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 <u>THE</u> GATE TO CONSCIOUSNESS**
- **NEUROSCIENCE UNDERSTANDING ATTENTION (sensory/motor/reflective self)**
- **<u>WHAT ATTENTION MODEL => CONSCIOUSNESS?</u>**

CONTENTS

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**

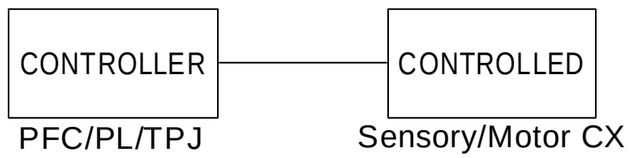
- **ATTENTION: SITES WITH 2 FUNCTIONS:**

  * **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)

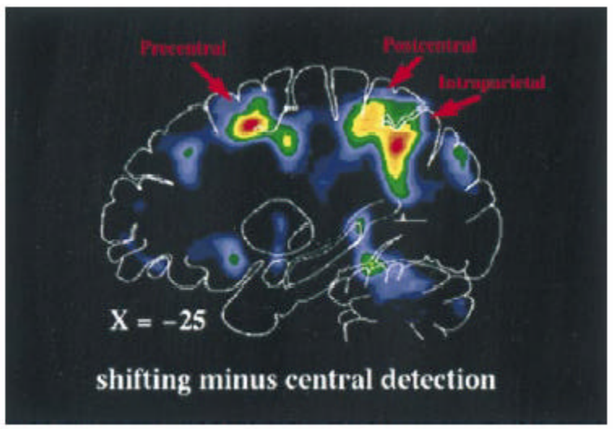
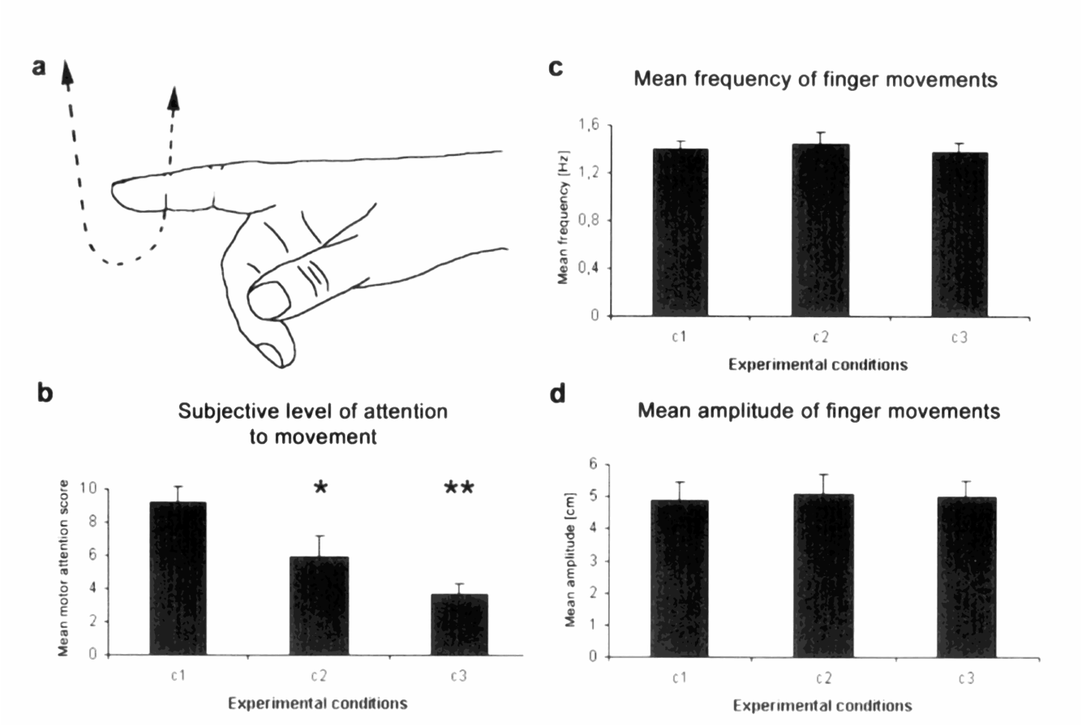


