COMMENTARIES

Is looking good enough or does it beggar belief?

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This is a commentary on Baillargeon (2004).

In this article, Baillargeon has presented a forceful case for her theory on the cognitive development of physical knowledge but I do not think that the violation of expectancy paradigm has demonstrated unequivocal evidence that infants have beliefs about objects and their properties. However, I do think that these studies demonstrate early physical knowledge. The problem is that knowledge is an unsatisfactory term because of the cognitive baggage that comes with it (Haith, 1998; Hood, 2001). In particular, the infant behaviour literally beggars 'belief'. I do not mean it is untrue. I mean it impoverishes the concept of belief. Belief is an explicit mental construct that supports a conviction to an explanatory framework. Although Baillargeon qualifies her position early in the article by the use of interchangeable phrases such as 'detect a violation', 'are surprised by a violation' and 'respond with increased attention to a violation', she soon slips into describing every demonstration of increased attention as a belief. And why not? We are so used to thinking about knowledge in terms of belief, that to challenge this assumption seems a petty semantic snipe at a remarkable body of work over the last 20 years. However, I do not think we have the evidence to talk about infant beliefs as Baillargeon does repeatedly throughout the article and I am not sure that we ever will.

Why is it so important to distinguish between a belief and an increase in attention? In this short commentary let me outline some of the problems. To begin, our attention will increase to many events in which there is no evidence for explicit awareness, let alone belief. There is a difference between detecting a violation and knowing what the violation is. In fact, we detect more discrepant events in the world that we could be possibly aware of. That is what attention is for. The past 30 years of neuropsychology have taught us that the notion of unitary representations within each of the domains of matter, space and time (the stuff of the human experience) is elusive. Representations are created to support both thought and actions but are not necessarily both and within each there may be a multitude of different representations (the way that objects are coded in space is a good example of multiple frames of reference). Some of these representations form the basis of explicit knowledge, whereas others operate as implicit knowledge beyond our ken. Cognitive neuroscience, drawing on typical and atypical populations, is peppered with examples of dissociations of implicit knowledge from explicit awareness such as blindsight, neglect, prosopagnosia and so on, which support the proposition that implicit knowledge and explicit awareness should be treated separately. Also, we know from studies of consciousness that we detect differences before we are aware of them and in many instances, we may not become explicitly aware of them. We can note a difference without knowing what the difference is. It was interesting to see that Baillargeon had included a change-blindness study in her article. Unfortunately for her position, this is exactly the sort of demonstration where adults detect a difference without being aware of what it is; sensing without seeing as it were (Rensink, 2004).

However, we are usually aware of what we are attending to and Baillargeon has obviously taken this as given. My examples could be dismissed as either foibles of unusual perceptual presentations or dissociations based on the brief temporal mismatch of awareness and detection or the rare case examples of patients who have awareness and discrimination dissociated through damage to structures that support one set of representation for action as opposed to perception (Goodale & Milner, 2003). Am I pushing the dissociation argument too

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strongly when dealing with events that involve representing the properties of unseen objects interacting with other unseen objects? Three lines of evidence suggest not.

As Baillargeon correctly pointed out in her introduction, the violation of expectancy paradigm was adopted to overcome the performance limitations of Piaget's search paradigm. However, the problem is that once children are no longer constrained by infantile performance limitations, representations that support looking do not always support action indicative of knowledge. Using tasks based directly on the infants' event paradigms, we and others have demonstrated that children fail to search accurately on tasks requiring the same mechanical knowledge (Berthier, DeBlois, Poirier, Novak & Clifton, 2000; Hood, Carey & Prasada, 2000) and yet look longer at violations of the same event sequences (Hood, Cole-Davies & Dias, 2003). These children know that a violation has taken place; they just do not know where to look for the object (Keen, 2003). Of course, toddlers have their own set of performance limitations. They are not fully immune to perseveration. They may have unforeseen motor limitations. They may not fully understand what is required in the task or they simply may enjoy mucking about. But you cannot dismiss the toddler findings on the basis of performance limitations anymore than you can assert the infant results in the absence of performance limitations. In other words, I would argue that overcoming the performance limitations is part and parcel of knowledge on an object retrieval task.

