Studying integrated cultural-cognitive systems: Evolutionary, computational and empirical approaches

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Overview

Cognitive science (CS) has long acknowledged the role of cultural systems in producing systematic differences in cognitive organization (e.g. Medin & Atran, 2004; Levinson, 2012; Barrett, 2020). At the same time, we lack general frameworks which would describe the nature of these systems — and their mutual relationship with specific cognitive structures: specifically, accounts articulated under the same formal frameworks (reflecting optimality principles in information processing) that have been used to capture universal features of the mind (e.g. Tenenbaum et al., 2011; Gershman, 2021), or in general evolutionary frameworks such as those used by cultural evolution.

Our symposium presents a diverse set of projects developing theoretical, computational and empirical approaches to integrating cultural systems into cognitive science: **IK** will review the systematic cognitive effects of formal schooling, and provide an evolutionary framework for thinking about how the effects of school and other cultural-cognitive systems predictably differ from the effects traditionally considered in CS. **TCZ** will present an information-ecological approach to how minds and cultural systems coevolve and present a computational account for the emergence of the analytic-holistic dimension of cross-cultural differences. **MC,** offering a perspective from information theory, will detail how the mathematics of compressibility and generalizability may underlie cultural-cognitive variation, using schooling as a case study. **RC** will highlight the relevance of this work across CS and AI by presenting data from schooled and non-schooled participants showing that performance on a "human universal" ARC-AGI benchmark in fact depends heavily on dispositions and skills arising from formal schooling.

Beyond capacity: Formal schooling and the structure of cultural-cognitive systems

Ivan Kroupin

Cognitive science has achieved substantial success in characterizing universal features of human cognition using formal, first-principles frameworks grounded in information processing and computation. At the same time, decades of cross-cultural research document large, systematic cognitive differences associated with cultural institutions such as formal schooling (e.g. Cole, 1996; Rogoff, 2003; and see Rogoff & Chavajay, 1995 for an account of the cultural-cognitive split). These effects are robust across domains—including categorization, reasoning, attention, and executive control—yet they remain difficult to characterize in mainstream, computationally-informed CS.

In this paper, I argue that this persistent gap reflects a deeper theoretical blind spot: Because cultural evolution operates on much faster timescales than that of organisms, the cognitive effects of cultural structures should primarily shape a distinctive set of cognitive structures — e.g. dispositions, and that govern how individuals engage with tasks and environments. This *kind* of effect is difficult to capture in traditional CS which has focused its theory and method development on identifying and characterizing universal cognitive capacities evolved as part of the human organism. I will show how applying this distinction allows us to both begin systematically integrating schooling effects into CS, and helps explain why they previously were not. In closing I zoom out to outline the importance of investigating integrated cultural-cognitive systems as well as some general principles for doing so.

Information ecologies and the cultural evolution of analytic-holistic thought

Tian Chen Zeng

Human cognition is deeply shaped by culture, affecting processes from attention and memory, to causal inference and concept representation. These psychological differences have often been descriptively organized in terms of the analytic-holistic spectrum of cognitive styles (Nisbett et al., 2008; de Oliveira & Nisbett, 2017). However, a unified mechanistic account of this variation remains elusive. This paper develops a computational account for the origins and function of analytic and holistic thought, as a case study in how cognitive adaptations can be induced by culture-specific information ecologies. We propose that cultural traits such as subsistence style, social structure, communication and teaching norms, knowledge institutions, and prevalent learning modalities alter how learners sample their observations, which in turn affects how strongly they favor parsimony in their mental models (i.e., the strength of Occam's razor). In our account, holistic thinkers tend to

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treat observations as weakly diagnostic of underlying structure (“weak sampling”, Xu & Tenenbaum, 2007) from experience, whereas analytic thinkers tend to treat observations as representative and strongly diagnostic (‘strong sampling’), leading respectively to weaker and stronger applications of Bayesian Occam’s razor. We show that Hierarchical Bayesian models instantiated with different sampling assumptions reproduce core A–H patterns across many domains. This offers a computational lens on a core empirical pattern in cultural psychology, and paves the way to further informational-ecological accounts for how culture shapes cognition.

An RDT-based Model of Cognitive Variation

Matthew Cashman

Here we offer a formal account of cultural-cognitive variation between populations, treating minds as constrained mappers optimized for differing types of territories. Using Rate Distortion Theory (RDT), we model cognition as learning a finite codebook of reusable tools (concepts, heuristics, schemas) under limits on capacity, attentional effort, and per-use deployment costs. Environments that have co-evolved with schooled minds have more standardized information ecologies, and so allow making maps that very efficiently compress the territory into representations that are useful across many modern contexts ("Red means stop"). In contrast, unschooled environments have very little standardization. They reward high-fidelity representations tuned to their specific niche, maximizing local performance while sacrificing portability ("Tracking deer by the river is hard when the wind blows from across the water"). We introduce a standardization weight (α) capturing developmental exposure to standardization, and derive distinct optima for toolkits shaped by different ontogenetic distributions. A key contribution is the notion of environmental standardization, defined via the slope of the distortion–rate curve: in highly-standardized environments, small informational investments yield large performance gains across many possible environments, favoring abstraction. In low-standardization environments, performance improvements require encoding substantial nuance specific to a particular environment. The framework also distinguishes universally distortion-reducing tools from tools which represent a trade-off, and it predicts mismatch losses when minds optimized for one ecology are tested in another (e.g., syllogism tasks vs. subsistence contexts). We explain observed variation as, in part, rational adaptation to differing environments.

How Schooling Shapes ‘Universal’ Cognition: A cross-cultural study of the Abstraction and Reasoning Corpus

Rachel Calcott

Cross-cultural research shows that reasoning strategies vary with education and everyday problem-solving demands, yet benchmarks such as ARC-AGI (Chollet, 2019) assume that universal human capacities are sufficient to drive performance on abstract, decontextualized reasoning tasks. We examine how educational and cultural environments shape performance on ARC-style analogical reasoning tasks by comparing U.S. participants, Himba participants with formal schooling, and Himba participants without formal schooling. Using a multiple-choice adaptation of ARC tasks suitable for field settings, we tested Himba participants from Namibia’s Kunene region. Among those who passed comprehension checks, formal education strongly predicted performance: schooled Himba participants were over twice as likely to answer correctly as unschooled participants, who performed at chance levels. Schooled Himba participants performed above chance but substantially below the established U.S. baseline. These findings suggest that formal education is fundamental to the kind of decontextualized abstraction involved in measures used to measure ‘universal’ human cognition. These results highlight the importance of developing models which capture a broader range of human environments and reasoning styles in our definitions of reasoning, and in our attempts at creating synthetic analogues.

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