Novel Technique in Intraoperative Behavioral Experiments: Simultaneous Microelectrode Recording and Motion Capture

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Introduction

Intraoperative microelectrode recording provides a unique opportunity to observe individual neuron activity in awake humans performing behavioral tasks [1]. Simultaneous motion capture offers a potentially powerful tool to optimize intraoperative data acquisition. We demonstrate the feasibility of co-registering simultaneous hand movements and neuronal firing recordings intraoperatively

Methods

A female patient receiving deep brain stimulation for Parkinson's Disease underwent midbrain microelectrode insertion. The recorded electrical potentials were 300-Hz high-pass filtered by clinical equipment (Alpha-Omega, Israel). The signal was then transferred to a neural signal processor (Blackrock Microsystems, Salt Lake City) recording at 30 kilosamples/second. Our behavioral task required the patient to signal a response by opening or closing her hand. We recorded hand movement by placing one infrared marker on the DIP joint of the patient's third finger and one on the IP joint of the thumb. An infrared motion capture camera (ProReflex, Qualisys AB, Sweden) controlled by a laptop using RealBasicPro (RealBasic, Austin, TX) recorded marker movement at 110 samples/second. The camera angle was perpendicular to the plane of movement. Marker position data was two-dimensional (X, Y) with relative distance between markers calculated by ((X_marker1 – X_marker2)^2 + (Y_marker1 – Y_marker2)^2)^(1/2). Temporal disparity between the microelectrode and motion recordings was corrected during post-processing by syncing each system to an identical, simultaneously recorded audio signal, as shown in **Figure 1**.

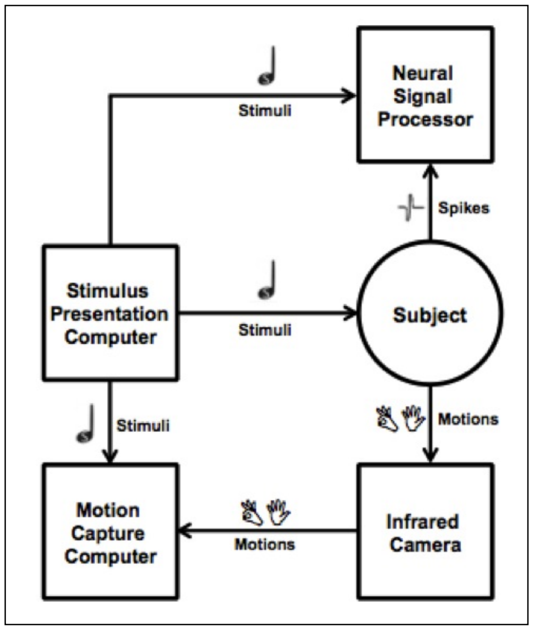

Fig. 1. Schematic of intraoperative setup (above). A presentation computer produces auditory stimuli, represented as musical notes, to the subject's headphones. The audio signal is split so that the same stimuli are also transmitted to neural signal processor as well as the infrared camera. The infrared camera records finger movements from the subject, while the neural signal processor records neural activity from the microelectrode, after this signal has passed through a 300 Hz high pass filter (not shown).

Figure 2. Onset of hand opening compared to substantia nigra neuronal firing (right). Panels A, B, and C depict the activity of a neuron from the substantia nigra, where 0 seconds represents the moment hand opening began. This moment is calculated as the first data point of 110 ms of continuously increasing distance between fingers following a stimulus. **A** | A raster plot, where each dot represents one neuronal spike, with all nine trials depicted. **B** | Average firing rate for each 50 ms interval relative to movement onset. The red line depicts a smoothed calculation (Gaussian). **C** | Representative trace of finger movement in one trial. Increasing distance between fingers begins (solid black line) following a stimulus (dotted black line).

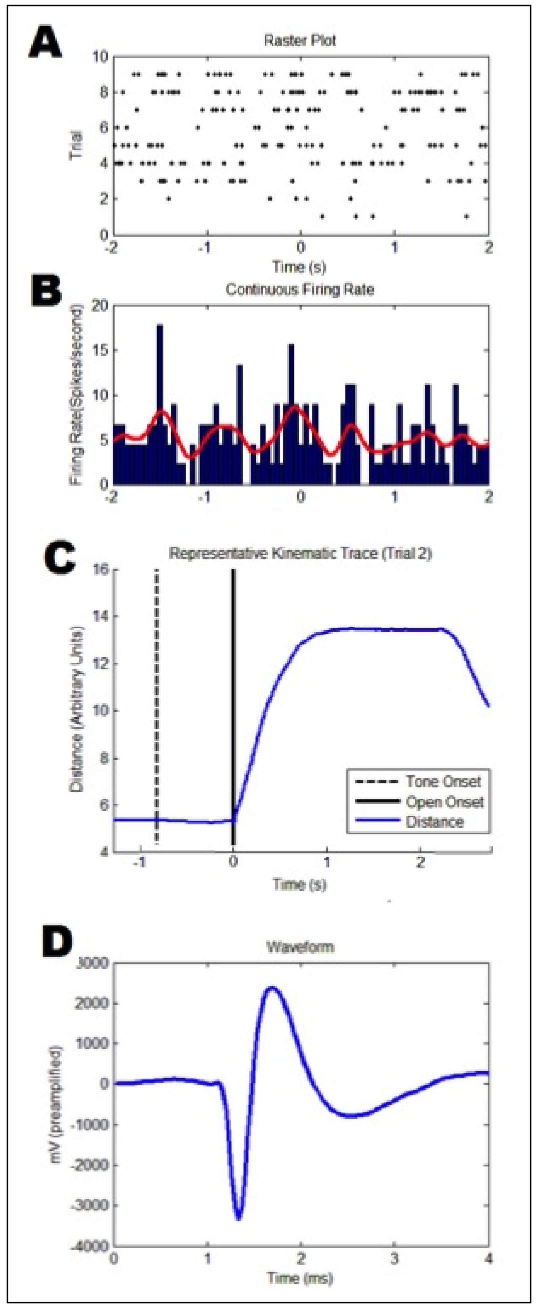

Figure 2 (continued). D | Depicts the neuron's average waveform.

Results

Co-registration of neuronal firing with kinematic data was successful and provided a reproducible interval (e.g., initiation/cessation of hand movement) to analyze neuronal activity during behavioral tasks, as shown in **Figure 2**.

Conclusions

Combined intraoperative microelectrode recording and motion capture, improves the ability to investigate the relationship of basal ganglia activity to movements by enabling precise spatio-temporal analysis. The increased flexibility will facilitate creative and innovative studies of motor program selection and learning.

Learning Objectives

By the conclusion of this session, participants should be able to:

- Describe the importance of accurately quantifying and co-registering behavioral responses with simultaneous single unit neuronal activity.
- Identify an effective method of accurately quantifying and co-registering a subject's hand movement with simultaneously recorded single unit neuronal activity using infrared motion capture technology.

References

1. Zaghloul, K.A., et al. Human substantia nigra neurons encode unexpected financial rewards. Science 323, 1496-1499 (2009).