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**Comparative Cognition: Perspectives, Challenges, and Prospects**

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**Abstract**

The publication of the centennial year of the *Journal of Comparative Psychology* is an occasion to reflect on the state of our discipline. In this article, I focus on one aspect of comparative psychology, namely comparative cognition. This focus stems from my long-standing interest in comparative cognition. The trends and challenges in comparative cognition share many of the trends and challenges in the broader field of comparative psychology. In the first part of this article, I outline my perspective on the field. Next, I consider challenges. I end with a section on prospects for the future.

Keywords: comparative psychology, comparative cognition, interdisciplinary research

### **Comparative Cognition: Perspectives, Challenges, and Prospects**

The publication of the centennial year of the *Journal of Comparative Psychology* is an occasion to reflect on the state of our discipline. In this article, I focus on one aspect of comparative psychology, namely comparative cognition. This focus stems from my long-standing interest in comparative cognition. I view comparative cognition as a hub at the intersection of animal behavior, ecology, evolutionary biology, cognitive science, neuroscience, and philosophy. I note a limitation at the outset that the trends and challenges in comparative cognition are likely to overlap incompletely with those of the broader field of comparative psychology. I also write from a particular vantage point, university-based research in the United States, recognizing that conditions are different in other parts of the world. In the first part of this article, I outline my perspective on the field. Next, I consider challenges. I end with a section on prospects for the future.

#### **Perspectives**

Where will new and exciting advances come from in the future? What factors can be harnessed to promote these advances? The future is always uncertain, but I attempt to outline my outlook on these questions. Some projections about the future examine the past. But other projections focus on new approaches.

One answer to the questions posed above focuses on interdisciplinarity (Crystal & Glanzman, 2013). Comparative Psychology has always borrowed from related fields, such as animal behavior, experimental psychology, and developmental science. Increasingly, science is accomplished with teams. A broader outline of interdisciplinarity integrates comparative psychology with ecology, evolutionary biology, neuroscience, cognitive science, informatics,

philosophy and other disciplines. Comparative psychologists are experts in behavioral approaches. In many cases, neuroscientists seek a functional endpoint in behavior but lack expertise in behavioral approaches. A behavioral endpoint in neuroscience research ensures that the insight gained on the neuroscientific front has a connection to something functional. Comparative psychologists can improve neuroscience research by bringing expertise in understanding the natural behaviors of animals and an evolutionary perspective. Integration with neuroscience is likely an important factor in future research. But integration with neuroscience is not without challenges. In collaborations with neuroscientists, the neuroscientist often wants the behavioral endpoint to be efficient; one day of behavior is ideal from this perspective, two days is tolerable. Experts in behavioral approaches typically invest a significantly longer amount of time. Many interesting behavioral phenomena cannot be investigated in a day or two. A potential solution to disagreements about time horizons focuses on a division of labor across labs; for example, an agreement may be reached in which long-term behavioral studies are conducted in the comparative cognition lab, and the animals are transferred to the neuroscience lab for brief periods (e.g., surgeries, tissue collection, etc.).

Many individuals do most of their research with members of their own labs (e.g., grad students) and like-minded colleagues. Large interdisciplinary teams are uncommon in our field in the United States. Projects in Europe and Japan are ahead of the US in this respect. Integration with philosophers is another promising avenue for future research. Philosophers bring expertise in analysis of problems that can transform the experimental techniques of comparative psychology. For example, theory of mind research has benefited from the critical

analysis of philosophers (Allen & Bekoff, 1999; Andrews, 2020; Bugnyar et al., 2016). Again, Europe and Japan are ahead of the US in advancing this type of collaboration.

I will describe two examples of large interdisciplinary projects. The first case comes from “The Science of Mental Time: Investigation in the past, present and future” which is led by Shigeru Kitazawa in Japan. They refer to mental time as an awareness of time over past, present, and future. The project involves an active collaboration of neuroscientists, psychologists, clinical neurologists, linguists, philosophers, and comparative ethologists. Examples of diverse accomplishments of this project include a better understanding of how the hippocampus encodes locations of self and others (Danjo et al., 2018), how novelty is encoded in the hippocampus (Mizunuma et al., 2014), and insights into the dysfunction of time perception and counting in patients with Parkinson disease (Honma et al., 2016). A second example comes from “Constructing scenarios of the past: A new framework in episodic memory” which is led by Sen Cheng in Germany. The project combines computational neuroscience, psychology, and philosophy, in an effort to answer fundamental questions about scenario construction during episodic memory recall. An example of an accomplishment of this project is an improved understanding of the interplay between episodic memory and sensory processing (Görler et al., 2020).

