Shedding light on nocturnal behavior: A cost-effective solution for remote, infrared video recording in the field

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Abstract: For behavioral ecologists who study nocturnal animals, recording behavior at night is essential, but expensive. Infrared (IR) sensitive camcorders can easily cost over $1,000 USD, yet these pricey cameras rarely stand up to the elements in the field, and pose great financial risk if left unattended overnight. Here, I provide a field-tested method to record nocturnal behavior at a fraction of the cost. I have had great success modifying inexpensive, commercially available action cameras (GoPro Hero4 camcorders) to be IR sensitive, powering these units with cellular phone power banks, and continuously recording behavior overnight while using an array of a dozen cameras. In total, all components of a recording kit are available for under $150 USD at the time of this writing, in the summer of 2023, and can be easily assembled using the following guidelines. This paper provides researchers with an economical strategy to record continuous behavior in nocturnally active animals, at any scale, from small individual animals to widely distributed animal groups. As such, I hope these methods increase the accessibility of science and expand the experimental toolkits of biologists interested in the fascinating, but much understudied world of nocturnal animal behavior.

Introduction:

Recording animal behavior at night can be difficult. Given the million-fold decrease in environmental illuminance following sunset (Land and Nilsson, 2012), the average camcorder is useless at night without an additional light source brightening the scene. Since most nocturnal animals are sensitive to light in the visible spectrum, often more-so than their diurnal relatives (Warrant, 2004), adding white light to a nocturnal scene will unquestionably alter behaviors observed. However, light with wavelengths longer than that of the visible spectrum (i.e. infrared [IR] light) can be used to monitor animals at night without disrupting natural behavior. Accordingly, IR sensitive camcorders and lighting have become gold standards for observational studies of nocturnal behavior.

Unfortunately, camcorders specialized to emit and capture IR light can be extremely expensive, easily costing over $1,000USD for high quality recording devices. These pricey cameras are also not considered "field-ready," as they lack waterproofing and may perform poorly in highly humid or rainy environments. Poor battery life is also a drawback of most IR camcorders, as stock batteries struggle to surpass 3 hours of continuous operation time and require access to an electrical outlet to continuously power. Taken together, most commercially available IR camcorders fall short as an ideal option for field biologists studying nocturnal behavior, especially those working with a limited budget. Few good options exist and I have tried many of them.

As a sensory ecologist interested in visually-mediated behaviors of nocturnal spiders, a major struggle I encountered early in my career was how to monitor these creatures throughout the night on a tight budget. My first field recordings were based on the kit proposed by Pierce and Pobprasert (2007). My kit consisted of a closed-circuit television surveillance camera ($139USD) connected to a netbook computer ($255USD) using a video capture device ($75USD). The kit was powered by a 12v lawnmower battery ($71USD). While this kit worked in the most technical sense (Supplementary video), resulting in my first dissertation chapter (Stafstrom and Hebets, 2016), and was less expensive than the $1,500USD entry-level IR cameras available at the time (my kit = $540USD total), there were many drawbacks to using this equipment in the field. The weight of batteries prevented me from setting up more than two cameras at a time. The recording software would save each observation as a single, massive file. Paired with an easily corruptible video capture device, I lost more than 100hrs of recordings during my first field season. Years later, I purchased second-hand, commercially available IR camcorders (~$250USD; Sony HDR-SR10) and created my own waterproof housing for field recordings. While price, portability, and recording quality all improved (Supplementary video), maximum battery life for each camera was 1.5hrs. These experiences, among others, pushed me to continue looking for better solutions.

The recording kits I currently use are built around a modified action camera, are powered by a pocket-sized battery, and are far more affordable and user-friendly than any system I have previously used. I have filmed many spiders in the field using these kits with great success. For example, I recently worked in the wet season within the Daintree Rainforest in Far North Queensland, Australia. Taking only 5min to set up and initiate recording, I could easily record from an array of a dozen cameras each night, resulting in over 2,000hrs of continuously recorded nocturnal behavior by the end of my field season (Supplementary video). This system has numerous benefits over other options currently available including i) low cost [entire kit = $145USD], ii) 12hr+ continuous recording times, iii) "field-ready" with waterproof housing, iv) lightweight and extremely portable, v) films in macro or wide-angle, vi) high-definition recording at 4k 30fps, and vii) high-speed recording at 720p at 240fps. The following step-by-step guide will allow users to configure an affordable, user-friendly, and field-tested IR video recording system.

