Product Design Specifications

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Primate Portal

BME 300/200 Section 304

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Function

The primate portal is intended to be a primate positive reinforcement training device. From a higher-level perspective, the primate portal is a touchscreen interface, outputting a liquid reward for the primate when it successfully completes a task on the touchscreen. From a more detail-oriented perspective, the primate portal is a touchscreen interface controlled by a Raspberry Pi. The Raspberry Pi contains a simple python-based user interface and database to train the

primates (more specific software will be developed by client's research team). Once a correct input is received, the Raspberry Pi will output a signal to a peristaltic pump to reward the primate for its correct actions by dispensing a liquid of the operator's choice. The entire system will be safely mounted to the primate's cage and enclosed in a protective box. Overall, the system is used to gain an understanding of the cognitive function of complex neural behaviors.

Client requirements

- Product must only dispense juice when primate successfully completes challenge
- Product must have notification system if primate isn't getting any liquid
- Product electronics must be enclosed and away from primate to ensure electrical safety
- Product touchscreen must be secure with no risk of falling off the cage bars
- Product must be easily put on and taken off by lab assistants
- Product must be easily modifiable to support different future experiments
- No incorrect training – failures stop reward output
- Highly emphasize safety
- Modular for future applications and studies
- Ease of use for operators
- Compatible with primate environment
- Data accessible through usb or ssh
- Minimal exposed wires
- $5000 budget

Design requirements

1. **Physical and Operational Characteristics**
    a. **Performance requirements –** The primate portal product has three distinct fields in which it must meet different performance requirements. These fields are to do with the circuitry/code of the design, the enclosure as well as the peristaltic pump delivery system. The device is to be used daily, being loaded and unloaded at morning and night respectively.

        As for the circuitry/code, there must be a well-defined and documented system in which, when there is a correct input passed (through the touchscreen display), a 5V pulse be output. This must be modular in the sense; it is very easy for an operator to develop a new "training application" that outputs the correct signal. This output will be further discussed when considering the peristaltic pump. As for a failure case, it is expected that the electronics of this system will not cause any harm to the user or operator.

        Performance requirements with respect to the enclosure are of the utmost importance as to protect the users, operators and the primate portal system itself.

The enclosure must be able to be easily mounted and removed from the cages holding the primates. It should be lockable in the sense only a human can remove the system, with interlocks connected to the electronics, providing a failsafe in the case the enclosure is mounted incorrectly. Most importantly, the enclosure must be safe, meaning no sharp edges, no exposed electronics and no accessible items to the primates. In no way, shape or form, should the primates be able to damage or mess with the system when it is in the enclosure.
Lastly, the peristaltic pump has its own set of unique performance requirements. The pump must respond to the 5V signal sent from the microcontroller and accept a 24V signal (variable input but 24V standard) signal to activate the pump. Back EMF effects or any other mechanical related possible issues should be accounted for. The pump must be easily accessible to swap out and clean the tubing containing the liquid. Lastly, following the same pattern as the other performance requirements, the pump system must be safe.

b. **Safety –** Safety is of the utmost concern in any biomedical device with the primate portal not being an exception to this. It is imperative that no injury can be sustained through use and setup of the device. As per IEC 61010-1 [1], the system must be operating under 60V, or it will need extra protection. Any current carrying wire must meet clearance regulations provided by IEC 61010-1, with a 3mm separation distance. No component in the system can exceed 60 degrees Celsius as to protect the primates. The IEC also outlines ingress protection ratings of which this device should fall under IP54 or better [2].

   It is important to also consider the Code of Federal Regulations, title 9, chapter 1, subchapter A, part 3, subpart D, focusing on the specifications for the Humane Handling, Care, Treatment, and Transportation of Nonhuman Primates [3]. This states that the device must be safe, no sharp edges, no free cabling, no toxic materials or any other hazards. This aligns with what the Institution animal Care and Uses Committe (IACUC) looks for during primate research inspections. IACUC can be thought of as the “FDA” for animal research.

c. **Accuracy and Reliability -** Touchscreen has to be responsive to primate touch. The juice pump must deposit x mL with a 2% margin of error when the primate successfully completes a challenge. No failure should be seen on the software or hardware side and should be rigorously tested. The enclosure must be able to withstand forceful impact (primate punches and kicks), exposure to liquids and temperature changes without any faults. If anything is to fail, the system must stop training completely and pause the output of the liquid reward until fixed.
d. **Life in Service –** The primate portal is expected to be used daily for up to 8 hours a day. It should be fully functional for 3-5 years without fault (not accounting for consistent excessive tampering from primates). The peristaltic pump as well as the touchscreen display are expected to operate for the full 3-5 years.

