DogCam: a Way to Measure Visual Attention in Dogs

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ABSTRACT

Modern technology, including lightweight cameras and eye tracking equipment now seem to afford the possibility of tracking where an animal's visual attention is directed in real time and with greater precision than can be had by fixed cameras or third-party observers. The current hypothesis is that a dog-mounted camera can provide a reliable source of precise information about the dog's moment-to-moment visual attention at a resolution that exceeds other techniques for assessing gaze direction. In particular, we are interested in gaining precision at scales of 10cm or less, and 500ms or less, which will allow us to say where dogs look at when are engaged in communicative signaling, such as during a stereotypical play bow or petting situation.

With this new technology we will put some of the techniques that have been effective in generating knowledge about human cognition to work in studying dog-dog and dog-human interaction.

Author Keywords

Social attention, dogs, eye-tracking, animal cognition methods.

INTRODUCTION

Social cognition is one of the most studied areas in current cognitive-neuro-endocrinological research; its relevance and applicability are of great interest to the scientific community. Research on social cognition has importantly increased our understanding of relevant aspects of non-human and human social behaviors, e.g. empathy, theory of mind and its relevant malfunctioning in humans, such as autism spectrum disorder (ASD) and anxiety disorders, among others [4].

The current project is evolution-oriented and takes the intriguing model of the dog as its focus. The study of dogs could shed light on interesting aspects of evolution in general and social cognition in particular. Research on dogs grew out of criticisms of research conducted on non-human primates. Non-human primates are generally considered to provide the best model for interspecies comparisons that would improve our understanding of human cognitive abilities and disorders. However, there are ethical, methodological and financial stumbling blocks that hinder non-human primate research. These issues have led researchers to adopt two solutions. Some researchers have pursued the strategy of running experiments in locations where they can count on the presence of a high population of certain primates. An example is this approach is the study of the rhesus monkeys at El Cayo Santiago. However, because this species was highly habituated to human presence, questions have been raised about generalizability of the results.

Another solution researchers on animal cognition have adopted has been to find new models. The study of domestic dogs (*Canis lupus familiaris*) is ideal for two reasons: for their cognitive abilities they possess and for the fact that they live among humans, so that their *natural* environment is one in which humans play a central role [8]. Dogs are a unique case in nature, as humans domesticated them 15,000 years ago [3]. The specifics of the domestication processes are still not clear, but what is clear is that the domestication was successful. An apparent co-evolution with humans is one of the factors that make this inter-species relationship unique. Dogs are extremely social animals; notably, dogs are able to understand and to work with social cues such as pointing, head nodding and gazing, among others. These sophisticated social skills may be specialized as a result of domestication and possibly co-evolution. Finally, dogs are also sensitive to attentional states in humans and they also have been shown to be sensitive to the visibility of human's eyes [5, 6].

This last point was a major motivating factor to develop this project: if dogs are attentive to faces and look at the eye region searching for information (as some research has suggested) that would make them even more unique in nature. It would not be unreasonable to think that they have evolved a specialized system that allows this social behavior. For example, apes do not look at human's eyes without previous training [7]. This does not mean that they are not capable of this particular behavior; rather, because

apes, such as chimpanzees, have a strict social hierarchy, eye contact can be read as a sign of aggression.

Interestingly, the dog's closest relative – the wolf - does not look spontaneously at faces, does not follow gazes, and, in general, performs worse in all of the aforementioned tasks than dogs do.

Domestication processes could explain why dogs can and do look at faces. And even though dogs are not 'visual animals', the simple possibility of measuring the visual field or measuring the dog's gaze is a huge step in animal cognition research, where third-person view recordings and behavioral description has been the leading approach. In the next section we will explain the methods a little bit further.

METHODOLOGICAL APPROACH

Unfortunately, the evidence for social cognitive abilities in non-human animals, specifically of gaze-related behaviors, is still weak. Researchers in animal cognition rely primarily on third-person behavioral measures. Studies typically focus on where the animal looks and use video cameras to record the experimental sessions. Due to several practical constraints, data gathered in this way does not tell much about the exact location of where the animal's attention is directed.

