Infants' representations of causation

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Abstract: It is consistent with the evidence in *The Origin of Concepts* to conjecture that infants' causal representations, like their numerical representations, are not continuous with adults', so that bootstrapping is needed in both cases.

Representations involving causation play a special role in *The Origin of Concepts*, grounding Carey's view that there are "central representational systems with innate conceptual content that is distinct from that of core cognition systems" (Carey 2009, p. 246). For infants' causal representations are held to be innate but not grounded in core cognition, unlike representations of objects, numbers, and agents, which do involve core cognition. After discussing the distinction between core cognition and central representational systems, I shall argue, contra Carey, that infants' causal cognition might depend on core cognition after all. This matters for two reasons. First, we are left without a clear case of innate representation outside core cognition. Second, it suggests that, as in the case of number (see Ch. 8), there may be a developmental discontinuity between infants' and adults' causal notions. If so, understanding "how the human capacity for causal representation arises" (Carey 2009, p. 216) will require explaining how humans bootstrap themselves across the discontinuity.

Let me first outline part of what motivates the distinction between core and central cognition. Officially, core cognition is characterised by six properties (pp. 67–68), but for my purposes it is useful to start from motivation for one aspect of the distinction. At what age do infants typically first know that solid barriers stop rolling balls? This is a hard question because, as Carey explains, there is compelling evidence for apparently inconsistent answers. Infants' looking behaviours reveal that infants have different expectations about the trajectories of objects depending on the presence and positions of solid barriers (Baillargeon et al. 1995; Carey 2009, pp. 76ff.; Spelke & Van de Walle 1993; Wang et al. 2003). Yet at $2\frac{1}{2}$ years, their reaching behaviours systematically indicate a failure to understand interactions (Berthier et al. 2000; Carey 2009, pp. 111–15; Hood et al. 2003). Carey's view involves distinguishing "two kinds of knowledge" (p. 115) or "two types of conceptual representations" (p. 22). There are principles that are *known* (or, better, *cognised* [pp. 10–11]) in this sense: Abilities to individuate and track objects exploit the approximate truth of these principles. We can explain the sensitivity of infants to solid barriers on the hypothesis that they do know that solid barriers stop rolling balls in this sense of knowledge: Where the principle that solid barriers stop rolling balls is violated, infants cannot compute a continuous trajectory for an object, and their attention is drawn to it for the same sorts of reasons that cause them to attend to anomalous appearances and disappearances (p. 140). But in another sense, principles are *known* only if they can serve as reasons that explain and justify purposive actions, or only if they could in principle become elements in intuitive theories with explanatory potential (Ch. 10). We can explain the failure of 2-year-olds' reaching behaviours to deal with solid barriers on the hypothesis that they do not know that solid barriers stop rolling balls in this sense of knowledge.

If (as I think) Carey's interpretation of these apparently conflicting findings is right, we must be cautious when attributing knowledge, concepts, or representations. This applies to the case of causation. Some of the best evidence for causal representations in infancy comes from extensions of Michotte's launching paradigm (Carey 2009, p. 218). What is the nature of these representations? Abilities to individuate and track objects involve sensitivity to cues to object identity such as continuity of movement and distinctness of surfaces. As Michotte noted, the causal representations he identified arise when there is a conflict between these cues (Michotte 1946/1963, p. 51). This and other evidence (see Butterfill 2009, pp. 420–21, for a review) suggests that we can characterise Michottian causal phenomena in roughly the same way that Carey characterises infants' knowledge that solid barriers stop rolling balls: it is a side-effect (although perhaps a developmentally significant one) of the computations involved in core cognition of objects.

