Representation of Objects and Events: Why Do Infants Look So Smart and Toddlers Look So Dumb?

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Abstract

Research has demonstrated that very young infants can discriminate between visual events that are physically impossible versus possible. These findings suggest that infants have knowledge of physical laws concerning solidity and continuity. However, research with 2-year-olds has shown that they cannot solve simple problems involving search for a hidden object, even though these problems require the same knowledge. These apparently inconsistent findings raise questions about the interpretation of both data sets. This discrepancy may be resolved by examining differences in task demands.

Keywords

infant cognition; development; search tasks

A paradox has emerged in the developmental literature. On the one hand, a wealth of research from more than a decade of exciting studies shows that very young infants have knowledge of physical laws concerning continuity and solidity (Baillargeon, Graber, DeVos, & Black, 1990; Spelke, Breinlinger, Macomber, & Jacobson, 1992). On the other hand, recent work has revealed a surprising lack of such knowledge in children between 2 and 3 years of age (Berthier, DeBlois, Poirier, Novak, & Clifton, 2000; Hood, Carey, & Prasada, 2000). The question is raised: Are there true discontinuities, even regressions, in children's concepts of the physical world? Or can the discrepancies between the infant and the toddler data sets be resolved by pointing to differences in task requirements? Or perhaps the explanation lies in differences in methodology. For example, in the infant studies the dependent measure is looking, and in the toddler studies it is active search. Whatever the explanation, this paradox must be resolved before a comprehensive theory of early cognitive development can be constructed.

Beginning with the seminal article by Baillargeon, Spelke, and Wasserman (1985), the emerging picture of infants has been that 3- to 4-month-olds show a stunning sophistication in their perception of the physical world. The typical paradigm in this line of research entails the presentation of an event (e.g., a rotating screen in Baillargeon et al., 1985; a rolling ball in Spelke et al., 1992) during repeated trials (referred to as *habituation* trials). Test trials consist of equal numbers of "possible" (*consistent*) events, which accord with the natural laws of physics, and "impossible" (*inconsistent*) events, which break those laws. The assumption is that if infants look longer at inconsistent than at consistent events, they have detected an incongruence with the physical law.

INFANT STUDIES ABOUT OBJECT AND EVENT REPRESENTATION

The procedure in the infancy studies can be clarified by considering an example from Experiment 3 in Spelke et al. (1992). During habituation trials, 3-month-old infants saw a ball roll from the left and disappear behind a screen. A bright blue wall protruded above the screen. When the screen was lifted, the ball could be seen resting against the wall on the right side of the display. Following these trials, an obstacle was placed on the track to the left of the wall, with the topmost part of the obstacle, as well as the blue wall, showing above the screen. On test trials, the ball was again rolled from left to right. For the inconsistent event, when the screen was raised the ball was resting in the old place by the wall, so that it seemed to have violated rules of solidity (i.e., two solid objects cannot occupy the same space at the same time) and continuity (objects exist continuously and move on connected paths over space and time). By appearing at the far wall, the ball seemed to have moved through the solid obstacle or discontinuously jumped over it. For the consistent event, when the screen was raised the ball was resting against the obstacle, a novel position but one that conformed to physical laws. The infants looked significantly longer at the inconsistent event than at the consistent event. A control group saw the ball in the same positions when the screen was raised, but the ball's movement had not violated any physical laws. This group looked at the ball equally in the old and novel locations, thus indicating that they had no intrinsic preference for either display and no preference for the original position.

From this and other experiments, investigators have drawn the conclusion that very young infants reason about objects and events by drawing on some form of knowledge about solidity and continuity (Baillargeon, 1993; Spelke et al., 1992).

SURPRISING RESULTS FROM TODDLERS

The discordant results from toddlers come from experiments presenting the same type of physical event—a rolling ball that goes behind a screen and stops—but in this case the child's task is to actually find the ball (Berthier et al., 2000). The apparatus (see Fig. 1) features a wooden screen with four doors that hides the progress of the ball down the track. The ball is always stopped by a barrier, which can be positioned at any of the four doors. The cue to the ball's location is the top of the barrier protruding several centimeters above the screen. If the child understands physical laws of solidity and continuity, he or she should open the door by the barrier. Test trials consist of the experimenter placing the barrier on the track and lowering the screen to conceal the track. Then the experimenter draws the child's attention to the ball and releases it at the top of the track. Finally, the child is invited to open a door to find the ball.

