Decoding Deception:
Analysis of ERP and fMRI Data Relevant to the Detection of Deception

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Outline

- Introductory Information
  - Anatomy, Physiology and Interview Characteristics
  - Origins and Generation of ERPs

- The Two-Stimulus Paradigm
  - Data Acquisition and Behavioral Findings
  - Standard Analysis Techniques

- Cognitive Activity Measures
  - ERP Power and Energy
  - Attention Based Load-Switching

- Continuing Efforts
  - Misinformation Study
  - A Quantum Hypothesis
Introductory Information

- Anatomy, Physiology and Interview Characteristics
- Origins and Generation of ERPs
Basic Neurophysiology

- **Frontal Lobe**
  - Planning, Organizing, Deciding

- **Temporal Lobe**
  - Sorting, Short-Term Memory

- **Parietal Lobe**
  - Sensory Cortex, Language

- **Occipital Lobe**
  - Visual Reception, Recognition
Attention and Performance

- **Yerkes-Dodson Law (1908)**
  - Arousal/Attention
    - Related to Anxiety, Work Capacity
    - Motivator for change
  - Optimization
    - Lower for difficult cognitive tasks
    - Higher for tasks requiring endurance

- **Michael Posner (1990)**
  - **Attention System of the Human Brain**
    - Anterior Attention Network (AAN)
      - Executive Control
    - Temporal Parietal Junction (TPJ)
      - Orienting Response
    - Posterior attention Network (PAN)
      - Processing (Alerting)
Test for Espionage and Sabotage (TES)

- Two Series of Questions
  - Relevant and Irrelevant
  - Directed-Lie Comparison, and Sacrifice Relevant

- Examples:
  - Irrelevant
    - Are you now in Virginia?
  - Sacrifice Relevant
    - Do you intend to answer these questions truthfully?
  - Directed Lie Comparison
    - Have you ever stolen office supplies for your personal use?
  - Relevant
    - Have you committed sabotage against the United States?
Current Screening

- Screening Applications (Polygraph)
  - Pre-employment Screening (law enforcement)
  - Pre-clearance Screening (national security)
- Ongoing Screening of employees
- Sex-offender Status

- Known Issues
  - Not single-issue tests
  - Range of behaviors can be large
  - Examinee’s may be unclear of their guilt
Physiological Mechanisms of Deception

- Orienting Response (Salience)
  - Generalized descending arousal
  - Likely generates the responses measured by the polygraph (Pollina & Ryan, 2003)

- Attention Shifting
  - Reflex-like attention switch to new stimulus
  - Associated with heart rate decelerations, delays in breathing, and cessation of ongoing behaviors (Näätänen, 1992)

- National Academy of Sciences
  - “Report on Polygraph” states that Base Rate very low such that several hundred innocent found deceptive (false positives) for every correct identification of a guilty individual
Cortical Control of Evoked Electrodermal Activity (EDA)

- **Emotion:** *Ipsi-lateral*
  - Hypothalamus and Limbic System

- **Attention:** *Contra-lateral*
  - Prefrontal and Pre-motor Cortex

- **Control:** *Contra-lateral*
  - Reticular Activating System
Introductory Information

- Anatomy, Physiology and Interview Characteristics
- Origins and Generation of ERPs
EEG Spectrum and Morphology

Theta (5 – 7 Hz)  Alpha (8 – 12 Hz)  Gamma (35 – 50 Hz)
Affective/Temporal  Relaxed/Parietal  Sleep/Frontal
ERPs from EEGs

- Time Lock to Stimulus
  - Average Across Trials (\( SNR \propto \sqrt{N} \))

- Data Filtering
  - Butterworth ("Maximally Flat"); \( \frac{dG}{d\omega} = -nG^3\omega^{2n-1} \)

- Extract variance related \textit{dimensions}
  - Segment and export

Images Adapted from: http://neurocog.psy.tufts.edu/images/
Origin and Generation of ERPs

- Human Cortex: ~100 Billion Neurons
- Single Neuron: ~100 Trillion Synapses
- Microtubules: ~10 Million / Neuron
- Quantum Decoherence: ~10 Million / Neuron

Quantum Decoherence

\[ \tau \equiv \frac{1}{N n \sigma} = \frac{\sqrt{m k T}}{N g q^2 n} \sim 10^{-20} \text{s} \]


