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REVIEW ARTICLE **OPEN ACCESS**

Significance of Animal Behavior Research and Its Impact On Zoological Studies

Yogesh Kumar Gupta
Department of Zoology, Swami Kalyananad Mahavidhyalay,Neoradev,Hardoi (UP)

ABSTRACT
Animal behavior is the bridge between the molecular and physiological aspects of biology and the ecological. Behavior is the link between organisms and environment and between the nervous system, and the ecosystem. Behavior is one of the most important properties of animal life. Behavior plays a critical role in biological adaptations. Behavior is how we humans define our own lives. Behavior is that part of an organism by which it interacts with its environment. Behavior is as much a part of an organisms as its coat, wings etc. The beauty of an animal includes its behavioral attributes.
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INTRODUCTION

A survey of recent publications in behavioural biology suggests that research in this field often lacks a formal approach linking theory and empiricism, which implies that there is scope for improvement. Frequently, hypotheses guiding empirical work are merely based on plausibility arguments, which is not necessarily wrong and may be useful especially at the early stages of an investigation. Behavioural studies based on a theoretical framework usually test qualitative predictions from a general model either with data from natural situations or by experimental scrutiny. Rarely, a quantitative approach is used where a model is parameterized by existing data and therefore generates precise, testable predictions. In general, there is a lack of awareness that much more is to be learnt from a mismatch between predictions and data than from accordance. The latter is prone to cause the 'pseudo-proof fallacy', which is widespread in behavioural ecology. Behavioural physiology, on the other hand, often suffers a lack of proper theoretical models. Much can be gained in both fields if empiricists and theoreticians collaborate more closely towards the ultimate aim – to unravel the mechanisms of behaviour at both, ultimate and proximate levels. Scientific research ought to be based on a theoretical framework. This truism is reflected also in the 'aims and scope' of Ethology, stating that this journal of
behavioural biology 'contains scientific articles of general interest … that are based on a theoretical framework'. But what exactly does this mean? How do behavioural researchers base their studies on theory? And is this basement well founded?

The use of theory may come in different flavours. In ethology we aim to understand the causal mechanisms underlying behaviour, at both the ultimate (evolutionary) and proximate (mechanistic) levels [1, 2]. Often empirical research is simply based on plausibility arguments. This may be adequate especially at the early stages of an investigation, e.g. when investigating the largely unknown recognition abilities of a species, or when a research question is based on very general expectations. For example, when the relationship between predators and prey is at issue, one may wish to confirm that conspicuousness or other handicaps increase preda scientific research ought to be based on a theoretical framework. This truism is reflected also in the 'aims and scope' of Ethology, stating that this journal of behavioural biology 'contains scientific articles of general interest … that are based on a theoretical framework'. But what exactly does this mean? How do behavioural researchers base their studies on theory? And is this basement well founded?

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When a research question is based on very general expectations. For example, when the relationship between predators and prey is at issue, one may wish to confirm that conspicuousness or other handicaps increase predation risk [3] or that vigilance and other behaviours are influenced by the risk of predation [4, 5]. In a different context, it seems logical that rearing conditions and social learning influence social preferences and discrimination of kin [6].

For the same reasons that we study the universe and subatomic particles there is intrinsic interest in the study of animals. In view of the amount of time that television devotes to animal films and the amount of money that people spend on nature books there is much more public interest in animal behavior than in neutrons and neurons. If human curiosity drives research, then animal behavior should be near the top of our priorities.

Research on animal behavior and behavioral ecology has been burgeoning in recent years despite below inflation increases (and often decreases) in research funding. Two of our journals Animal Behaviour and Behavior Ecology and Sociobiology rank in the top six behavioral science AND zoological journals in terms of impact as measured by the Science Citation Index. From 1985 to 1990 Animal Behaviour has grown from quarterly to monthly publication and its page budget has more than doubled. Many related journals have increased their size and frequency of publication in the same period. Ours is an active and vital field.

While the study of animal behavior is important as a scientific field on its own, our science has made important contributions to other disciplines with applications to the study of human behavior, to the neurosciences, to the environment and resource management, to the study of animal welfare and to the education of future generations of scientists.