Camera

This kit is based around a commercially popular action camera, the GoPro Hero4 series of camcorder. I have had excellent results with these models, as they are extremely easy to modify, produce high quality footage at a variety of resolutions and speeds, and are easy to locate and purchase on the secondhand market. There are two editions of the GoPro Hero4: the Silver edition and the Black edition. The Silver edition has a maximum recording resolution of 2.7k at 30fps and a maximum recording speed of 120fps at 720p. At the time of this writing, the 30 most recent Hero4 Silver edition cameras purchased on eBay.com had the mean price of $51.80USD (min = $40USD, max = $70USD, std = $8.86USD). The Black edition has a larger CMOS sensor and can thus shoot at higher resolutions (maximum resolution of 4k at 30fps) while also shooting at higher frame rates (maximum recording speed of 240fps at 720p). While the MSRP of the Black edition was $100USD higher than the Silver edition, price differences on the secondhand market are currently minimal (Black edition mean price = $54.62USD, min = $35USD, max = $80USD, std = $11.72USD). Both models can be easily modified to film in IR. Physical dimensions of both cameras are identical, such that all following methods and equipment are interchangeable between models. The main differences between the cameras are i) the enhanced sensor of the Black edition and ii) the rear-facing LCD screen on the Silver Edition, and the lack-thereof on the Black edition. I typically shoot all video in 1080p at 30fps and I do not find the LCD screen to be useful. As such, I frequently use both camera models while out in the field.

Lens

Most commercially available cameras and camcorders use physical filters, known as IR-cut filters, to block long wavelength light from reaching their digital sensors, improving sharpness and color saturation during daytime scenes. In GoPro cameras, these filters are adhered to the back of the stock lens, and are the only barrier between IR sensitive recording. Accordingly, replacing the lens is the most important part of this process. My modification is simply removing the stock lens and replacing it with a lens lacking an IR-cut filter. The stock lens can be easily removed using a gentle amount of torque, applied counterclockwise, using a standard wrench or locking pliers. There are many affordable options for filter-absent replacement lenses. The diameter (12mm) and pitch (0.5mm) of threading on Hero4 lenses are commonly used in CCTV cameras, IP cameras, and other circuit board-level cameras like those used in Raspberry Pi applications. These lenses are commonly referred to as "S-mount lenses" and can be purchased for as little as $1USD. I personally have had the greatest success using wide-angle lenses with a focal length of 3.6mm and f/2.0 aperture, but there is a great variety of lens options available to fit the needs of any given project. While more recent versions of GoPro cameras can be altered in a similar fashion, the threading pitch of newer models (0.35mm) is much less common. Replacement lenses with a pitch of 0.35mm are consequently harder to find and 10x more expensive when compared

to the S-mount.

Lighting

After replacing the lens, the camcorder is now IR sensitive. The next step in configuring a kit is adding an IR light. Most commercially available IR illuminators operate at peaks of 850nm or 950nm light. Both wavelengths can be detected by the camera sensor, but 850nm illuminators are more common and less expensive. If nocturnal behavior is being filmed in a laboratory setting, using an illuminator that plugs into an AC power source is the easiest solution. Field recordings require a more portable solution. Battery powered IR flashlights are an easy option as illuminators in remote locations, but I find maximum battery life for these lights to fall between 5 and 6hrs. I prefer to create my own IR illuminators consisting of a single LED powered by AA batteries. I solder together a high-intensity (3.3V) 850nm LED light board module ($1.50USD) to a AA battery holder ($0.50USD). One pair of AA batteries (2,000mAh capacity or greater) can power the LED for more than 12hrs. Flexible rubber twist ties ($1USD) work well to secure the LED in position for filming.

Power

I advise users to replace used GoPro brand batteries included with their camera, as battery capacity decreases with age. New replacement internal batteries ($6USD) can provide approximately 2hrs of continuous filming at 1080p 30fps. To boost battery life to 12hrs, an external battery is required. Luckily, GoPro camcorders can be powered by any 5v source with a mini-USB output, and cellular phone power banks are an excellent solution. A 10,000mAh power bank ($10-$13USD), can power a GoPro Hero4 for 10-12hrs, depending on environmental conditions. For longer recording times, higher capacity power banks (20,000mAh capacity) are readily available at the price range of $20-$30USD.

Storage

GoPro Hero4 cameras record data onto microSD cards which have become extremely affordable. A 256gb microSD card can be purchased for $13-$20USD, depending on the write speed of the card. Using a standard write speed (100MB/s) 256gb capacity memory card, 23.52hrs of footage can be recorded at 720p, 30fps. At 1080p, 30fps, 17.46hrs of footage can be recorded.