Two Theories of Origination

- Originate from *event-related activations* of neural assemblies distinct from background dynamics
- Produced by *phase resetting* of ongoing oscillatory neuronal activity

These three waveforms may work together in a process of deception in which a question is asked, attention is switched, workload demands are assessed, memory for the truthful information is accessed, motivation to deceive is considered, and then a decision to deceive is made.
The Two-Stimulus Paradigm

- Data Acquisition and Behavioral Findings
- Standard Analysis Techniques
Data Acquisition

EGI Systems
“Geodetic Sensornet”

Data Display
(4*40*225*39 = 1404000 pts)

128 Channels
(Vertex Reference)

Amplifier
(Isolated Common)

“Netstation”
(Pre-Processing)
The Directed Lie Paradigm

Participants respond truthfully to one color and lie to the other.

- **CT**
  - The grass is green.
  - Response: TRUE

- **IT**
  - The grass is green.
  - Response: FALSE

- **IL**
  - The grass is green.
  - Response: TRUE

- **CL**
  - The grass is green.
  - Response: FALSE

Times:
- STIM 1: 2500ms
- FIXATION: 750ms
- STIM 2: 2000ms
- BUTTON:

**Task Sequence:**
- TASK
- STIM 1
- FIXATION
- STIM 2
- BUTTON
Experimental Procedure

- Directed Lie Procedure
  - Participants view autobiographical statements that are true or false (randomly presented; 40 of each response type) followed by a second stimulus to which they respond with a key press (agree/disagree).

- Experiment 1: Low Workload
  - Know truth value and task at stimulus 1
  - Demographics: Aged 18-43 ($M = 21.38$); $N=39$

- Experiment 2: High Workload
  - Experiment: Know truth value only at stimulus 1
  - Demographics: Aged 18 to 21 ($M = 19$); $N=15$
Signal Processing

1 Raw Segment

Stimulus 1 (2500ms)

Fixation Prompt (750 ms)

Stimulus 2 (Response Termination)

2 Filter Segment

3 Correct Segment

4 Average Segment
Reaction Time Findings

- Reaction time (RT)
  - Latency between STIM 2 and subject response
  - RT less for truthful responses

- No Interaction
  - Congruity and deception not related
  - Incongruent data not discussed here
The Two-Stimulus Paradigm

- Data Acquisition and Behavioral Findings
- Standard Analysis Techniques
Region of Interest (ROI) Waveforms

- Channels for Posner Networks
- ROI Averaged Waveforms
Waveform Peak and Latency

- **Waveform Peak**
  - Determine maximum amplitude in chosen “window”

- **Waveform Latency**
  - Time from stimulus onset to waveform peak amplitude
Cognitive Activity Measures

- ERP Power and Energy
- Attention Based Load-Switching
ERP Power and Energy

- We integrate the instantaneous channel-power over successive time intervals to obtain a measure of the energy emitted during individual response trials:

\[
E_n^{(C)}(t, \tau) = \frac{1}{z} \int_0^t V_n^{(C)}(t)V_n^{(C)}(t - \tau) dt
\]

where \( z \) is the impedance value.

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Power</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>( ~10 MicroVolts)</td>
<td>( ~100 eV / ms)</td>
<td>( ~10 KeV)</td>
</tr>
</tbody>
</table>

- Voltage: ~10 MicroVolts
- Power: ~100 eV / ms
- Energy: ~10 KeV
We define the *Cognitive Activity* for an ROI with a weighted sum of the ratio of the channel-energy for one state to the total energy from both states:

\[
\eta_{ROI}^{C_i}(t) = \sum_{n \in ROI} \frac{E_{n}^{C_i}}{E_{n}^{C_1} + E_{n}^{C_2}},
\]

The sum over all channels is unity. i.e.,

\[
\sum_{n=1}^{128} \eta_{n}^{C_1}(t) + \eta_{n}^{C_2}(t) = 1.
\]
Cognitive Activity Measures

- ERP Power and Energy
- Attention Based Load-Switching
“Attention-Switching”

- **Attention Based Activity**
  - Cognitive activity over the AAN tends toward a minimum value at nearly the same time that activity over the PAN reaches its maximal value.

