Lamontagne, S.J., Kuhlmeier, V.A., & Olmstead, M.C. (In Press). Comparative Cognition and Cognitive Ecology in the Classroom. *Canadian Journal of Experimental Psychology*.

Comparative Cognition and Cognitive Ecology in the Classroom

Running Title: CC in the classroom

Steven J. Lamontagne^a, Valerie A. Kuhlmeier^{a,b}, & Mary C. Olmstead^{a,b}

^aDepartment of Psychology, Queen's University

^bCentre for Neuroscience Studies, Queen's University

Correspondence concerning this article should be addressed to Mary C. Olmstead, Department of Psychology, 62 Arch Street, Queens University, Kingston, Ontario K7L 3N6. E-mail: olmstead@queensu.ca

Abstract

The scientific study of animal cognition has roots in both experimental psychology and evolutionary biology, with researchers often working in related disciplines such as neuroscience, computing science, or ecology. The interdisciplinary nature of the endeavour is both a strength and a challenge for the field. We begin this review with a brief history of comparative cognition and cognitive ecology, focusing on cognitive processes as a mechanistic link between ethology and behaviourism. We then present a ‘snapshot’ of modern-day undergraduate courses in Canada, the United States of America, and the United Kingdom that focus on animal cognition, highlighting the various course names and host departments. We emphasize the value of keeping (or adding) this subject material within curricula, either as independent courses or as enhanced material in other courses. We also present pedagogical approaches to teaching animal cognition that include techniques in large lecture-based courses and in smaller courses that emphasize hands-on experiential learning.

Keywords: education, teaching, evolution, psychology, biology

Public Significance Statement: Comparative cognition unites researchers from traditionally disparate disciplines, presenting both benefits and challenges to training students in this field. Here, we emphasize the value of teaching comparative cognition to a broad undergraduate population, noting that courses in this discipline foster critical thinking, exemplify the value of hypothesis testing using the scientific method, and introduce students to practical applications of the field.

1. Introduction

This special issue on Comparative Cognition and Cognitive Ecology is devoted to ‘uniting research and researchers from traditionally disparate backgrounds’. The interdisciplinary nature of the endeavour is both a strength and a challenge for the field. In this paper, we explore how the material can be presented to the next generation of scientists through formal teaching at an undergraduate level.

In line with other thinkers (Shettleworth, 1993), we employ a broad definition of cognition that includes mechanisms by which organisms acquire, process, store, and act on information from the environment. Research in comparative cognition examines cognition in at least two species, though multiple species may not be tested in the same experiment (e.g., research on theory of mind in chimpanzees may only refer to previous results from studies with human children). Cognitive ecology, similar to comparative cognition, represents an integration of cognitive psychology and ecology, examining cognitive processes that allow animals to solve fitness-related problems (Real, 1993). Comparative cognition and cognitive ecology are thus integrated by the common goal of understanding how cognition is manifested in behaviour. Although the two fields may, at times, employ different techniques (e.g., studies in the laboratory or in natural habitats), both provide insight into proximate and ultimate explanations of cognition. Throughout this paper, therefore, the two are discussed as one field. Additionally, for simplicity in this paper, we reserve the term ‘animal’ for non-human species.

2. History of Comparative Cognition and Cognitive Ecology

Aristotle (c. 384–322 B.C.) provided one of the first comparative studies of psychological topics with his description of intellectual and moral propensities in different species (Vicchio, 1986). Philosophical writings on this subject continued over the centuries, based on the

assumption that animals lacked critical skills and abilities (e.g., thought, reasoning) that set humans apart. Descartes (1596-1650), in particular, argued that animal behaviour was governed by automatic or fixed responses to sensory input (Boring, 1950). Only humans had volitional control of their actions, arising from species-specific attributes, like consciousness, and an understanding of abstract concepts, such as time.

Darwin's theories of natural selection and continuity of species (1859, 1871) introduced the idea of human-animal similarities in mental faculties including memory, language, and emotions. He acknowledged that these may exist to a lesser degree in other species, but pointed out that animal displays of psychological traits were the building blocks of more complex expressions in humans. Darwin's work launched a proliferation of research over the next century comparing the cognitive abilities of humans and animals. Eventually, the idea emerged that a cross-species examination of specific processes (e.g., memory) can inform the study of cognition itself. This perspective was mutually beneficial, enhancing the understanding of basic cognitive processes and expanding knowledge of cognitive abilities across species (Shettleworth, 2013).

Although Darwin's theories helped to establish future studies in comparative cognition, the idea that humans and animals share psychological traits was not readily accepted by the scientific community. In addition to the concept of natural selection, which itself was controversial, many people criticized the means by which Darwin and his colleague, George Romanes, collected data. Both relied heavily on anecdotal reports of 'human-like' abilities in animals, making it difficult if not impossible to replicate their findings. Indeed, Morgan (1894) and later Thorndike (1911) challenged Darwin's claims of animal intelligence, noting that experimental evidence provided no support for insight, problem solving, or other complex thought in animals. Their systematic investigations of 'trial and error' learning in different

species laid the foundation for behaviourism that dominated North American Psychology in the first half of the 20th century. Although often viewed as an antidote to Darwinian views, behaviourism inherently adopted evolutionary theory with the premise that principles of learning, established in animal laboratory experiments, could be extended to humans. A comparative analysis of cognition, focused on understanding unique and/or shared traits across species, was de-emphasized during this period, although not completely absent (see Maier & Schnierla, 1935).

