ATTENTION & CONSCIOUSNESS AS CONTROL SYSTEMS IN THE BRAIN

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HOW IS CONSCIOUSNESS CREATED IN THE BRAIN?

- CONSCIOUSNESS = HIGHEST LEVEL OF COGNITION
- ATTENTION IS THE GATE TO CONSCIOUSNESS
- NEUROSCIENCE UNDERSTANDING ATTENTION (sensory/motor/reflective self)
- WHAT ATTENTION MODEL => CONSCIOUSNESS?
CONTENTS

1) NATURE OF ATTENTION
2) CONTROL MODEL FOR ATTENTION
3) SENSORY-MOTOR ATTENTION CONTROL MODEL
4) FROM ATTENTION TO CONSCIOUSNESS
5) THE STRUCTURE OF CONSCIOUSNESS
6) THE CODAM MODEL FOR CONSCIOUSNESS (PRS)
7) RELATION TO OTHER MODELS
8) OVERALL CONCLUSIONS
1. NATURE OF ATTENTION

- ATTENTION = SELECTION OF PART OF SCENE FOR ANALYSIS
  (acts as ‘filter’ on input)

- AMPLIFICATION OF ATTENDED + INHIBITION OF DISTRACTORS
  (in sensory & motor cortices, & higher sites)

- DETECT ATTENTION CONTROL SIGNAL IN NETWORK OF CORTICAL REGIONS
ATTENTION: SITES WITH 2 FUNCTIONS:

* AMPLIFY/DECREASE SENSORY INPUT

* CREATE CONTROL SIGNALS FOR THIS:
“Attention-related activity in frontal and parietal areas does not reflect attentional modulation of visually evoked responses, but rather the attentional operations themselves.”
(Kastner & Ungerleider, 2001)
Shifting Attention Network (Corbetta, PNAS 95:831, 1998) (remove controlled regions)

Fig. 1. Sagittal PET section, 25 mm left of midline, of group-averaged subtraction images between shifting attention and central detection tasks.
Motor Attention Amplification
(Binkofski et al, J Neurophysiol 2003)
INCREASED ACTIVITY IN MOTOR CORTICAL SITES BY ATTENTION TO RESPONSE
Binkofski et al, J Neurophysiol 2003
Attention at Single Cell Level

- Modulation of V4 Cell Response
  (Maunsell et al, J NSci 19:431, 1999)

**FIG. 2.** Data from one V4 cell showing enhanced response in the attended mode (black) relative to the unattended mode (gray).
CONCLUSIONS ON ATTENTION

- 2 SORTS OF ATTENTION CONTROL:
  - sensory
  - motor

- DATA ⇒ 3 SEVERAL CONTROL MODULES
  (attention signal generator, goals, buffer/forward model, monitor)

- EXPLORE BY DETAILED CONTROL MODEL
2. CONTROL MODEL FOR ATTENTION

- ENGINEERING CONTROL THEORY WELL DEVELOPED ->
- USE AS ‘FUNCTIONAL MODEL’ FOR VISUAL ATTENTION

CONTROL MODEL:

- Goals
  - PFC
  - Monitor (errors)
  - PL/ACG

- Attention Controller
  - PL
  - Forward (predicts)
  - PFC/PL

- Visual CX
  - TL/VLPFC
  - Objects

- (move attention)
CONTROL MODEL COMPONENTS:

Inverse model controller (IMC)
- state(t)
- desired state(t)
- control(t)

Forward model/observer
- state(t)
- control(t)
- state(t+1)
- state(t+1)
CONTROL MODEL COMPONENTS:

Forward Output Model

\[
\text{state}(t) \quad \text{estimated sensory feedback (t +1)}
\]

Error Monitor Module

\[
\text{state}(t) \quad \text{error}(t) \\
\text{desired state}(t)
\]
<table>
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<tr>
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<th>CX SITE</th>
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<td>MON</td>
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<td>VAL</td>
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<td>100/130</td>
<td>Sem/Act</td>
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Posner benefit task: how much does attention help?
Posner benefit results

![Diagram showing reaction time (in ms) for valid and invalid cue validity conditions. The graph indicates a trend of increased reaction time for invalid cues compared to valid cues.]
SIMULATION OF SENSORY ATTENTION MOVEMENT (with M Rogers: Neural Networks 15:309-326 (2002))

Figure of Invalid Cueing (Posner Benefit - exogenous)  Figure of Invalid Cueing (Posner Benefit - endogenous)

Figure of Validity Benefit as function of CTOA
3. SENSORY-MOTOR ATTENTION CONTROL MODEL (+NF)