ANIMAL BEHAVIOR AND HUMAN SOCIETY

1. Many problems in human society are often related to the interaction of environment and behavior or genetics and behavior. The fields of socioecology and animal behavior deal with the issue of environment behavioral interactions both at an evolutionary level and a proximate level. Increasingly social scientists are turning to animal behavior as a framework in which to interpret human society and to understand possible causes of societal problems. (e.g. Daly and Wilson's book on human homicide is based on an evolutionary analysis from animal research. Many studies on child abuse utilize theory and data from studies on infanticide in animals.)
2. Research by de Waal on chimpanzees and monkeys has illustrated the importance of cooperation and reconciliation in social groups. This work provides new perspectives by which to view and ameliorate aggressive behavior among human beings.
3. The methodology applied to study animal behavior has had a tremendous impact in psychology and the social sciences. Jean Piaget began his career with the study of snails, and he extended the use of careful behavioral observations and descriptions to his landmark studies on human cognitive development. J. B. Watson began his study of behavior by observing gulls. Aspects of experimental design, observation techniques, attention to nonverbal communication signals were often developed in animal behavior studies before their application to studies of human behavior. The behavioral study of humans would be much diminished today without the influence of animal research.
4. Charles Darwin's work on emotional expression in animals has had an important influence on many psychologists, such as Paul Ekman, who study human emotional behavior.
5. Harry Harlow's work on social development in rhesus monkeys has been of major importance to theories of child development and to psychiatry. The work of Overmier, Maier and Seligman on learned helplessness has had a similar effect on child development and psychiatry.
6. The comparative study of behavior over a wide range of species can provide insights into influences affecting human behavior. For example, the woolly spider monkey in Brazil displays no overt aggressive behavior among group members. We might learn how to minimize human aggression if we understood how this species of monkey avoids aggression. If we want to have human fathers be more involved in infant care, we can study the conditions under which paternal care has appeared in other species like the California mouse or in marmosets and tamarins. Studies of various models of the ontogeny of communication in birds and mammals have had direct influence on the development of theories and the research directions in the study of child language. The richness of developmental processes in behavior, including multiple sources and the consequences of experience are significant in understanding processes of human development.

7. Understanding the differences in adaptability between species that can live in a variety of habitats versus those that are restricted to limited habitats can lead to an understanding of how we might improve human adaptability as our environments change.
8. Research by animal behaviorists on animal sensory systems has led to practical applications for extending human sensory systems. Griffin's demonstrations on how bats use sonar to locate objects have led directly to the use of sonar techniques in a wide array of applications from the military to fetal diagnostics.
9. Studies of chimpanzees using language analogues have led to new technology (computer keyboards using arbitrary symbols) that have been applied successfully to teaching language to disadvantaged human populations.
10. Basic research on circadian and other endogenous rhythms in animals has led to research relevant to human factors and productivity in areas such as coping with jet-lag or changing from one shift to another.
11. Research on animals has developed many of the important concepts relating to coping with stress, for example studies of the importance of prediction and control on coping behavior.

ANIMAL BEHAVIOR AND NEUROBIOLOGY

1. Sir Charles Sherrington, an early Nobel Prize winner, developed a model for the structure and function of the nervous system based only on close behavioral observation and deduction. Seventy years of subsequent neurobiological research has completely supported the inferences Sherrington made from behavioral observation.
2. Neuroethology, the integration of animal behavior and the neurosciences, provides important frameworks for hypothesizing neural mechanisms. Careful behavioral data allow neurobiologists to narrow the scope of their studies and to focus on relevant input stimuli and attend to relevant responses. In many case the use of species specific natural stimuli has led to new insights about neural structure and function that contrast with results obtained using non-relevant stimuli.
3. Recent work in animal behavior has demonstrated a downward influence of behavior and social organization on physiological and cellular processes. Variations in social environment can inhibit or stimulate ovulation, produce menstrual synchrony, induce miscarriages and so on. Other animal studies show that the quality of the social and behavioral environment have a direct effect on immune system functioning. Researchers in physiology and immunology need to be guided by these behavioral and social influences to properly control their own studies.

ANIMAL BEHAVIOR AND THE ENVIRONMENT, CONSERVATION AND RESOURCE MANAGEMENT

1. The behavior of animals often provides the first clues or early warning signs of environmental degradation. Changes in sexual and other behavior occur much sooner and at lower levels of environmental disruption than changes in reproductive outcomes and population size. If we wait to see if numbers of animal populations are declining, it may be too late to take measures to save the environment. Studies of natural behavior in the field are vital to provide baseline data for future environmental monitoring. For example, the Environmental Protection Agency uses disruptions in swimming behavior of minnows as an index of possible pesticide pollution.
2. Basic research on how salmon migrate back to their home streams started more than 40 years ago by Arthur Hasler has taught us much about the mechanisms of migration. This information has also been valuable in preserving the salmon industry in the Pacific Northwest and applications of Hasler's results has led to the development of a salmon fishing industry in the Great Lakes. Basic animal behavior research can have important economic implications.
3. Animal behaviorists have described variables involved in insect reproduction and host plant location leading to the development of non-toxic pheromones for insect pest control that avoid the need for toxic pesticides. Understanding of predator prey relationships can lead to the introduction of natural predators on prey species.
4. Knowledge of honeybee foraging behavior can be applied to mechanisms of pollination which in turn is important for plant breeding and propagation.
5. An understanding of foraging behavior in animals can lead to an understanding of forest regeneration. Many animals serve as seed dispersers and are thus essential for the propagation of tree species and essential for habitat preservation.
6. The conservation of endangered species requires that we know enough about natural behavior (migratory patterns, home range size, interactions with other groups, foraging demands, reproductive behavior, communication, etc) in order to develop effective reserves and effective protection measures. Relocation or reintroduction of animals (such as the golden lion tamarin) is

not possible without detailed knowledge of a species' natural history. With the increasing importance of environmental programs and human management of populations of rare species, both in captivity and in the natural habitat, animal behavior research becomes increasingly important. Many of the world's leading conservationists have a background in animal behavior or behavioral ecology.

