Emotional and Cognitive Decision-Making Modeled using EEG Imaging

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Southeast Biofeedback and Clinical Neuroscience Association
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Description

• This workshop will present current results using an EEG-based activation model that takes advantage of sLORETA imaging of frontal regions of interest, in combination with a structured stimulus and analysis procedure. We will present event-related brain activation data from a range of participants and situations including nonclinical, clinical, and forensic populations. The results illustrate instantaneous patterns of frontal activation that are indicative of individual emotional and decision-making patterns.
Objectives

• Recognize EEG patterns associated with specific emotional responses and states.
• Explain how the frontal cortex participates in the creation of emotional responses to stimuli.
• Describe the brain locations involved in positive and negative emotional responses in normal processes.
• Describe aberrations in normal brain processing, that can lead to abnormal emotional responses or states.
• Explain how different interventions have differing effects on the dynamic control of emotion.
Background

- Frontal asymmetry associated with mood
- Davidson, Rosenfeld, Baehr
- Left = “positive”
- Right = “negative”
- Past work used alpha asymmetry
- New work is using gamma
- Not trait only – now looking at state responses to stimuli
- Incorporation of decision-making model
New Methods

• Use of Gamma (activation) rather than Alpha (relaxation)
• Use of sLORETA (brodmann, ROI) rather than surface
• Note that many frontal dipoles are lateral (parallel to surface)
• Use of event-related paradigms
• Separation of state and trait characteristics
• Development of emotional and ethical decision-making methods
ISF Correlation Coefficients- ISF Signal

Correlation Coefficients between ISF (0.002 – 0.05) and conventional band magnitudes

100 seconds of data sampled 8 times/second

Left Parietal area using sLORETA ROI estimation

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Toward an Operational Model of Decision Making, Emotional Regulation, and Mental Health Impact

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ABSTRACT
Current brain research increasingly reveals the underlying mechanisms and processes of human behavior, cognition, and emotion. In addition to being of interest to a wide range of scientists, educators, and professionals, as well as laypeople, brain-based models are of particular value in a clinical setting. Psychiatrists, psychologists, counselors, and other mental health professionals are in need of operational models that integrate recent findings in the physical, cognitive, and emotional domains, and offer a common language for interdisciplinary understanding and communication. Based on individual traits, predispositions, and responses to stimuli, we can begin to identify emotional and behavioral pathways and mental processing patterns. The purpose of this article is to present a brain-path activation model to understand individual differences in decision making and psychopathology. The first section discusses the role of frontal lobe electroencephalography (EEG) asymmetry, summarizes state- and trait-based models of decision making, and provides a more complex analysis that supplements the traditional simple left-right brain model. Key components of the new model are the introduction of right hemisphere parallel and left hemisphere serial scanning in rendering decisions, and the proposition of pathways that incorporate both past experiences as well as future implications into the decision process. Main attributes of each decision-making mechanism are provided. The second section applies the model within the realm of clinical mental health as a tool to understand specific human behavior and pathology. Applications include general and chronic anxiety, depression, paranoia, risk taking, and the pathways employed when well-functioning operational integration is observed. Finally, specific applications such as meditation and mindfulness are offered to facilitate positive functioning. (Adv Mind Body Med. 2014;28(4):18-33.)
Event-Related EEG Imaging
Key emotional regulatory centers
primary and secondary emotional response
Emotional sensation -> emotional perception
Emotional Response to Stimuli
A relative balance in beta and gamma waves creating asymmetry in the activity in the frontal lobes is associated with normal mood and emotional state. Increased activity within the left prefrontal cortex can indicate an elevation in mood and positive feelings. De-activation in the left prefrontal cortex alone or in combination with an increase in activity within the right prefrontal cortex can suggest the opposite, being associated with depressive mood or negative thoughts. Instances in which only the right prefrontal cortex activates quickly with an strong increase in gamma waves suggest a strong dislike or avoidance of a particular exposure.

Example Images:
These example images depict the amount of gamma activity present in subjects frontal lobes as they are exposed to different stimuli invoking neutral, positive, and negative responses.

Raw EEG and event markers
The event stimuli being reviewed in this case is: 
“A lover’s embrace.”

*Each event marker represents a single stimulus.

