

Video Article

High Density Event-related Potential Data Acquisition in Cognitive Neuroscience

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Abstract

Functional magnetic resonance imaging (fMRI) is currently the standard method of evaluating brain function in the field of Cognitive Neuroscience, in part because fMRI data acquisition and analysis techniques are readily available. Because fMRI has excellent spatial resolution but poor temporal resolution, this method can only be used to identify the spatial location of brain activity associated with a given cognitive process (and reveals virtually nothing about the time course of brain activity). By contrast, event-related potential (ERP) recording, a method that is used much less frequently than fMRI, has excellent temporal resolution and thus can track rapid temporal modulations in neural activity. Unfortunately, ERPs are under utilized in Cognitive Neuroscience because data acquisition techniques are not readily available and low density ERP recording has poor spatial resolution. In an effort to foster the increased use of ERPs in Cognitive Neuroscience, the present article details key techniques involved in high density ERP data acquisition. Critically, high density ERPs offer the promise of excellent temporal resolution and good spatial resolution (or excellent spatial resolution if coupled with fMRI), which is necessary to capture the spatial-temporal dynamics of human brain function.

Video Link

The video component of this article can be found at <https://www.jove.com/video/1945/>

Protocol

I. Introduction

In the field of Cognitive Neuroscience, functional magnetic resonance imaging (fMRI) has become the standard method of analysis. The popularity of fMRI stems in part from readily available data acquisition and analysis techniques in addition to easily interpretable results that highlight the brain regions associated with a given cognitive process. However, fMRI has poor temporal resolution and thus cannot track the rapid temporal dynamics of the functioning brain. If Cognitive Neuroscientists continue to primarily use fMRI, the resultant picture of brain function will be severely deficient. Event-related potentials (ERPs) are used much less frequently even though this method offers excellent temporal resolution. The purpose of the present article is to detail the key techniques involved in high density ERP data acquisition. It is hoped that this information will foster the increased use of ERPs in Cognitive Neuroscience.

II. General Equipment Setup

ERP data are typically measured in a location with a low level of ambient electromagnetic field strength to minimize interference with the neural signal. To minimize such interference, ERPs are often measured in a shielded metal chamber (i.e., a Faraday cage) but it may be possible to find an unshielded location with an acceptable level of ambient field strength (1 mg or less, which can be measured using an electromagnetic field meter). Each electrode connects to an amplifier which in turn connects to a data acquisition computer. A separate computer is used for stimulus presentation. To minimize interference with the neural signal, only essential powered components should be housed inside the shielded chamber or near the recording location, such as the stimulus display and the response keyboard (for example, lamps can be used to assist in electrode application but should be powered off during recording). A video switch can be used to display either the data acquisition computer or the stimulus presentation computer on a single monitor. If a shielded chamber is used, all cables can run through a small conduit in the wall (that is a few inches in diameter) or a cracked door. Participants should be seated in a comfortable chair with arm rests and a back height that provides shoulder support to minimize neck muscle artifact, but allows access to posterior inferior electrodes for subsequent electrode impedance reduction. We use a shielded chamber (constructed by Global Partners in Shielding, Inc., Passaic, NJ) and a 128-channel Quik-Cap/SynAmps² NeuroScan system (Compumedics USA, Charlotte, NC).

III. Cap Placement and Electrode Digitization

Electrodes are typically embedded in a spandex cap which significantly reduces application time. However, the relative electrode locations in a cap are fixed which eliminates the possibility of using standard electrode configurations, such as the 10-20 electrode system¹ or a higher density variant such as the 10-5 electrode system², that are precisely positioned on an individual participant basis. For presentation of the final results in a standard format, we position electrode Oz for each participant at the approximate location dictated by the 10-5 electrode system (and then label all of the electrodes according to their approximate 10-5 electrode system positions). When applying the cap, ensure it has left-right symmetry, with midline electrodes placed over the midline of the head, and that the most posterior-inferior electrodes are superior to the skull-neck boundary to avoid neck muscle artifact. While a chin strap will adequately maintain the cap in position, attaching the side straps to a custom made belt at waist level using velcro fasteners can improve lateral electrode contact with the head. Electrodes adjacent to the eyes can also be applied for subsequent removal of eye-movement or blink artifacts.

Although it is reasonable to assume that electrode placement is relatively consistent across participants, differences in head size and electrode cap placement will produce electrode location variability. To address such variability, electrode locations can be measured for each participant. We use a Polhemus FASTRAK digitizer (Colchester, VT) which includes a transmitter, three receivers which mount on the cap using velcro (to correct for participant motion), and a stylus for recording each electrode location (this hardware is compatible with Neuroscan's SCAN/3DSpaceDx software that we use for data acquisition). Regardless of which digitizer is used, it should be setup according to the specified guidelines, such as avoiding proximity to large metal objects and separating transmitter and receiver cables. The digitizer should be calibrated and tested for accuracy and should be moved, if necessary, to a different location until spatial localization is accurate.