Paralleling the work in North American labs, a separate tradition of studying animal behaviour in the natural environment was developing in central Europe (Danchin et al., 2008). Building on the work of naturalists, such as Jean-Henri Fabre (1823-1915), scientists began to systematically examine how factors like motivational state or the presence of external stimuli impact naturalistic behaviours (e.g., mating, foraging, parenting, etc.). The focus on causal determinants of responses that were part of an organism's behavioural repertoire helped to establish the emerging field of ethology, headed by Konrad Lorenz, Niko Tinbergen, and Karl von Frisch (Dugatkin, 2004). The theoretical perspective of ethology broadened with Tinbergen's four questions: 'What causes the behaviour?', 'How does it develop in an individual?', 'How does it function?', and 'How did it evolve?' (Tinbergen, 1963). Behavioural ecology, which emerged as a subdiscipline of ethology, focused on the latter two 'ultimate' questions, promoting the idea that behaviour is subject to the laws of natural selection. Like physiological traits, behaviours that increase the survival and reproductive advantage of an individual are more likely to be transmitted to the next generation (Hinde, 1970).

The three founders of ethology were awarded the Nobel Prize in Physiology in Medicine (1973), which confirmed the impact of their work and helped to establish the study of naturalistic

behaviours in the United Kingdom and North America. Behaviourists slowly recognized that animal responses must be interpreted with some knowledge of the environment to which the species is adapted. A critical turning point occurred with the demonstration of differential sensitivity to specific cue-outcome associations (Garcia & Koelling, 1966). As one of the pioneering figures in comparative cognition noted, this paper ‘changed how we think about animal learning and its relationship to the rest of biology’ (Shettleworth, 2010, pg. R910). Subsequent work verified the ubiquity of adaptive specializations (also called biological predispositions, responses preparedness, or constraints on learning), confirming that behaviour was tied to a biological system that had evolved to meet the functional needs of a particular species (Hulse, 2006).

Both behaviourism and behavioural ecology developed with little or no consideration of cognitive processes that may control the behaviours under study. By the second half of the 20th century, it became clear that even seemingly simple responses involved some level of information processing. Strengthened stimulus-response associations, the mainstay of behaviourism, could not explain phenomena like blocking or latent inhibition without reference to internal mechanisms such as surprise, attention, or expectation. Field studies of caching or habitat selection revealed that animals store and process large amounts of information over extended periods of time. These scientific developments coincided with the rise of cognitive science, spurred by advances in computing and linguistics in the 1950s and 60s (Leahey, 2017). Within the next two decades, researchers studying animal behaviour often adopted a cognitive framework, using underlying mechanisms such as spatial navigation, memory, or decision making to explain behavioural change (Shettleworth, 2013). A natural outcome of this work was

the recognition that cognition is an adaptive trait, meaning that cognition (e.g., memory, decision making, timing, etc.) evolved to solve fitness-related problems.

By the late 1960s, it was clear that the goals and interests of ethology and behaviourism were complementary (Hinde, 1971) and that cognition provided a mechanistic link between the two. The study of animal cognition as a distinct discipline was set in motion by a conference on animal memory at Dalhousie University in 1969 (Hulse, 2006), followed by an edited volume from these talks (Honig & James, 1971). Reviewing experimental findings within the next decade, Macphail (1982) proposed that there were no differences in intelligence across invertebrates (with the exception of humans), which may have helped to move the field away from discussions of general intelligence to specific cognitive processes adapted to unique ecological niches (Pearce, 2008). By the early 1990s, an increasing number of researchers integrated principles of cognitive psychology into studies of how animals solve ecologically-relevant problems. At the same time, technical advances in neuroscience research provided the tools to investigate proximal explanations (i.e., neural mechanisms) of specific cognitive processes. By the early 1990s, a small group of these scientists (Ron Weisman, Mark Bouton, Marcia Spetch, and Ed Wasserman) planned and executed a gathering of like-minded colleagues, the first Conference of Comparative Cognition (CO3) held in Florida in 1994¹ (Weisman *et al.*, 2015). CO3 expanded rapidly, leading to the formation of the Comparative Cognition Society in 1999 and establishment of the society's online journal, *Comparative Cognition and Behaviour Reviews*, in 2007. Initially, most researchers working in the field of comparative cognition were associated with psychology departments, although many had cross-affiliations with other departments and/or received training in related disciplines. In that sense, the founders of the field

¹ The conference program can be found at: <https://www.comparativecognition.org/>

promoted interdisciplinarity, facilitating expansion to other departments, which occurred in the subsequent decades.

