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An Inexpensive Low-cost Video Monitoring System for Automated Recording of Behavior and Ecological Interactions

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Active, real-time observation of behavior is a time-consuming task, and heavily resource-limited. At the same time, simultaneous observation of several individuals is often paramount to increasing statistical rigor as well as to eliminating potential temporal or environmental bias, especially in natural settings. This paper describes a low-cost video recording system created by using "off-the-shelf" components. The system is easy to use and can automatically record a wide variety of behavior and related ecological interactions and evolutionary processes. The system is sensitive enough to record the behavior of a broad range of animals from microorganisms and small insects to humans. The behavior of plants can also be measured. The system will also work during daylight hours or at night and can run continuously and autonomously for 48 hrs or longer if the video capture is motion-triggered or if bigger capacity batteries and data storage facilities are used.

Keywords: apparatus, automation, ethogram, observation, video

Active, real-time observation of behavior, whether in a laboratory setting or the field, is a time-consuming task, which is heavily resource dependent with regard to personnel, time, and funds. The simultaneous observation of several individuals and/or species is paramount to increasing statistical rigor and eliminate potential temporal or environmental bias. Recording behaviors for later analysis is a common workaround although one of the challenges facing researchers interested in observing behavior is the high cost of equipment. Video monitoring tools can easily cost several thousand dollars. Such cost is prohibitive for researchers working at smaller institutions with limited grant money. Graduate and undergraduate students, "stay-at-home" naturalists, and "citizen scientists" wishing to make substantial contributions to the literature will also find the cost prohibitive (Abramson & Bowser, 2006).

A similar situation exists for commercially available control equipment and behavioral apparatus. The price for mazes, operant chambers, and classical conditioning units, can easily run into thousands of dollars. This cost increases when computers and associated software are used to automate the apparatus.

Microcontrollers have mitigated the expense of control equipment (Varnon & Abramson, 2013, 2018). Moreover, 3-D printing has dramatically lowered the cost of apparatuses (Hitesh & Abramson, 2020). Our rationale behind the current paper is to provide researchers with a low-cost alternative to observe behavior automatically. This effort is similar to our earlier endeavors in the areas of 3-D printing, the use of the parallax microcontroller as a controller, and the use of the parallax microcontroller to detect and record infrasound (Bergren et al., 2019).

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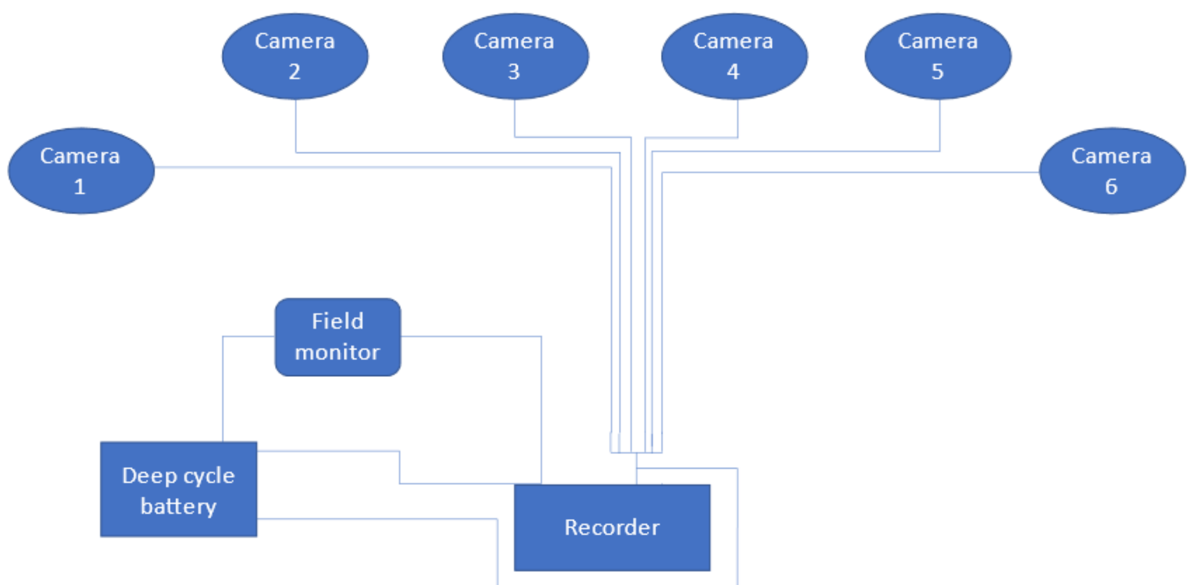
This paper introduces a low-cost video recording system. The price of the system is approximately \$500.00 (USD) and constructed from readily available components. The system is fully portable and is equally useful under laboratory or field conditions. Our system is effective day or night and can record the behavior of animals as small as microorganisms. It is possible to record from a distance if zoom lenses are used. Moreover, it is also possible to record the behavior of plants over long periods during the day or at night (e.g., Abramson & Calvo, 2018; Abramson & Chicas-Mosier, 2016; Ponkshe et al., 2023).