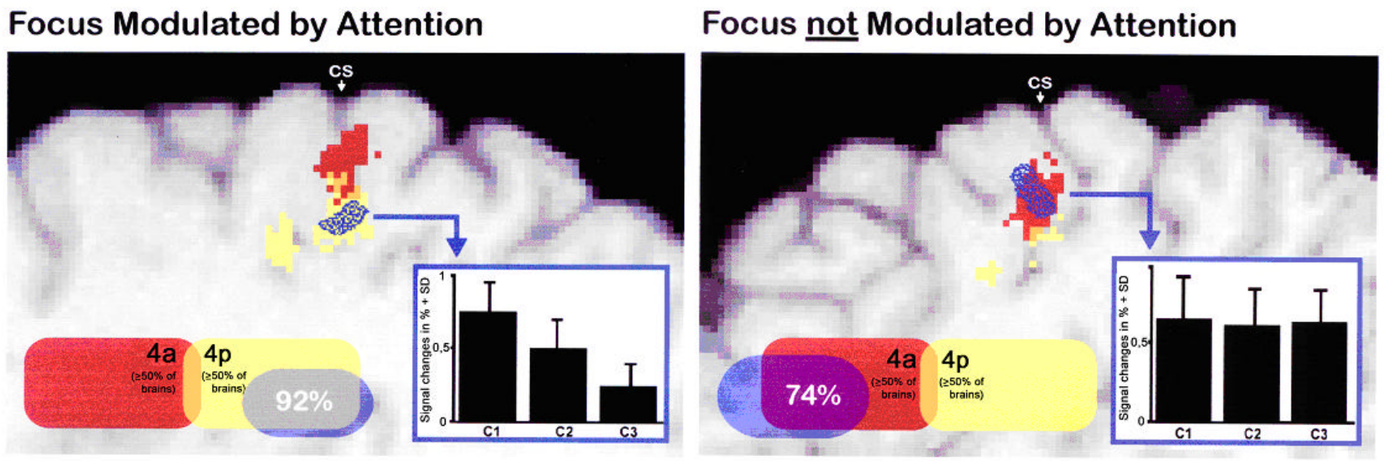
FIG. 1. Sagittal PET section, 25 mm left of midline, of group-averaged subtraction image between shifting-attention and central-detection tasks.

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)**

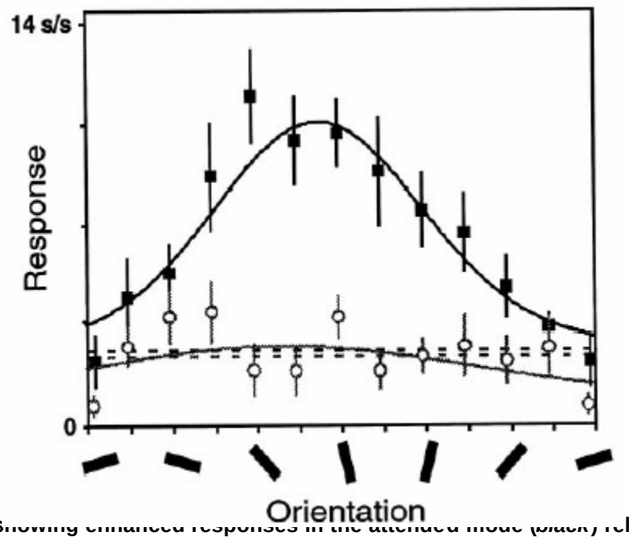


FIG. 2. Data from one V4 cell showing enhanced responses in the attended mode (*black*) relative to the unattended mode (*gray*)