3. Comparative Cognition in the Modern Curriculum

Given that comparative cognition emerged as an interdisciplinary endeavour, it is not surprising that researchers who identify with this field are represented in a number of academic departments. As a consequence, undergraduate students may encounter comparative cognition literature in different courses, degrees, or programs depending on the institution. This could explain the apparent belief that students are not receiving adequate training in this area. As an example, in 2015, the Comparative Psychology section of the journal *Frontiers in Psychology* published an opinion paper by Abramson entitled “A crisis in comparative psychology: Where have all the undergraduates gone?”. The paper garnered much interest and excitement. By this writing, there have been approximately 32 citations, including over 10 commentaries in that same journal that were written by researchers and instructors, as well as an expanded piece by Abramson published in 2015 in *Comprehensive Psychology* (hereafter, Abramson, 2015b). The crisis, Abramson suggested, was reflected in “the need to recruit undergraduates as the next generation of comparative psychologists”, a need which is arguably being unmet due, in part, to insufficient graduate programs, course materials (e.g., textbooks), and undergraduate courses in comparative psychology (Abramson, 2015b, p. 1). Among those who commented on the original paper, there was much agreement with Abramson in relation to strategies to increase student interest (some of which we aim to expand upon in the next section). Yet, there was also considerable disagreement, mostly focused on the conceptualization of *comparative psychology*, which, unlike Abramson, many commenters did not construe as a separate and distinct discipline. Instead, they described thriving curricula and research programs

that exist under other names, like *comparative cognition* or *cognitive ecology* (e.g., Brodbeck & Brodbeck, 2015; Kuhlmeier & Olmstead, 2016; McMillan & Sturdy, 2015; Osvath & Persson, 2015; see also Krause, 2018, who considers comparative psychology and comparative cognition to be “sister disciplines”).

Here, we present a ‘snapshot’ of the modern curriculum in relation to comparative cognition, comparative psychology, and cognitive ecology. We conducted an online search of a sample of university course catalogues. The search was focused on courses with a main emphasis on animal learning and cognition (e.g., a course entitled “Animal Behaviour” was included if the course description included either the word “learning” or “cognition”, or if the available course materials included these words). Our goal was to search for the presence, not absence, of this course material, such that institutions were not chosen at random. We conducted a directed search based on institutions with faculty members who have presented research at the meeting of the Comparative Cognition Society or who are regularly cited by these researchers. A stopping point was set at approximately 60 courses. Thus, the resulting list was not intended to be exhaustive, and we acknowledge that online sources may not present a completely accurate representation of courses that are currently offered.

Our snapshot of the modern curriculum (Table 1) is divided into broader survey courses and more specialized courses (e.g., applied frameworks, advanced laboratory courses, and courses with a focus on limited species or orders). In North American institutions, the courses typically were found in psychology departments as an elective course rather than a ‘core’ course such as developmental, clinical, social, and cognitive psychology or behavioural neuroscience, though these core areas often have some related content (e.g., discussing theory of mind in nonhuman animals within a developmental psychology course or animal models of spatial

memory in a behavioural neuroscience course). In our sample, only three programs offered courses specifically with the phrase “comparative cognition”, and none contained “cognitive ethology”.

Table 1 is the result of a specific search for courses focusing on animal learning and cognition: an appreciation of the history of the field puts us in agreement with Papini (2011), who suggested that, “As a field, comparative psychology is almost interdisciplinary by definition...[and] demands not only knowledge of psychological theories and techniques, but an understanding of behavioral neuroscience, comparative neurology, behavioral ecology, developmental biology, and evolutionary theory” (p. 211; see also McMillan & Sturdy, 2015). In practice, creating an undergraduate experience that contains these courses in addition to relevant psychology coursework may be constrained by specific departmental requirements, though we did see evidence of programs that encourage interdisciplinary study. For example, some courses are cross-listed among psychology, anthropology, or biology (e.g., “Human Cognitive Evolution” at Duke University, USA), and some schools offer specializations that combine two traditionally distinct departments (e.g., the Biology-Psychology specialization at Queen’s University in Canada, the certificate in Animal Behaviour at Dalhousie University in Canada, and the Animal Behaviour Bachelor of Science program at the University of St. Andrews in the UK).

Notably, many of the biology degree programs that we searched offered at least one course in animal conservation, which we would suggest adding to Papini’s (2011) list of topics related to comparative cognition. These courses teach students how the effects of global climate change affect interactions between animals and their environment (as well as with other species) to drive co-evolutionary processes. They also often teach the science, management, and welfare

of zoo and captive animals, as well as the use of genetics to maintain the survival of endangered species. This, along with mandatory fieldwork components, offers students a glimpse into the practical applications that can arise from the study of comparative cognition (discussed further in the next section).

In sum, our undergraduate curriculum search suggests that comparative cognition, comparative psychology, and cognitive ecology material is well-represented in North American and UK programs. Thus, we do not think that there is a “crisis” *per se*, although unlike Abramson (2015a, 2015b) we do not consider comparative psychology to be a separate and distinct discipline, but rather an interdisciplinary field. Although it is beyond the scope of the current review, further analysis may reveal that animal cognition topics are often embedded in other course offerings. Comparative cognition education would be facilitated by coordinating curricula among departments of psychology, biology, and anthropology (and others), thereby giving students the opportunity to consolidate information and form connections between topics (Jones, 2010). Additionally, although not detailed here, it would be beneficial to incorporate material at an earlier stage than the courses represented in Table 1, with a stronger introduction to animal learning and cognition within broad first-year courses (Domjan & Purdy, 1995).

