LS/MCB100 |
Computational Ethology

WEEK 0 |

INTRODUCTION

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Introduction to

ETHOLOGY

- **Let's start with discussing the basics of ethology, the scientific study of animal behavior, and how we "design" experiments to answer questions on behavior.**
- **A big part of scientific investigations is data collection and analysis, and you will start learning the basics of computation needed for ethological studies from the lab part.**
- **By the end of reading this document, you will have a taste of ethology, a clearer view of your own questions on animal behavior, and computational necessities to answer those.**

WHAT IS "BEHAVIOR"?

Series of coordinated muscle contractions which are then organized into motor patterns or units.

"The total movements made by the intact animal" (Tinbergen, 1955)

"Externally visible activity of an animal, in which a coordinated pattern of sensory, motor and associated neural activity responds to changing external or internal conditions" (Beck et al 1981)

"Observable activity of an organism; anything an organism does that involves action and/or response to stimulation" (Wallace et al 1991)

Behavior could be a visible change of the body posture, or making audible and inaudible (to us) sounds, or releasing some body-generated chemical (pheromone).

Food for thought

Is a) sitting idle, b) sleeping, c) free-falling a behavior? Why?

WHAT IS ETHOLOGY?

- The scientific study of animal behavior that includes
    - observing and describing animal behavior, ideally in their natural habitat,
    - framing a scientific “testable” question - HYPOTHESIS,
    - testing hypothesis by quantitative measurement of behavior
- One of the earliest disciplines that humans actively studied.
- The modern science of ethology is usually considered to have arisen as a discrete discipline with the work in the 1920s of the Dutch ethologist Nikolaas Tinbergen and Austrian ethologist Konrad Lorenz. They shared the Nobel prize, along with the German-Austrian ethologist Karl von Frisch, in 1973.
- Strongly integrated with other disciplines like neurobiology, ecology, and evolution.

Food for thought:

Does ethology encompass studying human behavior?

Task_1:

Think about any behavior you have observed in an animal. Frame a hypothesis and an experimental design for testing your hypothesis.

WHY STUDY ETHOLOGY?

- **Understanding animals is important for**
  - *Human survival*

    Since prehistoric times, humans are trying to understand the behavior of animals that are crucial for human survival (like predators and prey). In many cave paintings across the globe, prehistoric humans depicted behaviors of many animals. You can read this article on the earliest cave paintings and watch this National Geographic video on cave arts of animals made almost 17,000 - 40,000 years ago. And this holds true even today - I get calls from neighbors when they need to get rid of a wasp nest, a honeybee swarm, or a carpenter ant nest.

  - *Exploiting animals to make life easy*

    Exploiting other animals for the benefit of humans need an understanding of behavior shown by the target animals. The ability to domesticate other animals demarcates one of the greatest milestones in human history. Humans started domesticating animals at least 12,000 years ago and have been benefitting from them ever since. You can read this paper on animal (and plant) domestication for fun. However, exploiting other animals is not limited to domestication or animal husbandry - biological pest control is another example.

    Fun fact:
    Humans are NOT the only species that "domesticated' other animals. If you are interested to know more, check this.

  - *Animal welfare, conservation, and mitigating human-wildlife conflict*

    The welfare of domestic, laboratory as well as wild animals requires an understanding of what animals need, which they often express with their behavior. Similarly, conservation of wild animals needs expertise in several associated fields like captive breeding, species reintroduction, reserve connectivity, and wildlife management - all of which require a thorough understanding of the behavior of the target animals (as well as some other animals that interact with the target animals). You can read this paper to have a detailed understanding of applying

ethology in conservation. Likewise, understandings of animal behavior are required to make strategies for mitigating human-wildlife conflict!

- **Understanding ourselves better**
  - *Understanding human behavior better (or at least serves as a source of hypotheses)*

    As animals can provide a "mirror" to us, understanding the behavior of animals - especially the social ones - have often been useful for developing new learning techniques for human, marketing strategies, and mitigating conflict of interest. However, human ethology itself has flourished as an independent subject, and studies that involve understanding human behavior from the behavior of other animals need a very careful comparative approach.