Method

Description

Figure 1 presents a schematic diagram of the system. In this configuration, six cameras are used. The cameras are connected to a video recorder, which in turn is connected to a field monitor. The entire system is connected to a 12V DC deep-cycle battery although even standard 12V car batteries, which are considerably less expensive will work for shorter durations. A short video on how to set up the system is available at: https://www.youtube.com/watch?v=gVFpmUbQ3ok&t=1s.

Figure 1
Schematic Diagram of the System.



Cameras

Each camera is connected to the recorder via a 25 m video cable so that an area of up to 50 m in diameter can be covered if the recorder is placed in the center. The cameras are connected to the 12V direct current (DC) deep cycle battery via a 1-8 splitter and 25 m cable for electricity. The cameras are mounted on separate adjustable tripods. Each camera is fitted with a varifocal zoom lens. The cameras are capable of recording infrared light. Infrared lamps on tripods can be used to illuminate objects of interest at night.

Monitors

A small 12V (DC) field monitor connected to the recorder allows for simple adjustments to the recording settings while in the field. As the field monitor is small and may be difficult to read, we recommend using a standard monitor to set up the system while in the laboratory. Once the system is set and taken to the field, the smaller monitor can be used to make adjustments. For all adjustments, a standard universal serial bus (USB) computer mouse should be connected to the recorder.

The Recorder

The standard closed-circuit television (CCTV) recorder has pre-installed capture and editing software and is fitted with a 1 terabyte (TB) hard drive to record video continuously, triggered by movement or according to scheduled timetables. The sensitivity and trigger areas (up to six) within each camera view can be easily adjusted. Within one camera view, it can be set to be sensitive to movement. Movement (above the set sensitivity level) within any of these areas will trigger recording. For example, if you want to observe six artificial flowers simultaneously within the same camera view, you can select one specific flower to turn on the recording device when it is visited (Wells & Wells, 1983). To playback the recorded videos, a large monitor is recommended. Each video contains a timestamp for easy reference. The videos can be fast-forwarded and viewed frame by frame.

Battery

A 12V DC deep cycle battery with 90A allows for continuous recording using two cameras for at least 48 hrs, or much longer if set to motion-triggered recording. Several batteries can be connected in parallel to increase battery capacity.

Parts List

A complete parts list is provided below. The cost for all components is approximately $500.00 (USD). The price could be much less depending on where the components, or an individual component, is obtained.