4. Teaching Comparative Cognition

Among the commentaries following Abramson (2015a) were some that discussed the pedagogy of comparative cognition in higher education (e.g., Furlong et al., 2015; Krachun, 2015). Our sample of courses, detailed in Table 1, indicates that current curricula offer courses that are primarily lecture based, as well as courses with hands-on laboratory activities in addition to lecture. Some are offered as fully online courses. Here, we consider some of the broader benefits of including the material in the undergraduate curriculum, including benefits that extend

beyond the goal of increasing our ranks and more generally encourage scientific thinking and training in Science, Technology, Engineering, and Math (STEM). We also consider some of the challenges inherent to including comparative cognition and/or cognitive ecology in the curriculum.

Student engagement in comparative cognition course material will, of course, vary across individuals, although the topic capitalizes on the fact that humans possess an innate curiosity towards animal behaviour (Manfredo, 2008). In fact, people of all cultures, across human history, have shown interest in observing and recording animal activities (Valenzuela et al., 2015). Instructors may capitalize on this enduring appeal by presenting videos of animal behaviour. These provide a number of pedagogical advantages, including (but not limited to) the following: (1) multiple modes of presentation can increase student engagement and improve learning outcomes (Mayer, 2002; Miller & Redman, 2010); (2) given ethical restrictions on using animals in teaching and research, video presentations offer an alternative for live animal demonstrations (Doijad & Kamble, 2013; Fawver et al., 1990); (3) videos are a primary tool for analyzing and coding animal behavior, so students can acquire skills and experience in this methodology; and (4) videos provide access to a variety of species in different habitats which students may, otherwise, never encounter. In terms of specific examples, a discussion of visual perception or communication may include videos of mating dances of male birds of paradise (<https://www.youtube.com/watch?v=W7QZnwKqopo>). In addition, a discussion of olfactory perception or the concept of secondary reinforcement could include a video of landmine detection by Gambian pouched rats (<https://www.youtube.com/watch?v=L0swUc492hU>) or scent detection training in the more familiar domestic dog (<https://www.youtube.com/watch?v=KJZ7rlP77zY>).

Presenting comparative cognition research in educational settings has the potential to guide students through a process of hypothesis development and testing that may extend to other disciplines. More specifically, students can follow the trajectory of specific research studies in comparative cognition that begin with observations of behaviour in the natural environment. They could then learn how researchers develop hypotheses to explain these behaviours and test their ideas in a carefully controlled experimental setting (Wasserman & Zentall, 2006). As an example, field studies reveal that macaques in the wild transmit false information to, or withhold information from, conspecifics concerning the location of food or presence of predators (Byrne & Whiten, 1992). The hypothesis that these seemingly deceptive strategies were advantageous was tested in an experimental lab setting, revealing that captive macaques that used a variety of deception strategies (e.g., distraction and concealment) were more successful at obtaining food in a competitive context (Canteloup et al., 2017). These field observations of animal deception inspired similar laboratory-based experiments with other primates (Overduin-de Vries et al., 2015) and canines (Heberlein, Manser, & Turner, 2017). The work has also informed research with humans, such as that examining theory of mind in children. By highlighting other examples that follow this pattern, comparative cognition courses can emphasize how seemingly abstract theories and concepts may be tested using the scientific method.

Topics such as deception and theory of mind have a rich research history in comparative cognition, one that includes substantial controversy (see Olmstead & Kuhlmeier, 2015, for a summary). Comparative cognition is, thus, ideally placed to encourage critical thinking (White, 2007). Students have the opportunity to learn how to integrate information from different sources, question assumptions, and form opinions about those topics. Indeed, even topics that researchers have reached a relative consensus on – like the inability of animals to produce human

language – see a resurgence in the popular media with events such as the death of Koko the gorilla or videos of dogs associating a large number of words with objects. Students provided with both the scientific literature and the popular press can be taught to evaluate information from each source, assessing how pre-existing biases may influence the debate. By applying these skills, students may become more attractive job candidates in the workforce, particularly as employers value problem solving and the ability to think critically about broad-based issues (Abramson, 2015a).

Such critical thinking is aided by an historical perspective that captures how initial assumptions were made, how they were tested, and how results were interpreted within the prevailing academic and cultural context. In that respect, the historical tradition of comparative cognition is enlightening. It allows students to understand that, although the influence of traditional ethology and animal behaviourism declined in the late 20th century, approaches and theories developed in these areas continue to play an important role in contemporary research. Without an historical perspective, students may dismiss traditional ethological and behavioural concepts (e.g., fixed action patterns, stimulus-response learning) without recognizing that these schools of thought provided both a framework for analysing complex behaviours and the tools to investigate their underlying cognitive processes (Shettleworth, 2013). There is further opportunity to inform students of the many practical applications that developed from traditional behaviourism experiments with rats or pigeons, such as applied behaviour therapy for autistic individuals, organizational management, and flooding as a treatment for therapy, among others (Mazur, 2013).