In Figure 2, the columns labeled "opaque" show individual performance on this task in the study by Berthier et al. (2000). Children under 3 years old performed no better than would be expected if they were simply guessing at the ball's location. Of 16 children in each age group, no 2-year-old and only three 2.5-year-olds performed above chance levels; 13 of the 3-year-olds did so, however. (Note: Data for 3-year-olds are not displayed in Fig. 2.) The almost total lack of success for children under 3 years of age was quite surprising, and in a series of studies my colleagues and I have sought to understand why their performance is so poor.

Fig. 1. View of the apparatus used for the toddler task. The child is opening the third door, and the ball, resting against the wall, is visible through the door. From "Where's the Ball? Two- and Three-Year-Olds Reason About Unseen Events," by N.E. Berthier, S. DeBlois, C.R. Poirier, J.A. Novak, and R.K. Clifton, 2000, *Developmental Psychology*, *36*, p. 395. Copyright by the American Psychological Association. Reprinted with permission of the author.

Offering more visual information about the ball's trajectory seemed like a reasonable way to help the toddlers (Butler, Berthier, & Clifton, 2002). We replaced the opaque wooden screen with a transparent one of tinted Plexiglas, leaving four opaque doors to hide the bottom of the wall and the ball's final resting position. Otherwise we kept the procedure and the rest of the apparatus the same. Now children had a view of the ball as it passed between doors, with the additional cue of no emergence beyond the wall. Despite this substantial increase in visual information about the ball's whereabouts, 2-year-old children still had great difficulty in searching accurately: Only 6 out of 20 children performed above chance. Of the 12 children tested at 2.5 years of age, 10 were above chance, so this age group benefited notably from the additional information (see data in Fig. 2 labeled "clear").

We also recorded eye gaze, monitored from a digital video camera trained on the child's face. Children at both ages were highly attentive as the ball was released, and they tracked its movement down the ramp on 84% of trials. Two aspects of their tracking behavior predicted their response: the point where they stopped tracking the ball and whether they broke their gaze before choosing a door. For older children, tracking the ball to its disappearance was the most typical pattern, and this virtually guaranteed they would open the correct door. A different story emerged for the 2-year-olds. Like 2.5-year-olds, they typically tracked the ball to its final location, but this did not ensure success. If they looked away after correctly tracking the ball, they made errors, although this was not the case for 2.5-year-olds (Butler et al., 2002).

