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Can bootstrapping explain concept learning?

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ABSTRACT

Susan Carey's account of Quinean bootstrapping has been heavily criticized. While it purports to explain how important new concepts are learned, many commentators complain that it is unclear just what bootstrapping is supposed to be or how it is supposed to work. Others allege that bootstrapping falls prey to the circularity challenge: it cannot explain how new concepts are learned without presupposing that learners already have those very concepts. Drawing on discussions of concept learning from the philosophical literature, this article develops a detailed interpretation of bootstrapping that can answer the circularity challenge. The key to this interpretation is the recognition of computational constraints, both internal and external to the mind, which can endow empty symbols with new conceptual roles and thus new contents.

If concepts are the constituents of thought, the thoughts we can think are limited by the concepts we can have. It thus matters a great deal whether humans can learn new concepts throughout their lifespans. Enter Susan Carey's magnum opus, *The Origin of Concepts*,[1] which develops some of Quine's metaphors about concept learning into a full-blown account that Carey calls *Quinean bootstrapping*. While *Origin* is widely regarded as a *tour de force*, commentators disagree about whether Quinean bootstrapping (hereafter: bootstrapping) manages to do the work Carey requires of it.[2] In part, this disagreement traces to the difficulty of the task. There are powerful reasons, tracing to Plato's *Meno* and honed in recent decades by Jerry Fodor, to think that concept learning is impossible. But the disagreement also exists because *Origin* is, at least in places, a difficult text to interpret. It is not always clear just what Carey takes bootstrapping to be. In his review of *Origin*, Fodor (2010, p. 8) puts the point this way:

> Reading Susan Carey's book feels a little bit like coming in at the middle of a movie: you can sort of figure out what's going on, but you wouldn't bet the farm that you've got it right.

Fodor, of course, is an outspoken critic of Carey's. But it is not only her critics who have trouble pinning her down. Carey charges many of her would-be allies with misinterpreting her as well.[3]

This paper aims to charitably elucidate Carey's account of bootstrapping—to rewind to the start of her movie and play it back in slow motion, pausing at key points with new distinctions and clarifications. In so doing, I will not defend every aspect of bootstrapping, but I will defend it from one prominent line of criticism. Multiple critics allege that bootstrapping cannot explain how new concepts are learned without circularly presupposing that learners already have those very concepts. Drawing on developments from the philosophical literature on concept learning, I will show how it can.

One caveat. Although the resulting account of bootstrapping is inspired by Carey's writings, I am far from certain that she would endorse every aspect of it. Thus, while I will attribute the account to Carey, one might more cautiously view it as one promising way of developing her views.

1. Introducing bootstrapping

Carey is not interested in just any type of concept learning. A thinker that possesses the concepts FEMALE and FOX, and then learns

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[1] Hereafter: *Origin*. Unless otherwise noted, all page references are to this book (Carey, 2009a). Carey's mature account of bootstrapping is also summarized and developed in several articles (Carey, 2004; Carey, 2009b; Carey, 2011a; Carey, 2014).

[2] For broadly sympathetic commentaries, see Shea (2009), Margolis and Laurence (2008), Margolis and Laurence (2011) and Piantadosi, Tenenbaum, and Goodman (2012). For more critical commentaries, see Fodor (2010), Rey (2014), Rips, Asmuth, and Bloomfield (2006), Rips, Asmuth, and Bloomfield (2008) and Rips and Hespos (2011).

[3] Inspired by *Origin*, Piantadosi et al. (2012) present a computational model of bootstrapping, but Carey (2014) objects that it is not really a model of *bootstrapping* (see §4.2 below). See also Carey's (2011b, p. 162) reply to Shea's (2011) interpretation of bootstrapping, as well as the other exchanges between Carey and her commentators in that volume.

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that a VIXEN is a FEMALE FOX, arguably learns the new concept VIXEN.[4] It is doubtful, however, that the thinker alters her expressive power since VIXEN has the same content as FEMALE FOX. Such an episode thus would not count as bootstrapping.

Nor is Carey interested in the learning of a single new primitive concept, as when you meet John Doe for the first time and thereby acquire the concept JOHN DOE. Such cases arguably count as increasing one's expressive power (now you can think thoughts about John Doe; before you couldn't), but Carey does not include them in her discussion of bootstrapping.

Rather, Carey is occupied by cases wherein thinkers learn a batch of new concepts all at once that are at least partially inter-defined, such as concepts of positive integers (pp. 287–333), concepts of rational numbers (pp. 344–359), and concepts of physical entities such as matter, weight, and density (pp. 379–411). To relay the difficulty of such episodes of concept learning, Carey deploys the bootstrapping metaphor. But whereas hoisting oneself by one's own bootstraps is literally impossible, Carey believes that learning these concepts is merely difficult.