Indeed, many theoretical concepts investigated today are the same ones that have been studied for decades. Although the questions are fundamentally similar, the research methods now

used can be drastically different from those of the past. Students can analyse how sophisticated tools have changed our interpretation of findings across history. Along with the benefits of technological advancements (e.g., more precise measurements), there is an increasing concern that these sophisticated tools promote reductionism in research. For example, single-unit neuron recording is becoming increasingly more sophisticated and accessible; however, the contribution of single neurons to brain function can be inconsequential without considering how these neurons interact with larger networks to generate complex cognitive processes. Importantly, many researchers still recognize the advantages of early ethological and ecological approaches of studying animals in the wild (including urban settings, e.g., MacDonald & Ritvo, 2016; Wong & Candolin, 2015), particularly as complements to laboratory studies. Students might compare naturalistic and laboratory-based studies of the same phenomenon (e.g., spatial learning, problem solving) to elucidate the advantages and disadvantages of each approach (i.e., evolutionary vs. learning history).

Both laboratory- and field-based research methodology can be incorporated into undergraduate coursework. Dog parks and zoological parks offer locations for video recording of behaviour that can be coded and analyzed in the classroom. Simulated labs, which are usually computer-based models (e.g., Cyber Rat) or imitations of actual experiments, offer students the ability to conceptualize elements of a laboratory experiment. Although there are benefits to this method (e.g., lower cost, greater efficiency), some argue that simulated labs may create a disconnect between a virtual space and a real experimental setting (Ma & Nickerson, 2006). In contrast, live experimental labs offer students a more realistic depiction of the experimental setting and allow for unexpected events to generate valuable “teachable moments.” As an example of the latter, Abramson and colleagues (2011) advocate the use of invertebrates in the

classroom. We have incorporated this into our advanced comparative cognition lab course: students conduct classical conditioning experiments using *Aplysia californica*. With guidance and direction from experienced lab facilitators, students learn fundamental processes of research, including hypothesis testing, data collection, and proper scientific and ethical practices. Following data collection, students conduct statistical analysis and write a scientific paper. Using this approach, students get a glimpse into the entire research process, while enabling them to integrate material from lectures and readings into an experimental setting. In sum, there are broad benefits of including comparative cognition material in the undergraduate curriculum, including benefits that encourage scientific thinking and promote further STEM training. It is particularly important that students are made aware of the value of comparative cognition courses and research, and that they are able to articulate the skills they have acquired through training in this discipline.

Despite the advantages, we (Kuhlmeier & Olmstead, 2016) and others (Abramson, 2015a; Beran et al., 2015; Brodbeck & Brodbeck, 2015; Furlong et al., 2015; Krachum, 2015; McMillan & Sturdy, 2015; Osvath & Persson, 2015) have noted challenges in teaching comparative cognition courses. Given that the field is strongly interdisciplinary, some programs encourage students from a wide range of backgrounds and varying foundational knowledge to enrol in courses, which in turn makes it difficult for instructors to ‘calibrate’ the delivery of material. In our own courses, and those we found during curriculum search, there are ways in which instructors appear to be mitigating this concern. Many courses invite experts from cognate disciplines (e.g., philosophers, computer scientists, geneticists) to provide guest lectures, which some specialists in higher education suggest increases student engagement (e.g., Li & Guo, 2015). These lectures introduce students to perspectives from varied disciplines, encouraging

them to consider the larger scope of the subject. In the same way, weekly tutorial components could enhance the learning experience as students in smaller groups interact and solve problems using their respective strengths. Although the efficacy of peer-to-peer teaching is disputed (Rees et al., 2016), this approach can be ideal for cross-disciplinary courses if they are delivered with careful facilitation and direction. Specifically, students that are unfamiliar with some concepts may benefit from input from peers that have more extensive knowledge and experience in these areas. In fact, this form of instruction promotes a greater conceptual understanding of topics because it encourages students to integrate newly-learned information with existing knowledge, which is imperative in higher education (Stigmar, 2016).

Another challenge to teaching comparative cognition is to overcome an assumption, held by some students, that animal research is irrelevant to their specific interests within a major program (e.g., clinical psychology). To convince students otherwise is difficult, especially given the sparse coverage of comparative cognition in introductory psychology textbooks. Since introductory courses lay the groundwork for subsequent courses in the discipline, the absence of comparative cognition in these materials is detrimental to the field (Abramson, 2015a). In the 1990s, animal researchers noted that introductory textbooks failed to adequately acknowledge the contribution of animal research in psychology, often omitting or misrepresenting findings as though they were performed in humans (Domjan & Purdy, 1995). Unfortunately, this holds true decades later (Capitanio, 2017; Ormandy & Schuppli, 2014), although a recent open access psychology textbook has a chapter devoted to animal learning and cognition which emphasizes the contribution of animal studies to the broader field (Bouton, 2019). As with any academic endeavour, an awareness of prior knowledge in the field is an important prerequisite for intellectual advancement.

