 3.2 cm wide. Each block also had 4 small holes, 2 on the bottom and 2 on the back, to help secure the block on the stand.

The two wooden rods were identical except for the size of their diameter. They were both 30.77 cm long and painted deep blue. One rod, which we will refer to as the habituation rod, had a diameter of .97 cm; the other, which we will refer to as the fat rod, had a diameter of 2.9 cm.

The plastic rod was made of clear plexiglass. It was 39.7 cm long and .97 cm in diameter.

The lights of the room in which the infants were tested were off during the experiment, and the stage was brightly lit by four clip-on lights (each with a 40-W lightbulb) attached to the back and side walls of the apparatus. This was done to keep the infants' attention focused on the stage only. Two wooden frames, each 182 cm high and 71 cm wide and covered with blue cloth, stood at an angle on either side of the apparatus. These frames isolated the infants from the experimental room. A muslin-covered frame 61 cm high and 100 cm wide, used as a curtain, was lowered in front of the opening in the front of the apparatus at the end of each trial.

Events

Experimenter 1 (E1) manipulated the objects on the floor of the apparatus to produce the experimental events, while Experimenter 2 raised and lowered the curtain between trials. To help E1 perform the event at a consistent rate, a metronome beat softly once per second. As the events are

described below, the number of seconds taken to perform each part of the event is listed in parentheses after the description of the action.

Block-Down Habituation Event. At the start of this event, the metal stand stood in the center of the apparatus floor, 26 cm from the back wall of the apparatus and 40 cm from the infant. The block with the small hole lay to the right of the stand with the hole facing the infant; the habituation rod lay to the right of the block. E1, wearing a bright blue glove, lifted the block into the air and held it, with the hole facing the infant, at the infant's eye level (see Figure 1). After the infant had looked at the block for 4 cumulative seconds, E1 placed the block on the stand (2 s) horizontally so the hole was still visible to the baby (the screws on the stand fit into the small holes on the bottom of the block so that the block was secured in place). Next, E1 picked up the habituation rod (1 s), rotated it in the air next to the block horizontally and vertically (4 s), moved it to the hole at the back of the block (2 s), pushed and pulled the rod through the block (4 s), and finally took the rod out of the block and returned it to its original position on the floor of the apparatus and rested there (3 s). E1 repeated this 16 s cycle until the computer signaled that the trial had ended (see below).

Block-Up Habituation Event. This event was identical to the block-down habituation event, except that E1 placed the block on the stand vertically instead of horizontally. In this case, the infant only saw the hole at the very beginning of the each trial, before the beginning of the 16 s cycle of action, but not during the cycle, because when the block was placed vertically on the stand, the top of the block was too high for the infant to see. As the rod was pushed through the block, the infant could not see it come through the hole in the bottom because this was hidden by the green skirt attached to the square portion of the stand (they did see the rod appear below the skirt, but were unable to see the hole). (see Figure 1)

Possible Test Event. At the start of the possible test event, the block with the small hole stood vertically on the stand; the infant could not see the hole from the top or bottom. Laying side by side on the floor of the apparatus to the right of the stand were the habituation rod and the plastic rod. E1 tapped the plastic rod lightly on the floor of the apparatus until the infant had looked at the rods for 4 cumulative seconds. Next, E1 lifted the plastic rod and rotated it horizontally and vertically next to the block (4 s), moved the plastic rod to the hole at the top of the block (2 s), pushed and pulled the plastic rod through the block (4 s), and finally took the rod out of the block and placed it

back in its original position next to the habituation rod (3 s). The motions in this 13 s cycle were identical to the motions in the habituation event (after the point when E1 placed the block on the stand and reached for the habituation rod), and the cycle was repeated until the trial had ended.

Impossible Test Event. This event was identical to the possible test event except for the following: (a) the block with the large hole was used instead of the block with the small hole, although to the infant, who couldn't see the hole, this block appeared identical to the block used in the possible test event (they were not given any information which would lead them to believe that this was a different block); and (b) the fat rod was used in place of the plastic rod. Although this fat rod was much too large to fit through the small hole, and therefore should have disrupted the event, the event proceeded with no disruption. To adults, this would seem to be impossible.

Procedure

Prior to the experiment, each infant was allowed to manipulate the 3 rods, the metal stand, and the wooden block with the small hole (the infant was never shown the block with the large hole) while his or her parent filled out some consent forms. During the experiment, the infant sat on the parent's lap in front of the apparatus. The parent was asked not to interact with the infant during the test trials. At

the start of the test trials, the parent was instructed to close his or her eyes so as not to influence the infant's reactions to the event.