Three theses form the core of Carey's account of concept learning. First:

Discontinuity: Over development, thinkers acquire new batches of concepts that alter their expressive power.

One type of discontinuity involves a pure *increase* in expressive power, whereby the thoughts one could think prior to the bootstrap form a proper subset of the thoughts one can think after the bootstrap. For example, while many two year olds can recite a portion of the count list ("One, two, three, ... "), they don't seem to know what the words in the list mean. If asked for *n* pennies from a pile, or to point to the card with *n* fish, they will respond with a random number of pennies or point to a random card. Moreover, their failures consist of more than ignorance of language. While further experimental probing reveals evidence of representations with quantitative content—including *analog magnitude* representations of approximate numerosities, *object file* representations that track the numerical identity of individual objects in parallel as their spatiotemporal position changes, and *natural language quantifiers* that are a part of each child's universal grammar—Carey makes a persuasive case that these representations all lack the expressive power to represent the integers. Carey concludes that two year olds lack the representational resources to think about the integers. Four year olds, by contrast, have those resources; they succeed on the point-to-a-card and give-me-*n* tasks.[5]

When children first memorize the count list, it serves as a mere placeholder structure. It encodes serial order ("three" comes after "two," which comes after "one"), but the nature of that order is not defined for the children. It's as though they were saying "eeny, meeny, miny, mo." Nevertheless, Carey maintains that this placeholder structure plays a crucial role in explaining how children acquire integer concepts, and that similar placeholder structures play an essential role in other episodes of concept learning.

Placeholder: Placeholders play an important role in generating conceptual discontinuities.

In defense of Placeholder, Carey argues that people who lack the relevant placeholder structures often fail to acquire new networks of concepts. For example, children who grow up in linguistic communities without a count list never become cardinal-principle knowers (pp. 302–4). Moreover, intelligent animals that lack language, such as chimpanzees, can laboriously learn precise integer concepts piecemeal, but never seem to extrapolate beyond those concepts to induce concepts of further positive integers (pp. 329–33). However, an African Gray Parrot that first learned "seven" and "eight" as mere placeholder terms was able to infer their cardinal meanings upon learning their serial locations in an ordered count list (Pepperberg & Carey, 2012). Finally, Carey observes that curriculum interventions that place an emphasis on placeholder structures outperform other curriculum interventions in generating conceptual change (pp. 479–84).

Carey's third thesis is:

Bootstrapping: There is a learning process called *bootstrapping* that draws on placeholders to bridge conceptual discontinuities.

Carey explicitly takes bootstrapping to involve not just a description of succeeding discontinuous conceptual systems, but a *learning process* that explains *how* thinkers get from the first conceptual system to the second. In support of this contention, Carey maintains that children must *somehow* manage to use placeholders to bridge conceptual discontinuities, and that it's hard to believe that learning isn't involved given that conceptual discontinuities are often bridged as a result of instruction and study, with success predicted by the particular curriculum that one's teachers adopt. Of course, any learning process must be *psychologically realistic*. Thus, a bootstrapping explanation of integer concepts must only appeal to representational resources that we are justified in believing that children actually have, such as analog magnitude and object file representations.

Carey's parade case of bootstrapping involves the acquisition of natural number concepts such as THREE, SEVEN, and TEN (pp. 287–333). The bootstrap begins when children memorize the count list placeholder system, typically by age two. Some months later they become "one-knowers." They'll give you one penny or point to the card with one fish, but respond randomly with larger values. Six to eight months later children become "two-knowers." They succeed on the give-me-a-number and point-to-a-card tasks for one or two, but no more. Several months later they become three-knowers, and then sometimes four-knowers. According to Carey, children at this stage have learned to use their object file systems to place models stored in long-term memory in one-to-one correspondence with objects in the world, and to associate such states of one-to-one correspondence with the first four number words. So they know that there is "one" object when the object is in one-to-one correspondence with a model of a singleton in long-term memory {i}; that there are "two" objects when the objects are in one-to-one correspondence with a model of a pair of individuals in long-term memory {j, k}; and so on, up to four (the upper bound of the object file system). Carey calls children at this stage "subset-knowers" and calls the system they use "enriched parallel individuation." Finally, by three-and-a-half or four years of age, children assign meanings to the remainder of the terms in their count list. According to Carey, this happens when children notice a "critical analogy":

> The critical analogy that provides the key to understanding how the count list represents number is between order on the list and order in a series of sets related by an additional individual.

[4] Carey (p. 5) takes concepts to be mental representations with semantic as well as non-semantic properties that serve as the constituents of thoughts, including beliefs. This minimal characterization should suffice for our purposes.

[5] Carey also recognizes a second type of discontinuity, *conceptual change*, which not only involves thoughts that one can think after the bootstrap that one could not think before the bootstrap, but also thoughts that one could think before the bootstrap that one cannot think after the bootstrap.