5. Conclusion

Researchers in any field make an invaluable contribution to their discipline by training the next generation of scientists. Just as importantly, many of these educators have the opportunity to prepare students who will not pursue scientific careers to be informed consumers of science. This can be accomplished, most effectively, with interdisciplinary studies as these foster the development of critical thinking and promote an understanding of philosophical foundations across disparate fields. These principles are exemplified in the field of comparative cognition which assimilates knowledge across disciplines and incorporates state-of-the art techniques to address questions that have fascinated humans for centuries. Our brief overview of training at post-secondary institutions reveals that comparative cognition is well-represented in many undergraduate programs at English-speaking institutions in the UK and North America. Given the interdisciplinary nature of the field, it is not surprising that this material is integrated into a variety of departments. As a consequence, students in comparative cognition courses have the opportunity to engage with colleagues in other disciplines and to acquire a range of skills that could be beneficial for future careers.

Acknowledgements

Steven J. Lamontagne is the 2018 recipient of the Queen's University Alumni Award for Excellence in Teaching. This work was supported by Discovery Grants from the Natural Sciences and Engineering Research Council of Canada (NSERC) to MCO and VAK, and by an NSERC Alexander Graham Bell Graduate Scholarship and a Michael Smith Foreign Study Supplement to SJL. Queen's University is situated on traditional Anishinaabe and Haudenosaunee Territory.

References

- Abramson, C.I., (2015a). A crisis in comparative psychology: Where have all the undergraduates gone? *Frontiers in Psychology*, 6, 1500. DOI: 10.3389/fpsyg.2015.01500
- Abramson, C.I. (2015b). A crisis in comparative psychology: Where have all the undergraduates gone? Additional comments. *Comprehensive Psychology*, 4, 7. DOI: 10.2466/10.IT.4.7
- Abramson, C. I., Curb, L. A., Barber, K. R., & Sokolowski, M. B. (2011). The use of invertebrates and other animals to demonstrate principles of learning: Activities developed by the laboratory of Comparative Psychology and Behavioral Biology. *Journal of Behavioral Neuroscience Research*, 9, 1-6.
- Abramson, C. I., & Lack, C. W. (Eds.). (2014). *Psychology Gone Astray: A selection of Racist & Sexist Literature From Early Psychological Research*. Onus Books.
- Abramson, C. I., Onstott, T., Edwards, S., & Bowe, K. (2000). Classical-conditioning demonstrations for elementary and advanced courses. *Handbook of Demonstrations and Activities in the Teaching of Psychology: Physiological-comparative, Perception, Learning, Cognitive, and Developmental*, 2, 116.
- Baleni, Z. G. (2015). Online formative assessment in higher education: Its pros and cons. *Electronic Journal of e-Learning*, 13, 228-236.
- Barker, S. B., Knisely, J. S., McCain, N. L., & Best, A. M. (2005). Measuring stress and immune response in healthcare professionals following interaction with a therapy dog: A pilot study. *Psychological Reports*, 96, 713-729.
- Beran, M. J., James, B. T., Futch, S. E., & Parrish, A. E. (2015). Commentary: A crisis in comparative psychology: where have all the undergraduates gone? *Frontiers in Psychology*, 6, 1928.

- Boring, E. G. (1950). *A History of Experimental Psychology*. New York NY: Appleton-Century Crofts.
- Bouton, M. E. (2019). Conditioning and learning. In R. Biswas-Diener & E. Diener (Eds), *Nova Textbook Series: Psychology*. Champaign, IL: DEF publishers. Retrieved from <http://noba.to/ajxhcqdr>
- Brodbeck, M.I.R., & Brodbeck, D.R. (2015). It's just evolution. Commentary: A crisis in comparative psychology: where have all the undergraduates gone? *Frontiers in Psychology*, 6, 1873. DOI: 10.3389/fpsyg.2015.01873
- Byrne, R. W., & Whiten, A. (1992). Cognitive evolution in primates: evidence from tactical deception. *Man*, 609-627.
- Canteloup, C., Poitrasson, I., Anderson, J. R., Poulin, N., & Meunier, H. (2017). Factors influencing deceptive behaviours in Tonkean macaques (*Macaca tonkeana*). *Behaviour*, 154, 765-784.
- Capitanio, J. (2017). Animal studies in psychology: Serving a vital role in psychological science. *American Psychological Association*.
- Chang, V. (2016). Review and discussion: E-learning for academia and industry. *International Journal of Information Management*, 36, 476-485.
- Danchin, É., Giraldeau, L.-A., & Cézilly, F. (eds.). (2008). *Behavioural Ecology*. Dunod, Paris: Oxford University Press.
- Darwin, C. (1859). *On the Origin of Species by Means of Natural Selection*. London UK: Murray.
- Darwin, C. (1871). *The Descent of Man and Selection in Relation to Sex*. London UK: John Murray.

