

RESPONSE

Can 12 large clowns fit in a Mini Cooper? Or when are beliefs and reasoning explicit and conscious?

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This is a response to commentaries on Baillargeon (2004) by Hood (2004), Leslie (2004) and Bremner and Mareschal (2004).

A few clarifications

In their commentaries, Hood, Bremner and Mareschal raise several important and difficult questions about what can and cannot be attributed to infants based on their responses in violation-of-expectation (VOE) tasks. I address a few of these questions below.

1. Can we attribute to infants who detect a violation in a VOE task explicit knowledge of the physical beliefs involved in the task? Consider the 12-month-olds who respond with increased attention when a tall object becomes fully hidden under a short cover (Wang, Baillargeon & Paterson, in press). Can we say that these infants possess an explicit belief that ‘objects continue to exist when hidden’, or that ‘two objects cannot occupy the same space at the same time’, or that ‘tall objects cannot become fully hidden under short covers’? Surely not. It seems very unlikely that infants possess explicit beliefs about anything. What they do possess is an abstract computational system, a physical-reasoning system, which monitors physical events and flags those that do not unfold as expected for further scrutiny – hence the increased attention. The system is skeletal at first but rapidly improves as relevant variables are identified. However, it is highly doubtful that the knowledge used by the physical-reasoning system to monitor events is either explicit or conscious.

Hood, Bremner and Mareschal may ask why, if I believe that infants do not possess explicit or conscious knowledge about objects and events, I use terms such as ‘reason’ and ‘infer’ to describe the cognitive processes that underlie infants’ responses in VOE tasks. The answer is simple: it is not possible to do otherwise. The

7.5-month-old infants who are surprised when a tall object becomes fully hidden inside a short container must reason, in some manner and at some level, that the object is too tall to become fully hidden inside the short container (Hespos & Baillargeon, 2001). Similarly, consider the 3.5-month-old infants who are surprised when a toy mouse fails to appear in a screen’s low window (1) if the screen is lowered at the start of the trial to reveal only one mouse, but not (2) if the screen remains upright throughout the trial or (3) if the screen is lowered at the start of the trial to reveal one mouse and one small screen that is large enough to hide a second mouse (Aguiar & Baillargeon, 2002). We cannot make sense of these results without attributing to infants inferential processes that enable them to posit the existence of a second mouse in (2) and (3) but not (1). Infants could not respond as they do in VOE tasks without engaging in the appropriate reasoning and inferential processes; but it does not follow that these processes must be explicit or conscious, any more than their physical beliefs are.

To make these points clearer, consider an event in which 12 large clowns emerge one by one from a Mini Cooper. We would expect adults to readily detect the violation in this event; we would *not* expect them to be explicitly conscious, as they detected the violation, of the physical beliefs and reasoning processes that made it possible for them to do so. In this respect, adults and infants may not be fundamentally different. Of course, adults could, when pressed, describe at least some of the physical beliefs and reasoning processes that enabled them to detect the violation whereas infants could not; I return to this point below.

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2. Can we assume that infants who detect a violation are aware of doing so? I believe that the answer to this question is yes (just as it would be for the adults watching the 12 large clowns emerge from the Mini Cooper). Infants respond with increased attention not only to violation events, but also to ordinary events that happen to violate their limited and therefore faulty physical knowledge (Luo & Baillargeon, 2004, in press; Wang, 2003). What this means is that in their everyday lives infants naturally and frequently experience violations of their expectations. As Leslie points out in his commentary, attending to these experiences is crucial for learning: 'paying more attention is what you do if you are an active learner who has identified a learning opportunity' (Leslie, 2004, p. 418). An infant who recognizes that an event is not unfolding as she expected is an infant who is taking the first step toward revising and elaborating her physical knowledge so as to more accurately predict events in the future.¹

3. Can we assume that infants who fail to detect a surreptitious change in a change-blindness experiment did not register this change in any way? I think not. Consider the 11-month-old infants who show no increased attention when a tall cover is lowered over a short object and then removed to reveal a tall object (Wang & Baillargeon, 2004). Did these infants entirely fail to notice the change in the height of the object? My colleagues and I have speculated that when infants watch a physical event, different computational systems form different representations simultaneously, for distinct purposes (e.g. Wang *et al.*, in press). In particular, infants' *object-recognition* system represents detailed information about the objects in the event, for recognition and categorization purposes; at the same time, infants' *physical-reasoning* system forms a physical representation of the event, to monitor it as it unfolds and to interpret and predict its outcome. Our intuition is that the 11-month-old infants in our change-blindness experiment did encode the relative heights of the cover and object in their object-recognition system. However, because the infants had not yet identified height as a covering variable, they did not access their object-recognition system to retrieve this height information and include it in their physical-reasoning system. As a result, this information was not available and could not be interpreted in accord with infants' continuity and solidity principles. Note that this analysis predicts that 11-month-old infants presented with a task tapping their object-recognition

rather than their physical-reasoning system should give evidence of detecting the change in the height of the object. Experiments are planned to test this prediction.

Onward and forward

The commentators outline several exciting directions for future research, and I agree with their suggestions in this regard. As Leslie points out, we need to specify more precisely how the physical-reasoning system operates: for example, how infants go about forming event categories and identifying variables, and what roles infants' various core principles play in these processes. I am not sure I agree with Leslie's suggestion that infants' different event categories may simply reflect the influence of different core principles (or modules): infants treat events involving containers, covers and tubes as distinct event categories (e.g. Wang *et al.*, in press), yet all of these events clearly implicate the same principles.

Another research direction, suggested by Hood as well as by Bremner and Mareschal, is to better understand how infants come to use their physical knowledge to guide their actions. According to a recent proposal, whether infants reveal their physical knowledge in action as opposed to VOE tasks depends on the integration of their physical-reasoning system with the system responsible for planning and executing actions (e.g. Berthier, Bertenthal, Seaks, Sylvia, Johnson & Clifton, 2001; Keen, Carrico, Sylvia & Berthier, 2003). The research reviewed by Hood in his commentary makes clear that this integration process is a difficult and protracted one that goes on well beyond infancy. From my perspective, one appealing feature of this approach is that it gets us away from the simple (and mistaken) idea that infants should be able to reveal the same physical knowledge in *all* tasks, irrespective of the special demands posed by each task.

Yet another research direction, suggested by Hood and also by Bremner and Mareschal, is to determine how the piecemeal and implicit knowledge of the infant becomes the more explicit, conscious and theory-like knowledge of the older child and adult. Consider the 7.5-month-old infant who has identified height as a variable in occlusion and containment but not in covering and tube events (Hespos & Baillargeon, 2001; Wang *et al.*, in press). How does this infant become the older child who explicitly recognizes that height operates in exactly the same manner in occlusion, containment, covering and tube events? How is the infant's early physical knowledge re-described or re-invented to become the knowledge of the older child (e.g. Karmiloff-Smith, 1992)?

¹ At least two kinds of situations in everyday life must provide infants with 'learning opportunities': situations in which they face events that violate their limited physical knowledge, and situations in which they face contrastive outcomes consistent with, but unpredicted by, their limited physical knowledge (Baillargeon, 2002).

I believe that Hood is exactly right when he says that much of this research will require us to 'account for physical knowledge beyond infancy' (Hood, 2004, p. 416).

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