- ATTENTION CRUCIAL TO MOTOR LEARNING
- ∃ SEPARATION OF
  - spatial attention in R hemisphere: ∃ ICM_{AV}
  - motor attention in L hemisphere: ∃ ICM_{AM}
- ATTENTION GOALS (in DLPFC) & IMC (in PCx)
- MOTOR CONTROL CODES FOR MOTOR INTENTIONS:
  - object->action
- LEARN MOTOR ATTENTION CONTROL & GOAL MODULES
  (by DA/ACh/NA error-based from CX/subCX)
Left-Hemisphere Dominance for Actions (Schluter et al, 2001)
Outline of Visuo-Motor Control System
(JGT + NF, IJCNN’03)
Motor Preparation Paradigm
(Motor Posner Benefit)

- Determine benefit of motor attention (intention) by pre-cueing required response
- Two hexagons, one above, one below, fixation point
- Border of one brightens as a pre-cue
- Centre of same (valid) or other (invalid) hexagon brightens for response to separate buttons
- RT measured in valid and invalid cases
SIMULATING R-H & L-H DEFICITS IN RUSHWORTH et al. USING SIMULINK ARCHITECTURE
Rushworth et al. Neuropsychologia, 35 (9), 1261-1273

Group mean RTs (Rushworth et al.)

Group mean RTs (simulated)
CONCLUSIONS ON ATTENTION

- 2 SORTS OF ATTENTION CONTROL:
  * sensory
  * motor

- DATA ⟷ 3 SEVERAL CONTROL MODULES
  (attention signal generator, goals, buffer/forward model, monitor)

- EXPLORE BY DETAILED CONTROL MODEL
4. FROM ATTENTION TO CONSCIOUSNESS

- ‘Gorilla in the Midst’ (Igor)
- **Neglect**: Not focus attention => no awareness  
  (loss of parietal (TPJ/IPL/STS) by stroke)
- **Attentional Blink**: Not move attention from T1 to T2 in RSVP stream => no awareness (300msecs after T1)
- **Inattentional Blindness**: Inability to detect unattended change in environment (but semantic brain activations)
- “The further function of attention is to allow selected perceptual information a foothold in consciousness”  
  (Shapiro et al TICS, ‘97)
- **Must search in Attention for Consciousness**
5. CONSCIOUSNESS

- GUIDANCE TO CROSS MIND/BRAIN GAP

- ‘INNER SELF’ NOT IN MAIN-STREAM
  ‘CONSCIOUSNESS’ STUDIES: NO GAP
  (Reject by Descartes, Hume, West Cog Sci)

- BUT IN WESTERN PHENOMENOLOGY
  (Husserl, Sartre, Merlau-Ponty, Franck, Zahavi, Parnas)
Reflection Model of Self
(M Frank1964/ Zahavi, 1999)*

- Self-awareness: reflection R on perception P
- P to be grasped by act of reflection R, as = R
- R = P + belong to same stream of consciousness
- Difficulty: how does R (lacking self-awareness) know P & R belong to same stream?
- Needs further act of reflection ⇒ 8 regress
- Or R already self-aware ⇒ circular
- Also applies to HOT/HOP theories of consciousness
2 PARTS TO CONSCIOUSNESS
1) Non-relational Pre-Reflective Self (PRS)
2) Relational, contentful consciousness of External World

PROBLEM OF INTERACTION
Pre-reflective ‘Inner’ Self ↔ Outer World

PRS ≠ Body (Proprioception)
(claimed by Husserl, Merleau-Ponty, Gallagher: data shows not)
NEW STATES OBSERVED UNDER MEDITATION
PCE (pure conscious experience); DMS (dual mystical state); OMS (oceanic mystical state)

PCE HAS NO CONTENT
‘Reports of pure consciousness suggest that, despite the absence of mental content, the subjects knew that they remained aware throughout the period of pure consciousness (R Forman, 1999)
‘…awareness to recognize itself, without the mediation of conceptual objects’ (Andreason, 2000)
PCE has distinct physiological correlates, separating it from other ‘altered’ states (sleep, drug induced, OOB, hypnosis…)

Numerous experiments on PCE =>
- $\alpha$ wave synchronisation
- skin conduction $\uparrow$
- respiratory rate $\downarrow$
- brain imaging in PCE have shown
  - PFC/Parietal $\uparrow$
  - Sensory areas $\downarrow$
CONCLUDE:

- **TWO COMPONENTS TO CONSCIOUSNESS:**
  1) Contentful
  2) Pre-reflective (PRS): no content

- **TIMING NON-TRIVIAL** (gappy)

- **EXTEND PRS TO PCE, THEN DMS, THEN OMS?**

- **NEED TO EXTEND ATTENTION TO PRS/PCE**
6. THE CODAM MODEL FOR CONSCIOUSNESS


- SPLIT WM (forward model) INTO CD & INPUT COMPONENTS

- USES FAST RESPONSE FROM CD='OWNER'

![Diagram of CODAM model with nodes labeled Goals, Attention Controller, Cortex, Monitor, WMcd, WMinput, and Objects/Features. Connections illustrate the flow of information between these components.]
EXPLORE MENTAL STATES BY ANALOGY WITH THEIR KNOWN FEATURES
(eg light as EM radiation by Maxwell)