CONCLUSIONS ON ATTENTION

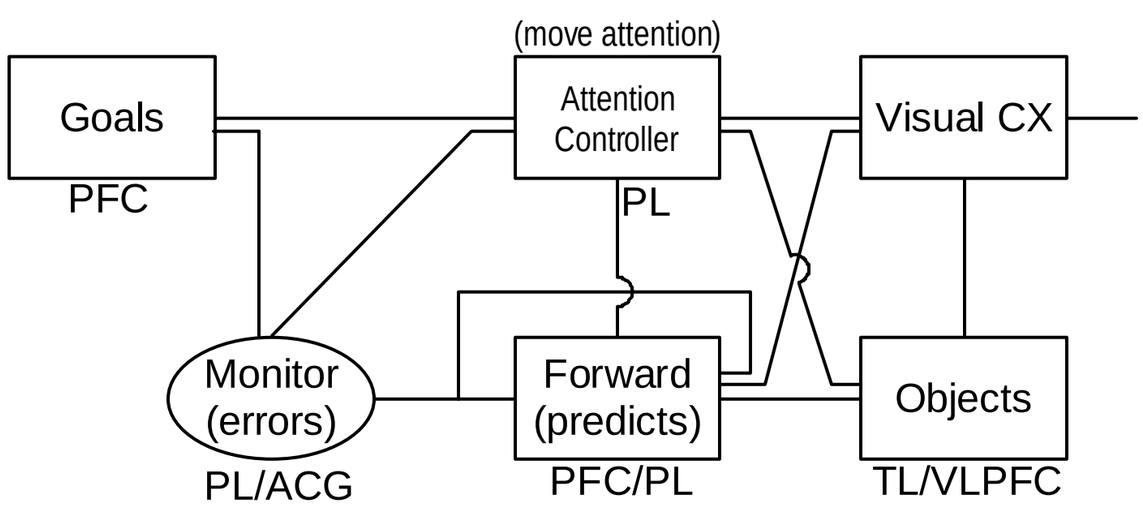
- $ **2 SORTS OF ATTENTION CONTROL:**
  - ***sensory**
  - ***motor**

- **DATA ⇨ $ SEVERAL CONTROL MODULES (attention signal generator, goals, buffer/forward model, monitor)**

- **EXPLORE BY DETAILED CONTROL MODEL**

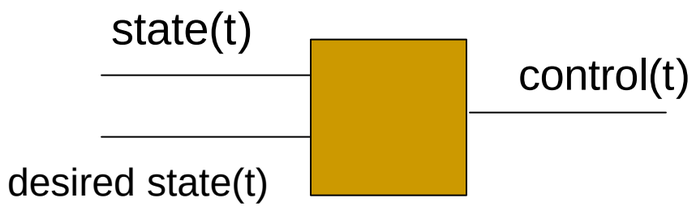
2. CONTROL MODEL FOR ATTENTION

- **ENGINEERING CONTROL THEORY WELL DEVELOPED -→**
- **USE AS 'FUNCTIONAL MODEL' FOR VISUAL ATTENTION CONTROL MODEL:**

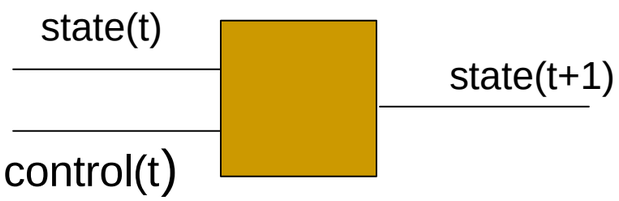


CONTROL MODEL COMPONENTS:

Inverse model controller (IMC)

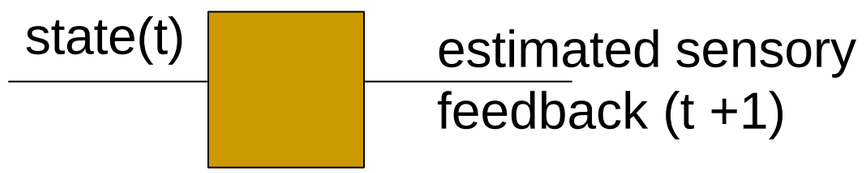


Forward model/ observer

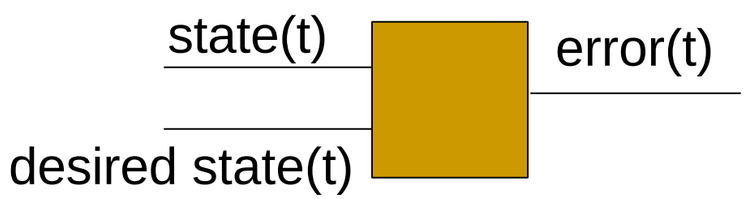


CONTROL MODEL COMPONENTS:

