The Detection of Deception using Event-related Potentials in a Highly Realistic Mock-Crime Scenario

THE UNIVERSITY OF ARIZONA
TUCSON ARIZONA

Ralf Mertens, John J.B. Allen, Nicholas Culp & Lauren Crawford

Introduction

- Memory evaluations utilizing ERP's have demonstrated high sensitivity and specificity, leading some proponents to suggest they may prove useful in forensic investigations
- Traditional methods of analysis (e.g. ANOVA, however, are not adequate for providing outcomes for *individual* subjects. Bayesian classification (Allen, Iacono, & Danielson, 1992) and Bootstrapping (Farewell & Donchin, 1991) provide methodologies to classify stimuli as familiar or unfamiliar to individual subjects, based on features of the ERP
- Most studies, however, employed simple list-learning tasks or inquired about benign demographics, rather than assessing the utility of ERP procedures in conditions emulating forensic work
- Moreover, few studies have assessed the potential vulnerability of ERP's to countermeasures (CM's)
- To this end, our current study employs Bayesian Analysis & Bootstrapping statistics to assess their robustness in mock crime scenario employing physical and mental countermeasures
- Since deception detection paradigms are limited in their scope due to ethical and moral concerns about the psychological well-being of participants, particular care was taken to
  - maximize the realism of the study and
  - ensure motivation of participants to perform to the best of their abilities

Methods

Participants:

- 75 undergraduate (36 M, 39 F, mean age=19.24, SD=2.41) students from the University of Arizona
- Free of neuropsychological disorders known to influence EEG
- Minimal drug use
- 5 Experimental groups, n=1 5
  - Innocent (no crime, touring virtual environment only)
  - Standard Guilty (CM0, crime only, no countermeasures)
  - Guilty, (CM1, mental countermeasure)
  - Guilty, (CM2, physical countermeasure)
  - Guilty, (CM3, complex countermeasure consisting of mental and physical activities)

2 stage procedure

- 1st stage: Consent, questionnaires, training with the virtual environment, informed to expect anonymous email telling them of their "mission"
- 2nd stage: "Crime", interrogation, ERP procedure
  - $10/hour for participation
  - eligibility for $100 jackpot only if able to beat procedure (i.e., avoid detection)
  - students admitting guilt at any time during the study were excluded from analysis
  - students entered office off-limits to undergraduate students and executed previously learned mission plan in virtual environment employing a total of 12 guilty knowledge items
  - participants were "apprehended" and subjected to interrogation
  - interrogation overviewed the test, informing the subject of the nature of the questions, and reviewed the multiple choice options (crime relevant and distractors) that would be presented during the ERP assessment
  - Following interrogation, participants learned list of 12 target words used during ERP procedure to ensure subjects responded to items in memory during assessment

EEG

- Midline electrodes (Fz, Cz, Pz)
- 250hz online, downsampled to 200 hz offline
- Online processing: High Pass 0.1hz; Low Pass 100hz; 500x amplification
- Offline analysis: 12.5 Hz, 96 dB low pass; ocular correction, epoched from -250 ms to 1750 ms

ERP procedure and stimuli

- Oddball paradigm, visual modality (16.7%, 16.7%, 66.7% probability)
  - 12 crime-relevant Probes, 12 learned Targets, 24 Unlearned items matched to Targets, 24 Unlearned items matched to Probes. All stimuli matched in word frequency ([5,20]=.153;p<.05). Unlearned words matched in semantic category to probes and targets
  - Total of 48 stimulus presentations for Probes and Targets. Stimuli were presented in randomized blocks (12 P, 12 T, 48 D), and repeated a total of 4 times, yielding a grand total of 288 trials
- Participants acknowledged target words via button press using dominant hand, ignored all others

Item Type	Probability	Behavioral response	P3 amplitude
Target	rare	"Yes"	large
Probe	rare	"No"	large if recognized
Unlearned	frequent	"No"	small

Table 1: Stimulus Summary: probability of stimulus types and predicted ERP response

Additional Materials

Virtual Environment

- Based on Quake3 Arena
- Full experimental control
- Photorealistic
- Flexible & adaptable across experimental conditions
- Relatively low cost, minimal hardware requirements
- Expandable to pursue multi-center studies and/or involve artificial intelligence actors