I have not yet suggested anything inconsistent with Carey's position. I also accept her arguments that (1) infants' causal representations are not limited to mechanical interactions and that (2) the Michottian phenomena are not "*the* [only] source of the human capacity for causal representations" (Carey 2009, p. 243; Saxe & Carey 2006). However, I do object to Carey's argument for the further claims that (3) "not all of an infant's earliest causal representations are modular" (p. 240) and that (4) infants "make complex causal inferences" (p. 242). The argument for all four claims hinges on an impressive series of studies showing that infants can represent causal interactions involving changes of state as well as of location, that they are sensitive to colliding objects' size or weight, and that they expect animate and inanimate objects to occupy different causal roles. These findings support (1) and (2) but not (3) and (4). Why not? Carey is surely right that these findings cannot be explained by supposing that there is core cognition of (or a module for) causation. But this is compatible with the hypothesis that sensitivity to causal principles is a feature of several individual modules. That many possibly modular processes require sensitivity to causal principles does not imply that any such principles are central. For example, cognition of speech is sometimes thought to be modular (Liberman & Mattingly 1991) and might even be characterised as a species of core cognition. Speech cognition involves sensitivity to causation in ways analogous to those discussed in *The Origin of Concepts*. For example, it requires categorising things by whether they are potential producers of speech, and identifying which bits of speech are coming from a single source. In fact, on one view, cognition of speech involves identifying the phonetic activities most likely to be causing observable sounds and movements (Liberman & Mattingly 1985). By itself, this is neither evidence for the existence of non-modular causal representations, nor for causal representations that are not aspects of core cognition.

But why think that causal representations are initially all embedded in core cognition?

As in the case of number, the answer concerns signature limits. Children in their second and third years of life show limited abilities to reason explicitly about the causal powers of solid objects and of agents. The principle considered earlier, that solid barriers stop rolling balls, is as much about causation as it is about objects. If infants' causal representations were nonmodular and if infants could make complex causal inferences, how could they fail to appreciate that solid barriers stop rolling balls?

If it is possible that infants' and adults' causal representations are discontinuous in the same sense that their numerical representations are (Ch. 4 and 8), how might humans bootstrap themselves across the discontinuity? In the case of number, numeral lists and counting routines play a key role. Tool use may play an analogous role in bootstrapping causal representations. Basic forms of tool use may not require understanding how objects interact (Barrett et al. 2007; Lockman 2000), and may depend upon core cognition of contact-mechanics (Goldenberg & Hagmann 1998; Johnson-Frey 2004). Experience of tool use may in turn assist children in understanding notions of manipulation, a key causal notion (Menzies & Price 1993; Woodward 2003).

Perhaps, then, non-core capacities for causal representation are not innate, but originate with experiences of tool use.

Concepts are not icons

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Abstract: Carey speculates that the representations of core cognition are entirely iconic. However, this idea is undercut by her contention that core cognition includes concepts such as *object* and *agency*, which are employed in thought as predicates. If Carey had taken on board her claim that core cognition is iconic, very different hypotheses might have come into view.

In her book, Carey (2009) says that the elements of core cognition include some very basic concepts, such as the concept *object* (p. 41) and the concept *agent* (p. 186). She also says that the representations of core cognition have an "iconic" format (pp. 68, 458). This appears to be a contradiction, because conceptual representations, even as Carey understands them, cannot be iconic. I vote for a resolution in favor of iconic format.

Carey says that concepts are "units of thought, the constituents of beliefs and theories" (p. 5) and that "words express concepts" (p. 247). Moreover, she frequently interprets infants as using their concepts as predicates, in thinking of something *as* an object or *as* an agent (pp. 41, 187, 268). Thus, concepts, for Carey, appear to be components of the sorts of thoughts we can express in sentences. If an infant possesses the concept *object*, then it can think a thought that we can express in words thus: "That is an object." That does not mean that only creatures that have language possess concepts, or that all concepts are word-like symbols, which Carey would deny (p. 68).

