Title
Methodological issues in the cross-disciplinary study of numerical cognition

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Advances in a wide variety of disciplines have begun to tackle the challenge of finding out what happens to which cognitive systems to allow us to develop numerical abilities, yielding mountains of data ripe with explanatory promise (Cohen Kadosh & Dowker 2015). The development of novel experimental methods have allowed ethologists and developmental psychologists to probe into the cognitive abilities and systems operating in preverbal infants and nonhuman animals, hinting at the boundary between our innate cognitive machinery and those formal abilities we develop by interacting with our cultural niche (Carey 2009). Uniting behavioral and brain data has produced strong support for the existence of cognitive systems recruited in the development of our formal numerical abilities (Feigenson, L., Dehaene, S., & Spelke, E. 2004).

Meanwhile, improvements in imaging technology allow archaeologists to study methods used to produce notched bones and other artificial memory devices that date back to the Upper Paleolithic (d'Errico et al. 2018), while anthropologists collect data on cognitive abilities of anumerate cultures (Gordon 2004) and linguists detail relations between geographical distribution of numerical terms and lack thereof across generations. Together, these disciplines are finally beginning to uncover the historical and ontogenetic development of numerical abilities.

However, this cross-disciplinary effort faces methodological and theoretical challenges that slow progress and undermine some of the conceptual commitments on which much of the empirical research rests. Scores of data attributing numerical content to innate systems are being questioned and re-interpreted in terms of non-numerical magnitudes (e.g. Leibovich, T., Katzin, N., Harel, M., & Henik, A. 2017). At the opposite end of the interpretative spectrum, researchers routinely attribute numerical abilities to animals, insects, and even deep learning networks (e.g. McClelland et al. 2016), despite the fact that more frugal interpretations of data are available in all cases. These numerous interpretation issues hint at growing conceptual chaos within the cross-disciplinary study of numerical cognition.

Bringing together perspectives from psychology, archeology, philosophy and mathematics, participants in this symposium will discuss conceptual and interpretation-related problems in the study of numerical cognition in order to identify patterns across disciplines and explore potential general solutions to these. **Pelland** is a postdoctoral researcher at the faculty of psychosocial sciences at the University of Bergen, working in the ERC Synergy Project "QUANTA: Evolution of Cognitive Tools for Quantification". **Mendoza Straffon** is a research fellow affiliated to the Centre for Early Sapiens Behaviour (SapienCE) and the Cognitive Psychology Unit at Leiden University (Netherlands), where her work on the perception and production of visual signs in phylogeny and ontogeny is funded by The John Templeton Foundation. **Parkinson-Coombs** has a masters degree in Pure Mathematics with a research focus in mathematical logic and complex analysis. He is currently a doctoral candidate at UC San Diego where he works with Rafael Nuñez on the origin and progress of mathematics. **Greenhill** is an associate Professor at the School of Biological Sciences at the university of Auckland. He previously worked as senior scientist at the Max Planck Institute for the Science of Human History in the Department of Linguistic and Cultural Evolution, and was a fellow at the

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Quantity isn't number

Jean-Charles Pelland

The study of numerical cognition has been hampered by 'optimistic' use of numerical terminology since its early days (e.g. Wynn 1992). This illustrates a general problem with numerical cognition research, that of separating behaviour based in numerical content with behaviour that co-varies with numerical aspects of the world. I discuss claims made in the study of nonhuman cognition – e.g. Howard et al.'s (2022) claim that bees have numerical abilities – and compare those to recent claims made of deep learning engines' numerical abilities (e.g. McClelland et al. 2016) to highlight problematic use of numerical terminology. As a solution, I offer a graded hierarchy of stages of numerical proficiency that can be used to eliminate broad generalizations, as well as over- and under-attribution of numerical abilities.

Inferring numerical cognition from Pleistocene technologies

Larissa Mendoza Straffon

Attempts to recover and reconstruct early numerical cognition have mainly focused on identifying evidence of potential notational systems of quantification (d'Errico et al., 2018). However, a wealth of past numerical knowledge can be inferred from other material culture domains. I review different Pleistocene taskscapes that imply numerical cognition and focus on weaving as a prime example of an activity that affords mathematical knowledge (Gerdes 2003). Looking beyond notational signs to other early technologies opens up new avenues of research for inferring and understanding the origins of human numerical cognition.

Enduring constraints on the global evolution of numeral base systems

Simon J. Greenhill

Languages around the world construct their numeral systems around many different base systems. Why have some languages seized on base 10 while others use binary or base 4? Here, I use a new global database of languages to quantify the evolution of numeral bases. The results point to the constraints - historical, regional, and cognitive - that have shaped the ways that different languages quantify the universe around them.

Theoretical myopia and experimental bias in the study of anumerate cultures

Oisin Parkinson-Coombs

Cultures whose languages lack numeral terms provide a unique perspective into questions concerning the origins of numerical cognition, and have been extensively studied (e.g. Gordon, 2004). Research targeting these populations has largely drawn its methods from developmental psychology, which is primarily concerned with how children in a numeral-rich environment acquire culturally-shared number concepts. I argue this research method make theoretical assumptions concerning what numbers are and that relying on such methods alone for research outside of a numerate context introduces a theoretical myopia and occludes data relevant to the origin of numerical cognition. I lay out experimental desiderata to avoid some of these issues and biases.

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