1. DC Power 1 female to eight male plugs cable splitter 5.5 x 2.1 mm for CCTV
2. 4.3 inch LCD TFT (thin-film-transistor liquid-crystal) foldable color monitor screen for car reverse rearview camera
3. Straight RCA male-to-male connectors, six pieces
4. Car battery terminal clip-on cigarette lighter power socket adapter 12V
5. Six BNC male plug to RCA female jack coax cable video adapter connector
6. Standard CCTV recorder (e.g. NOWSOOe 8 channel DVR video Grabador 960H HDMI CCTV Vigiancia H.264+1TB hard drive
7. Universal camera tripod stand
8. Car Cigarette Lighter Power Supply to DC Plug 5.5 x 2.1 mm cable
9. Wing butterfly nuts to attach the cameras to the tripods
10. CCTV mini 2.8-12 mm Varifocal HD lens for security surveillance camera
11. CCTV security camera IR infrared night vision lamp CCTV 48 LED
12. Waterproof, infrared 720P HD CCTV outdoor camera
13. USB 2.0 male plug to DC power jack 3.5 mm x 1.35 mm cord cable to connect the recorder to the 12V DC power supply
14. Mini DC 5-30V voltmeter LED panel 3-digital display voltage meter 2-wire, to monitor the charge level of the deep cycle battery
15. 5 m DC 5V 3.5 mm x 1.35 mm power extension cable for CCTV security IP cameras
16. AC100-240V To DC 12V 1/2/3/5/6/8A power supply adapter transformer to be able to run the system on AC power (e.g., in the laboratory)
17. Dual flash Bracket mount holder to mount one camera and one infrared light simultaneously on one tripod
18. Universal USB A male to 2.0-5.5 mm connector DC charger power cable adapter cord

Sample Data

To present some data on the efficacy of the system we provide video clips of ants and honey bees going to a feeder. As is shown, the ants and bees are easily seen. An artificial feeder was made by filling a 700 ml jar with 20% sucrose by weight. Instructions on how to create an artificial feeder are available (Abramson, 1990). The feeder was placed in a garden, in Mytilene, Lesvos Island, Greece, on June 18, 2022, at 11:00 a.m. The video system was located approximately 50 cm from the feeder and was programmed to turn on at 9:00 AM and set to continuously record until 1:00 PM. For three consecutive days, the feeder was replenished with sucrose every morning at 11:00 AM. In this demonstration, we used only one camera. To keep the insects in front of the camera we limited the 360^{o} space to 90^{o}. As the temperature was above 35^{o}C (95^{o}F), we also placed a screen on top of the feeder to reduce the heat around the feeder.

Two links to short clips on the activity of ants and honey bees on the feeder are below. These clips do not show the range of features offered by our system and are presented for illustrative purposes only. While any video camera can be used to record activity at a feeder, only more expensive systems include features that we offer such as 48-hr continuous recording during the day or night.

https://youtu.be/aJ7370c-yFc Ants on the feeder
https://youtu.be/YmWuRx2g6YM Bees on the feeder

An example of the type of experiment our system makes possible is the ability of honey bees to visit the feeder at a particular time of day. In an earlier experiment, using traditional operant conditioning methods to investigate timing, it was shown that honey bees failed to meet any of the seven criteria used to investigate timing in vertebrates (Craig et al., 2014). Much of the data purporting to demonstrate timing in bees is based on their visitations to flowers at times of the day when nectar is available. One of us (CIA) has extensive experience working with bees in free-flying situations where bees are captured at an artificial feeder (Abramson, 1990). While it is true that free-flying bees will visit the feeder at a particular time of day when the feeder is refilled, anecdotally, it is also true that foragers circle the feeder throughout the morning before the feeder is refilled. If this “pre-feeder” foraging behavior is to be captured, an experimenter must observe the feeder for several hours. This becomes problematic for the experimenter when the temperature becomes uncomfortable and/or fatigue sets in. With the video system described here, these issues are no longer a problem.

Discussion

Other low-cost systems are available to monitor behavior. Van der Marel et al. (2022) for example, reviewed six low-cost software applications for observing behavior using handheld devices. These software applications are different from our system in several ways. First, we do not use any external software. Second, our system works day or night and can run continuously. Third, up to six external cameras can be used. Fourth, our device is not handheld. Weber and Fisher (2019) present a system based on the Raspberry Pi microcontroller that in some ways is as flexible as ours.

The system presented here is low-cost and highly flexible. It can accommodate six cameras and operate continuously for 48 hrs day and night. This allows for the collection of more data (replicates) in a shorter time and with fewer personnel, making this approach efficient. The captured video material can be analyzed later in the comfort of the laboratory and outside the field season when researchers are often less pressed for time. The videos can also be stored for future reference, which is a great advantage over traditional approaches. The system can be used to observe the behavior of microorganisms, insects, large animals, and plants.