These methodological issues have led us to develop new methods to investigate with higher precision and accuracy where the dog's focus of attention is directed in socio-cognitive tasks; specifically, we have developed the use of a head-mounted camera since it can provide a reliable source of precise information about the dog's moment-to-moment visual attention at a resolution that exceeds other techniques for assessing behaviors.

In particular, we are interested in gaining precision at scales of 10cm or less, and 1000ms or less, which will allow us to roughly estimate gaze direction (and indirectly attentional focusing). Hence, we are able to determine, for example, precisely which portions of a play partner's body are relevant when the partner is engaged in communicative signaling, such as during a stereotypical play bow or petting situation. In order to relate behaviors between human and dog, the human participants wear a portable human eye-tracking system and the dog participant wear a DogCam. These video streams are synchronized in time. We have designed and built two DogCam models and we will briefly present them here.

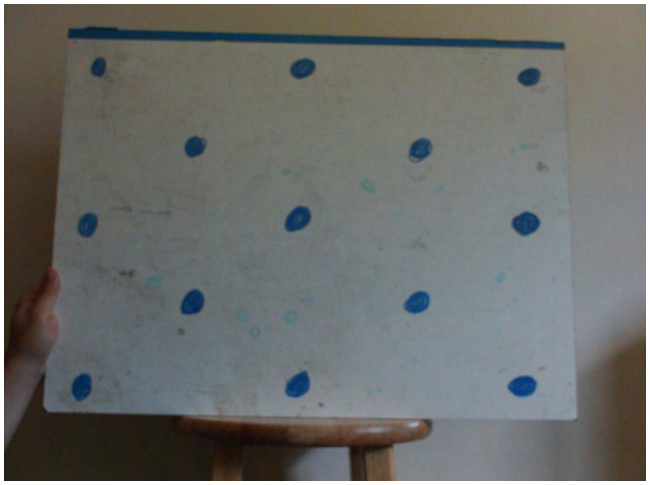

Figure 1. Whiteboard with calibration dots.

DogCam-v1. This model consists in a head-mounted camera using a specially designed harness that is comfortably adjusted to the dog's head. The participant dog is trained to wear the harness (without the camera) for a period of a week. During this accommodation period the dog has to play with the owner during 25 minutes or so in a daily basis. After this period we can carry on with the experiments. Even though, DogCam-v1 records the dog's visual field, in order to analyze the data we need to make a rudimentary calibration.

Calibrating DogCam-v1. The owner commands the dog to sit and we present a whiteboard in front of the dog. We position the whiteboard in order to fill the whole visual field that the camera can record (fig 1). In the whiteboard there are 13 calibration dots and we used a treat to attract the dog's attention to a dot (fig 2). After the dog looks at the treat (and therefore the calibration dot) we give the treat to the dog. After completing all 13 dots the experimental procedure can begin.

Analyzing DogCam-v1 data. The video stream is converted into frames. Our cameras record 30 frames per second; so in a normal 20-minute recording, 36000 images are obtained. The images are loaded into Matlab in order to be further analyzed. We use the calibration frames to define an 'interest area', this procedure is just a simple pixel cropping using the degrees of freedom of the dog's head movement plus the degrees of freedom of the dog's eye movement when attending to the treat as expressed in the recorded visual field (fig 3). Now within the new reduced resolution region-of-interest (ROI) we can count frames of important events or run a saliency map algorithm (or any other machine vision technique such as Image Segmentation, Event Detection or Object Recognition algorithms) to define important features. Preliminary data

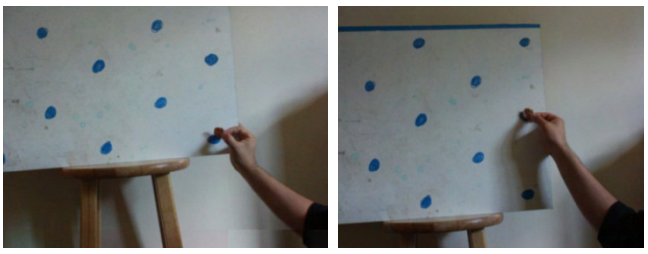

Figure 2. Two frames showing when the dog directs its attention to the treat. Each frame will contribute with 1 point that will help to define a ROI.

