AN INEXPENSIVE INFRARED DETECTOR TO VERIFY THE DELIVERY OF FOOD PELLETS

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The reproducibility of experimental outcomes depends on consistent control of independent variables. In food-maintained operant performance, it is of utmost importance that the quantity of food delivered is reliable. To that end, some commercial food pellet dispensers have add-on attachments to sense the delivery of pellets. Not all companies, however, offer such add-ons. Aside from availability, cost and temporary reduction in throughput may be a problem for smaller labs. The present paper outlines our recent development of a simple, inexpensive infrared device to detect and confirm the delivery of pellets. The in-line construction of the detector routes the falling pellet through a barrel so that it passes between an infrared emitter and receiver. The circuitry was designed to be compatible with all commercially available behavioral measurement systems, and so may be retrofit to any existing system. Our tests with the detector so far have shown that it is 100% accurate in detecting pellet delivery. The individual unit cost is approximately 25 dollars. The low cost and versatility of the device offer an easy method to ensure the integrity of food delivery in operant settings.

Key words: pellet, detection, infrared, reliability

Reliability and replicability of behavioral findings rest on the consistent control over independent variables (cf. Sidman, 1960). In the course of examining an animal’s behavior in an appetitive environment, it is crucial for the experimenter to control the amount and availability of food. In some of our research in choice and behavioral economics, for example, having exact control over food delivery is paramount because the specific ratios between responses and food amounts are the primary independent variables (e.g., Hursh et al., 1988; Madden, Dake, Mauel, & Rowe, 2005). Most behavioral researchers have a story, usually several, about how an apparatus failure resulted in the loss of data, disruption of a stable baseline performance, interruption of a dosing regimen, etc. Over the years, we have found many of these “war stories” of behavioral research surround pellet dispenser failures. In our own lab, for example, pellet dispenser failures are the primary cause for data loss or corruption.

Some companies have recognized potential errors in pellet delivery. Med Associates, Inc., for example, sells a pellet dispenser fitted with infrared detection circuitry to confirm pellet delivery (ENV-203-45-IR). Though the added cost of infrared detection is nominal when buying feeders new, adding detection circuitry to existing dispensers may be costly in terms of both money—as the current cost of retrofitting existing feeders is many fold the cost when buying new feeders—and time, as the feeders must be shipped to the company for retrofitting. For those using pellet dispensers manufactured by another company, the addition of pellet detection capabilities may not even be an option.

Our goal was to design and construct an inexpensive detection circuit that could be retrofitted to virtually any existing feeder system. The general idea behind the detector was to use an infrared detection circuit to count pellets as they passed between an infrared (IR) emitter and receiver. For ease of cleaning and versatility of use, it was important that the detector should be easily disassembled and reassembled. Our final design uses a detachable barrel coupled to infrared detection circuitry. The detector is relatively inexpensive, approximately $25 per unit, is easily maintained, and has the potential to be adapted to several different pellet sizes. In what follows, we detail our detection system so that other laboratories may add low-cost reliability in pellet delivery to their existing equipment.
MATERIALS AND METHODS

IR Circuit Board

Our detector board can be seen fully assembled in Figure 1A. The IR emitter and receiver are attached via ribbon cable to the pin connector; the fully assembled detector is shown in Figure 1B. A schematic of the circuit board is shown in Figure 2 to permit easy reproduction. Examining first the upper portion of the schematic, power is supplied to the circuit via J1. When powered, a light-emitting diode (LED) at D2 is illuminated to verify power is reaching the circuit. The board will take input voltages ranging from 8–32 VDC, which are converted to 5 VDC via a DC/DC converter (V7AH-03H5000) and supplied to the main event detection circuit via U1P.
Fig. 2. Schematic of IR detector circuits. Schematic by K. Ratzlaff.
Thus, the detector can be supplied by voltages from standard operant conditioning hardware and power supplies (usually 12–24 VDC).

The lower portion of the schematic illustrates the detection circuit and an optional feedback circuit. Events, in this case falling pellets, are registered via a 950-nm infrared LED (425–1026) coupled to an inverting receiver (QSE157). The implementation of the inverting receiver is such that events are not detected when a pellet interrupts the beam, but when the pellet passes through the beam and it is restored. Restoration of the beam results in the input line (Pin 1, J2) being taken low for 30 ms via a state change in the transistor (IRLML2803) at Q1. The direction and duration of the pulse width were selected because most operant conditioning hardware detects switches to ground, and 30 ms has been the industry standard pulse width for many years. The input line will sink 20 mA of current, which makes it compatible with commercially available hardware. The pulse is controlled by a monostable, or “one shot”, multivibrator (MM74HC123AM) at U1B. Immediately below the main detection circuit is a feedback circuit. One may see that the event detection is fed to a second multivibrator at U1A (the second circuit on MM74HC123AM), which causes a surface mount LED at D1 to flash during the pulse via a state change in the transistor (IRLML2803) at Q2.