The system can withstand the elements within reasonable limits. As such the cameras, infrared light sources, and cables are water resistant although heavy rain should be avoided. Prolonged sun exposure to the cameras could also pose a problem due to overheating. We suggest aluminum foil makeshift covers to shade the cameras. All central units such as the power source, the recorder itself, and the field monitor should be protected from rain, sun, and wind. A beach umbrella, which can also shade the operator, and a small portable camping table are a good solution.

We believe there is no better way to know your study subject than by observing its behavior and constructing an apparatus to capture its activities. Unfortunately, apparatus construction is a lost art (Varnon et al., 2018). Those who do not have the money to buy apparatuses—many are so expensive that only laboratories with significant grant funding can afford them—are at a distinct disadvantage. We believe that the system presented here, and our previous publications on 3-D printing and microcontrollers, will help ameliorate this problem.

One of the best uses of our system is the ability to create ethograms. Ethograms, also known as behavioral profiles, are the bedrock of experimentation. The data obtained in ethograms help researchers better design experiments by selecting, for example, suitable rewards, discriminative stimuli, and apparatuses (Abramson, 2023). This system can also be used in ecological research such as pollination studies where time-consuming observations are the norm (Westphal et al., 2008). Given the ever-increasing optical resolution of these cameras, it is also possible to distinguish species (Kantsa et al., 2022), which may be interesting for biodiversity studies. It is also possible to use the video material for automated species recognition in natural and agricultural settings (e.g., on pests) using artificial intelligence (AI) (see Kalfas et al., 2023 and references therein).

When integrating our system with AI a word of caution is in order. Siegford et al. (2023) notes that there is still much work to do before AI is fully integrated into behavioral observation systems. For example, the effectiveness of AI in identifying the behavior of interest is only as reliable as the information programmed into it. Moreover, any system using AI should be tested on a variety of species under a wide range of situations and be developed by a team of ethologists and engineers. In regards to the latter, we would suggest that comparative psychologists also be included in the design of such systems.

Another use of our system is to teach students how to observe behavior and to use apparatuses. With the increased use of computer simulations in the classroom, it is our experience that students are losing skills associated with "bench work." As our system is inexpensive, it can be incorporated into high school and college classrooms. Students in a course on comparative psychology and behavioral ecology can certainly benefit from learning how to observe behavior and how observations are used to design experiments (Abramson, 2023). It can also be used in the education of veterinarian students to help them better identify problem behaviors of, for example, farm animals and pets (Boughton & Abramson, 2023).

In conclusion, the system we describe is reliable, flexible, and inexpensive. It contains features found on commercial units that cost several thousand dollars. The system we describe can be used for research and teaching in various situations. The first author (TT) has used it for the past six years with excellent results.

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References

Abramson, C. I. (1990). *Invertebrate Learning: A Laboratory Manual and Source Book.* American Psychological Association.

Abramson, C. I. (2023). Research methods in comparative psychology: A tutorial. *Journal of Mind and Behavior, 44* (1,2), 111–135.

Abramson, C. I., & Bowser, T. J. (2006). In-home animal product evaluation using the Citizen Scientist™ program. In T. P. Lynons, K. A. Jacques, & J. Hower (Eds.), *Nutritional biotechnology in the feed and food industries: Proceedings of Alltech's 22nd Annual Symposium, Lexington, Kentucky, USA, 23-26 April 2006,* (pp.251–254).

Abramson, C. I., & Calvo, P. (2018). General issues in the cognitive analysis of plant learning and intelligence. *In*: M., Baluska, F., M. Gagliano, & Witzany, G. (Eds.) *Memory and learning in plants* (Springer series on Signaling and communication in plants), Springer. (pp.35–49).