  - *An integral part of neuroscience*

    As behavior is the outcome of the neural processes in response to an external or internal stimulus, ethology is an integral part of the studies dedicated to understanding the functions of the neural structures in animals - this gives rise to the discipline called neuroethology.

- **Developing tools**
  - Biomimetics (animal-inspired robots)
  - Algorithms (e.g. ant algorithm, artificial intelligence - reinforcement learning)

Food for thought: Can you think of any other reason for studying animal behavior?

WHY DO ANIMALS DO WHAT THEY DO?

- **Darwinian "fitness"**

  In simple words, Darwinian fitness refers to the lifetime reproductive success of an organism or genotype, calculated by the average number of offspring that it produces (i.e. the number of copies of its genes that it passes on to future generations). Hence, genes or behaviors that contribute to better Darwinian fitness survive in the course of evolution. Ethologists argue that most of the behavior that animals show can be related to their

  - Survival
  - Reproduction
  - Cost and benefit ratio of the behavior (e.g., in terms of gain in energy or a broader sense, in Darwinian fitness).

Food for thought:

Then why do we play or do something for fun or entertainment? Does that increase our survival and/or reproductive chances? Do animals do things for fun?

Task_2:

Identify some "behaviors" that animals need to perform for survival and reproduction (hint: foraging is one of the behaviors).

- **Factors affecting animal behavior**
  - *Morphological constraints*

    Whatever an animal can do is limited by its morphology, anatomy, and physiology.

  - *Evolutionary constraints*

    And the morphology, anatomy, and physiology of an animal are defined by its evolutionary history. Therefore,

we can expect similar behavior for any particular stimuli from animals that share a common evolutionary lineage. That is why we see similar "instinctive behavior" in related animals.

- *Environmental constraints*

  In the biological context, the environment of an animal encompasses living (biotic) and non-living (abiotic) surroundings of the animal. Animals show adaptation that enhances their survival and reproductive success in a particular environment. So, two animals that share a common evolutionary lineage, can show different behavior if they inhabit in two different environments. Also, animals often show different behavior in different seasons.

- *Personal lifetime experiences - learning and memory*

  And of course, behavior in animals can be influenced by what they learn and memorize. Ethologists discovered different methods of learning (like imprinting, conditioning, reinforcement learning, etc. You can check the Encyclopedia of the Sciences of Learning for more).

- *Animal age, sex and personality*

  Animals from different age groups and sexes can show different behavior to the same stimulus. Animals may also have individual personalities - animal from the same species, from the same gene pool, developed in and from the same environment can show different behavior.

Fun Fact: Similar to us, there are "lefty" and "righty" individuals (technically called "laterality") in many other animals including fruit flies.

Task_3: Now, refine your hypothesis invoking your understanding of the factors that may affect the behavior in an animal that you can observe.

HOW TO STUDY ANIMAL BEHAVIOR?

A typical ethological study starts with an observation of an interesting behavior or asking an intriguing question on animal behavior. It is followed by forming a hypothesis, collecting data to test the hypothesis, arranging/processing the collected data for analysis, data analysis, and reaching a conclusion.

- **Framing questions into *proximate* and *ultimate* questions:**
  - *Proximate questions ask about mechanisms - What is the mechanism that produces a behavior? how does it work?*
  - *Ultimate questions ask about how something has evolved - what is its selective advantage? What is its evolutionary history?*
  - *These two types of questions are complementary to each other for a holistic understanding of animal behavior.*

- **Tinbergen's four questions**
  - *What makes a behavior happen? (causation/mechanism)*

    This question examines the internal mechanisms - nervous, hormonal, physiological - that results in a specific behavior. When we ask this type of question, we test hypotheses about how nerves, muscles, hormones, physiology et cetera interact to produce behavior.

  - *What is the survival value of the behavior? (function)*

    How does behavior contribute to the survival and reproduction of the animal? Here, we consider the utility, or usefulness, of the behavior in terms of Darwinian fitness, or its adaptive significance.