7. Basic behavioral studies on reproductive behavior have led to improved captive breeding methods for whooping cranes, golden lion tamarins, cotton-top tamarins, and many other endangered species. Captive breeders who were ignorant of the species' natural reproductive behavior were generally unsuccessful.

ANIMAL BEHAVIOR AND ANIMAL WELFARE

1. Our society has placed increased emphasis on the welfare of research and exhibit animals. US law now requires attending to exercise requirements for dogs and the psychological well-being of nonhuman primates. Animal welfare without knowledge is impossible. Animal behavior researchers look at the behavior and well-being of animals in lab and field. We have provided expert testimony to bring about reasonable and effective standards for the care and well-being of research animals.
2. Further developments in animal welfare will require input from animal behavior specialists. Improved conditions for farm animals, breeding of endangered species, proper care of companion animals all require a strong behavioral data base.

ANIMAL BEHAVIOR AND SCIENCE EDUCATION

Many in our society are concerned with scientific illiteracy, the lack of interest that students have in science and the fact that women and minority groups are underrepresented in science. Courses in animal behavior and behavioral ecology serve as hooks to interest students in behavioral biology. At the University of Wisconsin, Madison more than 700 students a year take courses in animal behavior and behavioral ecology in the Departments of Anthropology, Psychology and Zoology, yet none of these courses serve as required courses for majors. Cornell University enrolls nearly 400 students in an Introduction to Behavior course that is required of only 60-70 students. Enrollment has grown by 30% in the last three years. At the University of Stirling, Scotland, 75% of graduates in Psychology enroll in the elective, non-required animal behavior course. At the University of Washington, Seattle, more than 300 students enroll each quarter in a basic animal behavior class. Similar results can be found on many other campuses.

For many students, especially females, these courses are their first introduction to behavioral biology. Many female undergraduates approach us to discuss graduate school and research careers after taking these courses. 75% or more of our graduate applicants are female. A good proportion of students enrolled in animal behavior courses become motivated for research careers, but there is little hope to offer them that they will actually be able to become practicing scientists when they finish due to severe limitations on research funding.

BEHAVIORAL PLASTICITY

Benefits, Limits and Costs

Since the 1970s, biologists have been aware that a single genotype can produce more than one alternative form of behavior in response to environmental conditions (behavioral plasticity *sensu* [7]). The obvious benefit gained by a plastic animal is that it can rely on a better behavior-environment match across more environments than would be possible by displaying a single behavior in all environments.

Due to the greater abundance of potential cues for regulating the expression of an 'immediate' (i.e. behavioral) adaptive response, behavioral plasticity was expected to evolve more readily than does any other form of phenotypic plasticity [7]. As a consequence, behavioral plasticity was acknowledged to play a prominent role in the initiation and amplification of phenotypic changes [7] and behavior was assumed to act as the 'pacemaker' of evolution

Limits and constraints of behavioral plasticity

With the integration of the behavioral plasticity perspective into decapod studies, it was assumed that the organisms exhibiting 'infinite' plasticity should be highly favored by evolution. In contrast, since the 1990s a number of studies has been showing that animals cannot consistently produce the optimum or else pay a large cost merely for the ability to be plastic [8] was the first to raise the question of why behavioral plasticity is so limited in hermit crabs, among other decapods. Four mechanisms, he claimed, are responsible of such limitation. The first is the limited sensory capabilities of these organisms. For

example, hermit crabs can smell octopuses and do modify both their shell choice when their odor is present and their placement behavior involving protective sea anemones.

SAMPLE SIZE IN BEHAVIOURAL STUDY

The choice of an appropriate sample size for a study is a notoriously neglected topic in behavioural research, even though it is of utmost importance and the rules of action are more than clear – or are they? They may be clear if a formal power analysis is concerned. However, with the educated guesswork usually applied in behavioural studies there are various trade-offs, and the degrees of freedom are extensive. An analysis of 119 original studies haphazardly chosen from five leading behavioural journals suggests that the selected sample size reflects an influence of constraints more often than a rational optimization process. As predicted, field work involves greater samples than studies conducted in captivity, and invertebrates are used in greater numbers than vertebrates when the approach is similar. However, it seems to be less important for determining the number of subjects if the study employs observational or experimental means. This is surprising because in contrast to mere observations, experiments allow to reduce random variation in the data, which is an essential precondition for economizing on sample size. By pointing to inconsistent patterns the intention of this article is to induce thought and discussion among behavioural researchers on this crucial issue, where apparently neither standard procedures are applied nor conventions have yet been established. This is an issue of concern for authors, referees and editors alike.

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