Separable Parietal and Temporal Generators of P3 in Dichotic Tonal and Phonetic Oddball Tasks: A Principal Components Analysis (PCA) of Current Source Density (CSD) Waveforms in Healthy Adults and Depressed Patients.

C.E. Tenke*, J. Kayser, S. Shankman, C.B. Griggs, P. Leite and G.E. Bruder

Department of Biopsychology, New York State Psychiatric Institute and Columbia University College of Physicians & Surgeons, New York

Poster available at : http://psychophysiology.cpmc.columbia.edu/mmedia/sfn2005/sfn2005.pdf

http://psychophysiology.cpmc.columbia.edu

Introduction

ERPs recorded during tonal and phonetic target detection ("oddball") tasks show a topographic specificity that is consistent with regional and hemispheric specializations based on stimulus content (e.g., Kayser et. al., 1998). However, dichotic listening tasks impose an additional processing challenge by presenting conflicting contra- and ipsilateral information, and may yield observable perceptual asymmetry measures: a right ear advantage for verbal dichotic material, reflecting specialization of left hemisphere regions for language, and a left ear advantage for some non-linguistic dichotic material (e.g. complex tones), related to right hemispheric dominance for pitch discrimination. These perceptual asymmetries have been used as a probe for abnormal hemispheric function in psychopathology.

The present study combined the advantages of a dichotic stimulus presentation with the simplicity of a familiar auditory oddball task. Reference-free CSD waveforms produced during dichotic tonal and phonetic tasks were simplified using PCA for a sample of healthy adults and depressed patients, and the results compared to previous findings a conventional oddball (Kayser and Tenke, in press a, b).

Dichotic Oddball Tasks

Stimuli were selected from dichotic listening tasks known to produce right (consonant-vowel syllables) and left (complex tones) ear advantages in healthy adults, and edited to equate their duration and loudness.

Tonal Stimuli: 250 ms square waves, linearly tapered over the first and last 20 ms, with fundamental frequencies corresponding to major notes G4 (388 Hz), A4 (444 Hz), and B4 (485 Hz)

Phonetic Stimuli: spoken consonant-vowel syllables /ba/ (maximum spectral amplitude at 674 Hz), /ta/ (703 Hz), and /da/ (742 Hz); pitch was *not* equated to prevent complete perceptual fusion and rather preserve the discriminability of the syllables

Matched Tasks: Pairs of nontarget tones (**G4**, **B4**) or syllables (/da/, /ba/) were presented simultaneously to each ear (L:R) in an alternating series:

G4:B4 B4:G4 G4:B4 B4:G4 G4:A4 …

or

/ba/:/da/ /da/:/ba/ /ba/:/da/ /da/:/ba/ /ta/:/da/ …

0 s — 2 s — 4 s — 6 s — 8 s — Time

with a constant 2-s SOA. A target tone (**A4**) or syllable (/ta/) replaced one stimulus of the dichotic pair (e.g., **G4:A4** or /ta/:/da/) on 20% of the trials, while maintaining the alternating stimulus sequence for the other ear.

To increase the comparability of phonetic and tonal stimuli, the nontarget syllable pair had no voice onset delay (/ba/ and /da/). The target syllable (/ta/) had a voice onset delay of 57 ms, and was like its tonal counterpart intermediate in pitch.

Each subject received 2 consecutive tonal (T) and phonetic (P) task blocks. Each of the 4 blocks consisted of a total of 120 trials, including 24 target trials (6-each of the 4 possible target/nontarget combinations). Participants responded as fast and accurate as possible to targets with a button press. Response hand and task order was counterbalanced across participants (e.g., TR-TL-PL-PR or PL-PR-TR-TL).

Behavioral Performance: Overall correct response and correct rejections exceeded 95% for both tasks in both groups. However, percent correct target detection was significantly reduced in patients (Tone: control M = 89.1%, patient M = 75.8%, $t(62) = 2.72$, $p<.01$; CV: Control M = 94.7%, patient M = 83.8%, $t(62) = 2.67$, $p = .01$). Behavioral asymmetry [LQ = 100 X (Right Hits - Left Hits) / (Right Hits + Left Hits] differed between tasks (Tone LQ $M = -3.2108$; CV LQ $M = 1.1359$; $t(59) = -2.25$, $p = .028$), but group differences were not significant.

