Hierarchical Temporal Intentionality

John Thornton
Institute for Integrated and Intelligent Systems
and School of Humanities
Griffith University Gold Coast
The Basic Message

• Phenomenology has a central role to play in the development of a correct theory of brain function, not just in providing empirical observational data to test a given theory, but in guiding the process of theory formation in the first place.

• For, if certain processes in the brain are absolutely (i.e. immediately) given to consciousness, and there is a lawful mapping between the abstract structure inherent in those processes and the structure of conscious experience, it should be possible to characterise the structure of those physical processes on the basis of a proper phenomenological analysis.
The Temporal Structure of Experience

• The unified overarching structure of conscious experience is that of a *temporal flow* within which *enduring* self-identical *objects* appear.

• Each moment of temporal experience appears within a *temporal horizon* of the immediate past and future.

• It is an *experience of succession* (flowing continuity) *not* a point like *succession of experiences*.
A Phenomenological Example
The Crow Call
Phase 0

INTENTION

NOW
Phase 2

NOW

A − a − a − a − a − r − g − h

Intentions

Intentional Object

Retention

Primal Impression

Protention

Phase 2
Phase 3

INENTION

Intentional Object

Retention

Primal Impression

Protention

A − a − a − a − a − r − g − h
Phase 4

INTENTION

Intentional Object

Retention

Primal Impression

NOW

A - a - a - a - a - r - g - h
Phase 5

INTENTION

Intentional Object

Retention

NOW

A – a – a – a – a – r – g – h
Intentional Object

INTENTION

Enduring Crow Call
(Intentional Object)

SYNTHESIS OF IDENTITY

STREAM OF CONSCIOUSNESS
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Call 1

NOW A – a
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Call 1

NOW

A − a − a − a − a
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression ← Protention

Crow Call Series

Call 1

A -- a -- a -- a -- a -- r

NOW
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Call 1

NOW

A -- a -- a -- a -- a -- r -- g -- h
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Call 1

A→ a→ a→ a→ a→ a→ r→ g→ h
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Call 1

Call 2

NOW

A -- a -- a -- a -- a -- a -- r -- g -- h A -- a
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Retention

Primal Impression

Protention

Call 1

Call 2

NOW

A – a – a – a – a – a – r – g – h A – a – a – a – a
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Retention

Primal Impression

Protention

Call 1

Call 2

NOW

A → a → a → a → a → r → g → h A → a → a → a → a → r
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Retention

Primal Impression

Protention

Call 1

Call 2

NOW

A → a → a → a → a → r → g → h
A → a → a → a → a → a → r → g → h
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Call 1

Call 2

NOW

A − a − a − a − a − r − g − h  A − a − a − a − a − r − g − h
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Call 1

Call 2

Call 3

A -- a -- a -- a -- a -- r -- g -- h A -- a -- a -- a -- a -- r -- g -- h A -- a

NOW
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Call 1

Call 2

Call 3

NOW

A — a — a — a — a — a — r — g — h  A — a — a — a — a — a — r — g — h  A — a — a — a — a
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention ← Primal Impression → Protention

Crow Call Series

Call 1

Call 2

Call 3

NOW

A -- a -- a -- a -- r -- g -- h A -- a -- a -- a -- r -- g -- h A -- a -- a -- a -- a -- r
Hierarchical Intentionality

Auditory Perceptual Intention

Retention ← Primal Impression → Protention

Crow Call Series

Retention

Call 1

Call 2

Call 3

NOW

A → a → a → a → a → r → g → h    A → a → a → a → a → r → g → h    A → a → a → a → a → r → g → h
Hierarchical Intentionality

AUDITORY PERCEPTUAL INTENTION

Retention of Crow Call Series

Primal Impression

Protention

Next Call Series

Primal Impression

Protention

Call 1

NOW

A − a
Hierarchical Temporal Memory

- Hierarchical Temporal Memory (HTM) is a model of neocortical function developed by Jeff Hawkins and colleagues from 2004 up to the present.
- It shares many key ideas from the hierarchical predictive coding model:
  - Neocortical processing is hierarchically structured error minimisation that infers causes from sensory input.
  - The neocortex implements the same underlying process across its entire area.
  - Stored ‘knowledge’ extracted from past experience is used to make predictions concerning future actions and perceptions.
  - Perception and action are determined via a process of reciprocal predictive feedback between regions within dynamically activated hierarchies.
HTM’s Innovation

