Getting the measure of behaviour… is seeing believing?

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INTRODUCTION

This article considers the ***challenges involved in measuring and interpreting animal behaviour***, specifically when trying to understand an animal's responses to a new system. A 'system' in this sense, might be a new computer-based system that the animal interacts with, or a new management system (such as housing, feeding etc.), where the animal-computer interaction element is actually the tools used to measure the observed behaviour. Reference to 'measuring' behaviour suggests that this process is straightforward and relies solely upon recording observable actions. The interpretation of what is observed is clearly a more challenging task and one which animal behaviour researchers have long grappled with, using additional physiological measures and comparative approaches to attribute meaning to what is observed. However, the challenges associated with recording behaviour and quantifying it in a meaningful way should not be underestimated. We present examples of issues that require resolving when designing a behaviour analysis tool that aims to facilitate this task. We hope that some of the experiences in observing, recording and interpreting animal behaviour that we recount here will go some way to highlighting important points to consider.

A BACKGROUND TO MEASURING BEHAVIOUR

Why study behaviour?

Animals' interact with their environment and other organisms to enhance their wellbeing and survival, from these outward expressions of behaviour inferences can be drawn to further understand biology, provide indicators of welfare or wellbeing, identify preferences, and provide insight into animal perspectives. By making measurements of behaviour; that is by the act of assigning values to our observations; reference values are created that permit further analysis and evaluation, thus enhancing the scientific rigour of our enquiries. The research surrounding behaviour has been a multidisciplinary effort, with origins in two scientific approaches: psychology (the study of the mind), and ethology (the biological study of behaviour). In the early 20th century, psychologists were concerned with elucidating the general processes of behaviour under laboratory conditions, this primarily focussed on the processes of learning. In contrast, ethologists were wary of experimental work and instead carried out fieldwork to gain understanding of behaviour in natural contexts. As research progressed, ethology established methodology for observing and measuring behaviour, whereas psychologists honed experimental design and quantification. In time, these methodologies would be shared across both disciplines, with additional contributions from other research fields including neuroscience, social science, including computer science.

The subject matters

It is time well invested getting to know our animal participants, both as individuals with their own unique life experiences, and also their species specific characteristics. Species characteristics should be reviewed broadly, recognising both psychological and physiological components. What are their sensory abilities and how do they perceive the world? Are there any features of their behavioural repertoire that will facilitate environment manipulation? For example, dogs fetch objects in their mouths, whereas a foraging species such as the horse would not typically do this. That is not to say behaviours cannot be learned (or taught), but we should check if their anatomy will permit or restrict their ability to operate a system. Are they a social or solitary species? What prior learning has taken place? What motivates them? What is their personality? Has their wellbeing (including health and emotional state) been assessed? Does their age affect their cognitive capacity or physical ability? Will they be inquisitive or fearful of the system? An animal's willingness to engage with a system may relate to prior experiences, have they seen this or something similar before and was it a good or bad experience? What was their environment like during important developmental stages, such as those sensitive periods when the young animal's nervous system is developing? Be aware of neophobia, a fear of novelty, this is an important survival strategy that can produce specific species reactions such as freezing or running away. This is not an exhaustive list but highlights factors to consider that will shape the animal's behaviour and interaction with a system; factors that should influence the design of systems, and subsequently influence how behaviours are interpreted.

What can be measured?

Our human senses gather information about the external world; this information is then sent to the brain for processing which creates perception; that is our reality of the world. With respect to gathering behavioural information, we are particularly tuned to process visual stimuli, such as features of morphology and movement. However, the level of detail that we perceive relies on the capacity of our senses, any training or experience we have to recognise these features, the ability to recall information, and even how fatigued the observer is. Ultimately, just how good a measurement is will depend on it fulfilling the criteria of: objectivity, reliability and validity. Where *objectivity* aims to eliminate judgement, bias or prejudice; *reliability* is how consistently a measurement can be made; and *validity* represents how accurately that measurement corresponds to the real world. Our human deficiencies may be enhanced with technological assistance.