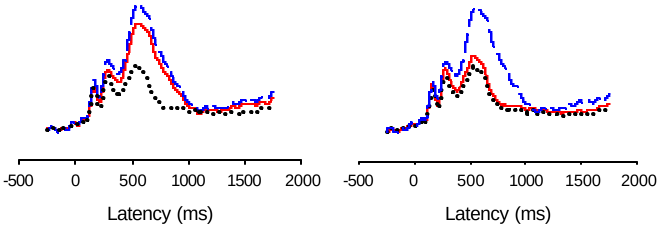
Analysis

Bayesian analysis:

To derive statistically supported decisions about learned vs. unlearned materials for each individual subject, Bayesian analysis (cf. Allen et al., 1992) was employed in the following fashion:

- For each subject, computation of average waveforms for each stimuli type (Targets, Probes, and 4 unlearned lists, so that each average was comprised of the same number of items)
- extraction of 5 measures based on these waveforms with the latter four through factor analysis based on the entire epoch (-150 to +1050)
  - P3 amplitude
  - four communality measures:
    - raw waveforms
    - 1st derivative (Slope at each time point)
    - 2nd derivative (change of the slope at each time point)
    - deviation waveform (grand average across all conditions per participant subtracted from each of the 6 item-type specific waveforms)
- Utilization of previously validated cutpoints on an intra-individual basis that determine when a specific indicator is "large" enough to differentiate learned from unlearned (see Figure 3)

Bootstrapping of cross-correlations



For each iteration, raw epochs were sampled – with replacement – to create an average for probes, targets, and unlearned items. One hundred iterations were performed, and on each iteration two correlations were obtained:

rProbe-Target, **r**Probe-Unlearned

Bootstrap statistic:

(# iterations/100) where (**r**Probe-Unlearned > **r**Probe-Target)

Guilty (recognized) if Bootstrap statistic = .10

Innocent (not recognized) if Bootstrap Statistic = .70

No verdict (indeterminate) if Bootstrap Statistic >.10 but < .70

Results

Legend, experimental conditions

- Innocent (no crime, touring virtual environment only)
- CM0: (Standard Guilty, crime only, no countermeasures)
- CM1: (Guilty, mental countermeasure)
- CM2: (Guilty, physical countermeasure)
- CM3 (Guilty, complex countermeasure consisting of mental and physical activities)

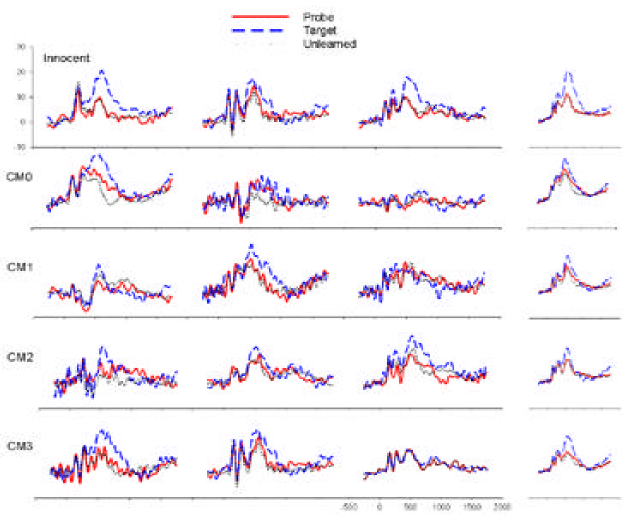


Figure 1: Comparison of individual subjects' waveforms for 15 participants across experimental conditions (please see legend above for description of conditions). Waveform plots in the right hand column are respective grand average waveforms (n=15) for each condition and emphasize the substantial difference in signal between individual and group averaged waveforms. Waveforms are plotted with positive amplitude up.