Forward Output Model



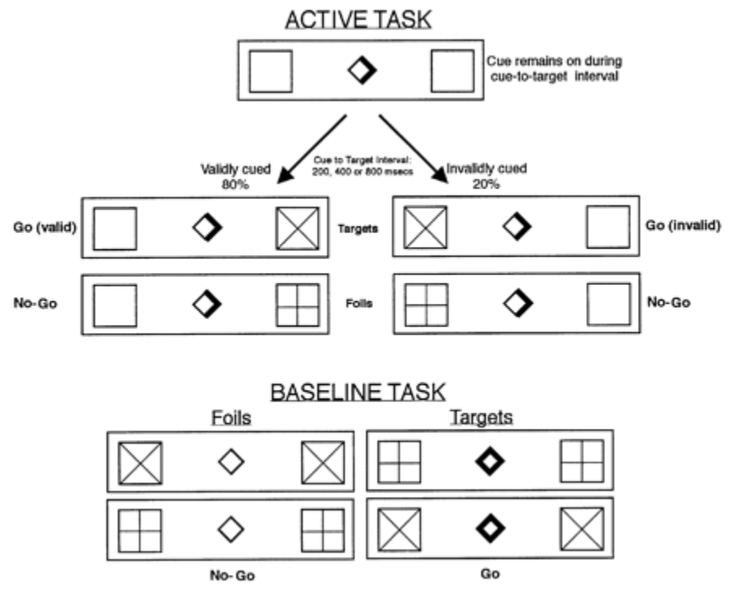
Error Monitor Module



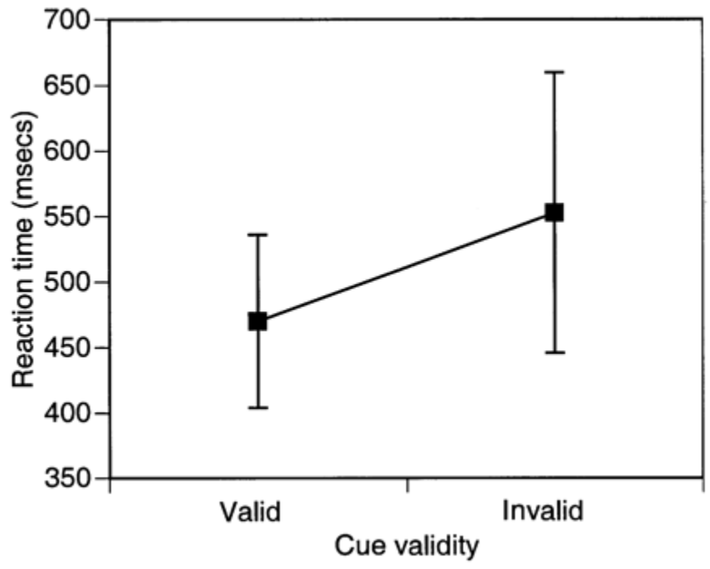
Brain Evidence for Control Modules

MODULE	CX SITE	TIMING	REPRES.	FUNCTION
IN	V1-V4	50ms C1	Features	Earl proc
OBJ	FG	170/400	Columns	Semant
IMC	IPS/SPL	200 N2	Spa/Obj	Control
WMsens	Parietal	300	WM map	Report
GoalEx	VPFCx	120-140	Spa/Obj	Exog
GoalEnd	8/9/46	For task	Spa/Obj	Endog
MON	CG	ERN	Error	Correct
VAL	AM/OFC	100/130	Sem/Act	Valence

Posner benefit task:
how much does attention help?



Posner benefit results



- **SIMULATION OF SENSORY ATTENTION MOVEMENT (with M Rogers: Neural Networks 15:309-326 (2002))**

Figure of Invalid Cueing (Posner Benefit - exogenous)

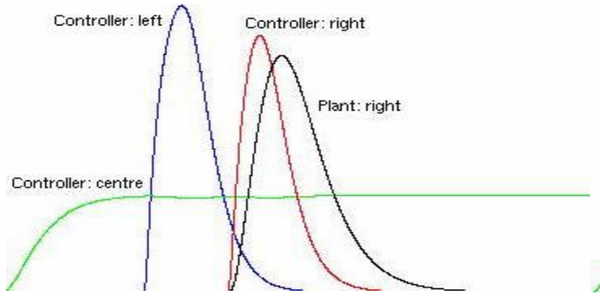


Figure of Invalid Cueing (Posner Benefit - endogenous)