RESEARCH APPROACHES TO MESAURING BEHAVIOUR

Approaches used to measure behaviour are many and varied and will depend upon the type of behaviour the researcher is interested in, which in turn depends upon the reason for the study. Specific methods have developed to answer specific questions. A mechanistic approach, involving the measuring of different aspects of behaviour independently of each other has formed the basis of many of the quantitative methods in use. The challenges to measuring behaviour in confined, laboratory or captive situations differ from those experienced in the field. The familiarity of the animal to human intervention, its habitat, social grouping, not to mention its size and physical features, all require careful consideration when deciding the approach to take. In addition, the study may require detailed observation of an individual, the behaviour of the group as a whole or behavioural interaction within the group, between groups or between species.

Observing behaviour

When choosing between 'live' observations and using video footage the choice is not obvious. Although video allows re-runs of footage to ensure accurate recording, re-visiting different individual animals, checks for inter- and intra-recorder consistency and retention of footage for future analyses, this approach does have limitations. The positioning of cameras to ensure visibility of the animals under observation, the potential for animals to move out of shot, light conditions and other environmental factors can result in footage that does not provide sufficient detail of the required behaviours. A human observer can move to maintain a clear view, follow animals if they move away, and monitor other occurrences that may affect the observed behaviour but could be off-camera. However, the human observer may influence the behaviour of the animals under observation and controlling for such effects is one of the golden rules of animal observation. In situations where the area for observation is restricted (as in cages and other animal enclosures), video footage recorded on camera(s) located to enable a view of the whole area is the best option. Once this continuous recording has taken place a vast amount of time is needed to analyse this data.

Measuring behaviour

The basis of measuring the behaviour of a specific species is the development of an ethogram that includes all features of its natural behavioural repertoire. Accurate descriptions of each behaviour are listed in order to minimise the potential for variance based on subjective judgement. The ethogram includes behavioural states (ongoing, generally mutually exclusive behaviours such as sleep, running, feeding) and behavioural events (momentary actions that may occur throughout a behavioural state or as the behavioural state changes). The duration of each behavioural state is generally recorded and the frequency of behavioural events noted. The Handbook of Ethological Methods (Lehner, 1996) is an invaluable source of information about the ethological approach to the study of animal behaviour.

Although there have been developments in the automation of video analyses, the systems currently available do not provide sufficient behavioural details in the majority of species and human input is still required. Video tracking software is used to monitor the behaviour in laboratory rodents in particular, and a recent development is the inclusion of mice and rat behaviour recognition (for example, grooming, sniffing behaviour) in addition to the monitoring of activity and movement patterns. Such automated behavioural recognition reduces the time required to analyse behaviour and removes the risk of human error. In laboratory species predominantly used for research within neuroscience, this is a valuable, timesaving tool. Currently, in the majority of species, behavioural analysis requires designing an ethogram and either inputting this into a behavioural analysis package or scoring the behaviour 'by hand'. Some packages require development of behavioural codes to use when scoring behavioural footage and output extensive analyses of the data.

Unfortunately, whichever process is chosen, the time needed to view and record the behaviour is likely to be greater than the duration of the footage. Very often, specific behaviours are of interest to the observer, for example, agonistic or affiliative animal interactions. A system that could identify such occurrences within the overall footage would speed things up considerably. Once identified, the human observer could record the nature of the interaction and the individuals involved, before fast forwarding to the next occurrence of interest. Unless there is behavioural synchrony within a group of animals, this will need repeating for each individual animal. This brings us to the challenge of identifying individual animals.

The identification of individuals within a group of animals is often problematic. In a flock of several hundred sheep, what features differentiate between individuals? In domestic/laboratory animals, coloured markers or symbols could be identifiers. This is not usually a possible or desirable method of identification in wild animals. Researchers familiarise themselves with individual animals, until they can reliably identify them. Certain species have markings unique to individuals. For example, an automated recognition tool uses a barcode scanning approach to scan the stripe patterns of zebra. This method offers the potential for identifying individuals in other species with patterned markings; but may struggle to identify animals with more uniform colouration.

In some studies, it is features of group behaviour rather than individuals that interests the researcher. The identification of individuals is still necessary, but it could be the role of each animal, the spatial distribution of individuals, the distance between different groups, or any number of factors relating to group behaviour that needs measuring. Group composition can be assessed by recording individual characteristics such as gender, age, familial ties etc. Intra-group interactions may provide information about hierarchical structure and competition for resources. Measuring the distance between individuals can provide a measure of affiliative ties, either by approximation (often using the animal's body length as a guesstimate) or by using a rangefinder. Social network analysis is a means of exploring spatial and other relationships between group members.

