The Activating Effects of Errors in High and Low-Socialized Students

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Abstract

Participants scoring extremely low or high on the socialization scale of the California Psychological Inventory participated in a forced-choice visual discrimination task under conditions of monetary reward or aversive punishment. Previously in this sample, the error-related negativity (ERN) proved differentially sensitive to errors under the two conditions for each group, such that low-socialized participants produced smaller ERNs during the punishment task than during the reward task, whereas high-socialized participants produced similar ERNs in both conditions.

The present investigation examined the time-frequency characteristics of errors under these conditions, focusing on gamma (20-55 Hz) and theta frequency (5-7 Hz) spectral power computed by a wavelet-based time-frequency analysis on individual response-locked epochs. Overall, error trials produced substantially greater high-frequency power than correct trials, although no differences among groups were found. These results suggest that, at least for the present sample, time-frequency characteristics of the ERN are not differentially sensitive to errors under punishment/reward conditions for these groups.

Introduction

- The error-related negativity (ERN): a response-locked event-related potential that indexes the detection or salience of an error during simple decision-making and cognitive tasks (Gehring,, Goss, Coles, Meyer, and Donchin, 1993).
  - Characterized by a negative-going wave appearing approximately 70ms after participants make an error response.
  - No (or very small) ERN present after correct responses.
- Low and high-socialized participants are differentially sensitive to errors during a forced-choice visual discrimination task under conditions of monetary reward or aversive (loud tone) punishment (Dikman and Allen, 2000).
  - Low-socialized participants produce smaller ERNs under conditions of punishment than reward.
  - High-socialized participants produce similar ERNs in both conditions.
  - This suggests that the ERN reflects differences in error salience for low- and high-socialized participants.
  - Consistent with avoidance-learning deficits in psychopathy.
- The present study sought to increase our understanding of error-monitoring by examining the time-frequency characteristics of the ERN under the above conditions across the theta (5-7 Hz) and gamma (20-55 Hz) frequency ranges.
- The theta range was chosen because the ERN has been proposed to partially reflect oscillatory theta activity (Luu and Tucker, 2001); gamma activity might reflect large-scale cortical activation associated with conscious awareness of errors, and preparation/coordination of subsequent error-correction processes.

Methods

Subjects

- 20 college students with scoring at extreme 3% of distribution (high or low) on the California Psychological Inventory socialization scale.
- 30 participants reported in Dikman and Allen (2000) with 20 subjects (Hi: n = 11;Low: n = 9) having complete data for the analyses reported here.

Discrimination Task:

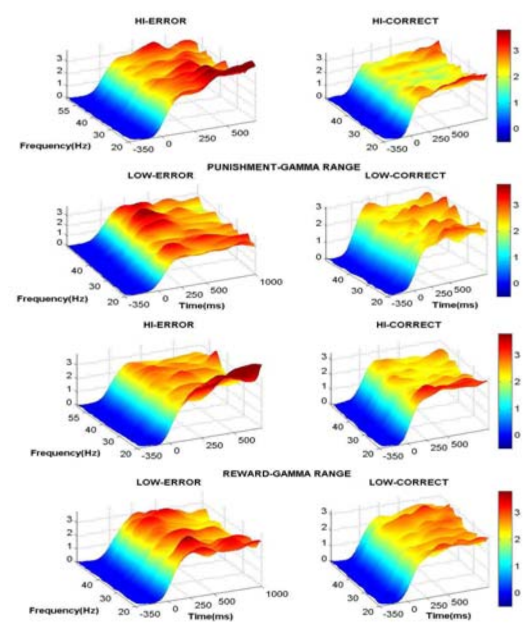
- Flanker task: Identify middle character of a 5-letter string of characters either compatible or incompatible with the central letter (‘SSSSS’, ‘HHHHH’, ‘SSHSS’, and ‘HHSHH’).
- Response mapping changed after each block of 80 trials.
- Task completed under conditions of reward (small monetary credit after correct responses) and punishment (loud 95 dB 1000 ms tone presented after errors).
- Feedback (“NO $” in reward condition, or noise blast in punishment condition) presented after incorrect response
- Participants could avoid consequences of error if they immediately self-corrected after an error was made.