To summarize briefly the circuit’s response to an event, the pellet passing between the LED emitter and receiver interrupts the LED’s beam. When the pellet successfully passes and the beam is restored, the input line at J2 is taken low for 30 ms. The surface mount LED flashes in response to a successful detection. Though the LED flash may be considered optional, it was extremely useful in the installation and development of the detector and continues to serve a useful feedback function in the daily testing of equipment prior to experimentation.

Pellet Barrel

When a pellet is released by the commercial dispenser it travels through a pellet barrel which we attached to the dispenser with tight fitting, but flexible, 3/8-in (9.5-mm) plastic tubing. Another small length of tubing provided a path from the other side of the barrel to the food receptacle. The pellet barrel is a small, nylon hose coupler (C0-6BN, Eldon James, St. Love-
land, CO) and is shown in Figure 3A. The upper of the two barrels shown in Figure 3A shows the 2-mm hole drilled through the width of the barrel. As shown in Figure 3B, the IR emitter and receiver were mounted to the sides of the barrel so that the IR beam passed through the hole in the barrel. Prior to this mounting, the sides of the barrel were ground and sanded flat to make smooth surfaces for the IR components. The IR emitter and detector were soldered to 0.6-cm × 0.6-cm circuit boards and adhered to the barrel with epoxy. The nylon barrel has an internal diameter of ¼ in (6.4 mm) at its smallest point of passage, which empirical testing demonstrated is the appropriate size to ensure 45-mg pellets reliably pass through the IR beam without becoming lodged in the barrel. Finally, the circuit board could be adhered to the side of the pellet dispenser (not shown). The manner of construction allowed the barrel to be removed for easy cleaning if necessary, or to change barrels if a different sized pellet is used.

RESULTS AND DISCUSSION

We have tested and verified the functionality of our detector on three separate pellet dispensers taken from our lab\(^1\). One dispenser was brand new; the other two dispensers had been in service in the lab for at least a few years. The tests were performed in a laboratory with a controlled environment (about 21°C, 50% relative humidity). The dispenser–detector assembly was tested for reliability by passing 45-mg pellets through the barrel in batches of 500 pellets. During each batch, the dispenser was activated once each second. After 500 pellets were detected, the batch was stopped and the pellets counted. Over the three separate dispensers, 8000 pellets were dropped and counted. At least 1000 pellets were dropped for each separate dispenser. The detector was 100% reliable in detecting the falling pellets. Interestingly, the testing method provided a chance to examine the reliability of our dispenser by comparing the number of dispenser activations required to drop 500 pellets to the nominal value. Across different tests, the dispensers required 502–511 activations to deliver 500 pellets, or 0.4%–2.2% error rates; the mean number was 505 pellets, rounded to the nearest pellet. Because we only worked with three dispensers, we are not suggesting that our determined error rates capture the error rates of the global population of pellet dispensers, rather we simply note that one additional feature of the detector is that the most error-prone feeders in a lab could be identified and alert the experimenter to need of repair, cleaning, or replacement.

A second set of tests was conducted to examine errors of commission, wherein an additional food item might slip through during the feeder cycle. To simulate extra pellets, the motor input on the new feeder was disconnected and the feeder was operated manually to drop several pellets in rapid succession. By quickly spinning the release mechanism, 2 to 3 pellets could be delivered in approximately 1 s. In this test, 500 pellets were dropped in the new dispenser and again the detector was 100% accurate. Only one of our feeders reliably passed multiple items during pellet delivery, and so it could be tested during normal operation. It was always the case with this particular dispenser that extra items were fragments, and not whole pellets. Fragments were a result of some mechanical idiosyncrasy in the dispenser such that some pellets were crushed or ground during its activation. The fragments often fell (about 30% of pellet drops) with a dropped pellet and were counted. The detection of such small fragments is a testament to the detector’s sensitivity, but it also raises its main limitation. The device is unable to distinguish a complete pellet from a fragment. On the other hand, we found that the problem could be remedied almost entirely by sifting pellets prior to use and by vacuum cleaning the feeders to remove the accumulation of fragments and dust. Thus, although our detector can register extra events when pellets are dropped, our experience suggests that prevention is the best course. It appears from our tests that errors of commission may be better overcome with regular cleaning and maintenance.