When observation is not possible

Some aspects of animal behaviour may be hard to observe either live or from video footage taken from a static camera. For example, ecologists are interested in the behaviour and movement of animals within the environment. In some cases, these movements are across great distances, in water, in the air or even underground. By using animal-borne video and environmental data collection systems, video footage from the animal's point of view is combined with data from other sensors (to monitor factors such as location and temperature). Attaching such devices to an animal requires the design of appropriate equipment, catching the animal, a means of attachment that is secure but does not restrict the animal's behaviour, and a way of removing and retrieving the equipment, not to mention an effective means of accessing the data collected. Monitoring movement patterns of animals with GPS tracking devices has become common practice, with equipment designed for hedgehogs, vultures, sharks and others. Advancing technologies enable continuous recording for longer periods, potentially for many months. Pedometers/accelerometers provide information about activity and time spent lying, moving, feeding etc. When large numbers of animals are involved and the interest in their behaviour is predominantly commercial, as in dairy cows, this equipment provides information about changes in activity that may relate to the onset of oestrus, calving or health problems.

Behaviour and learning

Behaviour changes in response to training provide measures of intelligence, learning ability and the effectiveness of the training method used/trainer. Learning trials designed to assess intelligence and perceptual ability, as well as training animals to fulfil specific human-oriented roles, all result in measurable changes in behaviour. The speed of any behavioural change, the accuracy of performance and the number of errors made are all ways of assessing learning. In human derived tasks, a set criterion for successful learning, or a behavioural response to a specific signal, indicates that the animal has learned the task. In their natural environment, animals adapt their behaviour in response to environmental cues, other animals, and according to the consequences of their actions. This association between behaviour and outcome forms the basis of adaptive behaviour and learning theory. The use of computer-assisted tasks, interactive screens and software developed to assess performance, has resulted in recent animal learning studies based on animal-computer interactions. While this development is inevitable, the need to design tasks and equipment with the animal species in mind is imperative. In the past, an anthropocentric approach to assessing animals has often resulted in an underestimation of their intelligence. Species-specific abilities and perception form the basis of any 'fair' intelligence test.

Interpreting behaviour

Using the objective, mechanistic approaches to measuring behaviour as described above, leaves us with the problem of how to interpret observations and their measurements. Sequences of behaviour, i.e. what behaviour generally follows or precedes another behaviour, can indicate what a particular behaviour 'means'. For example, if a horse approaches another with its ears back, then lunges forwards with its head/neck, then goes to bite the other, this is probably aggression. If this sequence of behaviour always occurs after ears back behaviour, then ears back takes on a specific meaning. Analysis of the frequency with which behaviours precede or follow other behaviours is a feature of some behavioural analysis packages. The 'meaning' of behaviour is not always clear however. Facial expression in some species is a good indication of how that animal is feeling and how it is likely to behave. The automated monitoring of facial expression in humans does not always reflect inner 'feelings'. Although animals are less likely to pull 'deceptive faces', it may not be possible to differentiate between a smiling and snarling dog from facial expression alone. Changes in circulatory patterns, particularly in area of the face, occur as part of an emotional response and in humans, with changes in peripheral blood flow resulting in changes in body surface temperature. Heating or cooling of specific facial areas such as the nose and area surrounding the eye are 'measurable' using infrared thermography. This technique offers some insight into emotional responses and the 'inner feelings' of animals but in species with facial hair measuring appropriate temperature changes is fraught with difficulty.

A 'whole animal' approach may take us closer to understanding what behaviour means. With empathy, humans may be able to judge how an animal is feeling and what its behaviour indicates. The system of 'free-choice profiling', (whereby observers describe the animal's interaction with its environment qualitatively) aims to assess the whole animal (Wemelsfelder *et al.,* 2001). This approach may still result in misinterpretation and is likely to be less effective in unfamiliar species. The whole is certainly greater than the sum of its parts, and the more mechanistic approach has not yielded all the answers. Offering animals choices and allowing them some control over their environment may add to our understanding. Perhaps someday it will be possible to put on the virtual reality helmet and become an animal for a day. This may for many be a very salutary experience.

CONCLUSION

To all system designers, please do not be put off by the challenges ahead - a solution is out there! We hope that sharing our experiences in observing, recording and interpreting animal behaviour will help get us a little closer to finding it. We await the emergence of an automated (accurate!) system with excited anticipation!

FURTHER READING

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