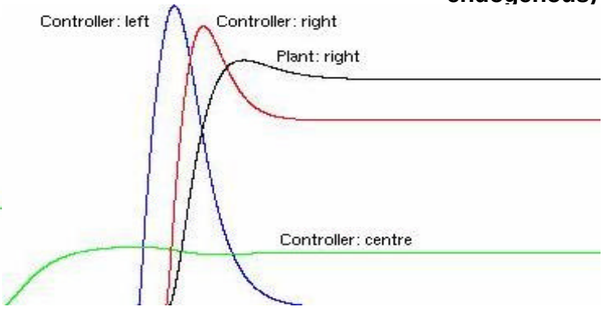
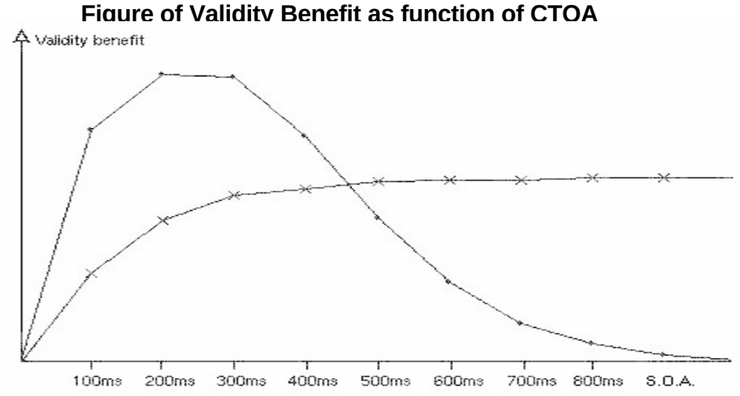


Figure of Validity Benefit as function of CTOA



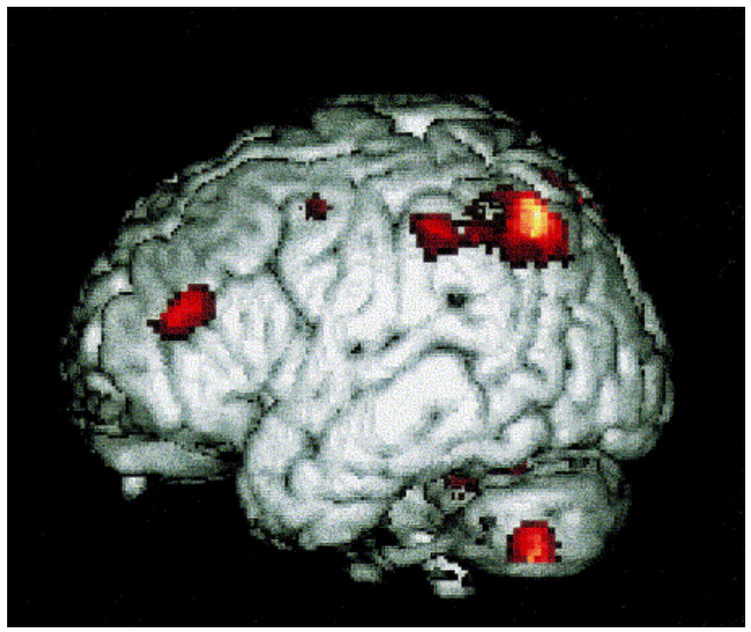
3. SENSORY-MOTOR ATTENTION CONTROL MODEL (+NF)

