A convenient off-line method for detecting electrolyte bridges in multichannel ERP recordings

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INTRODUCTION

Technological advances have substantially improved the spatial resolution of ERP and EEG scalp topographies, but demand precise and reliable measurements of subtle differences in scalp potentials between closely spaced recording sites. Leakage of electrolyte at the scalp/electrode interface has the capacity to effectively bridge electrodes, particularly at vertically-aligned sites. Such bridges cannot be detected with conventional impedance measurements, and may lead to effects ranging from a subtle smearing of localized activity to the introduction of systematic, localized artifacts. We now demonstrate an easy and objective offline method for identifying electrolyte bridges.

METHOD

Hjorth Laplacian. The Hjorth algorithm (Hjorth, 1980) is a method for computing a linear approximation of the surface Laplacian. The Hjorth waveform $H_i(t,N)$ is computed as the difference between the time-varying potential $P_i(t)$ at each electrode *I* and the scaled sum of the potentials $P_j(t)$ at each of *N* neighboring electrodes:

EQ. 1

$$H_i(t,N) = P_i(t) - \sum_{j=1}^{N} P_j(t)\, W_{i-j}(N)$$

where the weighting factor W_{i-j} for each neighbor is proportional to the inverse of the distance d_{i-j} between the electrodes:

EQ. 2

$$W_{i-j}(N) = \frac{1/d_{i-j}}{\sum_{k=1}^{N} (1/d_{i-k})}$$

This algorithm may be generalized to include any number of neighboring electrodes.

Intrinsic Hjorth. The intrinsic Hjorth, a "beta" feature of NeuroScan's EDIT module (version 3; NeuroScan, 1993), is a variation of the Hjorth Laplacian in which spatial distance is replaced by a nonspatial "electrical distance" measure reflecting the electrical similarity of electrodes (NeuroScan, 1995). For any pair of electrodes *i* and *j*, a potential difference waveform $P_{i-j}(t)$ may be computed as:

EQ. 3

$$P_{i-j}(t) = P_i(t) - P_j(t)$$

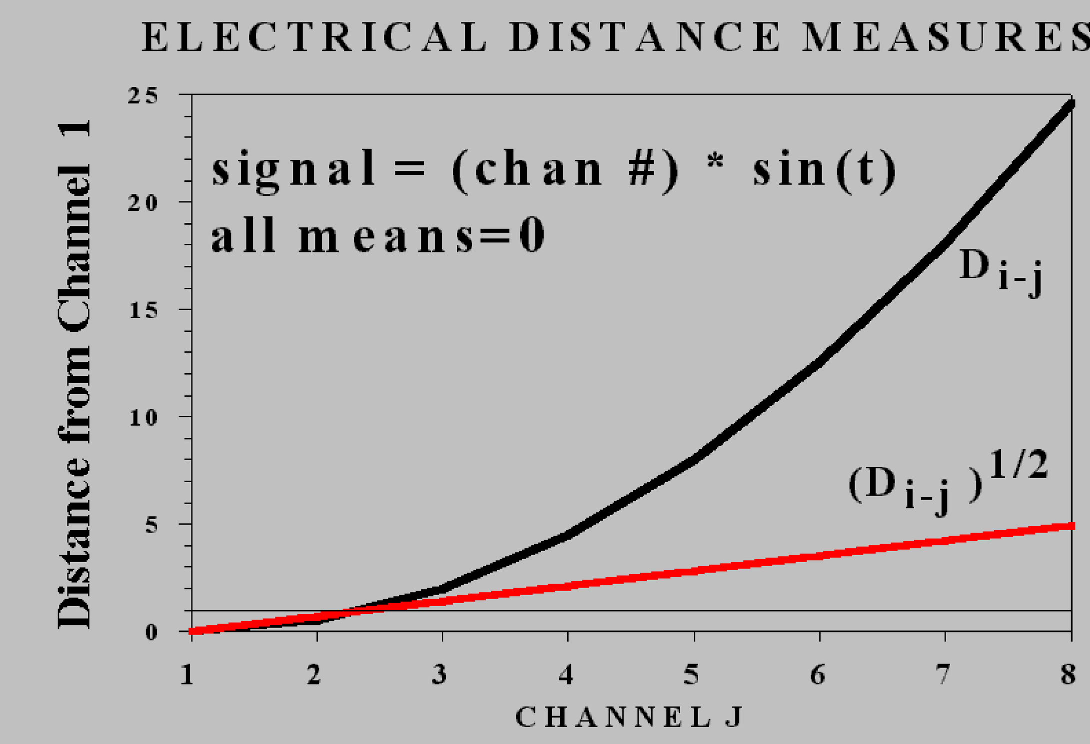
The "electrical distance" measure D_{i-j} is defined as the temporal variance of the difference potential waveform:

EQ. 4

$$D_{i-j} = \frac{1}{T}\sum_{t=1}^{T} (P_{i-j}(t) - \overline{P_{i-j}(t)})^2$$

The intrinsic Hjorth is produced by replacing d_{i-j} of Equation 2 with D_{i-j}. In the case of a single neighbor, the intrinsic Hjorth waveform is identical to the difference potential $P_{i-j}(t)$ for the nearest neighbors given by D_{i-j}. Since the intrinsic Hjorth waveforms converge to zero as any D_{i-j} approaches zero (i.e., $W_{i-j}(t)$ converges to one as the numerator and denominator of Equation 2 converge), they will be distinct from all other channels whenever two electrodes are bridged.