- *How does a behavior develop in an individual organism (ontogeny)?*

  Here, we ask where a behavior "comes from" - the relative contributions of genetics (the "innate" behaviors) and environmental (and experience-based) factors that give rise to behavior.

- *How has the behavior changed over evolutionary time, across species (evolution)?*

  Evolution, or phylogeny, tells us about the origin of behavior in distant times. When we ask this type of question, we test hypotheses about the beginnings of behavior in ancestral organisms and the evolution of the behavior in descendant species.

Read these two papers (1 & 2) for a better understanding.

Task_4: Refine your hypothesis keeping the four questions in your mind.

- **Observation and data collection**
  - *What to observe?*

    An observation could be serendipitous which could lead to a framed hypothesis. To make the hypothesis concrete, ethologists often make some additional qualitative observations. The next round of observation is question-driven - it depends on what exactly the ethologists want to know from observing an animal. And then, they observe pin-pointed behaviors that they can measure to answer the questions - this is where ethologists make quantitative data collection.

  - *How to observe?*

    Again, it depends on the question. If the ethologist wants to observe some natural behavior, ideally, the observer should not influence the behavior of the animal. However, if you intend to test an animal's capability (which animals may not show very frequently), or how an animal behaves in the presence of some unusual stimuli (e.g., when you want to see how a domestic or laboratory animal behaves in response to you or some other stimuli), you have to design your experiment accordingly. You should keep in mind that animals are often more aware of your presence than you are about theirs, especially in the wild.

- *Data collection*

Ethologists collect data by observing animals and recording/scoring quantitative data on their behavior. Quantitative data could be, for example, the number of times an animal shows some behavior like a body movement or a call in a given time/condition. Therefore, along with the behaviors, ethologists often also need to keep an account of the surroundings of the animal.

Observation and scoring are traditionally carried out manually, using a scoring sheet and pencil, and some devices like a compass or a stopwatch. With the advent of technology and the possibility (and necessity) of using those in ethological studies, complex electronic devices like audio/video recorders, GPS units, RFID readers, etc. became popular instruments for data collection. In the last 10 years, this field has started incorporating computationally powerful devices that can collect high-throughput data automatically. One of the major goals of this course is to get you familiarized with the cutting-edge technologies.

Keep in mind, all of these tools and methods are in use today, and for a good reason - every method has its pros and cons. For example, traditional manual observation allows the observer to experience even those sensory modalities which the observer primarily did not mean to record. However, such peripheral/additional observations often allow researchers to have a different perspective and deeper understanding of any behavior, and thus, generating future questions and hypotheses. Also, there are plenty of behaviors yet to be observed and described.

- **Data arrangement/processing and analysis**

The formats in which raw data are collected are often not ideal for further analysis, and therefore need to be rearranged or processed. One should be careful at this stage to avoid any data manipulation. Researchers arrange their data according to the analysis they want to perform next. In this course, you will also learn data arrangement/processing and some popular statistical tests for behavioral analysis.

COMPUTATION (LAB PART)

By next class please complete/attempt the following:

- Introduction to Python
- Introduction to Anaconda
- Guide 0 (try to do as much as possible; we can discuss during lecture or OH if there are some things you do not understand)
- Readings: Paper 1, Paper 2

BEFORE THE NEXT CLASS

Take a 2-minute video of an animal/human and try to apply the tricks you learned from the computational lab.

RELATED COURSES:

- OEB 57 (Animal Behavior)
- CS50 (Introduction to Computer Science)

SUGGESTED READING:

1. Animals in Translation: Using the Mysteries of Autism to Decode Animal Behavior (A Harvest Book) by Temple Grandin, Catherine Johnson
2. Tinbergen, N., 1963. On aims and methods of ethology. Zeitschrift für tierpsychologie, 20(4), pp.410-433.
3. Bateson, P., Laland, K.N., 2013. Tinbergen's four questions: an appreciation and an update. Trends in ecology & evolution, 28(12), pp.712-718.
4. Gadagkar, R., 2018. How to Design Experiments in Animal Behaviour. Resonance, 23(11), pp.1243-1257.