Modulation of the ERN in Lose / Lose Trials in Individuals with Obsessive – Compulsive and Depressive Symptomology

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Abstract

- ERN amplitude has been shown to predict accuracy in avoiding punishment during probabilistic learning. Obsessive Compulsive (OC) Disorder and related symptomology have been shown to predict a larger ERN amplitude. This experiment sought to examine the effect of OC symptom scores on punishment learning.
- Contrary to expectations, OC symptomology predicted smaller ERN amplitudes. There was no effect of OC on punishment learning accuracy.
- Unexpected results may be due to the neural systems underlying the 'ERN' in probabilistic learning: it has not been shown how probabilistic learning ERPs may differ from the ERN elicited due to motor error commission.
- The influence of co-morbid depressive symptomology was also examined, revealing probabilistic learning detriments which may be unique to mood.
- Follow-up studies are currently underway to explain OC and depression effects on reinforcement learning using the ERN, including a study which will directly compare ERNs between a Flankers task and this probabilistic learning task.

Background

- Excessive medio-frontal activity in the Anterior Cingulate Cortex (ACC) and other structures had been observed in Obsessive-Compulsive Disorder (OCD).
- Consequently, a negative cortical-striatal-thalamic-cortical feedback circuit in OCD had been proposed.
- This excessive neural activity is thought to underlie, in part, a "hyperactive error signal".
- Four previous studies using Stroop, Flanker, and NoGo Paradigms found enhanced ERN amplitudes in OCD patients and OC symptom samples (Gehring et al., 2000; Johannes et al., 2001; Ruchsow et al., 2005; Hajcak & Simons, 2002).
- A study using a reinforcement learning paradigm failed to replicate this effect (Nieuwenhuis et al., 2005).

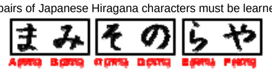
Methods

Participants

- > 1200 undergraduate students screened for OC symptoms to identify low medium, and high OC individuals.
- 74 students selected and tested. Included in this analyses are participants without medication, who learned the easiest symbol pair in the first and second task, and produced over 30 errors total.

Task

- A probabilistic learning (PL) task (Frank et al, 2004) proven to elicit response ERN and feedback-related negativities
- During the training phase three pairs of Japanese Hiragana characters must be learned solely due to the feedback provided after a forced choice.



- The feedback is probabilistic and will reinforce the correct choice only 80%, 70% or 60% of the time, depending on the stimulus pair.
- In a subsequent test phase, the symbols are paired with all other symbols and participants must choose amongst all possible choices without feedback.
- Positive ('Go') learning is characterized by the ability to choose A over C,D,E & F. Negative ('NoGo') learning is characterized by the ability to avoid B over C,D,E & F.

Questionnaire data

- The OCI-R (Foa et al., 2002) and the BDI data were skewed and therefore log-transformed.
- The OCI-R score of > 21 is considered clinically meaningful.

EEG recordings

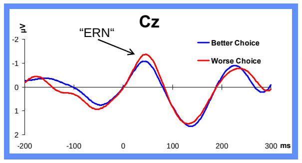
- NeuroScan SynAmps² with 64-Channel Ag/AgCl Quick-Caps were used (10-20 system).
- Four minutes of rest (OCCO or COOC) and two PL tasks were run for each subject.
- EEG was re-referenced to averaged mastoids prior to ERP averaging
- A regression algorithm were applied to reduce artifacts introduced by vertical eye-movements.
- The data were filtered between 1.5 Hz and 15 Hz, 96 dB/oct.

ERP & sLORETA measurement

- Correct and incorrect responses to the designated better choice in a symbol pair were averaged.
- The ERN Amplitude was defined as peak-to-peak difference between the highest negative deflection at **Cz** between 0 and 120 ms after the response, subtracted from the preceding trough (defined as 0 – 80 ms preceding the peak). Thus more positive values reflect larger ERN amplitudes.
- sLORETA Analysis procedures largely followed the methods of Pizzagalli et al. (2006).
- 2 minutes of non-overlapping 2.048 second epochs of eyes-closed rest were cleaned of artifacts using ICA (EEGLab). Remaining epochs were exported into sLORETA. (mean: 48 epochs / participant)
- Voxel-wise correlations were run in the non-parametric sLORETA stats package between theta band current density power and OCI-R Obsessive scores .
- ROI analyses were also run: all 6239 sLORETA voxels were normalized for the theta band within each subject to a total power of '1' and then log transformed. Voxels were averaged within ACC Brodmann Area (BA) ROIs thought to correspond to affective (rostral) and cognitive (dorsal) functions (Dorsal ACC = Z > 15 and Y < 35):

Rostral ACC: BA24_aff, BA32_aff; Dorsal ACC: BA24_cog, BA32_cog

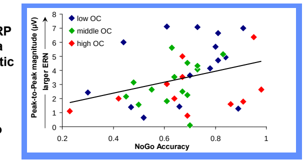
Probabilistic selection



$t(39) = 2.72$, $p = .01$

The "ERN" is defined as the ERP elicited during a worse probabilistic choice during testing.

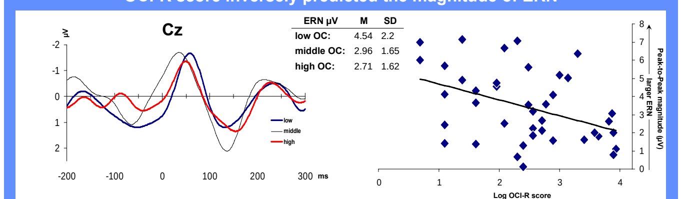
ERN amplitude predicted NoGo accuracy.



