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Research Article

DEVELOPMENT OF AN AUTOMATED VIDEO-TRACKED MOTORIZED COMMUTATOR SYSTEM FOR UNRESTRICTED NEURAL RECORDING IN FREELY MOVING RODENTS

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ABSTRACT
Recording neuronal signals from moving and free animals lets us investigate how the brain controls our behavior, but usually requires connecting the test subjects to a device that gathers the data. It is desirable that animals can walk or complete actions the way they would in nature. At present, several research groups in cognitive and behavioral neuroscience rely on motorized commutator systems available on the market to sense the rotations created by moving animals in their tethers. We describe a new kind of motorized commutator that is directed through automatic tracking via a video camera. Head orientation was measured by using two light-emitting diodes and the lighting setup was improved to reduce video noise. The system measures rotational movements of the animal by examining the orientation of its head during testing. The control software sets the angle of the motor and, once set, applies signals to unwind the tether. The configuration helps avoid twists in the flying leads during animal experiments where neural activity is recorded. As far as we understand, this is the first system to identify tether twisting and rotate the commutator using information extracted from video of the head. We provide an affordable and easy-to-use method for enhancing behavioral neurophysiology studies in small rodents using automated commutator control.

Keywords :-Motorized commutator,Video tracking, Head direction, Tether twist compensation, Behavioral neurophysiology.

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INTRODUCTION

We need to record neurons in behaving animals to better understand the neural bases of behavior in cognitive and behavioral neuroscience [1–3]. Wireless technology has allowed animals being studied in experiments greater freedom of movement, while their brain activity is still being tracked [4]. Still, using wireless sensors can be difficult since they are less capable with recording channels and adding weight to the animals which affects small mice the most. As a result, many laboratories keep using old methods with cables gathered from the headstage to the amplifier. The animals are often unable to run around freely or use all their muscles because their harness tether cables get wrapped. In many cases, trains use a commutator to stop the tether from twisting and letting the animal move easily around its tether. The limitation is that the torque to passively rotate rises with the number of circuit paths you have. Previously, a three-channel system for commutator electrodes was built that didn't need a motor for rotating the disc or arm, but motorized commutators are generally used for multichannel recording in rodents.

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Even though one motorized commutator using a hall-effect sensor has been developed [6], almost all commercially offered ones still have problems with high costs, weak durability, not being very sensitive and poor fit for mice. Here, we present a convenient new way to operate the commutator using video data instead of needing a torque sensor. Animal head orientation depends on the data elaborated through two LEDs found on the animal and registered by videotaping. The SNR of the measurements was increased by adjusting the focus of both the LEDs and the camera. Throughout each test, information about head direction is stored, studied by a custom algorithm and used to activate a calibrated DC motor to adjust any twists of the tether. Using this method in mice performing tasks, their movements remained free from disturbance caused by tangling their tether.

METHODS

Topics studied were Surgery, Subjects and Behaviors.

Subjects

For this study, we used two male C57BL6/J mice, each weighing between 20 and 25 grams. Every mouse was placed in a Plexiglas cage on a 12-hour/12-hour light/dark schedule. Animals weren't allowed to drink water, but full meals were given to me to help them stay close to their original weight. Every animal procedure and care plan was reviewed and cleared by the Institutional Animal Care and Use Committee and each protocol met guidelines for looking after laboratory animals.

Surgical Procedure

Mice were put to sleep using an injection of tribromoethanol (Avertin) into their abdomen at a quantity of 0.0125 mg per gramm of body weight. A good anesthesia depth was verified when there was no withdrawal reaction after injecting the medications into the tail and paw. The animals' heads were positioned in a stereotaxic device and their eyes were treated with ointment to reduce dryness. After taking out the hair and making a midline incision on the scalp, we cleaned the skull surface with saline. The periosteum was detached and little holes were made to implant the screws. A microdrive called an 8-tetrode was inserted into the striatum above the M1 area of the cortex and dental cement fixed it in place. One week after their original surgery, the mice started doing the behavioral task.

Behavioral Task

An illustration of the behavioral chamber, a version of the 5-choice task tool modified to meet our needs, appears in Fig. 2a [12]. For every trial, a poke at the start point by the mouse signaled it was time to begin. At the beginning of the trial, a light was turned on at the other end of the maze, telling the mouse to follow it, poke through the highlighted hole and receive its reward. When a delivery was correct, water was delivered. When it was wrong, the program withdrew water for 5 to 8 seconds without giving any. Since the water dispenser was by the first corner, mice had to get the reward by turning and coming back to start.