- **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:**

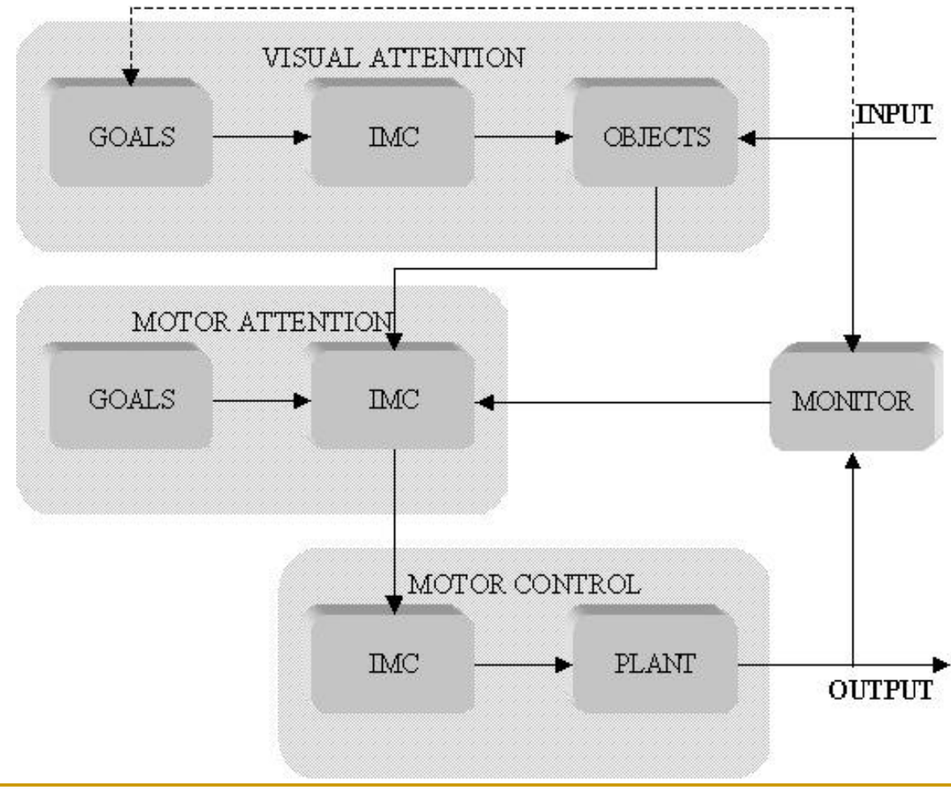
  object->action
- **LEARN MOTOR ATTENTION CONTROL & GOAL MODULES**

  (by DA/ACh/NA error-based from CX/subCX)

Left-Hemisphere Dominance for Actions (Schluter et al, ;01)



Outline of Visuo-Motor Control System (JGT + NF, IJCNN'03)

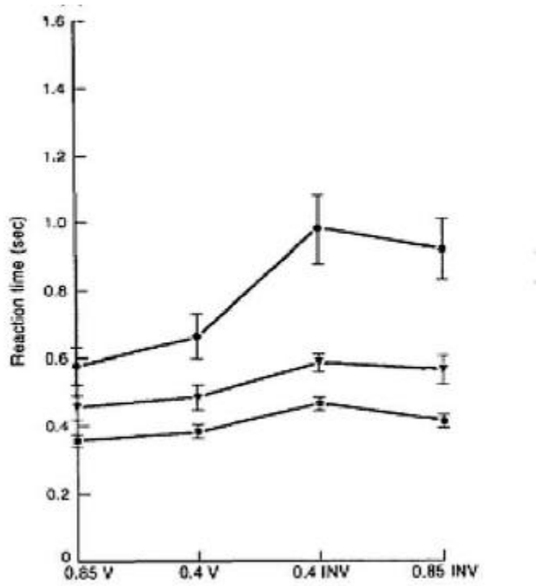


Motor Preparation Paradigm (Motor Posner Benefit)

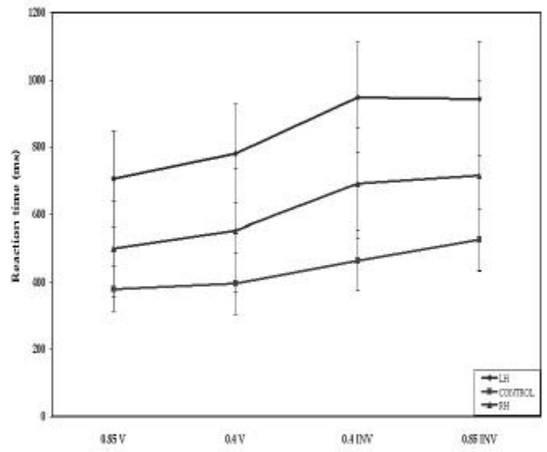
- **Determine benefit of motor attention (intention) by pre-cueing required response**
- **Two hexagons, one above, one below, fixation point**
- **Border of one brightens as a pre-cue**
- **Centre of same (valid) or other (invalid) hexagon brightens for response to separate buttons**
- **RT measured 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 ⇨ $ 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 =>**
  - ***a wave synchronisation**
  - ***skin conduction -**
  - ***respiratory rate –**
  - ***brain imaging in PCE have shown**
    - **PFC/Parietal -**
    - **Sensory areas –**

