An Event-Related Brain Potential Study of the effects of perceptual task difficulty on cognitive control mechanisms

Rowena Chin, David W. Shucard, Tom Covey, Janet Shucard
Division of Cognitive and Behavioral Neurosciences,
Departments of Psychology and Neurology, University at Buffalo, School of Medicine and Biomedical Sciences

Introduction

Our daily environment is constantly filled with information from different sources. When pursuing goals, cognitive control mechanisms allow us to allocate attentional resources to particular stimuli and to ignore irrelevant ones. However, as decision-making relies on contextual cues derived from our environment, making choices to attend or respond to relevant stimuli may be more difficult when perceptual ambiguity is present. In this study, we investigated the effects of perceptual task difficulty on cognitive control mechanisms by using two versions of a Go-NoGo continuous performance task(A-X CPT). In the first version, regular letters were used as stimuli, whereas in the second version, degraded letters were used to increase perceptual task difficulty. Dense EEG activity was monitored during the task, and event-related brain potentials (ERPs) were recorded. Two key ERP components (N2 and P3) were examined under both easy and difficult task conditions. These components have been found to be associated with mechanisms of cognitive control such as conflict monitoring and inhibitory control respectively.

Hypotheses:

1) As the P3 is related to response inhibition, we predicted an amplitude increase in frontal-central leads during the NoGo condition when participants had to inhibit their response.
2) However, we predicted a reduced P3 for the degraded trial type task compared to the regular task as a function of increased task difficulty.
3) As the N2 is associated with conflict monitoring, we predict an amplitude increase in the frontal leads during the degraded task condition compared to the regular task due to increased conflict.

Methods

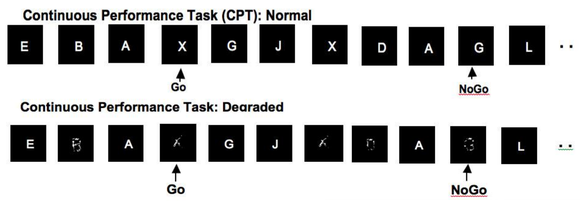
Participants: 11 participants, 3 female (27.3%) ; 8 male (72.7%).

	Mean	S.D.
Age	46.27	8.19
Education (years)	15.36	1.91
Estimated IQ (NAART)	115.51	4.59

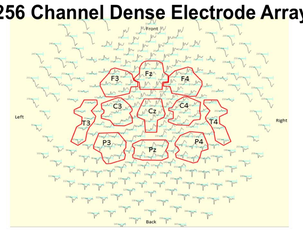
Go-NoGo Continuous Performance Task (A-X CPT):

Letters presented one at a time. Participants pressed a button to the letter "X" only if it was preceded by an "A" (Go), and withheld their response to any letter other than "X" that followed an "A" (NoGo).

- 410 letters presented (40 Go trials and 40 NoGo trials)
- Accuracy and reaction time (RT) measures were obtained
- Task presented under two conditions: Regular and Degraded. In the degraded condition, the Go and NoGo letters were degraded using Photoshop software.



256 Channel Dense Electrode Array



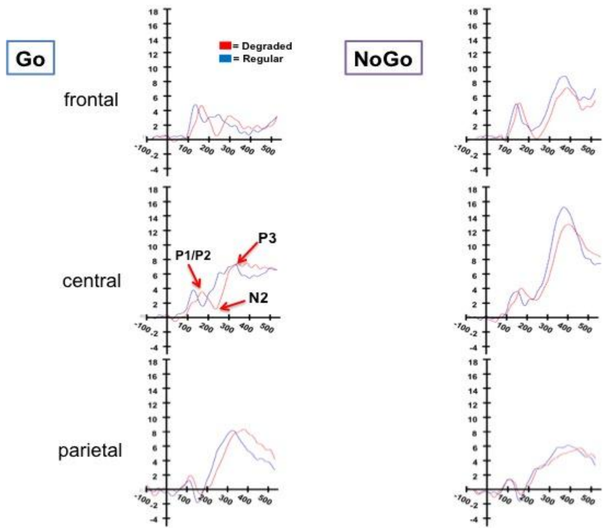
ERP Analysis:

Dense electrode EEG data were obtained with a 256 channel EGI system. ERPs were obtained for individual electrodes and averaged among electrodes within eleven clusters (see figure). We report the N2 and P3 ERP components obtained to Go and NoGo conditions during the Regular and Degraded trial types for midline clusters (Fz, Cz, and Pz). As the N2 is primarily found over anterior scalp sites (Folstein & Van Petten, 2008), only frontocentral clusters (Fz, Cz) were analyzed. The N2 amplitudes were calculated as the difference between the prior positive peak (P1/P2) and the N2 negative-going waveform.

Statistical Analyses:

Repeated measures ANOVA design: Behavioral measures (RT and accuracy): Condition (Go, NoGo) x Trial Type (Regular, Degraded); ERP measures (amplitude and latency): Condition x Trial Type x Cluster. Paired t-tests were used for post-hoc analyses. Level for significance p<.05.

ERP Grand Averages



Results

Behavioral Analyses:

	Regular	Degraded	p-value
Reaction Time (msec)	370± 95.9	440.2 ± 119.2	<.001
Total Correct	39.3 ± 1.68	38.8 ± 1.78	n.s.
Omission Errors	0.73 ± 1.68	1.18 ± 1.78	n.s.
Commission Errors (NoGo)	0.27 ± 0.65	0.73 ± 1.85	n.s.

Event-Related Potential Analyses:

P3 Amplitude:

FIGURE 1: Condition x Trial Type interaction [F=14.02, p=.004].