• The function of neocortical minicolumns is not only to resolve mismatches between bottom-up input and top-down feedback but also to learn temporal sequences in the input via the formation of short range lateral connections
  
  – Hierarchical predictive coding learns a generative model of the world in order to predict what will happen now – producing a succession of experiences
  
  – An HTM encodes patterns of column activation that retain past activity and predict future activity – producing an experience of succession that agrees with the phenomenology
Example HTM Implementation: The Cortical Crow Call
Hebbian Learning

First impression

Synapses forming

Prediction

Key:
- Pink cells are active
- Red cells are active and learning
- Blue cells were active in the last phase
- Green cells predict activity in a future phase
Hebbian Sequence Learning

Green axons connect cells active in the last phase with cells predicting activity in a future phase – thereby extending the sequence one step further back into the past.

Key:
- **Red** cells are active from bottom up input
- **Blue** cells were active from bottom up in the last phase
- **Green** cells are predicting being active from bottom up input in the next phase
Hierarchical Synthesis

Hierarchical Level $n + 1$

Hierarchical Level $n$
Hierarchical Synthesis

Hierarchical Level \( n + 1 \)

Hierarchical Level \( n \)
Hierarchical Synthesis

Hierarchical Level $n + 1$

Hierarchical Level $n$
Hierarchical Levels

AUDITORY PERCEPTUAL INTENTION

Crow Call Series

Level $n + 2$

Retention

Primal

Impression

Protention

Level $n + 1$

Call 1

Level $n$

Call 2

Call 3

STREAM OF CONSCIOUSNESS

A - a - a - a - o - r - g - h

NOW
Mapping to Temporal Structure

- **Blue** cortical column activity is the intersection of recent feed-forward activity with top-down feedback = retention
- **Red** cortical column activity is the intersection of current feed-forward activity with top-down feedback = primal impression
- **Green** cortical column activity is the intersection of lateral excitation with top-down feedback = protention
- In this way, the tripartite Husserlian structure of temporal consciousness can be mapped to the various activity states of the cortical columns that comprise a currently active intention-process
- This mapping occurs at every level of the neocortex – forming a unified hierarchical structure of temporal consciousness
Mapping to Intentionality

• Intentionality corresponds with the entire top-down process that specifies (at each level) the higher level temporally extended form of what is unfolding at the lower level

• Intentionality is **hierarchically temporally structured**:  
  – At level $n$ I intend *birdsong*, at $n – 1$ the *crow call series*, at level $n – 2$ *crow call 2*, at level $n – 3$ *phase 2 of crow call 2*  
  – For the intentional objects at each level I intend the same structure of retention/primal impression/protention  
  – The higher the level, the less the detail, and the greater the temporal scope
Mapping to Perception

• Perceptual experience corresponds with the meeting of top down feedback (intentionality) with bottom up (synthesised) sensory input

• The temporally enduring harmonious fulfillment of the predictions of top down and bottom up processes specifies that these processes correspond with something actual

• This correspondence is a correspondence of forms: it is one and the same crow-call-form expressed in the column activity and in the activity of the air molecules
Summary

• Hierarchical Temporal Memory extends Hierarchical Predictive Coding by proposing that the basic encoding units of the neocortex are temporal sequences – and not spatial instants ‘strung together’ by neocortical activity to form sequences over time
• In this talk we have shown how the HTM model can be mapped onto the basic structures disclosed by Husserl’s phenomenological analysis of temporal consciousness
• Hence we have renamed the model Hierarchical Temporal Intentionality
• We take this correspondence of the phenomenology of temporal consciousness with the neuroscience of cortical functioning to be evidence that the basic principles of neocortical function are beginning to emerge...