Of course, children do eventually solve our object retrieval tasks so the dissociation I have highlighted may be just a temporary mismatch in the knowledge representations that support looking and acting. Does one simply lag behind the other during development, only to catch up and synchronize at a later age? Not always; and in some species, not at all. Studies comparing search and looking time in both laboratory and free-ranging nonhuman adult primates also produce the same sorts of dissociation that I have been describing (Santos & Hauser, 2002). And it is not simply that monkeys always look longer but fail to search accurately as it appears that only certain types of object event sequences produce the dissociation (Hauser, 2003). When monkeys have to keep track of object location, both measures concur but while understanding mechanical object events is registered in the looking time, it does not support search leading to the hypothesis that representations for spatiotemporal physics are functional whereas those that support contact mechanics are not (Santos, 2004).

Finally, normal healthy human individuals also show the dissociation of object knowledge representations. Typically, adults and children hold intuitive misconceptions regarding the physics of object motion (McCloskey, 1983). When asked to predict the path of falling objects, they typically succumb to a variety of errors. However, when presented with simulations of these movements, they recognize that such motions are anomalous (Kaiser, Proffitt & Anderson, 1985) and in the case of children, they show the same significant increase in looking time to the impossible outcome in a violation of expectancy set-up (Kyeong & Spelke, 1999). But this begs the question, 'How can it be a violation of expectancy when the expectancy was for the impossible outcome?' Here we have contradictory implicit and explicit knowledge because what they believe differs from what they know. I do not want to make the case that these exceptions prove the rule, but we must be cautious of over-interpreting the looking time results; especially when it comes to reasoning about physics.

So what of looking behaviour? The looking time paradigm has opened our eyes to the sophistication of the types of physics representations that appear to be present in young infants but I do not think that Piaget would have been particularly perturbed by these amazing findings. His was a sensorimotor theory based on the efficacy of action. After all, Nature does not select for having a good idea. Baillargeon's findings have moved us on to a point where we must account for physical knowledge beyond infancy. But equally we should not unquestioningly accept that infants are operating with beliefs about the physical world. Karmiloff-Smith (1992) has made the transition of representations based on implicit knowledge to those that support explicit awareness a central tennet to her theory of cognitive development. I think that such an approach focusing on the initial state as demonstrated by Baillargeon combined with the study of processing that makes that knowledge available to control action is the way forward.

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Who's for learning?

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This is a commentary on Baillargeon (2004).

There's a rumor going round that nativists don't believe in learning. In fact, nativists are 'for' learning as much as empiricists are. The difference is that empiricists think that learning is easy and nativists think it is hard. I'm not talking about the subjective *experience* of learning – that some learning *feels* hard, effortful and halting, while other learning feels so easy we are not even aware of it taking place. No, what I mean is the difficulty of the computational problem that learning solves. There is an anecdote that vision scientists are fond of telling (e.g. Papathomas, 1995). Supposedly, in the 1960s a famous MIT computer scientist assumed the vision problem was so easy that he gave a new PhD student a summer project to program a computer so that it would see. Vision scientists chuckle over this because *computationally* vision is extremely complex. The great computer scientist had fallen into the trap of assuming that because seeing is so subjectively easy, it must *really* be easy and the objective processes simple. What separates nativists and empiricists is not whether they are 'for' or 'against' learning, but whether or not they assume learning is objectively easy.

The empiricist tends to believe that the environment takes care of the complexities of learning, by presenting the learner with what she needs to know in a transparent, accessible and timely manner, revealed through the statistics of its presentations. All the learner has to do is just passively soak it up by translating statistics into associations. If learning *really* is easy, then why shouldn't an individual learn all she needs in a few years, and certainly in a single life time! The nativist, on the other hand, tends to believe that learning is not computationally easy; that the endless complexity of even a single

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environment means that no two unconstrained learners are likely to passively converge on learning the same things about it, and that ambiguities and opacities abound. In short, the learner needs all the help she can get. The obvious source for that help is the accumulated expertise of phylogeny, delivered to the learner by evolutionary adaptation and descent.

One way to ease the learning process is to have an *active* learner, whose learning is organized under topic headings and who actively scans the environment for targeted information bearing on those topics. On the other hand, one can demand a passive learner who *also* learns what topics he should be learning about. Whether or not that seems like a good idea will depend on how objectively easy you think learning is.

Baillargeon favors an active learner. Her proposals for a domain specific learning mechanism that targets the physical world are intriguing and she provides a wealth of data from ingenious experiments to test and refine her ideas. Her detractors generally believe that learning is objectively easy, and that the infant needs no and gets no domain specific help from her phylogenetic past. Baillargeon has not ignored her detractors but has responded to their methodological scrutiny with new experiments and new findings. Many difficult questions remain, of course, and quite properly the debate and the quest for further insights will continue.