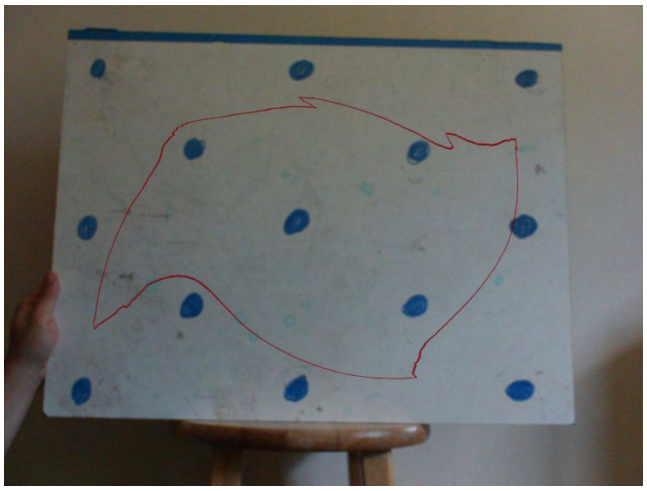

Figure 3. Same frame as fig 1. ROI plotted on top defined with 1950 points extracted from the calibration frames. Shape irregularity due to different dog's movement when looking at each treat/dot.

gathered using DogCam-v1 [5] have shown that when dogs are in a normal playing interaction with their owner, the owner's face stays within the ROI more time than any other part of the body. Hands and arms are highly salient as well. Presumably so as to gather information related to what it is going on at a specific moment in a given context. On the other hand when analyzing the same frames on the human eye-tracking data, we could see that humans look at the dog's eye and face during the interaction.

One may argue that dogs may benefit from having eye contact with humans and reading other biological movement produced by the owners. The explanation may be simple: domestic dogs live among humans and most of the time they are also reared among us. So they might have been pushed, evolutionarily speaking, to look where humans are most expressive, namely in the face. This might be an indicator of the dog's cognitive skills. If they actually developed the ability to make eye contact with humans and to react to this contact, several of the new data about dog-human interactions would thereby be explained.

After obtaining the Bloomington Indiana Animal Care and Use Committee (BIACUC, protocol number 09-002) approval, we ran several experiments aimed both at obtaining data and at learning what adjustments would have to be made for a successful head-mounted camera experiment with dogs.

DogCam-v2. Due to the questions raised by the DogCam-v1 data and the technical restrictions it has, we recently developed the next version. This model resembles a human eye-tracking system in its totality. The harness of the original DogCam was replaced by a set of Doggles, goggles for dogs, a popular pet accessory [9]. DogCam-v2 consists of two cameras, one of them is pointing to the world and the other one is pointing to the dog's eye. The accommodation period is done with the new model as well, in this case the dog has to get used to wearing the doggles, which takes almost no time (most owners have reported that their dogs seem to wear the doggles comfortably after just a couple of days).

Calibrating DogCam-v2. The calibration procedure is exactly the same that we explained in the DogCam-v1 calibration section.

Analyzing DogCam-v2 data. Now that DogCam is an actual eyetracker. We use ExpertEyes open source eye-tracking application to pre-process the data [1]. Now that human and dog participants are wearing eye-tracking systems we can apply the very same analysis techniques.

Right now we are gathering data with our new DogCam model in a simple playing situation and we expect to successfully combine the data with the human-eyetracker one. In the future we may want to explore interactions between conspecifics or create more sophisticated experiments in order to explore an isolated behavior or investigate some other interactions between humans and dogs.

CONCLUSION

Research on animal cognition gives some light to how cognitive processes work in different species and therefore may allow us to better understand human evolution through comparative analysis. Thus, it is not surprising that the literature in animal cognition has increased in number of papers submitted, methodologies and species used. Nevertheless new improvements in research methods are still needed to address complex questions about complex behaviors in animals.

The goal of this project is to develop equipment and techniques that can be deployed experimentally in future studies.

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