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The Future of Comparative Cognition: Answering Developmental Questions with Big Team Science

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I argue that the future of comparative cognition is not *what* we study but *how* we study it. I suggest that future scientists should ask questions from a developmental framework. I review common challenges in longitudinal research that scientists in comparative cognition encounter. Leveraging emerging large-scale collaborations within and across taxa (i.e., big team science) can enable us to overcome these challenges to answer how cognitive abilities develop. This appeal for a developmental lens will facilitate interdisciplinary discussion in comparative cognition.

Keywords: developmental, longitudinal, infant, comparative, big team science

When I read the call for short commentaries regarding the future of comparative cognition, the prompt "What kinds of questions should future scientists work towards answering?" drew my attention. I argue that it is not *what* we study, as the popularity of topics waxes and wanes, but rather *how* we study it. What's missing from comparative cognition is a developmental lens for characterizing change or continuity in cognitive abilities across time and taxa. To build my argument, I describe problems with the historical approach of comparing the performance of nonhuman (primarily adult) animals to developing children, outline the requirements for rigorous developmental research, and discuss barriers to asking developmental questions in comparative cognition. Finally, I propose that large-scale collaboration, aka big team science, is the solution for how future scientists in this field can answer developmental questions.

Why Do We Need Developmental Research in Comparative Cognition?

There is a precedent for scientists in comparative cognition to compare the performance of nonhuman animals—a group that is often predominantly or exclusively comprises adults—with the performance of children on the same or similar tasks. In my view, this approach is problematic for several reasons. First, it is heavily anthropocentric, creating a ceiling for nonhuman abilities and elevating human performance. Second, this type of comparison does not consider how cognitive abilities change across the lifespan within individual animals, yet a distinction is made between developmental periods in humans (e.g., infants, toddlers, preschoolers). Beran et al. (2014) similarly noted the lack of a developmental focus within animal cognition relative to research on human cognition. An additional problem leads to further difficulties in disentangling developmental phenomena: Historically, research in comparative cognition has tended to obscure individual differences that may exist within or across species (Thornton & Lukas, 2012), which further occludes the possibility of studying developmental trajectories. To be able to properly integrate development into comparative cognition, researchers need to also always consider individual differences.

Individual differences, coupled with measuring change or continuity over time, are an important source of variability in cognition because there is likely not a one-size-fits-all trajectory for the emergence of a particular trait. Differences in developmental experiences can have cumulative downstream effects—a phenomenon known in developmental science as *developmental cascades* (Iverson, 2021; Masten & Cicchetti, 2010). This concept appears widely in the child cognition literature (e.g., Bornstein et al., 2006), and developmental cascades was the theme of the 2022 International Congress on Infant Studies, suggesting contemporary interest among human infant scientists (presidential addresses: Oakes, 2023; Tamis-LeMonda, 2023). However, the concept of developmental cascades has yet to be widely adopted in comparative cognition. In addition to a gain in a cognitive skill having cascading effects on a later cognitive skill, a gain in another domain (e.g., motor) could have cumulative and cascading effects on a later cognitive skill (or vice versa, such that an early cognitive gain influences a later gain in another developmental domain). Thus, both within-domain and between-domain cascading effects are possible, opening many promising avenues for future studies in comparative cognition.

The inclusion of direct or indirect comparisons with children in comparative cognition does not necessarily ensure that we learn anything about development. Scientists may be searching for the origins of a particular adult human ability "X" in both the nonhuman and child groups tested (Rosati et al., 2014), and this approach indeed can tell us whether X occurs in either of these groups. However, these types of studies have not considered the origins of X in individual animals. Borrowing from ethology, "origins" in comparative cognition has largely been defined by phylogenetic differences (i.e., humans vs. other species) rather than ontogenetic differences (Tinbergen, 1963), such as characterizing developmental patterns. The role that differences in early developmental experiences play in creating differences in later cognitive performance is masked by the heavy use of adult animals and simultaneous underuse of longitudinal designs in comparative cognition.

A true developmental framework for comparative cognition scientists requires examining change or continuity in an aspect of cognition over time within the same individuals (i.e., multiple time points), within and across different phases of the lifespan, and within and across species. When this approach is not possible, sampling different individuals at multiple developmental time points can provide guideposts for other researchers. One possibility for why we don't (yet) have a rich tradition of developmental studies within the field of comparative cognition is that successfully carrying out rigorous developmental research in nonhuman animals is a daunting task, particularly for individual investigators. In the next section, I explore potential barriers to asking developmental questions in comparative cognition.

What Are the Barriers to Asking Developmental Questions in Comparative Cognition?

Longitudinal research is inherently labor intensive. Data must be collected from the same subjects across several time points, which delays study completion and subsequently imposes additional financial costs on the research team (e.g., increased expenses for per diems, travel to field sites). Time and budget considerations aside, longitudinal research in comparative cognition has two barriers related to measurement that may impede scientists from asking developing questions. The first barrier is sampling. It can be difficult for individual investigators to obtain a large sample size, which is needed for conducting statistical tests, when the target group is not adults. Juvenile or young subjects may not be available depending on breeding programs, or not available in sufficient number, at the site(s) with which the investigator is affiliated. In other cases, subjects in the target developmental group are available (e.g., infants), but the infrastructure is not available for them to participate in cognitive testing. Including infant nonhuman subjects in cognitive testing may require making modifications to the testing space or collecting data in social groups rather than separating individuals for testing (for a discussion on increasing accessibility for testing infants using examples from primate cognition, see Nelson et al., 2022).