IV. Reducing Electrode Impedances

After the electrode locations are digitized, the participant should sit comfortably in the recording chair. Some participants find it more comfortable when a folded hand towel is lightly tucked between their shoulders and the chair back. Then, the multi-electrode cap should be plugged into the amplifiers. The impedance of each electrode must be reduced such that it is below a predetermined threshold. This is done by injecting a conducting gel into each electrode opening, which will allow current to flow between the scalp and the overlying electrode. To eliminate the possibility of cross-participant contamination, a new sterile syringe and blunt tip needle must be used for each participant. It is notable that although 5 kΩ is a standard impedance threshold, a somewhat higher threshold can be used if the ambient electromagnetic field strength is very low. We use the NeuroScan SCAN software to measure electrode impedance, which displays impedance level by color for all electrodes in real-time. There are a number of techniques that can be speed up the impedance reduction process, which is the most time consuming aspect of ERP data acquisition. It is important to keep in mind that the aim is to restrict gel application between the scalp and the immediately overlying electrode. It is recommended that the dominant hand control the syringe and application of the gel while the non-dominant hand performs other functions. The syringe filled with conducting gel can rest against the head with no participant discomfort, but should never be pressed against the head. First, for a given electrode, it is often useful to make a few circles with the syringe while it rests against the head, to move the intervening hair. After this, while lightly pressing the electrode down with the non-dominant hand, a small amount of gel should be injected at the scalp and then the syringe should be pulled out while continuing to inject gel to make a gel bridge between the scalp and the electrode. Gel that protrudes from the electrode opening should be wiped off with a tissue and discarded. In some cases, conducting gel will connect adjacent electrodes such that impedances will be linked - this reduces spatial resolution but is usually of minor concern as there are a high number of electrodes. Gel should first be applied to the ground and reference electrodes, and if the first set of electrode impedances all remain high gel should be reapplied to these two electrodes. As gel usually becomes more conductive over time, one strategy is to inject gel in electrodes within a scalp quadrant (such as the right posterior scalp) until all impedances begin to decrease, inject gel in electrodes within the next quadrant until all impedances begin to decrease, and then cycle through the quadrants re-injecting gel into the highest impedance electrodes. It should be highlighted that the gel application process should never cause the participant discomfort, and it should be made clear to the participant that they should verbalize any discomfort so the corresponding action can be stopped.

V. Data Recording

Before recording commences, participants should be encouraged to get into a comfortable position and relax, to minimize neck muscle artifact, and avoid head movements that might produce contact between posterior electrodes and the chair back. It should be stressed to the participant that during recording they should remain relatively still, as significant movement of the chair (which typically contains a metal frame) can create electromagnetic interference. Participants should then receive a response keyboard and all non-essential equipment near the participant, such as lights, should be removed or turned off. To allow for subsequent event-related analysis, the onset of each stimulus event must be signaled/triggered by the stimulus computer and received and stored along with the electrophysiological data. We send these trigger pulses at each stimulus onset through the parallel port via E-Prime programs (Psychology Software Tools, Inc., Pittsburgh, PA), that include custom InLine port initialization and trigger scripts that are freely available³, and the triggers are received and stored by the SCAN software. Port configuration pin-outs should be referenced to ensure valid trigger values are used. Of relevance, most amplifier high-pass filter settings are acceptable as the aim is simply to remove very low frequency components (such as DC) that are irrelevant to the transient neural response. In contrast, acceptable low-pass filter settings vary depending on the recording environment. In environments with very low ambient electromagnetic interference a low-pass filter with a very high frequency cutoff (such as 200 Hz) can be used, which minimizes distortion of the neural response that does contain higher frequencies. In environments with higher levels of interference, a lower frequency cutoff (such as 80 Hz) and a 60 Hz notch filter can be used such that the electrophysiological response is dominated by the neural signal. Note that filtering can also be conducted in software after the data is acquired, although filtering at the amplifier stage often produces less signal distortion.

VI. Cleaning the Cap

The multi-electrode cap must be thoroughly cleaned and disinfected immediately after data recording is complete. We begin by soaking the cap in warm water for 5-10 minutes and then rinsing each electrode with a running water stream to thoroughly remove all of the conducting gel.

The blunt end of a wooden stick cotton swab can be used to clear the holes in the electrodes. Then we soak the cap in a soapy warm water bath (consisting of 4 quarts of water and 1-2 oz of Dial) for 30 minutes to ensure all the gel has been removed, followed by thorough rinsing with water. To avoid cross-participant contamination, the cap must be soaked for 15-30 minutes in an appropriate water/disinfectant mix (such as 4 parts of water to 1 part Envirocide) and then should be rinsed thoroughly with water. When hanging up the cap to dry, it should be placed symmetrically and without tension as it may retain some degree of its drying position, which if irregular can reduce the ease of subsequent impedance reduction.

VII. Analysis Overview

Data pre-processing⁴ consists of multiple steps including exclusion of electrodes that had poor or intermittent contact, removal of blink artifacts, baseline correction, and additional high-pass or low-pass filtering. Pre-processing is followed by event-related averaging, and spatial resolution can be improved by conducting ERP source localization⁵. We use the BESA analysis software (Gräfelfing, Germany) for pre-processing, event-related averaging, and source localization (BESA regularly offers two-day analysis courses), with additional analysis conducted on exported event-related average files using custom scripts written in MATLAB (The MathWorks, Natick, MA).

Disclosures

No conflicts of interest declared.

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