The infant's looking behavior was monitored by two trained observers who watched the infant through peepholes in the cloth-covered frames on either side of the apparatus. The observers could not see the experimental events, and they did not know the order in which the test events were presented. Each observer held a button linked to a MICRO/PDP-11 computer and depressed the button when the infants attended to the experimental events. Interobserver agreement was calculated for each trial on the basis on the number of seconds for which the observers agreed on the direction of the infant's gaze out of the total number of seconds the trial lasted. Disagreements of less than 0.1 seconds were ignored. Agreement in this experiment averaged 93% per trial per infant. The looking times recorded by the primary observer were used to determine when the trial had ended.

At the beginning of the experiment, all the infants saw four habituation trials: two trials of the block-up habituation event alternated with two trials of the block-down habituation event. Then each infant was shown three pairs of test trials, each pair consisting of one possible and one impossible test event. Half of the infants were

shown the impossible event as the first event in each pair, and the other half saw the possible event as the first event in each pair. Each habituation and test trial ended when the infant either (a) looked away from the event for 2 consecutive seconds after having looked at it for at least 10 seconds, or (b) looked at the event for 60 cumulative seconds. Thirty of the 32 infants completed three pairs of test events. One infant only completed two pairs of test events because of fussiness, and for another infant, the third pair of test events was eliminated because of low interobserver agreement.

Results

The infants looking times during the test phase of the experiment were compared by means of a 2 x 2 x 3 mixed model analysis of variance with Order (impossible or possible event first) as the between-subjects factor and with Event (impossible or possible event) and Pair (first, second, or third pair of test trials) as the within-subjects factors. The analysis showed no significant difference in the infants' looking times at the impossible than at the possible test events, $F(1,151) = .12$. However, it appeared that the older infants in the sample tested tended to look longer at the impossible than at the possible event, whereas the younger infants tended to look equally at the two events. To test this, Age was added as a between-subjects factor to our

model. We divided infants into two groups: Younger (11 months, 28 days to 12 months, 15 days) and Older (12 months, 16 days to 13 months, 3 days). This ANOVA revealed a significant Age x Pair x Event interaction, $F(2,41) = 3.14$, $p < .05$, indicating that the two age groups showed significantly different patterns of looking at the three pairs of impossible and possible test events (see Figure 2). Planned comparisons showed that on the first test pair, the older infants looked reliably longer at the impossible ($M=43.4$ s) than at the possible ($M=32.4$ s) event, $F(1,146) = 5.56$, $p < .05$, whereas the younger infants looked equally at the impossible ($M=34.8$ s) and the possible ($M=39.8$ s) events, $F(1,146) = 1.15$, $p > .05$. On the second and third test pairs, both the older and the younger infants looked about equally at the impossible and the possible test events, all F 's < 0.98 .

Discussion

The older 12-month-old infants looked reliably longer at the impossible than at the possible test event on the first pair of events. This suggests that they (a) identified rod-diameter as the relevant variable for the event, (b) predicted that the fat rod should not fit through the block, and hence (c) were surprised when the fat rod did go through the block. This is especially interesting because the plastic rod (with the irrelevant modifications) was

perceptually very different from the habituation rod and was therefore more novel than the fat rod, yet even though infants tend to look longer at perceptually novel objects, the older infants still looked much longer at the fat rod event, which was impossible. The novel appearance of the plastic rod could explain partially why a reliable difference in looking time is not shown in the second and third pairs of test events for the older infants. This will be discussed in Discussion of Experiment 2.

One difficulty with the design of Experiment 1 was that the infants could have looked longer at the impossible event simply because they preferred the fat rod to the plastic rod. Therefore, a control experiment (Experiment 2) was conducted in which infants were not given the information which would enable them to discriminate between the relevant and irrelevant modifications of the event (i.e. they were never shown the size of the hole in the block). If the looking patterns were similar to those in Experiment 1, then a simple preference for the fat rod would be the most parsimonious explanation for the results presented. However, if the looking patterns differed from those in Experiment 1, it could be taken as an indication that the infants in Experiment 1 used the information from the habituation phase to make predictions, and that their looking patterns were not simply due to a preference for the fat rod over the plastic

rod.

