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On the Nature of Numerosity and the Role of Language in Developing Number Concepts

A Reply to Everett

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In response to Everett, our article (Coolidge and Overmann 2012) was not “based in large measure on paleoanthropological data” (Everett 2013b:81); 60% of our 53 references were “relevant experimental findings on numerical cognition” (81). Two of the references cited by Everett—Everett (2013a) and Everett and Madora (2012)—we did not include, indeed due to their recency. While the former remains unavailable, we have reviewed the latter and disagree with Everett’s interpretation of his data. Further, we would share his discomfort that “reconcilability with experimental data is surely a *sine qua non* of any treatise on the genesis of symbolic thought” (81), were it the case that this description could truly be said to characterize our paper—but it cannot. Finally, we take exception to two of Everett’s claims in particular: first, that we “errantly” (81) assume basic numerical cognition to be uniform in extant *Homo sapiens*, and second, that we underestimate the degree to which human numerosity is shaped by language.

Everett’s questioning of whether basic numerical cognition is uniform across humanity demonstrates the crux of his misunderstanding: The essence of basic numerosity (hereafter referred to simply as numerosity) in humans and in other species is subitization, the ability to rapidly and unambiguously recognize small quantities (up to three or four), and magnitude appreciation, the ability to appreciate quantity differentials above a threshold of just-noticeable differences. Everett fails to demonstrate a lack of uniform numerosity in humans; rather, he himself notes that the Pirahã can subitize, and of his six references, three demonstrate subitization in extant *Homo sapiens* without conventional language for numbers (e.g., Nicaraguan homesigners). Thus, the idea that some humans lack numerosity is dispelled by Everett’s own work and references. Notably, the presence of numerosity in peoples whose languages contain limited numbers is well documented (e.g., Butterworth et al. 2008; Gordon 2004; Pica et al. 2004).

Regarding Everett’s second exceptional claim, our purported underestimation of just how much language shapes numerosity in humans, we note that providing such an es-

timation was not the intent of our article. Rather, we intended to demonstrate, through a large number of experimental findings on numerical cognition, that the lower level of abstraction involved in numerosity may serve as a feral cognitive basis for higher-level symbolic thinking, including higher number recognition, letter symbolism, and sequencing. Further, we based our suggestion that numerosity and language are largely independent on the presence of numerosity in prelinguistic 9-month-old human infants and many alinguistic species: monkeys can subitize (Cantlon and Brannon 2006), and even fish can recognize quantity differentials (Agrillo, Dadda, and Bisazza 2007).

Everett declares that language has a “fundamental role ... in shaping *basic* human numerosity” (2013b:81, emphasis ours), a curious claim given that the numerosity in humans is merely the same ability to recognize small and differential quantity shared by many species; the difference, as we explicated in our article, is that human numerosity is functionally integrated with abilities for the precise manipulation of fingers and objects and additional dimensionality in vision (Orban 2011; Orban et al. 2006). Everett also cites Hurford’s claim, “Without language, no numeracy” (Hurford 1987:305), finding it “prescient” (Everett 2013b:81). However, Everett has failed to recognize that Hurford has since softened his stance, claiming more recently, “Without using language, we still can’t go [higher than the subitizing range of about four]” (Hurford 2007:91–92). Hurford’s revision admits the possibility of apprehending some quantities—those at least in the subitizing range—without establishing vocabulary for them first.

Nor did we argue that language cannot shape higher number concepts, since it most obviously does. Exact higher quantities are readily learned through language: number words not only help modern children learn to count, they enable the apprehension and communication of quantities for which material scaffolds may be infeasible (e.g., millions), and as Everett himself notes, even Pirahã can learn higher-quantity numbers through linguistic exposure. Acquiring number concepts through linguistic exposure, however, is a different mechanism than the one we proposed; moreover, we suggest the linguistic-exposure mechanism entails that someone else has already developed the numerical concepts and labeled them with words that enable their communication. We are addressing a more fundamental question, which is this: Given subitization and magnitude appreciation, how do discrete quantities like “seven,” “eight,” or “nine” emerge out of the undifferentiated *many*, the universal term for quantities higher than the subitization range? In our article, we suggested that this happens through the interaction of numerosity with material culture, which acts to scaffold quantities beyond the subitizing range, enabling their “crystallization” as distinct visual and tactile entities (Pica et al. 2004:503). Indeed, were it true that meaningful higher-number words were a necessary prerequisite for developing higher-number concepts, it would be surprising if any society ever developed any.

Let us return to Everett's idea that language is somehow responsible for originating concepts of exact higher quantities, by which we assume he means quantities exceeding the subitizing range. Everett cites Spaepen et al. (2011), who argue that "exact quantities to which words like 'seven,' 'eight,' and 'nine' refer seem so basic it is hard to imagine that we might need the word 'seven' to have the concept *seven*" (3163). We counterargue that it is difficult to imagine because it is not true. The number "5," for example, which falls outside the range of anyone's definition of subitization, may perhaps be so readily understood because it combines "3" and "2," both of which are subitizable and might act as memory chunks (e.g., Gobet et al. 2001). We find it implausible that the number "9" would first require the word "nine" in order to have the concept *nine*, as Spaepen et al. (2011) would argue. In a linguistically informed environment (i.e., one with preexisting concepts of number imparted through language), when children first acquire a word like "nine," it is meaningless until they have mapped its semantic content onto their nonverbal representations of quantity (Cantlon et al. 2006; Dehaene 2007). In an environment lacking preexisting numbers, a concept such as *nine* might be gained by recognizing an idea of three sets of "3" acquired from subitization in interaction with material scaffolding.

There is the ethnographic evidence to support the view that subitized and higher-quantity concepts develop before their associated vocabulary and that they develop through interaction with material culture (e.g., Overmann 2012). Accordingly, our model assumes that number words indicate the presence of number concepts but do not necessarily exhaust them. We argue that numerosity is largely independent of language and that exact higher-quantity recognition is built upon numerosity in interaction with material culture. Absent the indigenous development of numeric concepts, we do not deny that exact higher-quantity concepts can also be acquired through the shortcut of linguistic exposure to cultures that have previously developed them.

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