QUALITATIVE FEATURES ONLY
Transparency, Closeness, Temporality,...
(‘Race for Consciousness’ MIT Press, ’99; C&C, 01)

CODAM MODEL DYNAMICS PREDICTIONS:
WMcd created early (150-200 msecs) on attention movement: identify with N2 (AAI + JGT, IJCNN03)
MEG Measurement of N2
(conjunction search, Hopf et al 02)
The PRS & CODAM

- CODAM MODEL AVOIDS HUME’S PROBLEM
- Divide Attention Signal, use as Label for Self
- LABEL => INFALLIBILITY OF ‘MINE’
- USES THE WMcd SIGNAL TO:
  a) Support attention amplification of input
  b) Provide early signal to attend more to goal
- FUNCTION OF CONSCIOUSNESS:
  SPEED UP ATTENTION MOVEMENT
- CODAM=> PCE BY TRAINING
Attentional Blink

- AB FROM RSVP (90-100ms lag between stimuli)
- LATER PRODUCTION OF SENSORY BUFFER SIGNAL = P3 (expected at 350-500 msecs, lost in AB)
- RELATED TO T1 INHIBITION (cause of AB, Shapiro et al)
- DETAILED MODEL OF AB DEVELOPED (N Fragopanagos, S Kockelkoren & JGT)
AB Error Levels

(a) T2 Accuracy (%Correct)

(b) T2 Accuracy (%Correct)
Nature of AB

- Depends on mask M1 for T1 & M2 for T2
- No M1 ⇒ much reduced AB
- No M2 ⇒ no AB
- Need to ‘protect’ T1 against M1 damage, cause more inhibition of T2
AB Architecture: monitor achieves damage limitation in IMC
WM potential for T2 at different lags (dashed=attn T2; full=attn to T1, then T2)
ERP SEQUENCE IN AB
Results for AB

- Obtain correct AB(M1) v reduced AB(no M1)
- Needs goals as endogenous (steady bias) + exogenous (trigger)
- AB by two mechanisms: a) inhibition of all others on IMC by WMcd b) monitor boost of T1 and inhibition of all others on IMC
- New MEG results becoming available supporting ‘compensation’ structure (+BBSRC)
CONCLUSIONS TO SECTION 6

- SPLIT WM BUFFER INTO
  * Sensory buffer (WM Sens)
  * Corollary discharge buffer (WMcd)
- WM Sens = ‘content of consciousness’
- WMcd = ‘ownership of that content’
  = pre-reflective self
- WMcd signal = N2/P2 at 180-240ms?
- WMcd signal = ‘echo’ of attention move command signal
7. RELATION TO OTHER MODELS OF CONSCIOUSNESS

- 40 HERTZ: bind object reps (at local level)
- MACHINE CONSCIOUSNESS: Use ‘Self-Management’ (in PFC): BUT No loss of consciousness when lose PFC => not basic
- PROTO-CONSCIOUSNESS (BODY): Not suff (nor nec) by proprio/ kinesthesia (loss)
- GLOBAL WORKSPACE: Available for report OK, but no ‘blackboard style (Woods & Grafman 03)
- WESTERN COG-SCIENCE: No ‘Ghost’ => No Owner => No problem (no consciousness!)
8 OVERALL CONCLUSIONS

- PROPOSE INNER SELF THROUGH ATTENTION
  (as gappy PRS/ Owner)
- ANN MODEL OF ‘INNER SELF’ PROPOSED
  (CODAM model, using CD of attention movement)
  - EXPAINS PRS
    (Not body, but by flow WMcd ⇒ WMsens)
- FURTHER ANALYSIS OF CODAM
  (By simulation and experiment, for range of paradigm, especially N2/P2; extend to mental disease)
Program to Follow

1) BUILD IT (ABC) – by cluster/grid computing – ABACCUS
(component models ready: Cb/HC/PFC/CODAM/Limbic)

2) CONFIRM CODAM & COMPONENT MODULES
(temporal dynamics: emotional AB/neglect/PRP)
(goal, monitor, controller, cd buffer)

3) SIMULATE DEFICITS (AB in schizophrenia, etc)

4) RELATE TO MENTAL DISEASES
(schizophrenia, OCD, autism, AD)
COLLEAGUES

- **King’s College London/Lobal Technologies**
  N Taylor (EPSRC Attention), M Hartley
  (Building LAD brain: PFC+Cb+HC+CX interacting)

- **King’s College London:**
  N Fragopanagos (IPNN/EC: ERMIS emotional recognition systems; Attentional simulation: BBSRC Emotional AB),
  S Kasderides (EC: ORESTEIA: Attentional agents/GNOSYS: cog robots)
  S Kockelkoren (Amsterdam: AB + other attention simulations)

- **BSI, Tokyo:**
  A Ioannides, L-C Liu (MEG: attention paradigms)
  + Dusseldorf/Oxford/Bangor/Birkbeck/GNOSYS