Methods

Participants: 26 healthy adults *(10 male; age = 30.3±1.3 yrs)* with no history of any psychopathology or neurological disorder; 38 depressed outpatients *(19 male; age = 35.0 ±1.7 yrs)*; all subjects right-handed *(Edinburgh Handedness Inventory: Controls = 76.3 ± 7.5; Patients = 72.1 ± 7.5)*

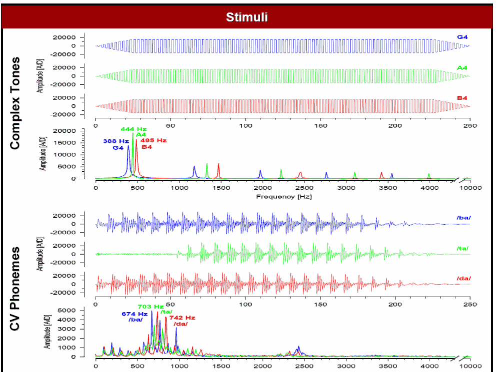
ERP methods: ERPs from 30 scalp sites (4 midline) referenced to nose tip (10K gain; 0.1 - 30 Hz band pass; NeuroScan at 200 samples/s); differential vertical and horizontal EOG; data artifacted at ±100 µV after blink correction (linear regression) under visual guidance (semi-automated); averages computed for correct trials, collapsed across *Response Mode* (left/right press) and *Ear* (left/ right).

CSD: Reference-free CSD waveforms (spherical spline Laplacian Perrin et al., 1989) computed from ERP averages to sharpen topographies, eliminate volume-conducted contributions from distant regions, and quantify underlying current generators (Kayser & Tenke, in press a,b; Tenke & Kayser, in press).

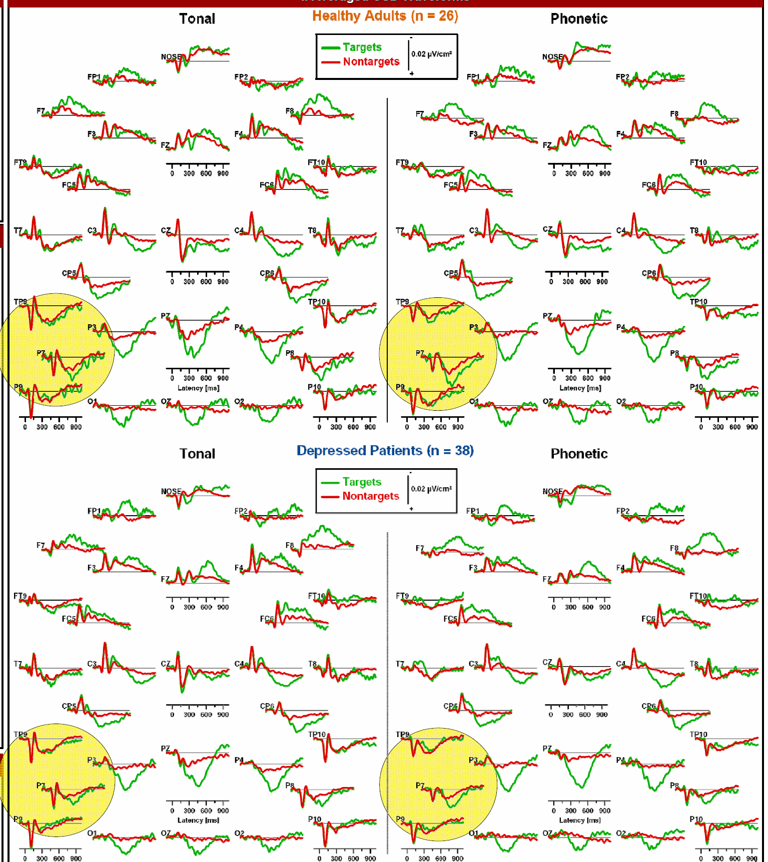
Temporal PCA: ERPs submitted to unrestricted PCA using covariance matrix [221 variables = samples -100 to 1000 ms; observations =7936; correct targets/nontargets (64 Subjects x 2 Tasks x 2 Conditions x 31 Sites (31)] followed by Varimax rotation (Kayser & Tenke, 2003).

ANOVA: For each PCA factor of interest, factor scores were submitted to repeated measures ANOVA using *Task* (tonal/phonetic); *Hemisphere* (right/left), electrode *Site*, and *Condition* (target/nontarget) where appropriate, as within-subjects factors, and *Group* (control/ depressed) and *Performance* (poor vs. good: >90% hits both Tasks) as between-subjects factors.