Experiment 2

Experiment 1 showed that the older 12-month-old infants looked reliably longer on the first pair of test events at the impossible event (fat rod) than at the possible event (plastic rod). Experiment 2 was designed to find out whether the infants simply preferred the fat rod over the plastic rod without understanding the impossibility of the fat rod fitting through the block.

This experiment was identical to Experiment 1 except that the infants were never shown the size of the hole in the block. Without this information, both test events could be possible, because the hole could be any size. Therefore, if the infants in this condition still showed a preference for the event with the fat rod, then it would not be possible to take this preference as an indication of surprise at the event in Experiment 1. However, because the experiment was identical in every other way, if these infants showed no preference for the event with the fat rod, it would be reasonable to suggest that in Experiment 1, the infants did use the information about the hole size and predicted that the plastic rod but not the fat rod could be pushed through the block.

Method

Subjects

Subjects were 11 healthy, full-term infants ranging in age from 12 months, 17 days to 13 months, 4 days (M = 12 months, 25 days). Three additional subjects were eliminated, two because of adverse conditions in the experimental room, and one because of procedural error.

Apparatus

The apparatus was identical to the apparatus in Experiment 1.

Events

All four habituation trials were identical to the block-up habituation events in Experiment 1, except that at the beginning of each trial, E1 held the block vertically (instead of horizontally) in the air so that the hole could not be seen by the infant. The rest of each trial proceeded exactly like the block-down habituation events in Experiment 1.

In Experiment 2 there were two test events, a plastic-rod event and a fat-rod event, identical to the possible and impossible events in Experiment 1 respectively. Notice that although these test events used the exact same modifications as the test events in Experiment 1, neither modification would necessarily disrupt the event. For ease in comparing the two experiments, we will refer to the test events in

Experiment 2 as possible (instead of plastic-rod event) and impossible (instead of fat-rod event) test events, although both events were actually possible.

Procedure

Prior to the experiment, all the infants were allowed to manipulate the three rods and the stand. They were not shown the wooden block. The procedure followed was exactly the same as in Experiment 1. Interobserver reliability averaged 95% per trial per infant.

Results

Figure 3 shows the mean looking times at the impossible and possible events of the older 12-month-old infants in Experiment 1 and of the infants in Experiment 2 (control condition). The looking times of the infants in Experiment 2 were analyzed by means of a 2 x 2 x 3 mixed model analysis of variance with Order (impossible or possible event first) as the between-subjects factor and with Event (impossible or possible) as the between-subjects factor and Pair (first, second, or third pair of test events) as the within-subjects factors. The results showed a significant effect of Event, $F(1,50) = 4.83, p < .05$, indicating that the infants looked reliably longer at the possible ($M=35.7$ s) than at the impossible ($M=29.9$ s) event.

Discussion

The results of Experiment 2 indicated that the infants had a reliable preference for the possible event (i.e. the plastic rod). This is consistent with two interpretations: (1) the plastic rod in the test event was perceptually more novel to the infants, and therefore, consistent with evidence that infants look longer at novel objects or events, they looked longer at this event; or (2) the infants had an intrinsic preference for the plastic rod over the fat rod. Either way, the absence of a preference for the fat rod provides evidence that the older 12-month-olds in Experiment 1 looked longer at the impossible than at the possible event not because they preferred the fat rod, but because they believed that the fat rod was too large to fit through the hole, and were surprised when it did. Why, then, did the infants in Experiment 1 show a preference for the impossible event on only the first pair test events? One possibility, supported by the results of Experiment 2, is that there were two opposing tendencies, one for the event with the fat rod which was impossible, and one for the plastic rod which was more novel. Another possible explanation is that the infants were initially surprised at the impossibility of the event with the fat rod, but built some type of explanation for it and quickly lost interest. For example, they may have decided that there must be two blocks, one with a very large hole, and therefore the fat rod was able to fit through. If

they built this explanation during the first pair of test events, then the impossible event would have lost its "magic", so to speak, and it would be understandable that the infants lost interest.

Conclusions

The combined results of Experiment 1 and Experiment 2 provide firm evidence for explanation-based learning in 12-month-old infants. The information given to the infants in Experiment 1 about the size of the hole in the block seemed to affect their interpretation of subsequent similar events (the test events). We suggest that they build some type of cognitive explanation for the event in which they identified the important variables, and were thus able to make predictions about future events. When the experimental manipulation violated these predictions, they looked longer, indicating surprise. If infants do have the capacity to build explanations from observing events, then this supports the assertion mentioned earlier by Baillargeon (1987) that infants are born with powerful learning mechanisms which allow them to learn in a variety of ways. Explanation-based learning may be one of those ways. In order to confirm this hypothesis (that infants are born with this ability to learn through building explanations), evidence for this type of learning must be found in much younger infants. Research such as this is currently underway.