The second barrier to asking developmental questions in comparative cognition is a lack of measures that are species fair (i.e., assessment is equivalent across all species tested) *and* developmentally appropriate for testing individuals outside of adulthood. The rise of

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comparative psychometrics, or cognitive test batteries, will likely better position scientists in comparative cognition to resolve this problem of which measurement tool to use (Shaw & Schmelz, 2017). A caveat, however, is that cognitive test batteries to date have been developed for adult animals only. Thus, some adjustments may be needed before testing younger animals. For example, Bray et al. (2021) conducted a longitudinal study across the first 2 years of life in candidate assistance dogs with a version of the Dog Cognition Test Battery (DCTB; MacLean et al., 2017) that was modified for use in puppies. Depending on the research question, investigators may consider using individual items or a subset from a test battery when collecting longitudinal data in young animals (e.g., Primate Cognition Test Battery—PCTB; Herrmann et al., 2007; Wobber et al., 2014). Finally, projects launched by large-scale scientific collaborations (ManyX groups; see Table 1) have developed or are developing standardized tasks to measure cognitive abilities within or across taxa. Eventually, these efforts to study aspects of cognition like reversal learning or inhibitory control could be scaled up into a larger test battery that captures cognition across the lifespan. In the final section of this commentary, I explore why future scientists should leverage big team science to answer developmental questions in comparative cognition.

How Can Future Scientists Answer Developmental Questions in Comparative Cognition?

Answering questions framed from a developmental lens in comparative cognition requires overcoming barriers in data collection, such as how to increase sample size and which measure is appropriate to use; these are solvable problems if future scientists leverage big team science. Big team science is an emerging approach where investigators pool resources to carry out a project that is beyond the scope of what any individual investigator could accomplish. Several large-scale collaborations have been formed by investigators working in comparative cognition over the past 5 years (ManyX groups; see Table 1). Three of these groups—ManyPrimates, ManyBirds, and ManyDogs—have published papers justifying the formation of their consortium, goals, and infrastructure (Lambert et al., 2022; ManyDogs Project, 2023a; ManyPrimates et al., 2019). Two of these groups, working with taxa that are widely studied in comparative cognition (i.e., nonhuman primates and dogs), have also completed their initial collaborative empirical study. ManyPrimates published its first project on short-term memory (ManyPrimates et al., 2022), and ManyDogs published its first project on dogs' understanding of human pointing gestures (ManyDogs Project, 2023b). In the remaining ManyX groups, procedures are currently in development or data collection is underway. Taken together, big team science has been successful in a relatively short time in comparative cognition.

These early efforts at using big team science in comparative cognition have largely been framed as a solution to the "replicability crisis," or the failure to reproduce the results of individual, and often influential, research studies. Projects are formed around topics of wide interest, and the result has been the development of best practices in the field to measure particular aspects of cognition. Procedures for collecting and coding data are prepared

Table 1. Big Team Science Groups in Comparative Cognition

Big Team Science Group	Project(s)	Status
ManyBirds (http://themanybirds.com)	Study 1: Neophobia	Data collection
ManyDogs (https://manydogsproject.github.io)	ManyDogs 1: Dog–Human Social Interaction	Published
ManyFishes (https://themanyfishes.github.io)	MFish1: Inhibitory Control	In development
ManyGoats (https://www.themanygoatsproject.com)	ManyGoats1: Goats and Human Attentive States	In development
ManyManys (https://manymanys.github.io)	MM1: Reversal Learning	In development
ManyPrimates (https://manyprimates.github.io)	MP1: Short-Term Memory	Published
	MP2: Delay of Gratification	Data collection
	MP3: Inference by Exclusion	In development

Note. ManyZoos (https://manyzoos.weebly.com) has formed but had not yet launched its first project as of the time that this commentary was written.

by the project team and preregistered. This aspect of the ManyX groups allows for the collection of large sample sizes using standardized protocols (e.g., ManyPrimates MP1, $n = 421$; ManyDogs ManyDogs1, $n = 455$). As these platforms and their data sets grow, future scientists may have opportunities to analyze data from individual animals who have participated in more than one project.

Future scientists should also be intentional about collecting longitudinal data from the start and including subjects across the lifespan. To date, ManyX groups have not used repeated measures designs or targeted data collection from a particular life stage, with open research calls instead inviting data from any subjects who complete the protocol only once. Contacting investigators who have previously contributed data for a big team science project to assess available subjects at a second time point would help establish feasibility for repeated measures designs (e.g., investigator buy-in, subject attrition rates). Further, launching a spin-off empirical project targeting infant or sub-adult data collection or a methodological project to develop solutions to testing infants or sub-adults in a particular taxa would create momentum for collaborative developmental work in comparative cognition, similar to what is currently being done in human infant research with the big team science group ManyBabies (https://manybabies.org). Critically, investigators interested in answering developmental questions in comparative cognition do not need to have access to nonhuman subjects. Big team science allows for contributions at any (or multiple) levels beyond investigation (e.g., collecting data) or providing resources (e.g., animal access, research supervision) such as conceptualization (e.g., formulating research aims), methodology (e.g., involvement in preregistration), analysis, and writing.

Conclusions

Future scientists in comparative cognition should ask questions that are developmental in scope, venturing into other life phases besides adulthood and incorporating longitudinal designs to examine change or continuity in cognitive abilities over time. This paradigm shift will allow investigators to examine the origins of particular traits in a manner that is consistent with human developmental science, including testing the concept of developmental cascades. Big team science, already successful in comparative cognition, can be leveraged to obtain a sufficient sample size and create standardized protocols to answer these developmental questions. The overall effect will be more interdisciplinary discussion and a deeper understanding of how particular traits develop across taxa.

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