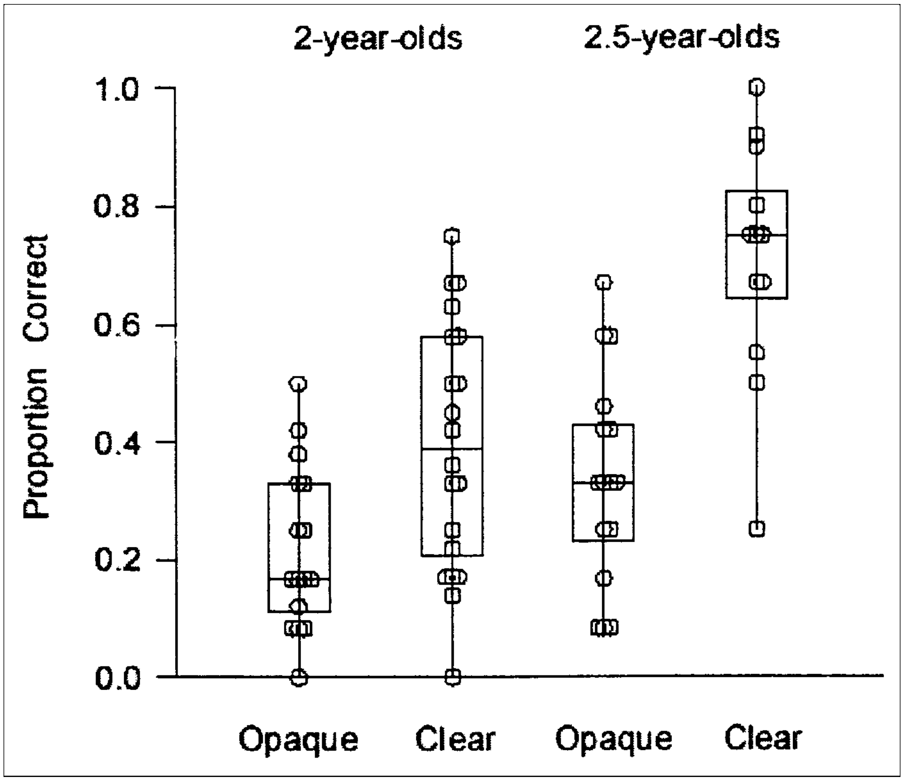

Fig. 2. Proportion of trials correct on the first reach for 2- and 2.5-year olds. Results are shown separately for trials with an opaque screen and a transparent screen. Each circle represents one child's performance. The boxes enclose the second and third quartiles of the distributions, and the horizontal lines in the boxes are the medians. From "Two-Year-Olds' Search Strategies and Visual Tracking in a Hidden Displacement Task," by S.C. Butler, N.E. Berthier, and R.K. Clifton, 2002, *Developmental Psychology*, *38*, p. 588. Copyright by the American Psychological Association. Reprinted with permission of the author.

IS THE PROBLEM KEEPING TRACK OF HIDDEN MOVEMENT?

A second visual manipulation was tried (Mash, Keen, & Berthier, in press). We hypothesized that if the children were given a full view of the ball's trajectory until it came to rest against a wall, they would be able to search correctly. In effect, we reversed the sequence of events that concealed the ball: In our previous studies (Berthier et al., 2000; Butler et al., 2002), the screen was first positioned in front of the ramp, hiding most of it from view, and then the ball was released at the top of the ramp, going out of sight while still moving. In this new study, the ball rolled down the ramp and came to a stop by a wall, then the screen was lowered to conceal both the ramp and the ball. At that point, the child's task was the same as in previous studies—open a door to find the ball. Note, however, that in this case the child did not have to reason about solidity and continuity in order to find the ball. Keeping track of its position behind the screen was all that was required.

Allowing complete access to the ball's movements benefited the older children somewhat, but the great majority of 2-year-olds still had enormous problems. Only two out of eighteen 2-year-olds tested performed above chance, whereas seven out of eighteen 2.5-year-olds did. As when we used the clear screen, gaze offered clues as to why children failed. If children looked at the ball as the screen was lowered and maintained this orientation until opening a door, they were correct about 90% of the time. Most children, however, broke their gaze, which resulted in errors. Merely watching as the screen was lowered over the ramp and ball did not aid search; only a continuous fixation up to the point of choosing the door led to success.

WHAT ABOUT TASK DIFFERENCES?

In the infant task, 3- to 4-month-old infants looked longer at physically impossible events than at possible events (Baillargeon et al., 1990; Spelke et al., 1992). No prediction was required on the infants' part, as they simply reacted to a visual array of an object in the wrong place or the right place. In contrast, the search task used with toddlers involved prediction and planning within a more complex apparatus. In order to make the infant and toddler tasks more comparable, we designed a looking-time task in which the same door apparatus was used, but the children never opened a door (Mash, Clifton, & Berthier, 2002). Instead, they observed the same events as before, but a puppet, Ricky the raccoon, opened the door.

Most of the time, Ricky opened the correct door and removed the ball. But on test trials, Ricky opened an incorrect door (no ball found, a physically possible, or consistent, event) or opened the correct door but found no ball (a physically impossible, or inconsistent, event). After the door was opened and no ball was found, the experimenter raised the screen to reveal the ball resting against the wall (consistent event) or beyond the wall (inconsistent event). This visual array is highly similar to what infants saw on the test trials of Experiment 3 in Spelke et al. (1992), described earlier. Like the infants, the toddlers looked longer at the inconsistent placement of the ball than at the consistent placement. This result was independently corroborated by a looking-time study with toddlers that used a similar apparatus but a different procedure in which the experimenter opened the doors while the child watched (Hood, Cole-Davies, & Dias, 2003).