Stimuli

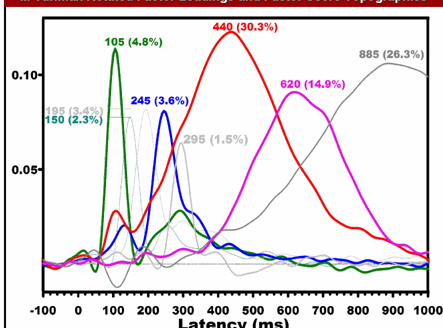


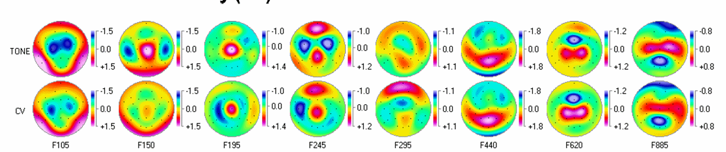
I. Averaged CSD Waveforms



Reference-free CSD Waveforms for correctly detected Target and Nontarget Tonal and Phonetic stimuli in Healthy Adults and Depressed Patients. Target-P3 source maximal at the parietal midline, but source extends laterally to inferior and temporal sites for both targets and nontargets, particularly over left hemisphere (yellow circles), where underside of N1 sink (i.e., matched source) is prominent.,

II. Varimax Rotated Factor Loadings and Factor Score Topographies





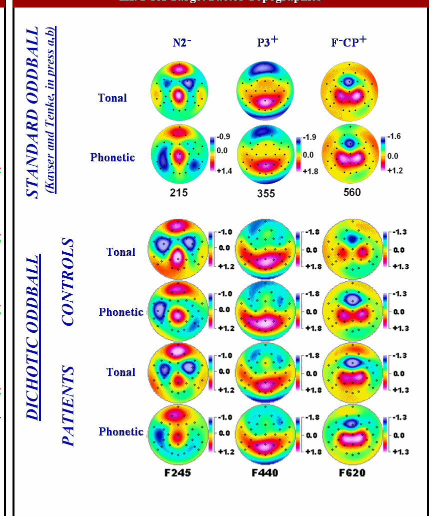
PCA solution: Covariance loading waveforms (top) for the first eight factors, and their corresponding factor score topographies for tonal and phonetic tasks (bottom).

Comparison of CSD Factors Across Paradigms

Dichotic Oddball *Factor (var%)*	Standard Oddball *Factor (var%)*	Previous Interpretation
F105 (4.8%)	F105 (4.5%)	N1⁻
F150 (2.3%)	F160 (3.9%)	Temporal N1⁻
F195 (3.4%)	(not present)	P2⁺?
F245 (3.6%)	F215 (5.3%)	N2⁻
F295 (1.5%)	F270 (2.3%)	(not interpreted)
F440 (30.3%)	F355 (23.0%)	P3⁺
F620 (14.9%)	F560 (24.0%)	F⁻CP⁺
F885 (26.3%)	F920 (25.6%)	SW±?

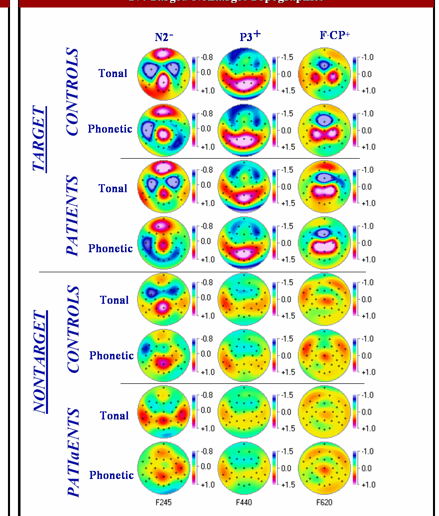
First eight PCA factors (by variance) show structure consistent with Standard Oddball (Kayser Tenke, in press a,b). Factors listed by loading peak latency (eg., F105). Component/ generator is *Source* (+) or *Sink* (-), e.g., **F ⁻ CP ⁺** is *Frontal Sink CentroParietal Source*

III. PCA Target Factor Topographies



Considered CSD-PCA factor score topographies (see Table). Delayed loading peaks for the Dichotic Oddball are consistent with the greater task difficulty. P3+ (F440) is reduced in patients, and has an asymmetric topography, with secondary branch extending lateral and anterior to temporal lobe.

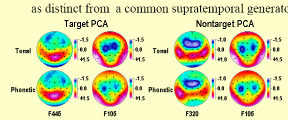
IV. Target/ Nontarget Topographies



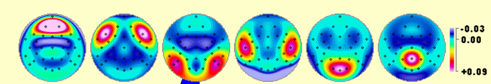
Target/Nontarget PCA topographies. In addition to the target-related topographies, F440 also shows a nontarget temporal lobe source in both tasks and for both groups, also larger for controls. The topography of nontarget F245 is less consistent, resembling target-N2 for controls, but not patients.

