Hierarchical Auditory Prediction

I predict, therefore I am

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Background

The Bayesian brain
generates predictions about the sensorium
Is evolutionarily driven to make better and cleverer predictions

Hierarchy of increasing complexity
Each perceptual level makes predictions And learns from its mistakes (prediction error)

Current thinking
Maybe the brain is Bayes-optimal

\[
p(\text{beliefs}_\text{new}) = p(\text{data}_\text{new}) \cdot p(\text{beliefs}_\text{old})
\]
Hierarchical Auditory Prediction

Layers I-III: Encode pred. err. and cause EEG

Layers V-VI: Encode predictions

Attention is the precision of prediction

Friston, 2008
EEG Experiment I: Laterality

Chennu et al., Journal of Neuroscience, 2013
**MMN (100-300ms)**
- Negativity indexing early prediction error
- Pre-attentional
- **Diminished** by top-down attention

**P300 (300-600ms)**
- Positivity indexing late prediction error
- Accompanies conscious perception
- **Sharpened** by top-down attention

**CNV (-600-0ms)**
- Slow drift that indexes *expectation*
- Modulates attentional focus to facilitate perception

*Chennu et al., 2013*
Dehaene et al., 1998; Wacongne et al., 2011; Chennu et al., 2013

Sources

* Dehaene et al., 1998; Wacongne et al., 2011; Chennu et al., 2013
Experiment II: Omissions

Chennu et al. In prep, 2014
Omission-evoked Responses

Modulating Attention

- attend auditory
- attend visual

Modulating Expectation

- expected omission
- random omission
Dynamic Causal Modelling

Mismatch Negativity

Omission
Interim Summary

Hierarchical predictive coding theory

- Prediction errors flow upward
- Predictions (shaped by expectations) flow downward
- Attention as the precision of prediction

Integrating common ERP components

- The MMN is pre-attentional and diminished by expectation
- The P300 is attention-dependant and enhanced by expectation
- The CNV is a fine-grained marker of this top-down expectation

Within this framework

- The omission is a response to the absence of an expected stimulus
- Hence a pure index of the expectation-driven prediction signal
- Which projects downward and interacts with attention
Applications in brain injury

• Prognosis
• Diagnosis
The Challenge

Acute CRS-R* 8-13 days post-ictus

Outcome CRS-R 60 days post-ictus

* CRS-R = Coma Recovery Scale - Revised

Silva and Chennu et al., in prep

Plum and Posner, 1982; Braakman et al., 1988; Choi et al., 1988; Yingling et al., 1990
Coma Patient Session 1 (CRS-R = 2)

Local Effect (100-300ms)

Coma Patient Session 2 (CRS-R = 2)

Global Effect (300-600ms)

* Statistically significant with single-subject non-parametric global field power (GFP) analysis.
Acute Prognosis

Statistically significant with single-subject non-parametric **global field power (GFP)** analysis.

**Behaviour**

- **Acute CRS-R** vs. **Outcome CRS-R**

**Local Effect**

- **GFP Score**
  - $r = 0.92$
  - $p < 0.0001$
Chronic Diagnosis

Bekinschtein et al., 2009; Faugeras et al., 2012
Why Does Prediction Matter?

For prognosis
Early prediction is temporally and spatially localised
Requires few cortical microcircuits
Presages the reestablishment of many more…

For diagnosis
Late prediction is temporally and spatially distributed
Engages many disparate microcircuits
Results in interoceptive state
externally akin to consciousness

Canonical Microcircuit for Predictive Coding
Bastos et al., 2012
Future Directions

Theoretical
Modeling failures of hierarchical prediction
Detailed understanding of the link between prediction and consciousness

Clinical
Quantitative control of EEG quality
Closed-loop calibration of derived ERP scores
Single-trial decoding, complexity analysis
Thanks!

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Prognosis

Primary Auditory Effect

\( p > 0.05 \)

Interaural Global Effect

\( p > 0.05 \)
Prognosis

Monaural Local Effect

$r = 0.63$

$p < 0.03$

Monaural Global Effect

$p > 0.05$