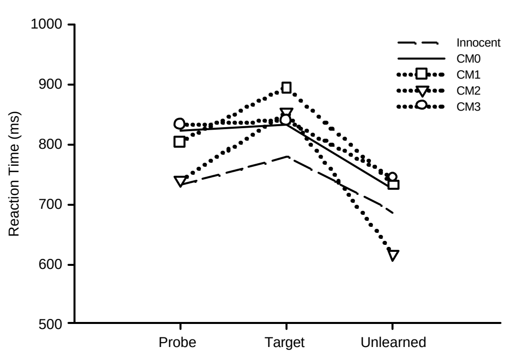


Figure 2: Reaction time (ms) for three stimulus types across five experimental conditions

Copy of Poster at: http://apsychoserver.psych.arizona.edu

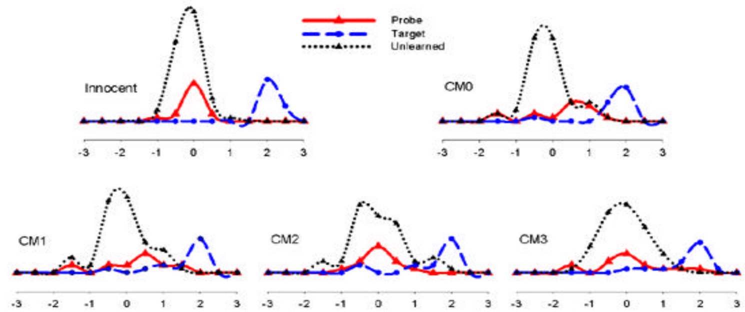


Figure 3: Frequency distribution of Z-scores across 5 experimental conditions for 75 participants per item type for P3 amplitude, one of the measures input to the Bayesian analysis. Targets (dashed) were commonly associated with larger Z-scores as compared to other items. Probes (solid) and Targets appear dissimilar in the Standard Guilty condition (CM0), however. Probes were similar to Unlearned (dotted) items in the 3 CM groups.

Discussion

- Both analyses produced surprisingly low rates of classification accuracy for guilty subjects. Standard guilty participants were only detected 47% utilizing Bayesian classification scheme or 27% of the time using Bootstrapping statistics
- Countermeasures further lowered this rate of detection
- Innocent subjects were correctly identified 94% of the time using Bayesian classification or 100% of the time using Bootstrapping statistics, although Bootstrapping left 56% of innocent participants unclassified
- These results highlight that:
  - Innocent individuals are adequately protected in this guilty-knowledge procedure, regardless of classification approach
  - Even the recent and salient knowledge of facts from a realistic mock crime does not ensure guilty individuals will be correctly classified
  - ERP procedures may be vulnerable to specific countermeasures
- Results of the current study produced significantly lower hit rates compared to previous investigations (cf. Allen, Iacono & Danielson, 1992; Farwell & Donchin, 1991). The current study may have over-emphasized Target items as suggested by z-score analysis of the standard guilty group depicted in Figure 3 (upper right hand panel, CM0)
  - This would suggest that ERP procedures under some conditions are sensitive to rather subtle and even unintended modification of testing parameters
  - This further could suggest the need to pre-validate a test prior to field use, a cumbersome procedure
- These results suggest that although a guilty verdict on such a test is informative, as only guilty subjects appear guilty on this test, an innocent verdict should not be taken as clear evidence of lack of guilt
  - Unfortunately, in the few instances in which this test has been used in field work, it has been used as evidence of innocence based upon a test verdict of innocent, precisely the verdict that the present results suggest cannot be trusted
- Further studies are needed to test:
  - whether less emphasis on target items during training increases subsequent hit rates
  - the type of countermeasures that could be most easily employed for maximal rate of evasion
  - whether differential conditions at time of encoding (e.g., intoxication) and testing (e.g., sober) could influence classification

References:

Allen, J.J., Iacono, W.D., Danielson,K.D. (1992). The identification of concealed memories using the event-related potential and implicit behavioral measures: A methodology for prediction in the face of individual differences. Psychophysiology, 29, 504-522.

Farwell, L.A., Donchin, E. (1991). The Truth Will Out: Interrogative polygraphy with event-related brain potentials. Psychophysiology, 28, 531-547.

This research was supported by a Homeland Security Grant from the Office of the Vice President for Research and Graduate Studies of the University of Arizona, Tucson, AZ, and efforts by Dean Klimchuk and Roman Matura at Scaled Environments (http://www.scaled-environments.com)