Baillargeon's 'categories and variables' reminded me of the 'principles and parameters' approach to language learning (Chomsky & Lasnik, 1995) and suggested a related way to think about her findings. First, let's assume that the two general principles, spatiotemporal continuity and solidity, have a quite different status. Continuity reflects the mode of operation of an object tracking or indexing mechanism (Leslie, Xu, Tremoulet & Scholl, 1998; Scholl & Leslie, 1999). Solidity, on the other hand, is associated with a module that represents mechanical properties of objects, including the resistance of bodies to penetration. I have called this the 'theory of body' module or ToBY (Leslie, 1994). Suppose that, in addition to continuity and solidity, the indexing and ToBY modules instantiate a number of other principles. For example, the indexing mechanism employs a BEHIND principle, governing the visibility of tracked objects that go behind other objects, while ToBY has a CONTAINMENT principle governing objects placed in containers. Suppose that these principles are parameterized and thus represented only skeletally at first. Learning will consist principally of fixing and refining the values for these parameters. Such an account will overlap with Baillargeon's 'categories and variables' but there are differences. One difference is dissociation of indexing (continuity) processes from mechanical representation. Another is that it explains not only why learning is category (or principle) specific but also why learning about the 'variables' – the parameter values – is also category (or principle) specific. Infants do not appear to learn about the general significance of, say, height, anymore than they learn the general significance of events. Having a tight connection between parameter and principle will direct the active learner to devote her attention to discovering the critical parameter *values* from experience. Baillargeon's bold teaching experiments suggest that critical data may be conveyed in a single learning trial.

Infants are not the only ones to think differently about screens and containers. Adults do too; Chomsky has pointed out that we judge an apple placed say 2″ to the left side of a box to be *near* the box. Curiously, we do not make the same judgment if the apple is again placed 2″ from the left side of the box but this time within the interior of the box. We seem to think of a container as including its interior space and not simply as the skin that surrounds that space. Furthermore, the apple remains, in our judgment, distinct from the box that contains it, so the interior space that is considered part of the box does not include any of the contents that may occupy that space. These judgments don't seem to reflect a matter of objective fact but just 'the way we think' about containers. Notably, we do not think about screens in this way: an apple 2″ from a screen is *near* the screen whether behind, in front or beside the screen. So we don't think of containers as wrapped-around-screens. Perhaps we simply learn this way of thinking as we interact with containers, screens and prepositions. But perhaps *what* we learn in these interactions bears traces of the very mechanisms that *did* the learning. Again what one is inclined to believe here will depend on whether one thinks learning is simple and easy or complex and, without specific support, hard.

Finally, I welcome Baillargeon's clarification of her use of the term 'surprise' in connection with her violation of expectation (VOE) method. Many researchers have been exercised by this term, worried that it anthropomorphized the infant. The term can easily be operationalized to mean 'look longer' or 'increase attention', if that seems better. Let's not forget, however, why the infant looks longer. Paying more attention is what you do if you are an active learner who has identified a learning opportunity. A violation of expectation happens when you detect that the world does not conform to your representation of it. Bringing representation and world back into kilter requires representation change and computing the right change is a fair definition of learning. Looking time experiments then are learning experiments and no one has understood this better than Renée Baillargeon.

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Reasoning . . . what reasoning?

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This is a commentary on Baillargeon (2004).

In her article, Baillargeon surveys an immensely impressive array of studies that go back over many years. Taken together, these studies provide a truly substantial database from which one can try to infer infants' understanding of objects, and especially of hidden objects. Of course, the best we can ever do is to infer what the infant's understanding is. This is true of all psychological investigations, because we can never have direct access to the participant's subjective experiences, but it is even truer of studies with infants because of their inability to verbalize any of their conscious experiences. Inevitably, this leads to the question of what we can legitimately infer from the observed behaviours. This is an especially important issue here, because Baillargeon makes very strong claims about the nature of the cognitions that underly infants' performance on her tasks. The use of such terms as 'inference' and 'reasoning' to describe infant behaviour strongly implies that their knowledge is conscious and explicit.

Implicit or explicit knowledge?