- Dixson, D. L., Munday, P. L., & Jones, G. P. (2010). Ocean acidification disrupts the innate ability of fish to detect predator olfactory cues. *Ecology Letters*, 13, 68-75.
- Doijad, V. P., & Kamble, P. H. (2013). A comparative study: Learning in Experimental Physiology with use of live animals V/S video demonstration as learning aids in first MBBS students. *International J. of Healthcare & Biomedical Research*, 2, 24-29.
- Domjan, M., & Purdy, J. E. (1995). Animal research in psychology: More than meets the eye of the general psychology student. *American Psychologist*, 50, 496.
- Dugatkin, L.A. (2004). *Principles of Animal Behavior*. New York, NY: W. W. Norton & Company.
- Fawver, A. L., Branch, C. E., Trentham, L., Robertson, B. T., & Beckett, S. D. (1990). A comparison of interactive videodisc instruction with live animal laboratories. *Advances in Physiology Education*, 259, S11.
- Furlong, E.E., AuBuchon, S., Kraut, J., Joiner, N., Knowles, J., Lewis, K., Win, M., & Furlong, J. From crisis to crowd control. Commentary: A crisis in comparative psychology: Where have all the undergraduates gone? *Frontiers in Psychology*, 6, 1729. DOI: 10.3389/fpsyg.2015.01729
- Gácsi, M., Szakadát, S., & Miklósi, Á. (2013). Assistance dogs provide a useful behavioral model to enrich communicative skills of assistance robots. *Frontiers in Psychology*, 4, 971.
- Garcia, J., & Koelling, R. A. (1966). Relation of cue to consequence in avoidance learning. *Psychonomic Sciences*, 4, 123-124.
- Goldin-Meadow, S. (1996). Kanzi: The ape at the brink of the human mind. *International Journal of Primatology*, 17, 145-148.

- Hart, L. A. (2006). Psychosocial benefits of animal companionship. In *Handbook on Animal Assisted Therapy* (pp. 59-78). Academic Press.
- Heberlein, M. T., Manser, M. B., & Turner, D. C. (2017). Deceptive-like behaviour in dogs (Canis familiaris). *Animal Cognition*, 20, 511-520.
- Hinde, R. A. (1970). *Animal Behavior: A Synthesis of Ethology and Comparative Psychology* (2nd Ed.). New York NY: McGraw-Hill.
- Honig, W. K., & James, P. H. R. (1971). *Animal Memory*. New York NY: Academic Press.
- Hulse, S. H. (2006). An essay on the study of cognition in animals. *Comparative Cognition*. New York NY: Oxford University Press.
- Hulse, S. H., Fowler, H., & Honig, W. K. (1978). *Cognitive Processes in Animal Behavior*. Hillsdale NJ: Erlbaum.
- Jones, C. (2010). Interdisciplinary approach-advantages, disadvantages, and the future benefits of interdisciplinary studies. *Essai*, 7, 26.
- Krachun C. (2015). Enhancing student interest in animals. Commentary: A crisis in comparative psychology: Where have all the undergraduates gone? *Frontiers in Psychology*, 6, 1897. DOI: 10.3389/fpsyg.2015.01897
- Krause, M.A. (2018). A place for comparative psychology in undergraduate curricula. *International Journal of Comparative Psychology*, 31, 1-7.
<https://escholarship.org/uc/item/9t5803kd>
- Kuhlmeier, V. A., & Olmstead, M. C. (2016). Keep Calm and Comp. Cog. On. Commentary: A crisis in comparative psychology: where have all the undergraduates gone? *Frontiers in Psychology*, 7, 20.
- Leahey, T. H. (2017). *A History of Psychology: From Antiquity to Modernity*. New York NY:

Routledge.

Li, L., & Guo, R. (2015). A student-centered guest lecturing: A constructivism approach to promote student engagement. *Journal of Instructional Pedagogies*, 15.

Ma, J., & Nickerson, J. V. (2006). Hands-on, simulated, and remote laboratories: A comparative literature review. *ACM Computing Surveys (CSUR)*, 38, 7.

MacDonald, S. E., & Ritvo, S. (2016). Comparative cognition outside the laboratory. *Comparative Cognition & Behavior Reviews*, 11.

Macphail, E.M. (1982). *Brain and Intelligence in Invertebrates*. Oxford: Clarendon Press.

Maier, N. R. F., & Schneirla, T. C. (1935). *Principles of Animal Psychology*. New York: Dover.

Mayer, R. E. (2002). Multimedia learning. In *Psychology of Learning and Motivation*. Academic Press, 41, 85-139.

Mazur, J. E. (2013). *Learning and Behavior*. New Jersey: Pearson Education.

McMillan, N, & Sturdy, C.B. (2015). Commentary: A crisis in comparative psychology: where have all the undergraduates gone? *Frontiers in Psychology*, 6, 1589. DOI: 10.3389/fpsyg.2015.01589

Manfredo, M. J. (2008). Who cares about wildlife? In *Who Cares About Wildlife?* (pp. 1-27). New York: Springer.

Miklósi, Á., & Gácsi, M. (2012). On the utilization of social animals as a model for social robotics. *Frontiers in Psychology*, 3, 75.

Miller, S. T., & Redman, S. L. (2010). Improving instructor presence in an online introductory astronomy course through video demonstrations. *Astronomy Education Review*, 9, 1-7.

Moran, G. (1987). Applied dimensions of comparative psychology. *Journal of Comparative*

Psychology, 101, 277.

Morgan, C. L. (1894). *An Introduction to Comparative Psychology*. London: Walter Scott.

O'Haire, M. (2010). Companion animals and human health: Benefits, challenges, and the road ahead. *Journal of Veterinary Behavior: Clinical Applications and Research*, 5, 226-234.

Ormandy, E., & Schuppli, C. (2014). Public attitudes toward animal research: A review. *Animals*, 4.

