A simple, wireless system for high-throughput behavioral training of nonhuman primates

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Introduction

Behavioral training of animals in the laboratory can be space and time consuming. Training animals directly in their home environment alleviates the need to transport animals and frees valuable laboratory space for neural experiments. Although training in the animal's home environment may be less controlled than in the laboratory, the rodent community has successfully used this approach to train dozens of subjects in parallel. **Inspired by the rodent model, we sought to develop a paradigm for high-throughput behavioral training in nonhuman primates (both macaques and marmosets) that would be affordable, scalable, easy to set up, and easy to use.**

Approach

While a number of home cage training systems exist for both rodents and nonhuman primates, we identified a number of factors that may have impeded these systems from gaining widespread adoption especially for nonhuman primate work. We built a system that met all of the conditions necessary for encouraging a general, easily adoptable solution to home cage behavioral training.

Software
- Platform independent
- No installation, no compiling
- Easy to deploy/update on multiple devices (client-side)
- Easy to administer (server-side)

Hardware
- Size, weight, and power (SWaP)
- Wireless
- Battery operated
- Precise stimulus delivery
- *Monkey proof*

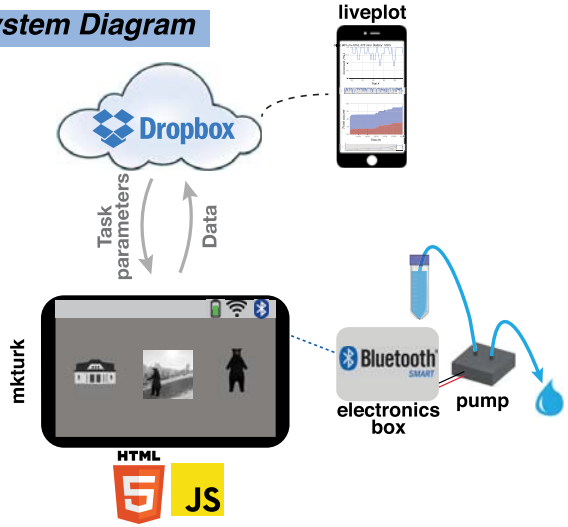
---> Cost < $1,000 per unit

Result: We developed a system that met all of our design criteria by synergistically combining across technologies. "MonkeyTurk" (or mkturk for short) leverages advances in mobile touchscreen technology, the continued evolution of html5/javascript and web app programming, low power pumps, low cost microcontrollers, and cloud based storage. The final result is a compact, homecage touch screen system that works on any platform (mac/pc/android) and on any device. There's no software to install, just a single piece of client side html code to run. The incoming data are viewable in near realtime, again from any device (e.g. smartphone) that has a web browser.

We are disemminating information about our system to the community in hopes of enabling the development of similar low-cost systems across labs. We view widespread adoption as a measure of this system's greater utility.

github.com/dicarlolab/mkturk

System Diagram



Components

Javascript/Html5: Web enabled technologies benefit from the availability of many APIs and the pace of development for a large user community. Also, web technology is less likely to go obsolete than other software.

Dropbox: Hassle-free solution for hosting web app, storing task stimuli, and fully versioned & backed up saving of data

Touchscreen tablet: Capacitive touchscreen technology has become very accurate and sensitive at a reasonable cost. Retina-displays allow for high-resolution image presentation. Processing speed and energy efficiency of tablets provides a powerful solution in a small device.

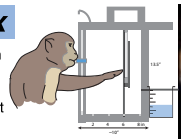
Bluetooth Low Energy: Widely supported, medium latency, low power communication which is ideal for low bandwidth signals like reward triggers

Pump: Accurate delivery of a fixed volume and allows for small fluid circuit compared to a gravity-fed valve system that depends on the height of the container.

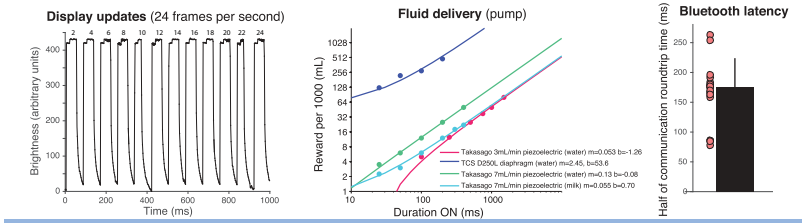
Cage-mount box

Macaque: reach into box through arm hole

Marmoset: enter box and interact directly with touchscreen



System precision



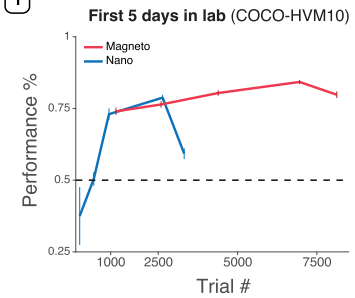
Comparison to Lab Setting

(1) When transferred to the lab setting, two subjects trained in their home cage using a tablet switched effectors from touch to eye tracking and performed the same 2AFC match-to-sample task within 1,000 trials (< 2 sessions).

(2) The reliability (correlation across trial split halves) of data collected in the home cage and in the lab is comparable.

(3) Object recognition errors showed similar patterns in the lab versus the home cage.

1 *10 monkeys trained & >1.5 million trials collected



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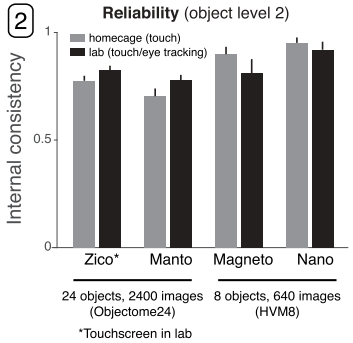

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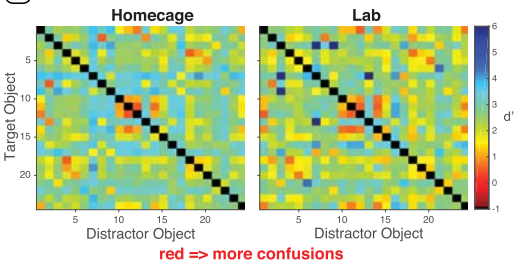

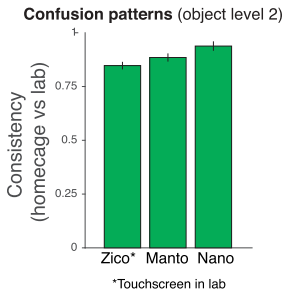

Future Enhancements

- Faster wireless communication with peripherals: millisecond resolution for communicating with an eye tracker

- Additional sensors: RFID identification, measure weight, & detect licking

- Additional GUIs: control task parameters & training regimen