Iconic representations are mental images. Iconic representations do not represent only sensory qualities such as color and shape, as Carey well knows (p. 135). Mental images can represent a sequence of events among objects. Our understanding of objects may consist largely in our being disposed to imagine that events will unfold in certain ways rather than others (p. 460). If I imagine a ball disappearing behind a screen and the screen coming down to reveal that very ball, I represent the ball as persisting through time and as hidden behind an occluder; in doing so, I utilize knowledge of object permanence. In imagining a hand striking a box behind an occluder, I may exercise an understanding of causation.

Iconic representations are never concepts. Iconic representations of a red ball and a blue ball do not represent what the two balls have in common, as the concept *ball* does. A concept, such as *dog*, has an argument place. By substituting a representation of a particular object into that place, we can form a whole thought, such as that Fido is a dog. An iconic representation does not have an argument place. There could be a kind of thinking in pictures in which a mental image of a collie did the work of the concept *dog* in forming the sorts of thoughts we express in English with the word "dog." But in that case, the mental image of a collie would cease to be an iconic representation of a particular collie. There are iconic representations of objects, but no iconic representation is the concept *object*.

Carey frequently infers that a representation is conceptual on the grounds that it cannot be defined in terms of sensory and spatiotemporal qualities and has an "inferential role" (pp. 97, 115, 171, 449). Infants' representations of objects are not merely representations of statistical relations between sensory qualities (p. 34), and they are intermodal (p. 39). In saying that a representation has an inferential role, she does not mean that it is governed by rules of inference defined over strings of symbols (p. 104). She means that it guides expectations (p. 61) and is integrated into several domains of cognition (p. 95). The concept *object* has an inferential role inasmuch as "objects are represented as solid entities in spatial and causal relations with each other" (p. 103).

But these considerations do not persuasively argue that the representations of core cognition can also be used as predicates. In expecting that there will be two objects behind the screen, not one, the child may be simply imagining two objects. There is no need to suppose that the child judges of each *that* it is an object and distinct from the other. An imagistic representation of the arrangement behind the screen may be a consequence of the infant's understanding of the way objects behave; it is not merely a synthesis of sensory qualities. It can integrate contributions from several sensory modalities. An imagistic representation can demonstrate an understanding of causal and numerical relations. That understanding can take the form of an imagistic understanding of what one can expect to perceive in the course of observing real objects. An infant can represent an object as solid without judging that it is solid by imagining that it will behave as solid objects in fact behave.

Carey introduces yet a third kind of representation, *object files* (p. 70). She thinks it's useful to imagine that the infant keeps a file on each object that it perceives, in which it stores information about that object's past. But an object file is not iconic, because an iconic representation is not a thing in which information is collected. And an object file is not the concept *object*, which we might put to use in representing every object. Yet in Carey's thinking, the notion of object file seems to blur the distinction between concept and iconic representation (p. 459).

Carey frequently attributes to infants a kind of conceptual thought that is not in any way reducible to iconic representation. She thinks experiments show that infants classify objects as agents (p. 186). In comparing explanations of looking-time studies of infants' reactions to causal scenarios, she pits an explanation in terms of the general concept *cause* against an explanation in terms of generalizations "stated over perceptual features" (p. 241). In considering how infants might solve individuation problems, the only options she considers are that they conceive of objects as falling under kinds and that they conceive of them as having properties (pp. 268–70). None of the options on offer is an explanation in terms of iconic representations.

If Carey had taken on board her own claim that core cognition employs iconic representations, then very different hypotheses might have come into view. Quite generally, an infant's understanding of the world might take the form of its being disposed to imagine certain sequences of events in preference to others. It is not obvious that skills in imagination can only be explained as deriving from prior conceptualizations.

The case for continuity

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Abstract: This article defends a continuity position. Infants can abstract numerosity and young preschool children do respond appropriately to tasks that tap their ability to use a count and cardinal value and/or arithmetic principles. Active use of a nonverbal domain of arithmetic serves to enable the child to find relevant data to build knowledge about the language and use rules of numerosity and quantity.