- for regular stimuli, Go amplitude was lower than NoGo [t=4.42, p=.001], and for degraded stimuli Go and NoGo amplitude did not differ.
- Regular NoGo amplitude was greater than Degraded NoGo [t=3.17, p=.01].

FIGURE 2: Condition x Lead interaction effect [F=20.45, p<0.001].

- Fz, and Cz greater for NoGo than Go [t=4.45, p=.001; t=4.36, p=.001]. Pz lower amplitude for NoGo than Go [t=2.78, p=.019].
- Go Cond: Pz and Cz amplitudes were greater than Fz [t=6.45, p<.001; t=6.15, p<.001].
- NoGo Cond: Cz>Fz [t=7.19, p<.001] and Cz>Pz [t=6.07, p<.001].

N2 Amplitude: **FIGURES 3 & 4:** No interactions were found. Sig Main Effects for:

- Trial Type [F=6.85, p=.026], Degraded N2 more negative than Regular N2.
- Lead [F=11.68, p=.007], Fz more negative than Cz .

Figure 1

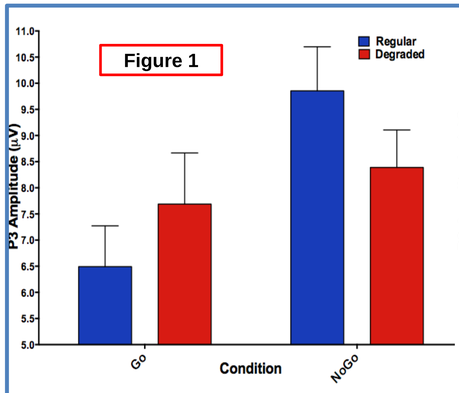


Figure 2

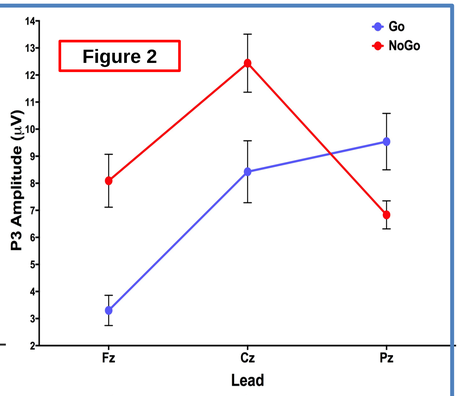


Figure 3

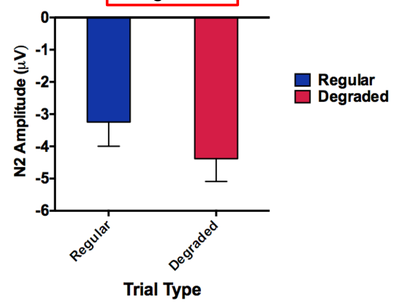
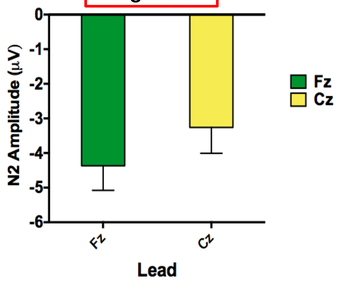
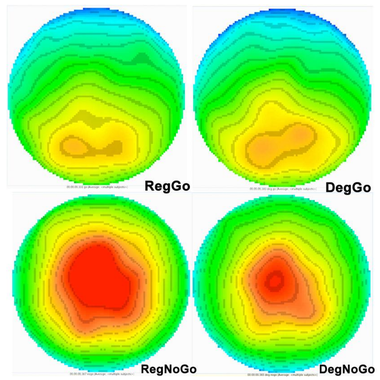


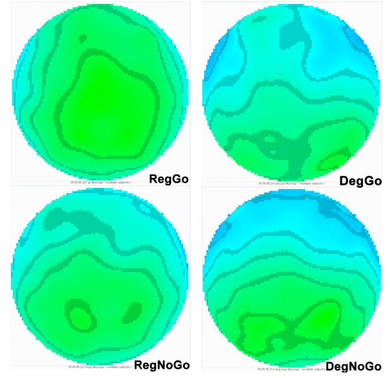
Figure 4



P3 Topo Map



N2 Topo Map



P3 Latency:

- There were significant Trial Type effects [F=22.92, p=.001] and Condition effects [F=16.55, p=.002].

N2 Latency:

- There was a Condition x Trial Type effect [F=8.34, p=.018]. Post-hocs showed Go>NoGo [t=3.729, p=0.005], Go > DegGo [t=2.233, p=0.052], and NoGo < DegNoGo [t=-3.537, p=0.005].

Conclusions

- The significant increase in N2 amplitude for Degraded verus Regular stimuli, independent of the Condition (Go/NoGo) lends support to the hypothesis that N2 reflects conflict-monitoring. Perceptual ambiguity (degraded stimuli) produces greater conflict.
- P3 amplitude showed a significant Go/NoGo effect for both trial types, with the classic anteriorization towards the frontocentral midlines during the NoGo condition. This finding supports the hypothesis that the P3 is related to response inhibition.
- However, the decrease in NoGo P3 amplitude from Regular to Degraded may be due to increased task difficulty, which is supported by studies that have attempted to increase task difficulty through other manipulations such as reducing response time.
- Latency effects were consistent with our hypothesis that central processing of the ambiguous stimulus would take longer than that for the regular stimulus.
- **The findings are significant because they provide a brain-behavior link between important cognitive functions such as ability to process information and inhibit a response and neuronal activity associated with these cognitive processes.**