Aquired EEG: An increase in both beta and gamma waves can be seen when also inspecting the aquired EEG of the event.
Baseline Mood State Depressed

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<table>
<thead>
<tr>
<th>Reaction to Chocolate Chip Cookies</th>
<th>Aversion to Beer</th>
</tr>
</thead>
</table>

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Physical Health Assessment

Initial Results

NOEL

Red Meat

Running

JENNY

Fresh Fruit

Body Fat

Obese People

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Data Sample: Enthusiastic

- **Spanish** (1st Language)
- **English** (2nd Language)
- **French** (3rd Language)
- **German** (4th Language)

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Select questions from depression section

- Sleep
- Deep Fried Foods
- Chocolate Chip Cookies
- Smoking
Response to “Dogs”
Gardening and Guns

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# Left-Right Functionality

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Parallel</th>
<th>Serial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemisphere</td>
<td>Right</td>
<td>Left</td>
</tr>
<tr>
<td>Data Representation</td>
<td>Holographic</td>
<td>Sequential</td>
</tr>
<tr>
<td>Perspective</td>
<td>Visuo-spatial</td>
<td>Temporo-linguistic</td>
</tr>
<tr>
<td>Analogous to</td>
<td>Pictures</td>
<td>Music, speech</td>
</tr>
<tr>
<td>Context</td>
<td>Global (this always…)</td>
<td>Local (in this particular case,…)</td>
</tr>
<tr>
<td>Orientation</td>
<td>Patterns</td>
<td>Lists</td>
</tr>
<tr>
<td>Tasking</td>
<td>Multitasking (may be stressful)</td>
<td>Single-tasking (focused, calm)</td>
</tr>
<tr>
<td>Perspective</td>
<td>Past</td>
<td>Future</td>
</tr>
<tr>
<td>Dimension</td>
<td>Space</td>
<td>Time</td>
</tr>
<tr>
<td>Attribute</td>
<td>Patterns (spatial)</td>
<td>Causality</td>
</tr>
<tr>
<td>Memory</td>
<td>Past patterns, “punishment”</td>
<td>Cause/effect experiences, rules</td>
</tr>
<tr>
<td>Mode of analysis</td>
<td>“the last time…”</td>
<td>“what if…”</td>
</tr>
<tr>
<td>Result</td>
<td>Avoid / Attack</td>
<td>Approach / Remain</td>
</tr>
</tbody>
</table>

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Left-Right Mood Regulation

<table>
<thead>
<tr>
<th>Emotion</th>
<th>Negative</th>
<th>Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision cycle</td>
<td>1 analysis</td>
<td>Sequence of n analyses</td>
</tr>
<tr>
<td>Activation sequence</td>
<td>1 “found”</td>
<td>N “not founds” then done</td>
</tr>
<tr>
<td>Priority</td>
<td>Detecting danger</td>
<td>Ensuring safety</td>
</tr>
<tr>
<td>Decision priority</td>
<td>Immediate</td>
<td>Long-term</td>
</tr>
<tr>
<td>Approach</td>
<td>Tactical, here &amp; now</td>
<td>Strategic, future outcomes</td>
</tr>
<tr>
<td>Equation parameters</td>
<td>Pp+1, Ppf=1</td>
<td>Ps+=1, Psf=1</td>
</tr>
<tr>
<td>Associated behaviors</td>
<td>Run; fight</td>
<td>Breathe; build</td>
</tr>
<tr>
<td>Neurotransmitter</td>
<td>Adrenalin</td>
<td>Serotonin</td>
</tr>
</tbody>
</table>

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Mesial – Dorsolateral distinction

- Mesial – primary emotional sensation
  - Fundamental, initial sense – "nice" or "not nice"
- Dorsolateral – secondary emotional perception
  - Integrated with memory
  - Put into context
  - Can turn interpretation “around”

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Emotional Decision Making Model
(why we downtrain alpha on the left dorsolateral frontal lobe)
Happiness as a process
Paranoid

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Chronic Anxiety

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General Anxiety

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Quantitative Model
Use of characteristic qualitative/quantitative types