If signal amplitude varies linearly over distance (e.g.activity volume conducted from a large distant generator), proportionality would have been better for standard deviation than for variance(D_{i-j}). However, for all cases with only one neighbor, W_{i-j} =1, and $H_i(t,N)= P_{i-j}(t)$.



Empirical validation. Sample EEGs/ERPs were recorded with a conventional 30-channel electrocap (see Tenke et al., 1993) and a 128-channel geodesic sensor net (Tucker et al., 1993). Bridges were inserted at selected adjacent electrodes: 1) by applying excessive amounts of electrolyte gel or potassium chloride solution; or 2) simulated by replacing their data with the mean of the pair and adding simulated digitizer noise to one channel (randomly changing the integer A/D values of the raw EEG epoch via a uniform distribution ranging from -1 to +1; .5 probability of change). The intrinsic Hjorth algorithm used the single nearest electrode (i.e., N = 1 neighbor in Equation 1).

CONCLUSIONS

1) The intrinsic Hjorth provides a simple means for identifying bridged electrodes.

2) The intrinsic Hjorth is recommended as a routine screening procedure for EEG and ERP data.

3) Direct examination of D_{i-j} values may be sufficient for an automated detection procedure.

RESULTS

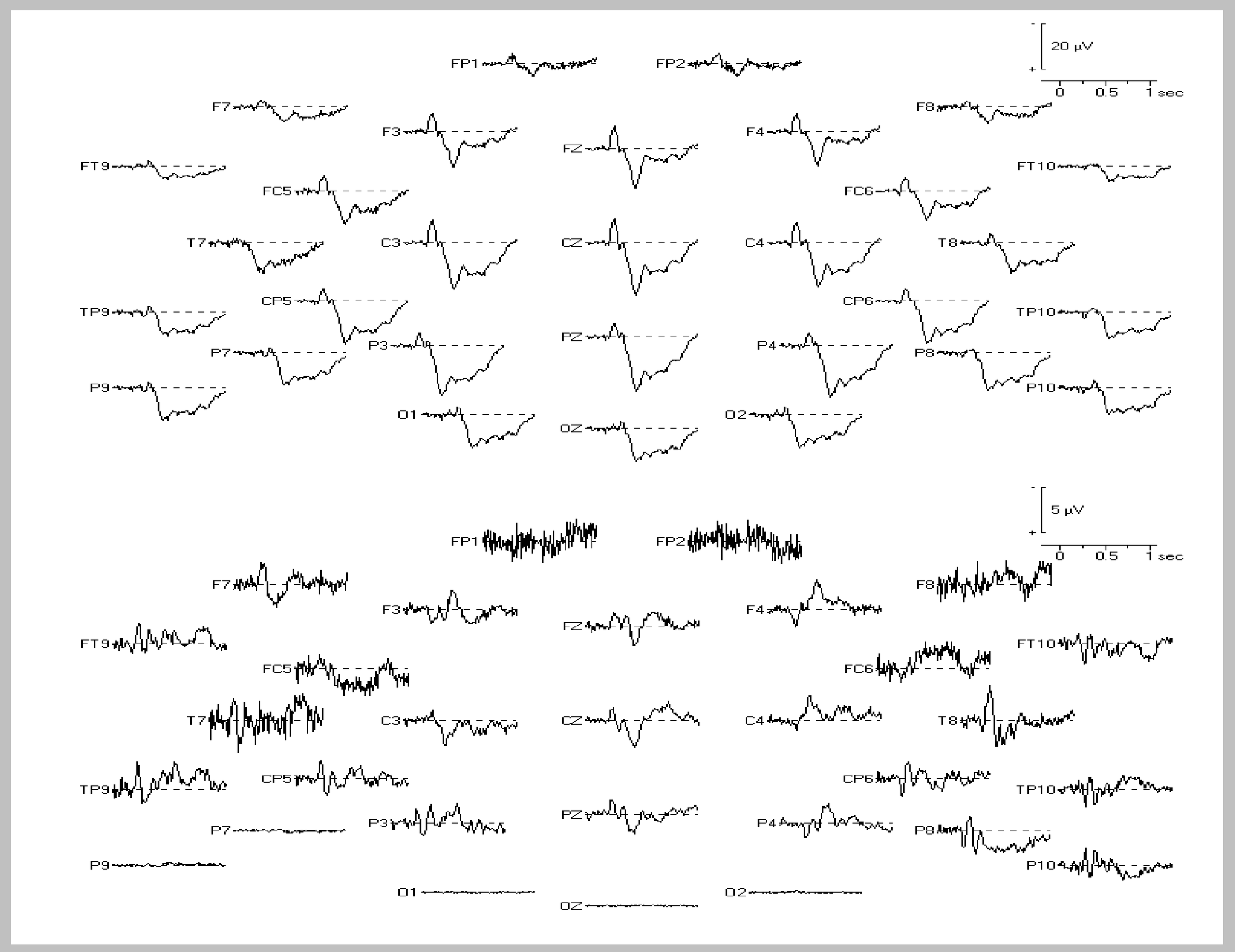


Figure 1. **A)** Averaged ERP waveforms from one individual at 30 electrocap recording sites during an auditory oddball task. Electrolyte bridges are between electrodes P7 and P9 (left inferior-lateral region), and between occipital sites O1, Oz, and O2. **B)** Corresponding intrinsic Hjorth waveforms computed for the single nearest neighbor, showing flat lines at bridged sites.

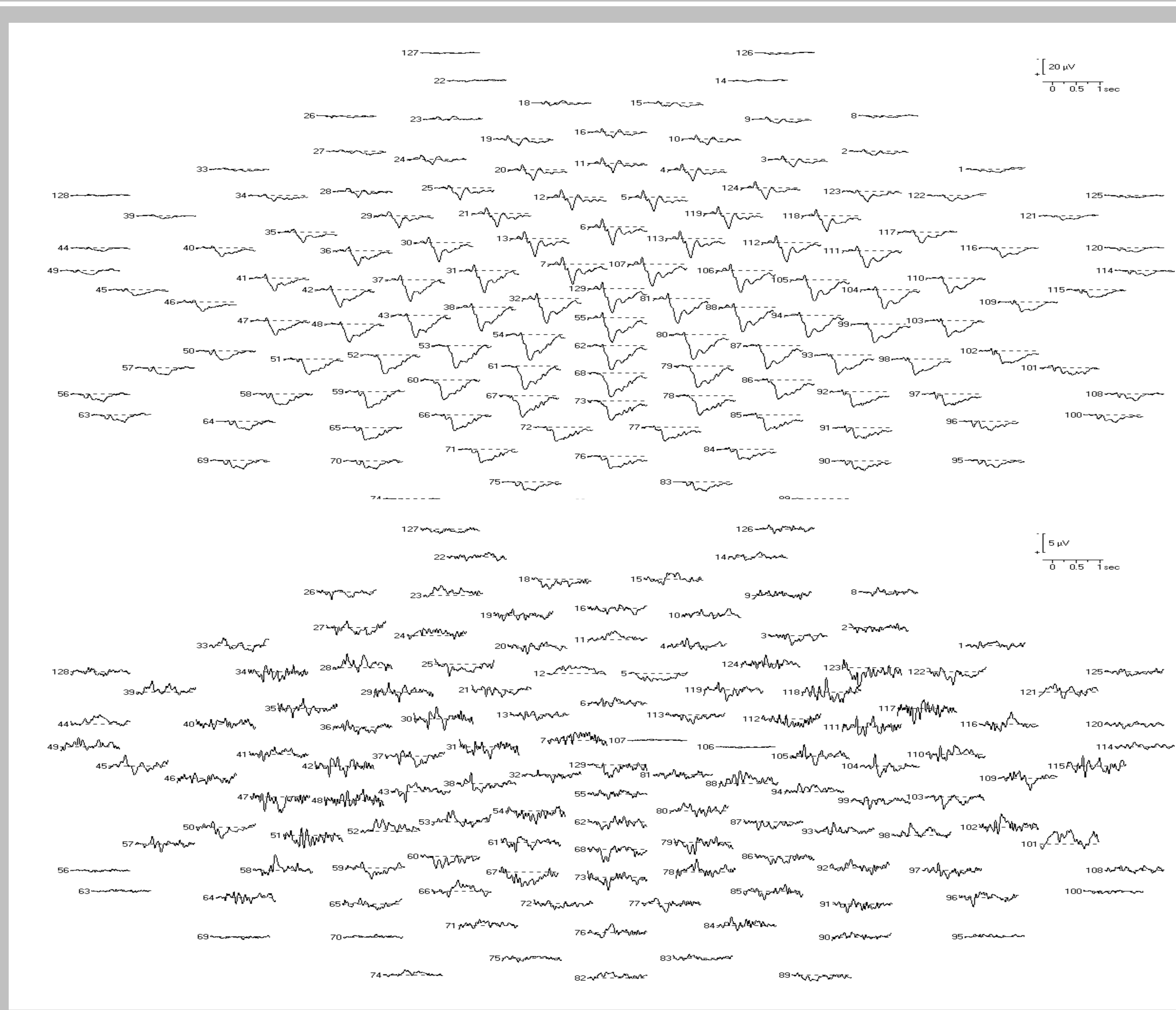


Figure 2. **A)** Averaged Event-related potential (ERP) waveforms for 128-channel sensor net. A simulated bridge is at right central electrode sites (106/107). **B)** The intrinsic Hjorth at these sites show distinct flat lines. Similar flat lines are also evident at left (i.e., 56/63, and 69/70) and right (i.e., 95/100) inferior-lateral sites, consistent with physical bridges

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