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?**

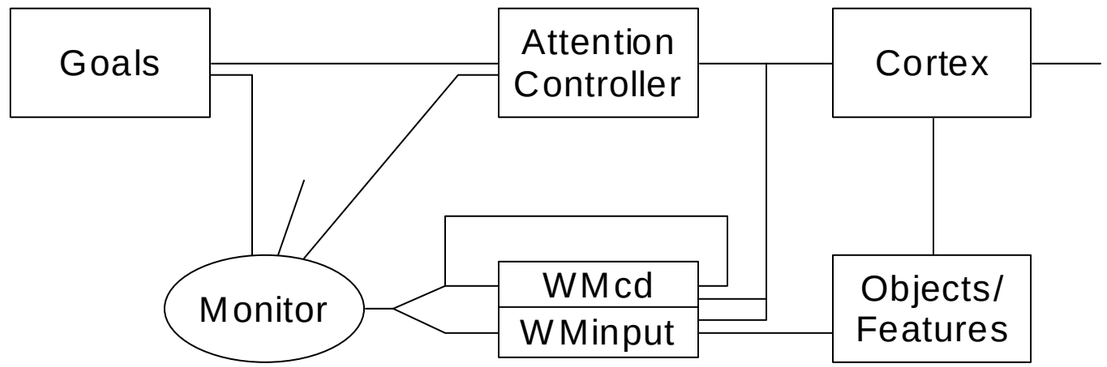
- **NEED TO EXTEND ATTENTION TO PRS/PCE**

6. THE CODAM MODEL FOR CONSCIOUSNESS

- **CODAM (Corollary Discharge of Attention Movement) MODEL (JGT: CODAM: TICS 6:206-210, 2002; JCS 9:3-22, 2002; NSci Abstr 26:2231, #839.3, 2000; Prog Neurobiol 2003)**

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

- **USES FAST RESPONSE FROM CD='OWNER'**



- **EXPLORE MENTAL STATES BY ANALOGY WITH THEIR KNOWN FEATURES**

  (eg light as EM radiation by Maxwell)

- **QUALITATIVE FEATURES ONLY**

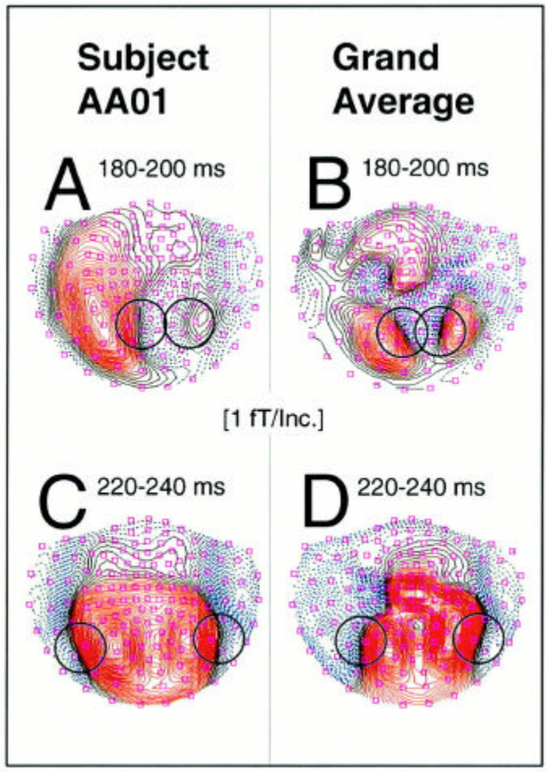
  Transparency, Closeness, Temporality,...

  (‘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)