Learning about the kinds of physical events discussed here involves learning about a sequence of visual stimuli that unfold through time (Mareschal & Johnson, 2002; Mareschal, Plunkett & Harris, 1999; Munakata, McClelland, Johnson & Siegler, 1997). With increasing age and experience, the infant presumably encounters many situations from which to learn about the structure of such sequences in the real world. Indeed, Baillargeon and colleagues begin to address this question in a series of experiments in which infants are taught contrastive outcomes across three teaching trials (e.g. Wang & Baillargeon, in preparation). However, this begs the question of what form the learning takes. Do infants learn the covariance between height of cover and outcome in a fast one-trial fashion as is expected in explicit sequence learning (Bauer, 2002; Bauer, Wenner, Dropik & Wewerka, 2000)? Or, are the infants acquiring their 'expectations' gradually over time, as can be the case for implicit unconscious sequence learning (Cleeremans & Jiménez, 2002; Cleeremans, Destrebecqz & Boyer, 1998; Destrebecqz & Cleeremans, 2001; Willingham, 1994)? Experimental manipulations of the amount and structure of training information that infants require to learn the sequence of events may help us to define more closely the kind of knowledge that they are acquiring, but for the moment this issue remains unresolved.

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The question of whether infant knowledge is implicit or explicit can also be illustrated by reference to the change-blindness studies described in the target article. Here again, Baillargeon discusses these results in terms of explicit knowledge by using terms such as 'reason' and 'infer' when discussing what infants do. However, increased looking at unexpected changes to visual scenes is perhaps one of the least likely behaviours to index explicit knowledge. Indeed, Henderson and Hollingworth (2003) have recently shown that adults, while not overtly detecting changes in visual scenes (an example of change-blindness), will nonetheless look longer at such changes than at no-change control scenes, suggesting a dissociation between their implicit knowledge (as measured by looking time) and explicit knowledge (as measured by button presses). Thus, differences in looking time do not support the conclusion that knowledge is explicit and accessible to overt reasoning processes.

Qualities of knowledge

Baillargeon also bemoans the lack of experimental methodology available to Piaget, suggesting that had such methodology been available, he might not have underestimated infant knowledge quite so dramatically (p. 391). We are thus given the impression that had Piaget had access to the visual preference methodology, he would have ascribed to young infants the same level of knowledge as is attributed to them here. However, Piaget (1936/1952) actually set quite different criteria for the acquisition of objective knowledge, and increased looking at novel sequences of events did not fulfil these criteria. For Piaget, objectivity was reached when originally separate schemas (e.g. looking and reaching) were coordinated. Indeed, Piaget actually describes a degree of object permanence (within a looking schema only) in infants of only 2–3 months of age:

> Observation 2. – . . . with Laurent at 0;2 (1). I look at him through the hood of his bassinet and from time to time I appear at a more or less constant point; Laurent then watches that point when I am out of his sight and obviously expects to see me reappear. (Piaget, 1937/1954, p. 9)

Piaget thus proposes, like Baillargeon, that even very young infants can react with expectations regarding perceptual phenomena, even occluded objects. However, he also states:

> . . . the vanished object is not yet for him a permanent object which has been moved; it is a mere image which re-enters the void as soon as it has vanished, and emerges from it for no objective reason. . . . In none of these acts is it possible to speak of the object as existing independently of the activity. (Piaget, 1937/1954, pp. 11–12)

So, no matter how competent the infant is in noticing distinctive aspects of her visual field, this still does not fulfil Piaget's criteria for objective knowledge.[1] He requires that initially separate object schemas (e.g. looking and reaching) are fused into more global representational systems (what he terms reciprocal schemas).

Research from our laboratory suggests that this may not be so far off the mark. Mareschal and Johnson (2003) have demonstrated that infants' early spatial representations of hidden objects (e.g. location information relevant for reaching) do not appear to be bound to information about object identity (information relevant to visual recognition). These findings are consistent with the proposal that knowledge of objects, initially fragmented and possibly domain specific, has to be eventually coordinated into a more domain general representational system that supports coordinated intentional actions directed towards objects in the world. In fact, Baillargeon's own findings of domain specificity of event representations between containment and covering events suggests a similar conclusion; that early in development infants are simply learning visual contingencies (context dependent within visual perception), and not domain general objective knowledge about permanence or physicality.

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[1] It does not seem unreasonable to assume further that a minimum criterion for objective knowledge is that it be explicit and accessible to overt reasoning processes.

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