- **EEG Recordings:**
  - EEG recorded from 25 standard 10-20 scalp sites; EOG recorded from sites below each eye and at nasion.
  - EEG amplified 20,000 times; EOG and FP1/FP2 - 5,000 times. All EEG/EOG impedances < 5 kOhms. Signals sampled at 256 Hz.
  - All muscle artifacts were removed from the raw EEG record by visual inspection, and an automatic correction algorithm was implemented for the correction of eye movements and blinks (Neuroscan, Neurosoft Inc., Sterling VA, USA)..
- **Time-Frequency Analyses:**
  - Time-frequency analysis was conducted on each EEG epoch, and then averaged across like epochs
  - Error and correct raw EEG trials were approximately matched (separately for the punishment and reward conditions) in terms of reaction time, total number of trials, and total number of (corrected) eye blinks present with the 1000 ms period post-response.
  - 2x2 ANOVAs (Punishment/Reward by Error/Correct) confirmed the success of the matching, finding no significant differences between retained Error and Correct trials.
  - Bandpass filtered (central frequency: $f \pm 2$ Hz) EEG data for each condition was convolved offline with a complex Morlet wavelet having a Gaussian shape in both frequency and time (Lachaux, Rodriguez, Martinerie, & Varela, 1999).
  - Wavelet transforms were calculated for each electrode and epoch, followed by calculation of spectral power $P(t,f) = |W(t,f)|^2$.
  - Post-response data were normalized with respect to a □350 to -100 ms pre-response baseline on a trial-by-trial basis.
  - Normalized values were averaged across the gamma range for each electrode and subject to produce an average spectral power response over time for each condition and electrode.
  - Topographic plots were created by mapping 10-20 electrode positions onto a sphere of unit radius, and then canonically transforming the plots onto a 2D circle of unit radius.
  - Waveforms were further averaged across electrodes and subjects to yield a grand average spesctral power maps in the gamma (25-55 Hz) range. For theta (5-7 Hz) frequencies, analyses were restricted to site CZ (the locus of the ERN responses found in Dikman and Allen (2000).
  - Power maps were averaged across frequency and time periods (gamma: 0-300ms and 300-750 ms; theta 0-150 ms); differences assessed by ANOVA.

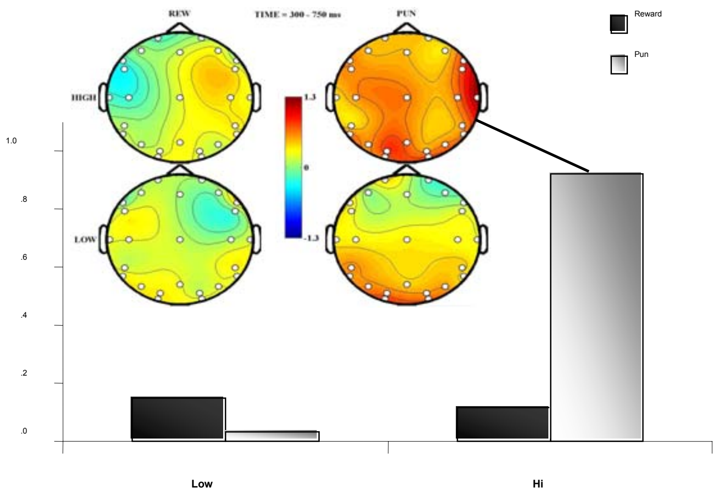
Results

Gamma Frequencies (20-55 Hz)

- The grand-average T-F maps exhibited a main effect for Error vs. Correct conditions over the 0-300 ms period , $F(1,17) = 10.752$, $p<.004$, Greenhouse-Geisser corrected.
- No other main/interaction effects for this period were found.