Our present data suggest that the primary errors in pellet dispenser delivery are missed pellets, indicating the main benefit of the detector is the capability to correct for delivery errors at the time they occur. The Appendix provides some sample code written in Med-State Notation\(^\text{TM}\) illustrating our implementa-

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\(^1\)We purposely have left out the companies and model numbers of the pellet dispensers upon which we developed our circuit, lest our data be used by other companies to disparage their competitors. Suffice it to say, our testing feeders were all models obtained from a major supplier of operant conditioning hardware.
tion of the dispenser. The code is meant only as a guide; the final form of the software will depend on the particulars of the procedure. Two state sets control the feeder cycle. The first state set (S.S.1) simply counts events that occur on the detector input. Events on the first state set determine program flow through the second (S.S.2). Each time the pellet dispenser operates, the program checks to see if something was detected. If no pellet fell, the error counter is increased by one and the program signals to attempt another delivery. If five successive errors occur, a Z-pulse is sent to alert the program to the error (ideally this would be handled in a different set and is not shown here), and the cycle is ended. If something was detected, it is counted and the feeder is activated again until the criterion number of pellets is delivered. Zeroing the error counter after each successful delivery ensures that only consecutive errors send the error pulse. Finally, if more than one item is detected (D > 1), a flag is set so that appropriate action can be taken in another part of the program.

In conclusion, the detector described here offers an inexpensive, reliable pellet delivery system which may be retrofitted to any commercially available pellet dispenser. Our cost was approximately $25 per unit, including the use of manufactured, printed circuit boards (interested readers may contact us for information about the printed circuit boards). Our implementation, furthermore, was designed to be versatile; there is potential for the detection of mouse or monkey pellets by simply changing the size of the barrel. We hope the versatility and low cost will allow behavioral research to improve the reliability of food deliveries and, thereby, the replicability of data.

REFERENCES

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APPENDIX

\Example code to describe the implementation of the pellet detector

\\Feeder = the defined constant for the feeder output
\\Detector = the defined constant for the detector input
\\PelletNum = the number of pellets to deliver
\\Z^Reinforcer = starts the pellet cycle
\\Z^EndReinforcer = signals successful completion of pellet deliveries
\\Z^PelletError = signals criterion number of errors; feeder cycle is halted
\\A = Number of successful activations
\\D = Number of detected items
\\E = Number of errors
\\F = Flag
\\Count dropped pellets S.S.1,
\S1,
\#R^DETECTOR : ADD D ---> SX
\\Pellet Dispenser Control S.S.2,
**IR DETECTOR**

S1, \When contingency satisfied, a Z-pulse will start pellet delivery

\texttt{#Z\textasciitilde Reinforce: SET D = 0, A = 0, E = 0; ON\textasciitilde Feeder --- > S2}

S2, \texttt{Drive feeder for \(\frac{1}{2}\)-s; check to see what happened}

\texttt{0.5\textdegree: OFF\textasciitilde Feeder; IF D = 0 [@Nothing, @Something]}

\texttt{\textbackslash If nothing was detected, count the error. \textbackslash If 5 consecutive tries with nothing, signal the error with the Z-pulse \textbackslash and end the cycle.}

\texttt{@Nothing: ADD E; IF E = 5 [@Error, @TryAgain]}
\texttt{@Error: Z\textasciitilde PelletError --- > S1}

\texttt{@TryAgain: --- > S3}

\texttt{\textbackslash Activate the dispenser until the criterion number of pellets is \textbackslash delivered. \textbackslash If anything dropped, count the try as a success and reset the error \textbackslash counter. If more than 1 item was dropped, set a flag.}

\texttt{@Something: ADD A; IF A = \textasciitilde PelletNum [@Stop, @Continue]}
\texttt{@Stop: Z\textasciitilde EndReinforcer --- > S1}
\texttt{@Continue: IF D > 1 [SET F = 1]; SET D = 0, E = 0 --- > S2}

S3, \texttt{Wait 1/2 second, pulse the dispenser again}

\texttt{0.5\textdegree: ON\textasciitilde Feeder --- > S2}