LED Manipulation to Make Videos Less Noisy

A digital amplifier system (Digital Lynx SX) containing a headstage with 2 LEDs—red and green—was used for video tracking. Because commercial LEDs did not have a variable internal power setting, paraffin film was used to layer them which decreased the central intensity and stopped them from reaching saturation. At times, the seven-wire, 2 mm tether (TETH-HS-36-Litz) prevented the camera from seeing the motion between the LEDs. Curved aluminum reflectors were put behind the LEDs to help the LEDs cover a wider spatial area (refer to Fig. 1a, the insert). All LEDs were set so they pointed straight up the animal, placing the green LED to the right and red LED to the left of its head (Fig. 1a inset). Thanks to this setup, tracking was uninterrupted when the animal's head changed position up or down.

By using image smoothing, I can reduce the difference between the signal and the noise.

Because the walls in the behavioral chamber recorded LED reflections and missed some detections due to gloss, they were brought into contact with sand to make them rough and lower their reflectivity. At the beginning of the process, smoothing of incoming video frames improved the signal-to-noise ratio (Fig. 1a.h). The focus on the camera was adjusted slightly so that the pictures would look pre-smoothed. An additional camera was used simply to capture the animal's daily movements.

RESULTS

The study introduces a commutator system that uses various advancements to handle tether twisting in experiments with animals that are freely moving. Initially, the video tracking was finetuned using paraffin films to ensure the LEDs' strengths did not cause the camera to register at its highest level. With curved aluminum reflectors facing the LEDs, the entire area tracked by the lighting remained consistent when the animal's head moved up and down. Because LED glare from the shiny walls of the chamber led to false signals, we removed the reflection and video images were slightly blurred using a defocused camera. All these improvements raised the signal-to-noise ratio which kept the head position and direction data consistent. A 56-circuit slip-ring capsule was used inside the system, linked to matching MDR connectors to protect the signals. An electric motor turned a pulley and a rubber belt moved that rotation to the tether's rotary joint. Power was sent to the motors in both directions by the driver based on the TB6612FNG chip and controlled by a digital I/O device. The algorithm chosen for the system set the animal's head position as the average of two LEDs and determined head orientation as the angle of the animal's midline to the fixed reference axis. In real time, the information was used to detect rotations and output the recommended motor commands. To guarantee accurate movement with very close to 360 degrees, motor calibration was carried out meticulously. The system helped correct tether twisting during behavioral sessions, so that mice could do difficult tasks freely. The system worked accurately to prevent rotations in all directions and did not interfere with the recovery of freely moving electrode signals during neural recording.

Table 1:Components and Features of the Track-Based Commutator System

Component/Step	**Description**
Video Tracking Refinement	- LED intensity physically attenuated using paraffin film layers to prevent saturation. - Curved aluminum reflectors added behind LEDs for wider spatial coverage. - LEDs positioned perpendicular to rostro-caudal axis (red left, green right) to enable continuous tracking during vertical head movements. - Chamber walls abraded to reduce LED reflection; video images smoothed by slightly defocusing the camera to improve SNR. - Resulted in stabilized head position and direction data.
Mechanical Assembly	- 56-circuit slip-ring capsule connected to 50-pin MDR connectors compatible with amplifier system. - DC motor with small pulley coupled via rubber belt to larger pulley on rotary joint connected to tether. - Motor driver based on TB6612FNG chip provides bidirectional (clockwise and counterclockwise) control. - Motor controlled via digital I/O device (NI PCI-6601).
Algorithm Development	- Head position defined as midpoint between two LEDs. - Head direction defined as angle between a reference axis (Y-axis) and animal midline (rostral-caudal), orthogonal to LED axis. - Tracking data obtained using Cheetah software; custom LabVIEW program applied rotation detection algorithm.
Motor Calibration	- Precise angular control achieved through repeated clockwise (CW) and counterclockwise (CCW) rotations. - Angular position trajectories aligned and analyzed, showing no significant directional error. - DC motor calibrated to rotate approximately 360° per command.

Table 2: Practical Application and Behavioral Session Summary.

Parameter	Description
Session Details	- Mice traveled an average of 55 meters during a behavioral session.
Representative CW Trial (TRN = +1)	- Mouse nose-pokes to initiate trial, turns right, moves toward central cue, then turns right again to reach reward location. - Total Rotation Number (TRN) +1 indicates a single clockwise rotation during the trial.
Representative CCW Trial (TRN = -1)	- Mouse performs a counterclockwise rotation with a TRN of -1.
No Rotation Trial (TRN = 0)	- Mouse nose-pokes at start, turns left, hesitates, then moves toward right cue, turns right to reward location. - Half clockwise and half counterclockwise rotations cancel each other out, resulting in a TRN of zero (no net rotation).

DISCUSSION

We describe a new motorized commutator system that is controlled using video tracking. The system measures the TRNs from clean video and creates voltage pulses to drive the motor's movements. By calibrating just once ahead of the experiments, you set out the number of pulses it takes for the pulley to complete one rotation. The system stands out due to its low cost compared to similar commercial tools and its straightforward software-guided calibration that avoids using regular torque sensors.