- **Load-Switching Time**
  - We assess *neocortical interaction times* by determining the latency for extrema of the regional activity values. The load-switching time is the difference in the maximal PAN and minimal AAN latency values, i.e.,

\[
    t_{ls} = t_{PAN_{max}} - t_{AAN_{min}}
\]
“Neocortical Circuits”

- Compare Latency of Activity Extrema in ROIs
  - A straightforward model of cognition wherein access to memory (TPJ) precedes stimulus processing (PAN) and task execution (AAN) illustrates that truth and deception utilize similar neocortical circuits with different timing.

<table>
<thead>
<tr>
<th>EXP</th>
<th>TASK</th>
<th>PAN MAX (ms)</th>
<th>TPJ MIN (ms)</th>
<th>AAN MIN (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CT</td>
<td>200</td>
<td>124</td>
<td>244</td>
</tr>
<tr>
<td>1</td>
<td>CL</td>
<td>188</td>
<td>136</td>
<td>276</td>
</tr>
<tr>
<td>2</td>
<td>CT</td>
<td>220</td>
<td>132</td>
<td>248</td>
</tr>
<tr>
<td>2</td>
<td>CL</td>
<td>208</td>
<td>136</td>
<td>276</td>
</tr>
</tbody>
</table>

- It is plausible to assert that attention switching between executive control functions in the frontal areas and access to language processing skills in posterior regions may account for this.
Continuing Efforts

- The Misinformation Paradigm
- A Quantum Hypothesis
The man put out his cigarette in an ashtray next to a copy of _______ magazine.

Vogue  Elle
Participants (N=8) in two groups were shown 70 slides in which a repairman comes into an office and steals several items. Afterward participants performed a filler task for five minutes. Then they read a narrative of the slides to “refresh” their memories. The narratives each misnamed two items from slides.

Early executive control (AAN) appears evident in our pilot data for Deceivers. Responding deceptively to misinformation still takes longer: Ratio = -60/40.
200 trials of the two-stimulus type were presented to a participant \( N=1 \). On 100 trials he was directed to lie (\textbf{LIE}) and on 100 trials he was directed to tell the truth (\textbf{TRUE}); balanced across these trials were 100 trials in which he told a lie after telling the truth or told the truth after telling a lie (\textbf{SWITCH}), and 100 trials in which lies followed lies or truths followed truths (\textbf{NO SWITCH}). \( Z \) (Gaussian T/F) statistic images were threshold weighted using clusters determined by \( z > 2.3 \) and a (corrected) cluster significance threshold of \( p=0.05 \). All scans collected at 3T with Siemens Magnetom Trio System.

- Greater activation during deceptive no-switch trials occurs in Brodmann’s Area 10, and suggests that multiple internal comparisons during deception.
- Greater activations in PAN suggest there will be differences when one switches between lying and truth telling.
- Greater activations related specifically to switching to lie, suggests areas that may allocate resources during deception.
- Greater activation in right frontal and regions of the precuneous during deceptive trials than truthful trials.
Continuing Efforts

- The Misinformation Paradigm
- A Quantum Hypothesis
Theory Meets Application

- Refine ROIs (18 Regions)
  - Assess Load-Switching Times
- Portable Deception Detection?
  - Collect ERPs with a Palm Pilot
  - How robust is the effect?

[Graphs showing data on deception detection]

-[g.MOBIIlab (www.CortechSolutions.com)]
A Quantum Hypothesis

What do these ERP Energies look like?

What is their wavelength?

What is transition rate among states?

Subject Classification?
Transition Rate – Cognitive Activity Phase Diagrams

\[ \Delta E_k = E(t_{k+1}) - E(t_k) \equiv h \frac{c}{\lambda_k} \]

\[ \eta_k^{(C)}(t) = \sum_{m \in R} p_m^{(C)} E_m^{(C)} / p_n^{(C)} E_n^{(C)} \]

\[ E_n^{C_1} = E_n^{C_1} + k_B T \ln \left( \frac{N_n^{C_1}}{N_n^{C_1}} \right) \]
Acknowledgements

- Dr. Jennifer Vendemia
  - CO-PI (USAMRAA)
    - Testified before the senate to help get the $!
    - Finds time to write awesome sci-fi too!

- Graduate Students
  - Psychology
    - Rob Buzan, Eric Green, Scott Meek, Michelle Phillips
  - Physics
    - Richard Foster