Osvath, M., & Persson, T. (2015). What's in a name? Commentary: A crisis in comparative psychology: where have all the undergraduates gone. *Frontiers in Psychology*, 6, 1865. DOI: 10.3389/fpsyg.2015.01856

Overduin-de Vries, A. M., Spruijt, B. M., De Vries, H., & Sterck, E. H. M. (2015). Tactical deception to hide sexual behaviour: macaques use distance, not visibility. *Behavioral ecology and Sociobiology*, 69, 1333-1342.

Papini, M. R. (2011). Comparative psychology. In S.F. Davis (ed.). *Handbook of Research Methods in Experimental Psychology* (p. 211). Oxford, UK: Blackwell Publishing Ltd.

Pearce, J. M. (2008). *Animal Learning and Cognition*. 3rd edition. New York: Psychology Press.

Penn, D. C., Holyoak, K. J., & Povinelli, D. J. (2008). Darwin's mistake: Explaining the discontinuity between human and nonhuman minds. *Behavioral and Brain Sciences*, 31, 109-130.

Pepperberg, I. M. (2017). Animal language studies: What happened? *Psychonomic Bulletin & Review*, 24, 181-185.

Rabin, L. A., McCowan, B., Hooper, S. L., & Owings, D. H. (2003). Anthropogenic noise and its

- effect on animal communication: an interface between comparative psychology and conservation biology. *International Journal of Comparative Psychology*, 16.
- Real, L. A. (1993). Toward a cognitive ecology. *Trends in Ecology and Evolution*, 8, 413-417.
- Rees, E. L., Quinn, P. J., Davies, B., & Fotheringham, V. (2016). How does peer teaching compare to faculty teaching? A systematic review and meta-analysis. *Medical Teacher*, 38, 829-837.
- Reynolds, E. R. (2012). Creating cross-disciplinary courses. *Journal of Undergraduate Neuroscience Education*, 11, A72.
- Savage-Rumbaugh, S., Rumbaugh, D., & Fields, W. M. (2009). Empirical Kanzi: The ape language controversy revisited. *Skeptic (Altadena, CA)*, 15, 25-34.
- Scott-Phillips, T. C. (2016). Meaning in great ape communication: summarising the debate. *Animal Cognition*, 19, 233-238.
- Shettleworth, S. J. (2013). *Fundamentals of Comparative Cognition*. Oxford University Press.
- Shettleworth, S. J. (2009). The evolution of comparative cognition: Is the snark still a boojum? *Behavioural Processes*, 80, 210-217.
- Shettleworth, S. J. (2010). Clever animals and killjoy explanations in comparative psychology. *Trends in Cognitive Sciences*, 14, 477-481.
- Smith Jr, O. A., & Geis, A. D. (1956). Comparative psychology in wildlife conservation. *American Psychologist*, 11, 183.
- Stigmar, M. (2016). Peer-to-peer teaching in higher education: A critical literature review. *Mentoring & Tutoring: partnership in learning*, 24, 124-136.
- Strong, V., Brown, S., Huyton, M., & Coyle, H. (2002). Effect of trained Seizure Alert Dogs on frequency of tonic-clonic seizures. *Seizure*, 11, 402-405.

- Terrace, H. S., Petitto, L. A., Sanders, R. J., & Bever, T. G. (1979). Can an ape create a sentence? *Science*, 206, 891-902.
- Thorndike, E. L. (1911). *Animal Intelligence: Experimental Studies*. New York NY: Macmillan.
- Tinbergen, N. (1963). On the aims and methods of ethology. *Zeitschrift fur Tierpsychologie* 20, 410-413.
- Valenzuela, D., Santoro, C. M., Capriles, J. M., Quinteros, M. J., Peredo, R., Gayo, E. M., ... & Sepúlveda, M. (2015). Consumption of animals beyond diet in the Atacama Desert, northern Chile (13,000–410 BP): Comparing rock art motifs and archaeofaunal records. *Journal of Anthropological Archaeology*, 40, 250-265.
- Varnon, C. A., & Abramson, C. I. (2013). The propeller experiment controller: Low-cost automation for classroom experiments in learning and behavior. *Comprehensive Psychology*, 2, 7-8.
- Vicchio, S. J. (1986). From Aristotle to Descartes: Making animals anthropomorphic. In R.J. Hoage & L. Goldman (eds.). *Animal Intelligence: Insights into the Animal Mind*. Washington DC: Smithsonian Institution Press.
- Wasserman, E. A., & Zentall, T. R. (Eds.). (2006). *Comparative Cognition: Experimental Explorations of Animal Intelligence*. Oxford University Press, USA.
- Weisman, R. G., Bouton, M. E., Spetch, M. L., Wasserman, E. A. (2015). A social history of the founding of the Conference on Comparative Cognition and Comparative Cognition Society. *Comparative Cognition and Behavior Reviews*, 10, 109-110.
- White, D. A. (2007). Comparative psychology's relevance to a liberal arts education and personal development. *International Journal of Comparative Psychology*, 20.

Wong, B.B.M., & Candolin, U. (2015). Behavioral responses to changing environments.
Behavioral Ecology, 26, 665-673.