e. **Shelf Life** – The product should last upwards of ten years if not broken or tampered with. It should also be relatively easy to repair if it does break.
f. **Operating Environmen**t – The product would be placed on the side of the cage with the touchscreen inside the bars and a unit with the Raspberry Pi and other critical components on the outside. The client has stated that the device may be exposed to urine and/or other primate excrement and thus must have a waterproof touchscreen and protected wiring and components.
g. **Ergonomics** – The client has stated that the product should be easy to use for both the primates and the scientists. For the primates, the touchscreen should be easily accessible and large enough to ensure training is completed correctly. For the scientists, the product should be easily removable from the cage and should allow easy access to any data that is stored.
   Size – The touchscreen should be 7 to 15 inches to ensure that the macaque has an interactive platform for behavioral experiments. The protective case for the screen should be snugly fitted to the screen size to guarantee that the macaque cannot remove or damage the screen. Any cage attachment points will have to match the Allentown cage wire thickness [4]. The liquid holder must be able to hold enough liquid for a day's volume worth of trials or 100 mL [5].
h. **Weight –** The touchscreen portion of the project must be able to be moved easily by the person removing it from inside of the cage. The average person can easily move 15 pounds [6], so that is our weight constraint of the touchscreen portion. Most 12 inch touchscreens weigh around 3 pounds [7], allowing the case to weigh 12 pounds. The component box will not need to be moved as often so it can weigh up to 25 pounds. This will include the stand, case and components.
i. **Materials –** The project will need a touchscreen that interacts with the macaque. The touchscreen will need a protective case that can handle small impacts, as well as being waterproof. The most likely material for the case will be aluminum because it is easy to machine and not toxic to the macaque. The project will also need cable management. This will be some sort of polypropylene or adjacent tubing that keeps liquid and tampering failures from happening. The electronics portion will include a peristaltic pump which will dispense the liquid. It will also need wiring, a microcontroller, power supply, and data storage. These will be stored in a component box that is nonconductive such as PLA.
j. **Aesthetics, Appearance, and Finish –** There should be no exposed circuitry. All edges should be beveled to ensure safety. The touch screen should be unobstructed to allow for maximum interaction with the subject. All components that are within urine range should be covered or have a waterproof coating. Visually it should be pleasing but looks are not a priority.

2. Production Characteristics

a. **Quantity-** Client requested one prototype initially. If time permitted, more prototypes may be useful for the client. Making an easily replicable design would be highly desirable as well. The device should be able to move to different systems and easily detachable.
b. **Target Product Cost-** There is only one product similar pertaining to our client's needs; however, it is an expensive and non-adaptable product. Our goal is to create a product using our budget, roughly $5,000, to create a more inexpensive and reusable device.

3. **Miscellaneous**
   a. **Standards and Specifications –** IEC 60601 is an international standard regarding electrical safety for devices which could be used in a lab setting. Compliance with this standard is crucial to ensure the safety of the primates. Another standard we need to fall under is the Animal Welfare Act (AWA), specifically title 9 section 3.89. We need to ensure that our device is secured along with giving enough liquid to the primates. As outlined in the requirements, all nonhuman primates must be given water every 12-24 hours. 9 CFR [1] §3.75 Housing facilities, general also applies: in particular, the device must be "free of excessive rust" and "jagged edges or sharp points that might injure the animals." The device should also be able to be cleaned [8].
   b. **Customer –** David J. Herzfeld, a new professor in the Department of Neuroscience at UW–Madison. Prof. Herzfeld runs a systems neuroscience lab (https://herzfeldlab.neuro.wisc.edu/) in WIMR using a combination of animal behavioral experiments and computational modeling. Prof. Herzfeld hopes to use Primate Portal to run behavioral experiments with macaque monkeys.
   c. **Patient-related concerns –** The primates are water controlled and tend to urinate quite a lot; thus, the product must be able to withstand urination. The primates are also highly intelligent and are about the size of a toddler, so the screen should withstand shattering. The device should not have any sharp edges or wires exposed to ensure that the monkey cannot injure itself while using it. The device should have a failure mode and a way to notify the researcher if the device runs a trial in an unintended way (i.e., trains the monkey to do an unintended thing) so that the researcher can halt the experiment.
   d. **Competition –** While several in-cage primate training systems have been developed and published in the literature, the only commercially available competitor is Thomas RECORDING's InCage Training System (ICTS) (https://www.thomasrecording.com/thomas-incage-training-system-icts). However, the Thomas ICTS has little capacity for extensibility and is prohibitively expensive, costing roughly $100,000 (as informed by client).

References:

[1] Intertek, “IEC 61010 – Safety requirements for electrical equipment for measurement, control, and laboratory use,” *Intertek*, 2025. [Online]. Available: https://www.intertek.com/medical/iec-61010/. [Accessed: 18-Sep-2025].

[2] International Electrotechnical Commission, *IEC 61010-1:2010, Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*, 3rd ed., Geneva, Switzerland: IEC, 2010. [Online]. Available: https://webstore.iec.ch/en/publication/4279. [Accessed: 18-Sep-2025].

[3] U.S. Department of Agriculture, “9 CFR Part 3, Subpart D – Specifications for the Humane Handling, Care, Treatment, and Transportation of Nonhuman Primates,” *Electronic Code of Federal Regulations*, 1991. [Online]. Available: https://www.ecfr.gov/current/title-9/chapter-I/subchapter-A/part-3/subpart-D. [Accessed: 18-Sep-2025].

[4] Allentown, Inc., “Large animal housing – Primate,” *Allentown, Inc.*, 2025. [Online]. Available: https://www.allentowninc.com/large-animal-housing/primate/. [Accessed: 18-Sep-2025].

[5] University Committee on Animal Resources, “Policy on Macaque Food and Water Restriction,” *University of Rochester Medical Center*, 2016. [Online]. Available: https://www.urmc.rochester.edu/medialibraries/urmcmedia/ucar/policies/documents/macaquefoodandwaterrestriction.pdf. [Accessed: 18-Sep-2025].

[6] L. J. Capitanio and S. J. Emborg, “Contributions of non-human primates to neuroscience research,” *Lancet Neurology*, vol. 17, no. 12, pp. 1129–1140, Dec. 2018. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/29708048/. [Accessed: 18-Sep-2025].

[7] Beetronics, “12-inch touchscreen monitor,” *Beetronics*, 2025. [Online]. Available: https://www.beetronics.com/12-inch-touchscreen. [Accessed: 18-Sep-2025].

[8] Legal Information Institute, “9 CFR § 3.89 – Feeding,” *Cornell Law School*, 2025. [Online]. Available: https://www.law.cornell.edu/cfr/text/9/3.89. [Accessed: 18-Sep-2025].