$r(40) = .34$, $p < .05$

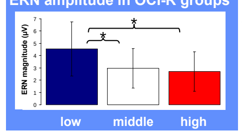
Obsessive Compulsive Inventory

OCI-R score inversely predicted the magnitude of ERN



ERN μV	M	SD
low OC:	4.54	2.2
middle OC:	2.96	1.65
high OC:	2.71	1.62

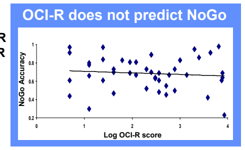
ERN amplitude in OCI-R groups



$F(2,37) = 3.84$, $p < .05$ ($\eta^2 = .17$)

ERN amplitude is correlated with OCI-R scores, yet the OCI-R score does not predict NoGo accuracy.

OCI-R does not predict NoGo

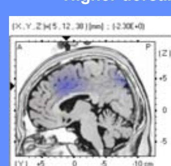


$r(44) = -.09$, $p = .55$

sLORETA

Resting EEG data were examined for tonic differences in resting ACC theta current density which may underlie OCI-R effects and ERN modulation.

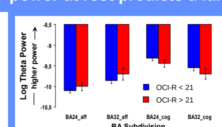
High OCI-R scores predict higher rostral and lower dorsal resting ACC activity. Higher dorsal ACC power at rest predicts a larger ERN difference μV.



sLORETA reveals lower resting dorsal ACC theta current density in participants scoring high (>21) compared to low (<21) on the OCI-R.

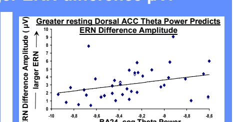
Value= -2.30 (X= 5 , Y= 12 , Z= 38) (MNI coords)

Best Match at 3 mm: Brodmann area 32



A **2** (**BA**: 24, 32) * **2** (**Subdivision**: Rostral, Dorsal) * **2** (**OCI-R**: <21, >21) ANOVA for normalized theta current density revealed that the expected **2** way (**Subdivision** * **OCI-R**) was the only significant effect: $F(1,56)=3.88$, $p=.05$.

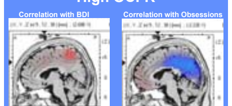
ROI analysis revealed that the high OCI-R group (>21) displayed relatively higher theta current density in "affective" ACC areas and lower theta current density in "cognitive" ACC areas, as compared to the low OCI-R group (<21).



ROI analysis revealed that only resting BA24_cog theta current density significantly predicted future ERN difference amplitude (ERN-Correct) during the probabilistic learning task $r(41)= .32$, $p<.05$.

BA24_cog and NoGo contribute independent variance towards ERN amplitude [$F(2,37)=4.48$, $p<.05$; **BA24_cog** $F(2,37)=4.25$, $p<.05$, **NoGo** $F(2,37)=4.7$, $p<.05$]

High OCI-R

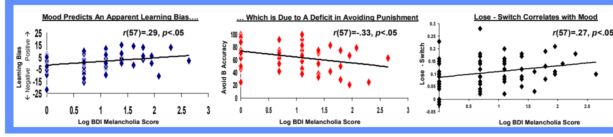


Neural systems which may underlie PL ERN generation (BA24_cog) may be different from those which underlie motor error-of-commission ERN (dorsal + rostral areas).

This hypothesis would explain a larger ERN in Flanker tasks in relation to OC, yet a smaller ERN in PL tasks: OC predicts differential resting power in ACC subregions.

Beck Depression Inventory

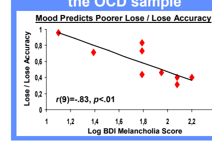
Pilot data has indicated that mood predicts sensitivity to negative feedback.



More lose-switch activity may be indicative of "over-sensitivity" to negative feedback in depression (Murphy et al., 2003).

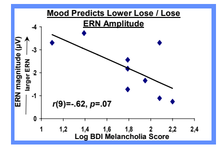
Paradoxically this led to worse probabilistic integration over time and therefore poorer discrimination between lose / lose trials in the test phase of the pilot data.

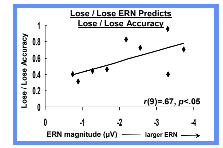
High BDI (>11) subjects in the OCD sample



These effects are replicated and extended in the present sample (BDI > 11), showing that diminished ERN amplitudes may mediate poorer lose / lose accuracy in depression.

The ERN may provide an index of ACC dysfunction during difficult negative choices.





Discussion

- Contrary to expectations, ERN amplitude was inversely correlated with OCI-R score. The only other study of probabilistic learning in OC, however, also failed to find larger ERN amplitudes. Although ERN amplitude predicted NoGo learning, there was no OCI-R effect on NoGo learning.
- The high OC group (M = 34.6, SD = 13.2, all above OCI-R recommended cutoff > 21) is fairly high compared to previous reports with patient populations, and mood effects seem to be specific to lose/lose situations.
- If Flankers task ERNs differ from PL task ERNs due to greater rostral ACC contribution, then these OCI-R effects may be explained: The high OCI group displayed relatively greater rostral ACC theta power, but lower dorsal ACC power at rest.
- Variance in the PL ERN was independently accounted for by NoGo accuracy and resting dorsal ACC power, indicating that separate and distinct neural systems may affect ERN amplitude.
- Considering the learning nature of this task, it is possible that other neural systems, such as the hippocampal formation might contribute to the group difference (Klein et al., 2007). It has also been suggested that the response monitoring system in OCD becomes hyperactive only when the stimulus-response contingencies are known (Nieuwenhuis et al., 2005).
- Two follow-up studies are currently underway: 1) To compare Flankers and PL task ERNs within a range of OCI-R scores, and 2) To investigate compromised lose/lose performance in depressed individuals.

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Handouts available: www.psychofizz.org / Contact the author at Gruendler@nf.mpg.de