More broadly, new, cutting-edge developments in interdisciplinary research are difficult to track. Some of this work is published in interdisciplinary, high-impact journals such as *Science*, *Nature*, *Proceedings of the National Academy*, and others. These articles are a small proportion of the research published in these outlets. In the past, most researchers stayed abreast of new developments by reading a small number of journals in the field, *JCP* among

98 them. Of course, this is a valuable source of information. However, monitoring cutting-edge  
99 developments in interdisciplinary research has the potential to open new opportunities for  
100 comparative psychologists to contribute to cutting-edge interdisciplinary research. To address  
101 this problem (important developments but difficult to find), I undertook an initiative when I  
102 became the editor of *Learning & Behavior* (Crystal, 2016). The journal launched a new section  
103 of the journal, called *Outlook*. The goal of Outlook papers is to allow readers to stay up to date  
104 on the latest findings, trends, important developments, and new ideas in the field. Outlook  
105 papers offer a short review (limited to 2 pages) of groundbreaking work reported in a recent  
106 target article, allowing the Outlook author to say something about the target article and expand  
107 to the author's views on this part of the field. By the time that this article is published, we will  
108 have published about 60 Outlook papers on varied topics. A measure of the impact of this effort  
109 includes over 100,000 accessions and downloads of Outlook papers.

110         One limitation of the focus on cutting-edge developments is that they sometimes lack a  
111 clearheaded assessment of alternative explanations. The effort to draw bold conclusions  
112 sometimes leads to a rush to judgment before adequate experimentation can restrain the  
113 conclusions. Theory of mind is a domain that has become more critical of itself over time (Call &  
114 Tomasello, 2008) Ultimately, to have a lasting impact on the field, converging lines of evidence  
115 are needed (Crystal & Suddendorf, 2019). A balance between critical judgments and promoting  
116 the field is needed; for example, it is important to not "eat the young" researchers, which may  
117 adversely impact their career development. Finding a balance along this continuum is not a  
118 unique problem for comparative cognition.

Another perspective focuses on selection of questions, problems, and approaches. Although variation along these lines is substantial across disparate domains of comparative psychology, I will outline my perspective on comparative cognition. I advocate the view that comparative cognition is primarily focused on comparisons of animals with human cognition. Research seeks to explore the evolution of cognition by identifying aspects of cognition that are widely distributed across species, although some aspects of cognition may be unique to people. This focus is not anthropocentric, in the sense that researchers adopt human-oriented ideas about animals. Instead, it is a perspective that views human cognition as a well-developed discipline to prompt questions about the evolution of cognition in animals. A wide range of views have been espoused about the role of a human-oriented perspective in animal behavior (Burghardt, 2004; Smith et al., 2012; Williams et al., 2020; Wynne, 2004). Animals may not have the same level of the capacities exhibited by humans, but it is likely that animals have important evolutionary precursors. The exact degree of similarity or dissimilarity remains to be empirically established.

A final perspective focuses on identifying limits in comparative cognition. Finding that animal X has process Y is an advance. This advance may be leveraged to explore the range and limits of the process in animals. For example, we recently described evidence that rats replay a stream of episodic memories (Panoz-Brown et al., 2018). This development prompts new questions about the similarities and differences in the replay of episodic memories in rats and humans. Insights in the evolution of cognition may come from identifying where the limits lie in this, and other, aspects of cognition (Crystal & Suddendorf, 2019). To identify limits, one needs

to not be afraid of failure because the outer limits of a phenomenon are defined by the boundary between successes and failures.

### **Challenges**

The field of comparative cognition faces significant challenges in the future. One challenge stems from different traditions in interdisciplinary research. An example above noted that neuroscientists sometimes seek behavioral endpoints that do not match the traditions in behavioral approaches. Comparative psychologists can contribute as equal partners to this type of interdisciplinary research, but success hinges on aligning styles and traditions adequately to make the undertaking successful for multiple parties.

Funding to support comparative psychology has been a significant challenge for a long period of time, and the problem is likely to intensify in the future. As funding to support pursuits of fundamental questions (i.e., basic research) declines, focusing on applications offers a pathway forward. Indeed, the prospect of interdisciplinary research is appealing because it offers a route to integrating comparative psychology with applications, such as animal models of human health (Crystal, 2012).

Training new scientists to be prepared to effectively carry out research with interdisciplinary teams is an additional challenge. Many senior investigators were trained in a model in which they were on track to self-replicate their mentors. This trend was sustainable when funding for basic science was more plentiful. However, this model will only intensify isolation of comparative psychology from interdisciplinary opportunities. Training in graduate school should emphasize team-science while preparing future researchers to collaborate with individuals with diverse skillsets.