<table>
<thead>
<tr>
<th>Emotion Vector</th>
<th>EV = (Rp, Pp+, Ppf, Ppd, Pps, Rs, Ps+, Psf, Psd, Psp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rp</td>
<td>Rate of parallel processing: patterns/second enters primary emotional sensation</td>
</tr>
<tr>
<td>Pp+</td>
<td>Probability that parallel processing will pass information on to secondary processing</td>
</tr>
<tr>
<td>Ppf</td>
<td>Probability that parallel processing with return &quot;found&quot; based on importance level of input</td>
</tr>
<tr>
<td>Ppd</td>
<td>Probability that parallel processing will return &quot;done&quot; after processing a pattern</td>
</tr>
<tr>
<td>Pps</td>
<td>Probability that parallel processing will pass finding on to serial processing if &quot;found&quot;</td>
</tr>
<tr>
<td>Rs</td>
<td>Rate of serial processing: scans/second enters primary emotional sensation</td>
</tr>
<tr>
<td>Ps+</td>
<td>Probability that serial processing will pass information on to secondary processing</td>
</tr>
<tr>
<td>Psf</td>
<td>Probability that serial processing with return &quot;found&quot; based on importance level of input</td>
</tr>
<tr>
<td>Psd</td>
<td>Probability that serial processing will return &quot;done&quot; after processing a pattern</td>
</tr>
<tr>
<td>Psp</td>
<td>Probability that serial processing will pass finding on to parallel processing if &quot;found&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Examples</th>
<th>Rp</th>
<th>Pp+</th>
<th>Ppf</th>
<th>Ppd</th>
<th>Pps</th>
<th>Rs</th>
<th>Ps+</th>
<th>Psf</th>
<th>Psd</th>
<th>Psp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Happy</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Paranoid</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Anxious</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>trauma</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

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Forensic Emotional Imaging

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Emotional Transition Model

Rs Rp Ls Lp

0000 - non-engaged
0001 - feels good
0010 - happy-risk taking
0011 - happy now + safe
0100 - feels bad
0101 - mixed feel
0110 - feels bad but might be ok
0111 - happy inspite of neg. feel
1000 - looking for danger
1001 -
1010 - mixed judgement
1011 -
1100 - avoid full
1101 - negative inspite of + feel
1110 -
1111 - full alert

Crystals in time
easier to remember bad experiences
build up in time need to mix +, - start
with Davidson Q&A as age, more
(-)'s can pile up.

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Patterns & Interactions

Full Avoid ("Defending you life")

Person A

Person B

Modeling Reinforcement Extinction Aversion

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HAIDT’S SOCIAL INITIATIVE MODEL

Modeling, how counselor reacts will shape client response pattern, reframe, challenge, reflect, etc.

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EMOTIONAL DECISION MODEL
EDM-2
4 COMPONENTS - S4

<table>
<thead>
<tr>
<th>Rs Rp</th>
<th>Ls Lp</th>
<th>00</th>
<th>01</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>NOT ACTIVATED</td>
<td>PRIMARY + PLEASURE &quot;Like&quot;</td>
<td>SECONDARY + SAFE &quot;Good&quot;</td>
<td>FULL + APPROACH &quot;Like+Good&quot;</td>
<td></td>
</tr>
<tr>
<td>01</td>
<td>PRIMARY &quot;Don't Like&quot; UNPLEASANT</td>
<td>PRIMARY + &amp;- &quot;Suspend Feeling&quot;</td>
<td>PRIMARY + SECONDARY+ &quot;Don't Like&quot; &quot;Good&quot; (DIETING)</td>
<td>PRIMARY + &amp;- SECONDARY+ &quot;Mixed Feeling&quot; &quot;Good&quot; FOLLOW HEAD</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>SECONDARY &quot;Not Good&quot; UNSAFE</td>
<td>SECONDARY + &amp;- &quot;Suspend Judgement&quot;</td>
<td>PRIMARY + &amp;- SECONDARY+ &quot;Like&quot; &quot;Mixed Judgement&quot; FOLLOW HEART</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>FULL &quot;Don't Like&quot;</td>
<td>FULL + &amp;- &quot;Not Good&quot; &quot;Not Good&quot; FOLLOW HEAD</td>
<td>FULL ACTIVATED + &amp;-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Insights

• It takes more work to be positive than to be negative
• Specific emotional/cognitive skills necessary for healthy mood
• Balance of negativity an positivity is essential for effective functioning
• Specific deviations associated with particular emotional/behavioral styles
• Response to stimuli as important (more important) than resting state
• Model for client-clinician interaction, other interactions

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New Hardware / Software
Emotional Decision-Making App
Summary

• Dynamical model of mood regulation and emotional decision-making
• Multicomponent model, distributed functions
• Identification of specific excesses/deficits
• Activation / deactivation
• Connectivity / isolation
• Correlation with EEG parameters, power, connectivity
• Methods for assessment, treatment, treatment effectiveness
• Recognition of trait and state individuality

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