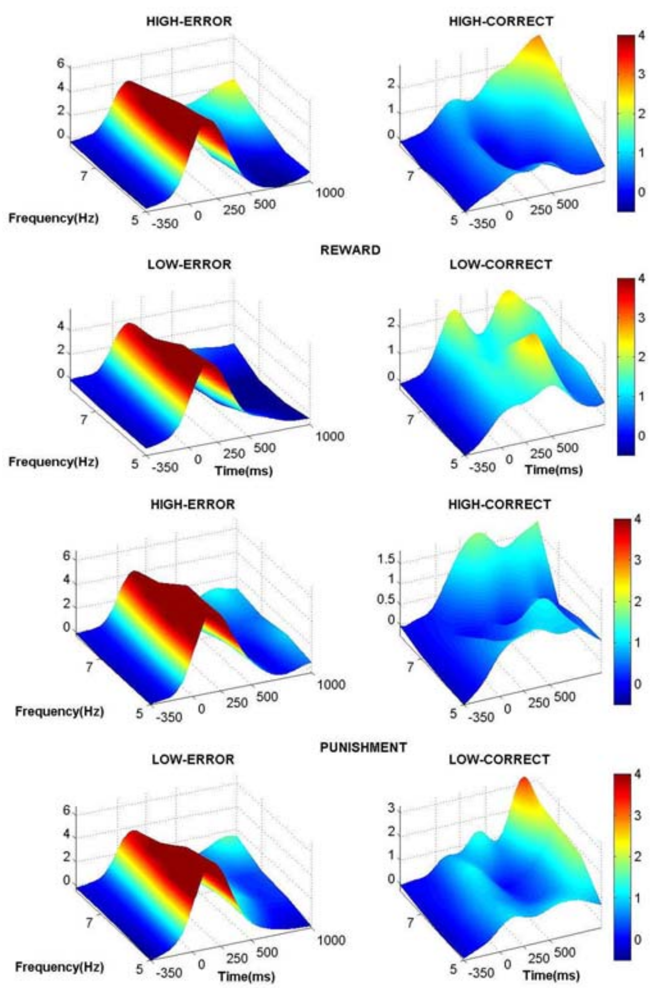
- For the 300-750 ms period, a significant punishment/reward by socialization interaction (F[1,17]=11.2, *p*<.01) revealed that whereas there was no difference in error-related gamma power as a function of reward or punishment for low-socialized individuals, high-socialized individuals demonstrated greater error-related gamma power when errors lead to the possibility of punishment.



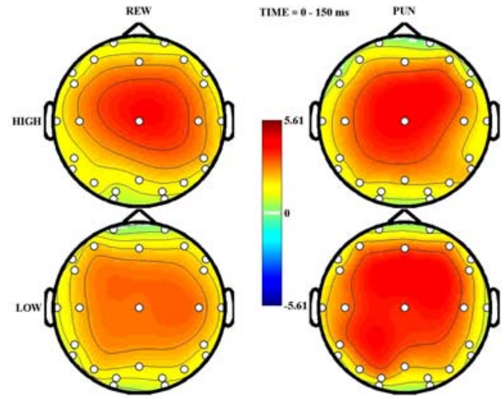
Error-Correct Gamma Power (300-750 ms) at individual sites (maps) and collapsed across sites (bars)

Theta Frequencies (5-7 Hz) at site CZ

- A main effect for Error vs. Correct conditions over the 0-150 ms period was found F(1,17) = 56.897, p<.001, Greenhouse-Geisser corrected. This was the result of greater theta power for errors than correct responses.
- No other main/interaction effects for this period were found.



Topography of Theta Power (5-7 Hz)



Topography of Error-Correct Theta Power (0-150 ms) mapped to a canonical transformation of a spherical representation onto a 2D circle of unit radius.

Discussion

- This study found significant differences between error and correct responses in the gamma and theta ranges.
  - Gamma effects were widespread across scalp regions; although this may reflect in part EMG activity, the scalp topography does not display effects entirely consistent with myogenic origin (e.g. temporalis effects)
  - Theta effect showed distribution similar to the ERN
- These effects are not the result of differences in number of trials, reaction time, or ocular artifacts between error and correct trials
- No differences were found between punishment and reward conditions, or high- and low-socialized groups.
- These results suggest that at least for the present sample, time-frequency characteristics of the ERN are not differentially sensitive to errors under punishment/reward conditions for these groups.
  - This may reflect that the wavelet-based time-frequency transform utilized here may not be sensitive to small differences in waveform amplitude due to the fact that transforms were applied and normalized on a trial-by-trial basis before averaging (thus being more greatly influenced by intertrial variability).
- Future research should compare time-frequency analyses on grand-averaged ERN waveforms and analyses based on single-trial T-F transformations.

References

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