CONCLUSIONS

To interpret the results of these studies, first consider what can be ruled out as an explanation of toddlers' poor performance in this search task. The results from the original study using an opaque screen (Berthier et al., 2000; and from Hood et al., 2000, as well) suggested that toddlers have no knowledge of continuity or solidity. In the clear-screen study (Butler et al., 2002), 2-year-olds again failed to recognize the barrier's role in stopping the ball. Maintaining gaze on the spot where the ball disappeared was the behavior most predictive of correct door choice—more evidence that toddlers did not reason about this physical event. But unexpectedly, taking away the reasoning requirement did not lead to success. Observing the disappearance of a stationary ball should have enabled the children to select the correct door if the problem were either hidden movement or the necessity to reason about the barrier's role (Mash et al., in press). The fact that performance remained poor in this condition rules out these explanations of toddlers' poor search performance. The puppet study, which used looking as the response rather than reaching, found that 2-year-olds, like infants, looked longer at the inconsistent event (Mash et al., 2002). This study rules out the disconcerting possibility that infants are endowed with knowledge about physical events that gets lost during development, and is regained around 3 years of age. Finally, although infants and toddlers both fail in search tasks that require a reaching response, previous work not discussed here demonstrated that 6-month-olds will reach for objects hidden by darkness (Clifton, Rochat, Litovsky, & Perris, 1991). Thus, it is not the response of reaching, in contrast to looking, that is the cause of infants' and toddlers' failure, but rather a problem of knowing where to search.

What could be the toddlers' problem in the search task? A distinct possibility, already mentioned, is the requirement of prediction. In order to plan and execute a successful search, toddlers had to know the ball's location in advance. Moreover, they had to coordinate this knowledge with appropriate action. Further research is needed to determine if either or both of these aspects are critical. One means of exploring this possibility is to devise new tasks that require location prediction but have fewer spatial elements to be integrated than the ball-barrier-door task and require simpler action plans.

A second prime issue needing further investigation is the relation between gaze behavior and search. Choice of the correct door was associated with continuous gaze at the hiding event; gaze breaks before searching were fatal to success. These data imply that children did not use sight of the barrier's top as a cue for the correct door. Likewise, adults faced with an array of 20 identical doors with no further marker might well use unbroken gaze at the point of disappearance as a strategy. If confusion among identical doors is the children's problem, then making the doors distinct should help. This manipulation coupled with careful analysis of gaze could determine whether the toddlers' problem is simply spatial confusion among identical doors. If so, the interesting question remains as to why the barrier's top does not cue location.

Finally, a theoretical issue is unresolved. The results for the looking-time task indicate that toddlers, and even infants, have some knowledge about the ball's expected location, but the contents of their knowledge is unclear. According to Spelke (Spelke et al., 1992), the principles of continuity and solidity are part of a constant core of physical knowledge that infants are endowed with. Infants of 3 to 4 months in age mentally represent hidden objects and can reason about an object's motion being constrained by continuity and solidity. Spelke et al. (1992) did not claim, however, that the infants in their study could predict the ball's location, and the toddler data suggest that infants' and even 2-year-olds' reasoning may be limited to recognizing after-the-fact incongruent events. If so, perceptual recognition of implausible event outcomes seems like a valuable building block on which to construct further knowledge, and eventually prediction, about the physical world.

Recommended Reading

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Note

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Why People Fail to Recognize Their Own Incompetence

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Abstract

Successful negotiation of everyday life would seem to require people to possess insight about deficiencies in their intellectual and social skills. However, people tend to be blissfully unaware of their incompetence. This lack of awareness arises because poor performers are doubly cursed: Their lack of skill deprives them not only of the ability to produce correct responses, but also of the expertise necessary to surmise that they are not producing them. People base their perceptions of performance, in part, on their preconceived notions about their skills. Because these notions often do not correlate with objective performance, they can lead people to make judgments about their performance that have little to do with actual accomplishment.

Keywords

self-evaluation; metacognition; self-concept; overconfidence; performance evaluation

Real knowledge is to know the extent of one's ignorance.

—Confucius

Confucius' observation rings just as true today as it did 26 centuries ago. To achieve and maintain an adequate measure of the good life, people must have some insight into their limitations. To ace an exam, a college student must know when he needs to crack open his notebook one more time. To provide adequate care, a physician must know where her expertise ends and the need to call in a specialist begins.

Recent research we have conducted, however, suggests that people are not adept at spotting the limits of their knowledge and expertise. Indeed, in many social and intellectual domains, people are unaware of their incompetence, innocent of their ignorance. Where they lack skill or knowledge, they greatly overestimate their expertise and talent, thinking they are doing just fine when, in fact, they are doing quite poorly.

IGNORANCE OF INCOMPETENCE: AN EXAMPLE

Consider the following example. In a sophomore-level psychology