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Infants, animals, and the origins of number

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Abstract: Where do human numerical abilities come from? Leibovich et al. argue against nativist views of numerical development noting limitations in newborns' vision and limitations regarding newborns' ability to individuate objects. I argue that these considerations do not undermine competing nativist views and that Leibovich et al.'s model itself presupposes that infant learners have numerical representations.

Leibovich et al. give two reasons for supposing that humans are not "born with the ability to discriminate numerosities": (1) newborns have poor visual acuity and (2) lack the ability to individuate objects. Their point is that to represent the number of items in a collection, you have to at least be able to see the items and represent each one as being distinct from the others. If newborns lack these minimal capacities, then they would not be in a position to apply numerical representations and would have no need for innate numerical representations. How do infants acquire basic numerical abilities then? According to Leibovich et al.'s model, "number sense develops from understanding the correlation between numerosity and continuous magnitudes" (sect. 8, para. 6). This understanding is grounded in experiences in which infants initially do not distinguish numerosity from continuous magnitudes or distinguish certain continuous magnitudes from others. Aided by exposure to number words, infants come to learn the correlation between number and continuous magnitudes and eventually to tease them apart. According to Leibovich et al., children also have to figure out that numerosity and continuous magnitudes do not always correlate (as in Piaget's number conservation task). This knowledge comes later as they learn to inhibit the tendency to form number-relevant judgments on the basis of continuous magnitude. It is only then that children are said to "really understand the concept of numbers" (sect. 8, para. 7).

What counts as really understanding the concept of numbers may be more of a terminological question than a point of substantive disagreement. The interesting question raised by Leibovich et al.'s model is how children come to be able to represent numerical quantities *if they do not start out with some numerical abilities to begin with*. Dehaene (1997) puts the problem vividly – and puts his finger on much of the theoretical motivation for nativist accounts of one kind or another: "[I]t seems impossible for an organism that ignores all about numbers to learn to recognize them. It is as if one asked a black-and-white TV to learn about colors!" (pp. 61–62).

Now it is important to keep in mind that nativist and empiricist approaches to explaining the development of numerical abilities occupy opposing regions along a continuum of positions, just like nativist and empiricist approaches to any other representational ability (Margolis & Laurence 2013). On the empiricist side are views that shun innate numerical representations and emphasize domain-general acquisition systems. On the nativist side are views that may include innate numerical representations and that rely on domain-specific systems working in conjunction with domain-general acquisition systems (where domain specificity should be understood as a graded notion). Leibovich et al. associate the nativist view with "the number-sense theory," which they take to include a commitment to an innate system for representing number that is automatic, not influenced by continuous magnitude, and realized by distinct neural circuitry. But nativists about numerical abilities need not accept these further commitments. For example, a nativist view might postulate an innate numerical system that is realized by neural circuitry that is in close proximity to a system that represents continuous magnitudes, or even an innate numerical system that physically overlaps with this other system. Such an arrangement would be plausible if the two use similar computations, provide input to common downstream processes, or are a product of an evolutionary history in which one developed out of the other.

What about Leibovich et al.'s claim that newborns should not be expected to possess innate numerical abilities? There are four problems with this claim. First, although newborns cannot see well, that only tells us about their ability to easily apply numerical representations to *visual* stimuli – a limitation regarding the expression of a potential innate representational ability, not a reason to suppose the ability is not there. (Given that newborns have excellent hearing, at best this observation shows that experimentalists should put more effort into tapping newborns' numerical abilities using auditory stimuli.) Second, it is not clear what to make of the claim that newborns cannot individuate items. Leibovich et al. do not explain what the problem is supposed to be – they merely cite Carey (2001) – but if it is that infants do not possess sortal concepts (as claimed in Xu & Carey [1996]), this is not a hindrance to numerical representation. One can still represent numerical quantities (e.g., how many times a lever is pressed or a light flashes) even if one cannot determine whether a cup that appears from behind a screen is distinct from a ball that appears later. Third, whether there is an innate system for representing number (or anything) is not settled by the discovery it is not present at birth (i.e., assuming we take this discovery at face value; but see Izard et al. 2009; Turati et al. 2013). Such a system may still require maturation or may be masked by performance factors. Fourth, for this reason, it is helpful to look at the evidence pertaining to nonhuman animals, particularly precocial animals (so that maturation is not an issue) where there can be tight controls in place regarding the experiences that they have prior to testing for numerical representation and where language surely is not driving conceptual development. And there is strong evidence that animals do represent number as such, pace Leibovich et al.'s claim that numerical stimuli in this literature are inherently confounded with continuous magnitudes.

Finally, we need to ask about the representational abilities that underpin Leibovich et al.'s model. They claim that children learn about number through experiences that allow them to recognize that numerical properties correlate with continuous magnitudes. But to establish these correlations, one would have to represent the variables being correlated – continuous magnitudes (of different kinds) and number. Rather than explaining where the initial representation of numerical quantity comes from, the model presupposes a certain amount of numerical representation. This may not make the theory identical to the "number sense theory" it opposes, but it does look like Leibovich et al.'s model helps itself to a certain amount of numerical representation, just as nativists claim is necessary for a viable model of numerical conceptual development.

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