The Role of Culture and Language for Numerical Cognition

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Numeracy is a paradigmatic example of the close dovetailing of culture, language, and cognition. The two systems central to the numerical competence—one for the exact representation of small numbers and one for the approximation of larger numbers—are relatively old in phylogenetic terms and available almost from birth. Together, they provide the basis for the specifically human ability to also assess larger numbers in an exact manner (Dehaene, 1997; Feigenson et al., 2004). Yet, while several scholars consider numeracy a core domain of knowledge (Spelke & Kinzler, 2007), its full development seems to presuppose cultural and linguistic input in the form of counting sequences, as indicated by studies on two Amazonian groups (Gordon, 2004; Pica et al., 2004). If, however, number representations are absent from both culture and language, their relative relevance for numerical cognition cannot be assessed unambiguously. This symposium attempts to advance this field of research, which is increasingly recognized as one of prime interest for cognitive science. It brings together researchers, who have contributed considerably to the expanding knowledge on numerical cognition.

- *Karenleigh A. Overmann* draws on insights from archaeology and various subfields of cognitive science in her investigation of how brains, bodies, and material artifacts interact to generate numerical cognition (Overmann, 2013, 2104).
- With his background in anthropology and linguistics, *Caleb Everett* uses intra-cultural variation to scrutinize the role of linguistic representations for numerical cognition (Everett, 2013; Everett & Madora, 2012).
- *Marie Coppola* has specialized in the role of language in number abilities, combining approaches from psychology and linguistics (Spaepen et al., 2011, 2013). With her student *Deanna Gagne*, she examines the effect of language proficiency on numerical cognition.
- Cognitive anthropologist *Stephen Chrisomalis* is the leading expert on numerical notion systems (Chrisomalis, 2004, 2010) and has developed an empirical test for scrutinizing their representational effects.
- *Andrea Bender* and *Sieghard Beller*, finally, combine anthropological and psychological expertise to analyze the relative importance of different representational tools for numerical cognition (Beller & Bender, 2008; Bender & Beller, 2012), thereby also wrapping up the symposium.

They all attempt to integrate insights from their various disciplinary backgrounds—including archaeology, anthropology, linguistics, philosophy, and psychology—thereby spanning almost all subfields of cognitive science in an exemplary manner.

Numeric Cognition from the Perspective of Material Engagement Theory

Karenleigh A. Overmann

Accounts of numeric cognition must explain both within-species similarity and cross-cultural variation. Numeric system similarities and differences are examined through the components of numeric cognition: brains, bodies, and material artifacts. Malafouris' (2013) *Material Engagement Theory* is applied to material counting technologies (bodies and artifacts) through three main ideas: extended mind, material agency, and the enactive sign. The extended mind hypothesis suggests that numeric cognition includes material devices for counting in a way that goes beyond mere causal linkage. Counting technologies have different affordances, which alters their material agency and varies numeric system outcomes. The enactive significance of material signs is compared to the communicative significance of lexical numbers to suggest that the potential for numeric system elaboration depends, at least in part, on the way in which they differ.

The Role of Intra-cultural Variation in Exploring the Confluence of Language and Numerical Cognition

Caleb Everett

How can data from populations without nonlinguistic or linguistic numeric representations shed light on the respective roles such symbols play in the shaping of numerical cognition? While this widely acknowledged issue is problematic, we suggest that it is not intractable to the extent sometimes assumed. Recent work has demonstrated that intra-cultural variation offers support for claims of linguistic primacy in the connection of our innate capacities for the exact and approximate recognition of quantities (Everett & Madora, 2012). While the relevant evidence is not dispositive, it does help to tease apart the roles of linguistic and nonlinguistic symbols in the construction of human numerical cognition. We discuss three Amazonian cases of intra-cultural variation in the usage of numeric language and suggest that researchers can and should exploit such variation, as they have exploited cross-cultural data (Everett, 2013), in the exploration of the nexus of language and numerical cognition.

Numerical Cognition with Inadequate Linguistic Input: Explaining (and Improving) Deaf Children's Poor Mathematical Performance

Deanna Gagne & Marie Coppola

Deaf and hard-of-hearing students perform more poorly in mathematics than their normally hearing peers. This is not a direct result of deafness or manual communication. Only 5% of American deaf children have culturally Deaf parents who use American Sign Language (ASL) with them from birth; these deaf children perform like hearing peers. Language and mathematical abilities are associated in hearing children (e.g., Levine et al., 2010), deaf preschoolers, orally educated deaf children, and home-signing adults with no linguistic input (e.g., Spaepen et al., 2011), but remain uninvestigated in *signing* deaf children. We compare native-signing deaf children to children exposed to ASL later (at school). Our studies will establish a baseline for native-ASL deaf children; compare effects of incomplete language access across modalities (signed/spoken); and relate number language to number cognition.

Representational Effects of Historical Numerical Notation Systems

Stephen Chrisomalis

Over the past twenty years, considerable attention has been paid to cross-cultural cognitive effects relating to numerosity, such as the SNARC effect and one-to-one correspondence. This literature can be augmented by considering representational effects associated with different numerical notations (e.g., Roman numerals, Maya numerals, Babylonian numerals). A methodological complexity is that, because there are few if any fluent users of many notations, it is challenging to compare them to one another or to Hindu-Arabic numerals. Previous studies frequently assume representational effects directly from the features of number systems, or rely on anecdotal report, with little consensus reached. An alternative is presented in which the features of numerical notations are abstracted, and cognitive tasks developed, to allow historical or obsolete representational systems to be compared to one another directly. Results from a pilot study conducted with American middle-school students demonstrate the feasibility of such comparisons on a broader scale.

Numeration Systems as Complex Cultural Tools

Sieghard Beller & Andrea Bender

Numerical competencies are considered a core domain of knowledge, and yet, the development of specifically human abilities seems to presuppose cultural and linguistic input by way of counting sequences. These sequences may be realized in different modalities (verbal, notational, or body-based) and constitute systems with distinct structural properties, the cross-linguistic variability of which has implications for number representation and processing (e.g., Bender & Beller, 2012, 2014). Here we contrast various numeration systems across languages and modalities, and analyze their representational effects. In doing so, we will also draw conclusions from the symposium more generally on the relative relevance of culture and language for numerical cognition.

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