How do infants learn about the physical world?

Possibly, as Piaget (1954) asserted, they learn some things by manipulating objects in the world. But this clearly does not give us the whole picture. Perhaps, as Spelke (in press) suggests, they are born with some initial object concept.

But clearly this concept changes and becomes more sophisticated over time. Explanation-based learning may help us to understand the changes in infants' perceptions of the physical world and give us a clearer view of infant development.

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Figure Captions

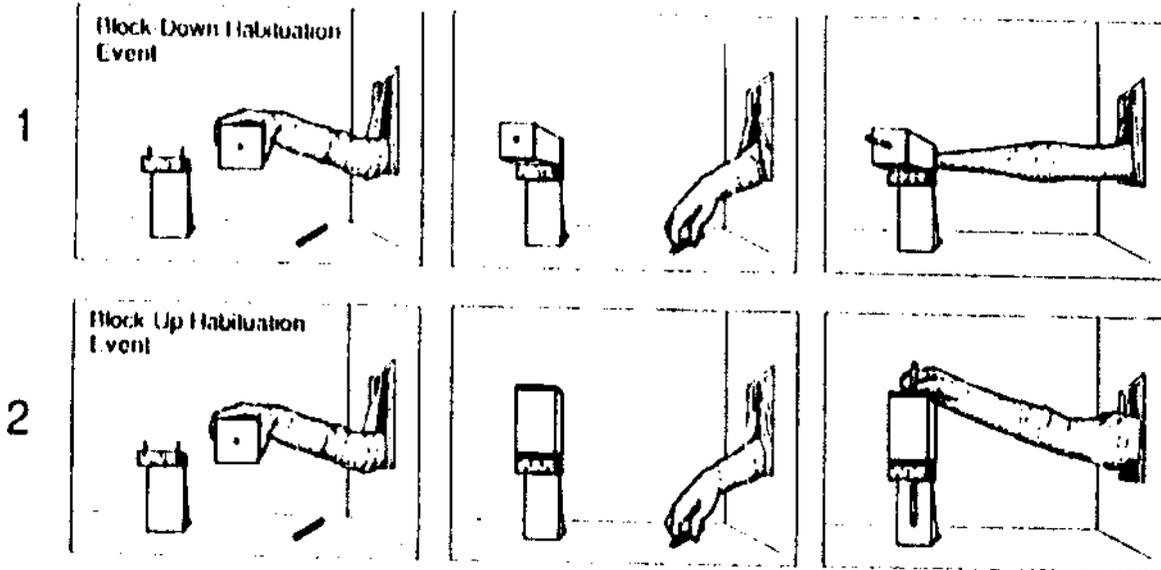
Figure 1. Schematic drawing of the habituation and test events shown to the infants in Experiment 1.

Figure 2. Mean looking times of the infants in Experiment 1 at the possible and impossible test events after they had been divided into two age groups, Young and Old.

Figure 3. Mean looking times of just the older 12-month-old infants from Experiment 1 and all the infants (also older 12-month olds) from Experiment 2 at the Plastic Rod Event (possible for both groups) and the Fat Rod Event (impossible in Experiment 1 but possible in Experiment 2).