Abramson, C. I., & Chicas-Mosier, A. M. (2016). Learning in plants: Lessons from *Mimosa pudica*. *Frontiers in Psychology*, *7*(1), 417. http://dx.doi.org/10.3389/fpsyg.2016.00417

Bergren, S., Latino, C. D., & Abramson, C. I. (2019). A portable system for detecting infrasound using a microcontroller. *International Journal of Comparative Psychology*. *32*(1), 1–15. https://escholarship.org/uc/item/49j4h509

Boughton, B.A., & Abramson, C.I. (2023). The role of comparative psychology in the training of veterinarians. *Animals*, *13*(14), 2315. https://doi.org/10.3390/ani13142315

Craig, D. P. A., Varnon, C. A., Sokolowski, M. B. C., Wells, H., & Abramson, C. I. (2014). An assessment of fixed interval timing in free-flying honey bees (*Apis mellifera ligustica*): An analysis of individual performance. *PLoS One*, *9*(7), e101262. https://doi.org/10.1371/journal.pone.0101262

Hitesh, V. D., & Abramson, C. I. (2020). The use of 3D printing in comparative research and teaching. *International Journal of Comparative Psychology*, *33*(1). https://escholarship.org/uc/item/0qm0k0h1

Kalfas, I., De Ketelaere, B., Bunkens, K., & Saeys, W. (2023). Towards automatic insect monitoring on witloof chicory fields using sticky plate image analysis. *Ecological Informatics*, *75*(1), art. no. 102037. https://doi.org/10.1016/j.ecoinf.2023.102037

Kantsa A., Garcia J. E., Raguso, R. A., Dyer, A. G., Steen, R., Tscheulin, T., & Petanidou T. (2022). Intrafloral patterns of color and scent in *Capparis spinosa* L. and the ghosts of its selection past. *American Journal of Botany*, *110*(1), e16098. https://doi.org/10.1002/ajb2.16098

Ponkshe, A., Barroso, J. B., Abramson, C. I., & Calvo, P. (2023). A case study of learning in plants: Lessons learned from pea plants. *Quarterly Journal of Experimental Psychology*, *in press*.

Siegford, J. M., Steibel, J. P., Han, J., Benjamin, M., Brown-Brandl, T., Dórea, J. R. R., Morris, D., Norton, T., Psota, E., & Rosa, G. J. M. (2023). The quest to develop automated systems for monitoring animal behavior. *Applied Animal Behaviour Science*, *265*(1), 106000. https://doi.org/10.1016/j.applanim.2023.106000

Van der Marel, A., O'Connell, C. L., Prasher, S., Carminito, C., Francis, X., & Hobson, E. A. (2022). A comparison of low-cost behavioral observation software applications for handheld computers and recommendations for use. *Ethology*, *128*(3), 275–284. https://doi.org/10.1111/eth.13251

Varnon, C. A., & Abramson, C. I. (2013). The propeller experiment controller: Low-cost Automation for classroom experiments in learning and behavior. *Innovative Teaching*. *2*, 2. https://doi.org/10.2466/07.08.IT.2.2

Varnon, C. A., & Abramson, C. I. (2018). The propeller experiment controller. *Journal of Mind & Behavior*, *31*(1), 1–153.

Varnon, C. A., Lang, H., & Abramson, C. I. (2018). Automated research in comparative psychology: Limitations and new directions. *International Journal of Comparative Psychology*, 31. https://escholarship.org/uc/item/8gf4d5tx

Weber, W. D., & Fisher, H. S. (2019). An inexpensive remotely-operated video recording system for continuous behavioral observations. *bioRxiv*. http://dx.doi.org/10.1101/596106doi

Wells, H., & Wells, P. H. (1983). Honey bee foraging ecology: Optimal diet, minimal uncertainty, or individual constancy? *Animal Ecology*, *55*(1), 829–838. https://www.jstor.org/stable/4422

Westphal, C., Bommarco, R., Carré, G., Lamborn, E., Morison, N., Petanidou, T., Potts, S. G., Roberts, S. P. M., Szentgyörgyi, H., Tscheulin, T., Vaissière, B. E., Woyciechowski, M., Biesmeuer, J. C., Kunin, W. E., Settele, J., & Steffan-Dewenter, I. (2008). Measuring bee diversity in different European habitats and biogeographical regions. *Ecological Monographs*, *78*(4), 653–671. https://doi.org/10.1890/07-1292.1

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