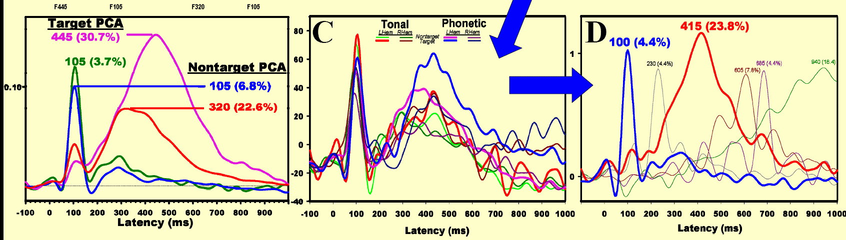
V. Spatiotemporal Separation of Posterior/Inferior Hemispheric Factors

A Temporal PCA of Nontargets is inadequate to separate P3 from N1 source. Loading waveforms also differ from Target/Nontarget or Target extractions, making it difficult to assert an unambiguous correspondence to classic P3b, as distinct from a common supratemporal generator.



B Spatial PCA (442 *variables* = 221 samples x 2 *Hemispheres*; 18 electrodes/hem; midline repeated) yields factors with hemispheric topographies as loadings and waveforms as scores (2 *Hemispheres* x 2 *Conditions* x 2 *Tasks* = 8 per subject). One factor loading topography resembles N1 (i.e., sink anterior and source posterior to the Sylvian fissure), with posterior/lateral maxima.





C. **N1 and P3 are Combined for Spatial PCA Factor Scores.** Grand averages across subjects show N1 sinks and P3 sources for all eight factor score waveforms (*Target/Nontarget; Left/Right Hemisphere; Tones/Phonemes*)

D. **Temporal PCA** of these scores separates P3 source (F415) from N1 sink (F100).

F415

- Greater for Targets (*Condition*: F[1,62]=9.78; p<.005) and Phonemes (*Task*: F[1,62]=12.09; p<.001)
- Greater over the left hemisphere (*Hemisphere*: F[1,62]=7.37; p<.01) both for Targets and Nontargets, particularly for phonemes (Task x Hemisphere: F[1,62]=15.9; p<.0005; Simple effect shows task effect only for Left Hemisphere).
- Reduced in Patients (*Group*: F[1,62]=8.11; p<.01), but no interaction with *Performance*

F100

- No amplitude difference for *Group* or *Performance*

References

Kayser, J., Tenke, C.E. (2003). Optimizing PCA methodology for ERP component identification and measurement: theoretical rationale and empirical evaluation. Clinical Neurophysiology, 114(12), 2307-2325.

Kayser, J., Tenke, C.E. (in press). Principal components analysis of Laplacian waveforms as a generic method for identifying ERP generator patterns: I. Evaluation with auditory oddball tasks. Clinical Neurophysiology.

Kayser, J., Tenke, C.E. (in press). Principal components analysis of Laplacian waveforms as a generic method for identifying ERP generator patterns: II. Adequacy of low-density estimates. Clinical Neurophysiology.

Kayser, J., Tenke, C.E., Bruder, G.E. (1998). Dissociation of brain ERP topographies for tonal and phonetic oddball tasks. Psychophysiology, 35(5), 576-590.

Perrin F, Pernier J, Bertrand O, Echallier JF. Spherical splines for scalp potential and current density mapping. Electroencephalogr Clin Neurophysiol 1989;72(2):184–7 [Corrigenda EEG 02274, Clin Neurophysiol, 1990, 76, 565].

Tenke, C.E., Kayser, J. (in press). Reference-free quantification of EEG spectra: combining current source density (CSD) and frequency principal components analysis (fPCA). Clinical Neurophysiology.

Tenke CE, Bruder GE, Towey J, Leite P, Sidtis JJ (1993). Correspondence between ERP and behavioral asymmetries in a dichotic complex tone test. Psychophysiology, 30:62-70.

Tenke CE, Kayser J, Fong R, Leite P, Towey JP, Bruder GE (1998). Response- and stimulus-related ERP asymmetries in a tonal oddball task: a Laplacian analysis. Brain Topogr, 10(3):201-10.

Support: MH36295 and MH50715

Conclusions

P3 source topography in Dichotic Oddball:

- mid-parietal maximum for *targets*
- extends lateral and anterior to *temporal lobes*
- greater over *left hemisphere*, regardless of stimulus content
- temporal topography also seen for *nontargets*

P3 source reductions in depression:

- topography includes *temporal lobes*
- prominent for *nontargets*
- independent of *performance*