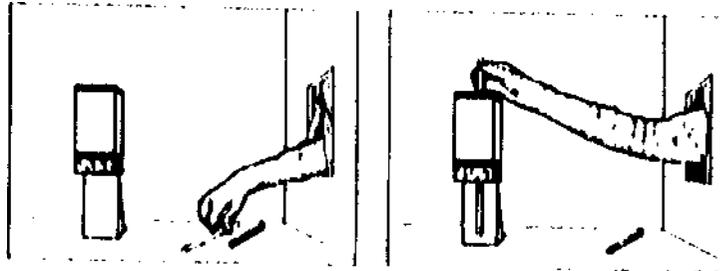
Figure 1
Experiment 1

Habituation Events



Test Events

Possible Event



Impossible Event

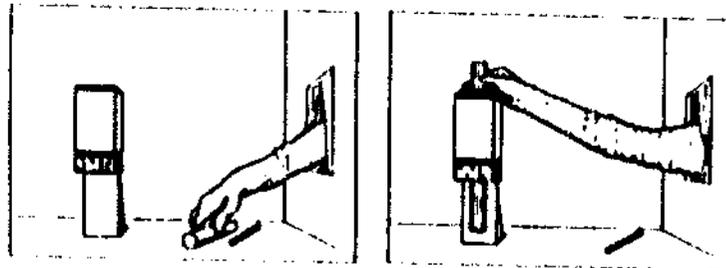


Figure 2
Experiment 1

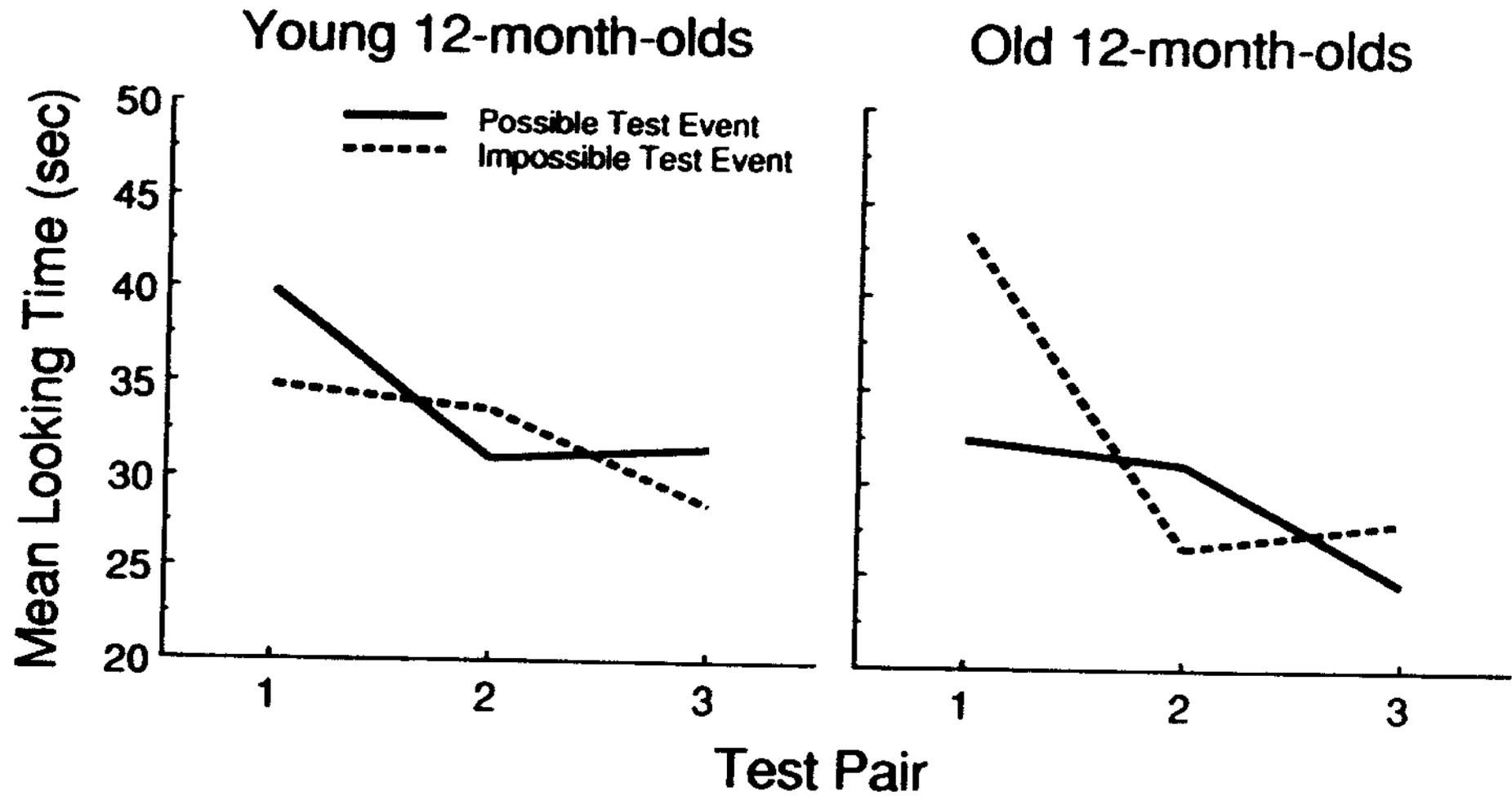


Figure 3
Old 12-month-olds