A final challenge comes from the aversion of being labeled anthropocentric. I view comparative cognition as an effort to leverage our knowledge about the species of animal to enable us to ask questions about advanced cognitive abilities in animals and the evolution of cognition. For example, rats have exceptional spatial cognition and olfaction. We (and others) have leveraged these propensities to graft complex problems onto domains in which rats naturally excel. I will give two broad examples of this approach. The first example focuses on spatial navigation. In a number of studies, we have investigated episodic memory in rats navigating on radial mazes. We do not teach rats about spatial cognition; rather they come to the experiments with naturally occurring foraging competencies. Our strategy was to layer elements of episodic memory on top of spatial navigation. By layering, I mean that we start with task requirements that tap into naturally occurring behaviors and abilities, and then we add additional features; this strategy has been used effectively by others (e.g., Clayton & Dickinson, 1998). This is a natural fit for one approach to episodic memory, which focuses on what-where-when memory (i.e., memory of an event or episode is demonstrated by knowledge of what happened, where did it occur, and when did it happen). Rats pass a number of tests of episodic memory in these preparations (Babb & Crystal, 2005, 2006a, 2006b; Naqshbandi et al., 2007; Roberts et al., 2008; Zhou & Crystal, 2009, 2011; Zhou et al., 2012). Again, this is a natural fit for a different approach to episodic memory, which focuses on the source (or origin) of memories (i.e., source memory). Rats pass a number of tests of source memory in these preparations (Crystal & Alford, 2014; Crystal et al., 2013; Crystal & Smith, 2014).

The second example focuses on olfaction. Again, rats come to the experiments with remarkable olfactory abilities. In a number of studies, we have investigated episodic memory in

rats making judgments about odors that they previously encountered. Again, our strategy was to layer elements of episodic memory on top of olfactory decision making. This is a natural fit for approaches to episodic memory that investigate the capacity to remember many episodic memories and the sequential order of episodic memories (Panoz-Brown et al., 2018; Panoz-Brown et al., 2016).

In both of these examples, we tend to agonize over the details of the design to ensure that we optimize conditions for the animals to succeed. Our view is that there are many ways to do these studies wrong, which provide limited insights. For example, treating rats as if they were little primates may lead investigators to place a rat in front of a touchscreen. Although rats are able to perform relatively simple discriminations in these preparations (e.g., Horner et al., 2013), it is unlikely that we would succeed in layering more complex problems in this approach. Visual acuity (unlike spatial cognition and olfaction) is not a strength in rats.

### **Prospects**

Prospects for the future are linked to challenges (described above) and our response to challenges. One challenge focuses on the declining investment in basic research by funding agencies. In the US, the decline in funding for basic research has accelerated as the focus on applications have increased. An illustration comes from comparing the growth in budgets for the National Institutes of Health and the National Science Foundation; in 2020, the NIH budget was over five times the budget of NSF. Advocacy in the field may try to mitigate this trend, but the focus on application is widespread in society and unlikely to abate. Thus, team science approaches to interdisciplinary research provides a route forward.

A promising prospect for the future of comparative psychology focuses on institutional support especially at universities that focus on undergraduate education (Highfill & Yeater, 2018; Krause, 2018). Research in this setting can be done using institutional support for undergraduate research. A subset of these institutions continues to invest in animal facilities to support training and research. It will be important to maintain this institutional support in the future. Vigilance and advocacy are needed to retain and increase resources. One strategy for securing resources focuses on connecting our training in research to entry into STEM fields. For example, the Center for the Integrative Study of Animal Behavior at Indiana University has operated an NSF-funded Research Experiences for Undergraduates program for 25 years. Our interns engage in rigorous, cutting-edge research in a faculty member's lab during a 10-week summer program. After completing our program, about 39% of recent interns presented their research at national meetings, and 26% presented at their home institutions or at regional conferences. An impressive 97% of recent interns say that they are more likely to pursue graduate study in science because of their participation in our program, and 78% of recent interns are currently pursuing or intend to pursue graduate degrees. These latter percentages are noteworthy because 77% of recent interns come from minority groups underrepresented in STEM, 80% are women or other-gendered, 41% are from low income families, and 38% are first-generation college students.

A final prospect for the future focuses on achieving a balance between repetition of well-established approaches and creativity to develop new approaches. Our confidence in a phenomenon is increased by replication, and converging lines of evidence requires some degree of continued focus on similar problems. Sometimes a field gets stuck in continual

repetition of the same experiments (Crystal, 2014). However, new advances will come from creative approaches to old and new problems. The creativity of new investigators is one of the most exciting prospects for the future of comparative psychology.

### **Conclusions**

A lot of comparative cognition research can be done relatively inexpensively. This strength may propel comparative cognition research as an exciting avenue of animal behavior research at smaller state schools and liberal arts colleges. More large scale research may be fostered by developing larger interdisciplinary and international research teams. Comparative psychologists can bring an understanding of the natural behavior of organisms and an evolutionary context that can strengthen neuroscience research. Team science is more likely to include comparative psychologists when we train our students to be conversant in more than one discipline. Knowing the language, methods, and problems of multiple disciplines will allow us to play a central role in new scientific endeavors. Along these lines comparative psychology has much to contribute to science as we progress toward the next century.

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