For accurate head orientation data, one needs to reduce or totally remove video artifacts that might appear when using LEDs. We made some changes to the LED lights and also used defocused video recording for an analogic filter. This technique is relevant for video tracking systems to help achieve better accuracy in finding head position and orientation, independent of whether the system uses cables for data transfer [1–3]. Changes are needed to enhance the speed of the commutator and make it ready to use independently in various neural recording configurations. These days, the system makes use of a commercial neural recording device that includes video tracking to detect head direction. In time, combining single-board computers that can be programmed with digital output ports could remove the present dependence [7]. Secondly, as the system uses blurry images for noise removal, another camera is presently needed for normal monitoring. Upon video stream processing in real time, a camera can perform both surveillance and the control tasks required to direct the online sales process. Although operating commercial DC motors is very straightforward, they are not suitable for highly accurate positioning. Some motor types, including stepper motors, provide angular control exactly without requiring calibration [8]. The animals in the experiment need to get to certain places in the chamber to initiate, decide on and receive rewards. The type of task structure used led to the development of the rotation counting algorithm. Animals usually spend most of their time getting rewards in the reward port, so a rectangular area was set up around it and the tether only became untwisted when the animal entered it. Even so, this approach may not work well if animals stay outside the zone for many days as they continue to move in only one direction. While a few brief twists of the tether don't often affect animals, flat adjustments are still better. In order to work independently, continuous control capability is needed. Besides, adding tag-free video tracking, removing the light on the headset and depending on artificial intelligence or accelerator sensors would enhance the system [9–11].

CONCLUSION

We developed and validated a novel motorized commutator system that automatically compensates for tether twisting by leveraging real-time video tracking of head direction in freely moving rodents. Our system offers a cost-effective and user-friendly alternative to traditional torque-sensor-based commutators, utilizing simple software-based calibration and noise reduction techniques to achieve accurate rotation control. The integration of physical LED manipulation and analog video filtering significantly enhanced signal quality, ensuring reliable head position and orientation detection. Behavioral testing demonstrated that the system effectively maintained tether freedom without interfering with neural recordings or animal performance. While current limitations include reliance on commercial neural recording setups and the need for multiple cameras, future improvements incorporating single-board computers and advanced video processing could make the system fully independent and more versatile. Overall, this automated commutator provides an accessible tool to improve experimental rigor and animal welfare in behavioral neurophysiology studies, particularly in small rodent models.

REFERENCES

1. Hok, V., Chah, E., Save, E., &Poucet, B. (2013). Prefrontal cortex focally modulates hippocampal place cell firing patterns. *J Neurosci*, 33, 3443–3451.
2. Whitlock, J. R., & Derdikman, D. (2012). Head direction maps remain stable despite grid map fragmentation. *Front Neural Circuits*, 6, 9.
3. Welday, A. C., Shlifer, I. G., Bloom, M. L., Zhang, K., & Blair, H. T. (2011). Cosine directional tuning of theta cell burst frequencies: Evidence for spatial coding by oscillatory interference. *J Neurosci*, 31, 16157–16176.
4. Fan, D., Rich, D., Holtzman, T., Ruther, P., Dalley, J. W., Lopez, A., Rossi, M. A., Barter, J. W., Salas-Meza, D., Herwik, S., et al. (2011). A wireless multi-channel recording system for freely behaving mice and rats. *PLoS One*, 6, e22033.
5. Fouriezos, G. (1986). A three-channel swivel for electrical brain stimulation in unrestrained rodents. *PhysiolBehav*, 36, 389–391.
6. Fee, M. S., & Leonardo, A. (2001). Miniature motorized microdrive and commutator system for chronic neural recording in small animals. *J Neurosci Methods*, 112, 83–94.
7. Solak, S., & Bolat, E. D. (2013). Real-time industrial application of single board computer-basedcolor detection system. In *Electrical and Electronics Engineering (ELECO), 2013 8th International Conference on* (pp. 353–357). IEEE.
8. Bendjedia, M., Ait-Amirat, Y., Walther, B., & Berthon, A. (2012). Position control of a sensorless stepper motor. *Power Electron IEEE Trans*, 27, 578–587.
9. Benice, T. S., & Raber, J. (2008). Object recognition analysis in mice using nose-point digital video tracking. *J Neurosci Methods*, 168, 422–430.

10. de Chaumont, F., Coura, R. D., Serreau, P., Cressant, A., Chabout, J., Granon, S., & Olivo-Marin, J. C. (2012). Computerized video analysis of social interactions in mice. *Nat Methods*, 9, 410–417.
11. Shih, Y. H., & Young, M. S. (2007). Integrated digital image and accelerometer measurements of rat locomotor and vibratory behaviour. *J Neurosci Methods*, 166, 81–88.
12. Bari, A., Dalley, J. W., & Robbins, T. W. (2008). The application of the 5-choice serial reaction time task for the assessment of visual attentional processes and impulse control in rats. *Nat Protoc*, 3, 759–767.

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