Housing

GoPro Hero4 cameras frequently come with waterproof housing as part of a bundled package. If housing is not included, replacement waterproof cases can be purchased for $9USD. To connect the camera to an external battery, and to enable live-focusing (explained in sections below), it is essential that the USB and HDMI ports remain accessible while housed. There are several methods to accomplish this. One method is to utilize a “frame mount” or “skeleton case” to house your camera, both of which are great options for filming in a controlled laboratory environment. However, these options are not advised if working in the field, as both types of housing expose the camera to potential water damage from rain at multiple points. My preferred approach for housing in the field is to drill small holes into the side of stock waterproof housing above each port (3/8’’ diameter for mini-USB, 5/16’’ diameter for HDMI), through which cords can be threaded. Subsequently, I cover these inputs with electrical tape to seal the camera from outside moisture, which has proven effective even during heavy rainstorms.

Placement

Deciding where to place and point the camera will determine the composition of the recording. Fortunately, there are many options for mounting GoPro cameras onto a variety of surfaces. One easy option is mounting the camera atop a standard tripod, which can be accomplished with a $2USD tripod mount adapter. This provides the user with a range of heights at which the camera can be placed. In my

experience filming small animals, adapters that allow for more free movement of the camera are greatly beneficial. As such, I use goose-neck clamp mounts, which are slightly more expensive ($11USD), but provide a greater range of motion for placing the camera. I typically clamp my camera to the leg of a tripod, while also securing the IR illuminator and power bank atop the tripod (Figure 1). This allows for widest range of heights and angles for the camera to film, while also providing a sturdy base for batteries and lighting equipment.

Focus

Since GoPro cameras do not have an auto-focus feature, focusing the camcorder must be done by hand. Manually twisting the lens back and forth will adjust the focus. As action cameras do not possess optical viewfinders, digital options must be used to ensure proper focus. With a Silver edition Hero4, live feed can be viewed on the rear-facing LCD screen. Black edition cameras do not have this option. Live feed can also be viewed using the GoPro app on a smart phone. Both of these options, however, compress video size and resolution, compromising observable video quality, therefore making accurate focusing more difficult. I find viewing live feed of lossless quality on a large screen (e.g. desktop monitor, laptop, or tablet) ideal for checking focus. This can be achieved using a combination of a mini HDMI to HDMI cable ($10USD) and a video capture card ($15USD). If using a laptop or tablet as a monitor, GoPro input will now be recognized as if it were a webcam. As such, any native software on the monitoring device used for capturing photos or videos will allow for viewing live-feed.

Conclusion

Traditional IR-sensitive camcorders are expensive and ill-suited for fieldwork. Here, a step-by-step guide provides users with a cost-effective and field-tested solution for recording nocturnal animal behavior. The kit described above offers many advantages such as affordable components, long recording times, portability, and high-definition/high-speed recording options. This approach aims to democratize the scientific exploration of nocturnal animal behavior, providing an economical and accessible method for researchers interested in studying a wide range of nocturnal creatures, from individual animals to distributed groups.

Author contributions

J.A.S. configured the recording system; J.A.S. and R.R.H. wrote and edited the manuscript.

Declaration of Interest

None

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References:

Land, M. F. and Nilsson, D. E., 2012. *Animal Eyes*. Oxford University Press, Oxford.

Pierce, A. J. and Pobprasert, K., 2007. A portable system for continuous monitoring of bird nests using digital video recorders. *Journal of Field Ornithology*, *78* (3), 322-328.

Stafstrom, J. A. and Hebets, E. A., 2016. Nocturnal foraging enhanced by enlarged secondary eyes in a net-casting spider. *Biology letters, 12*(5), 20160152.

Warrant, E., 2004. Vision in the dimmest habitats on earth. *Journal of Comparative Physiology A, 190,* 765-789.

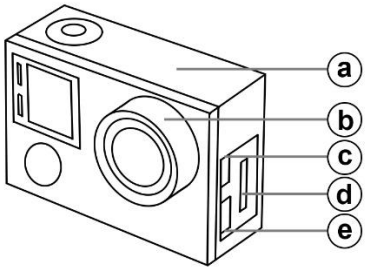

Figure 1. All components of the infrared recording kit. a) GoPro Hero4 Silver edition, b) replacement lens, c) mini-HDMI port, d) microSD card slot, e) mini-USB charging port, f) waterproof housing, g) mini-HMDI to HDMI cord, h) IR LED board module, i) AA battery holder, j) cellular phone power bank, k) rubber twist tie, l) mini-USB to USB cable, m) goose-neck clamp mount, n) tripod, o) video capture card, p) live viewing monitor.

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