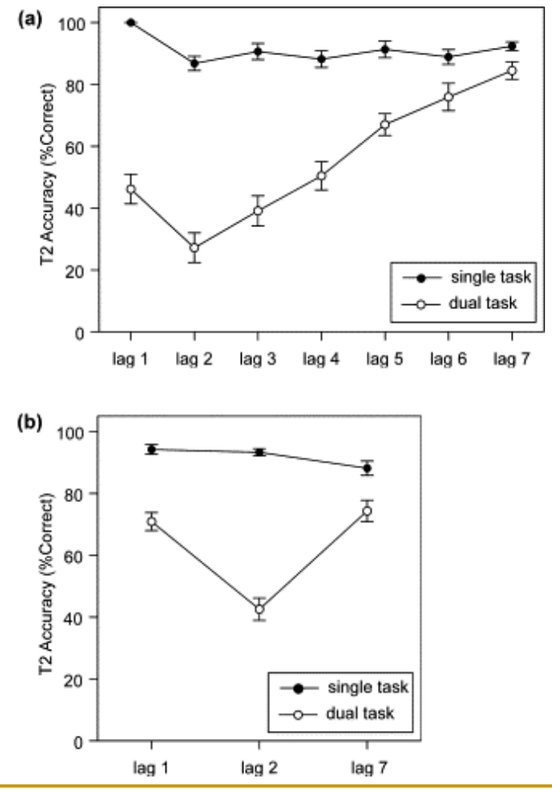
The PRS & CODAM

- **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)**

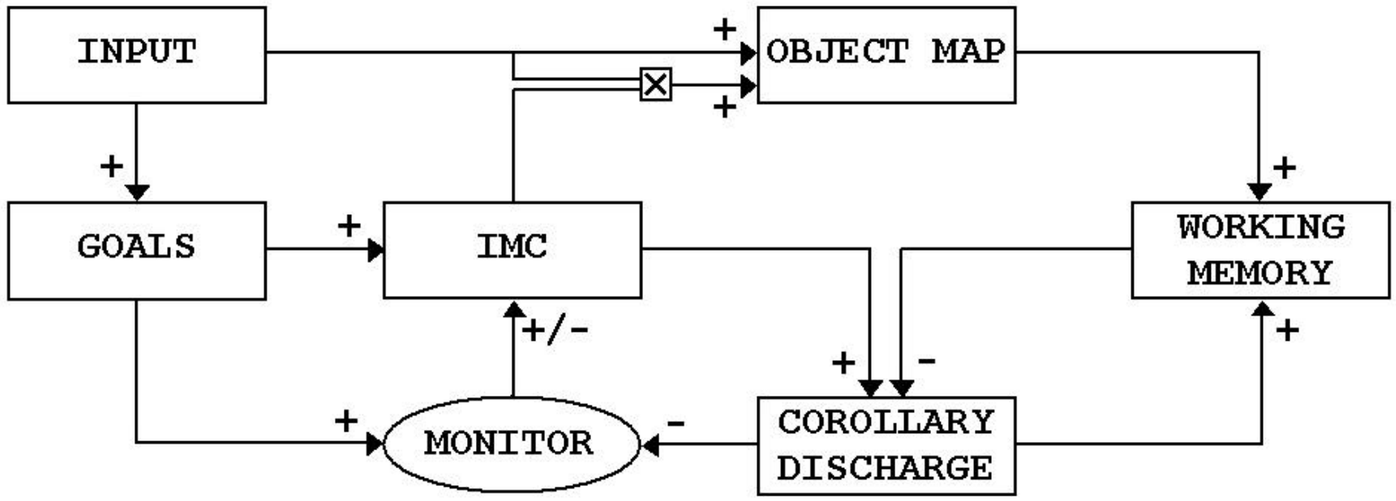
AB Error Levels



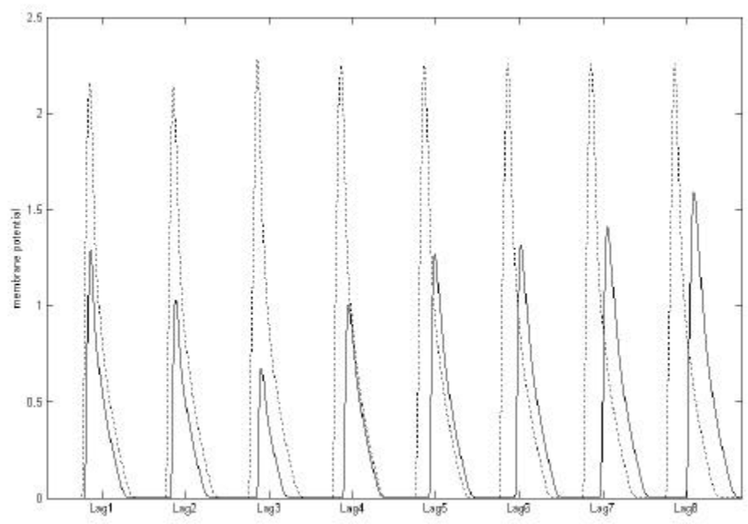
Nature of AB

- 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

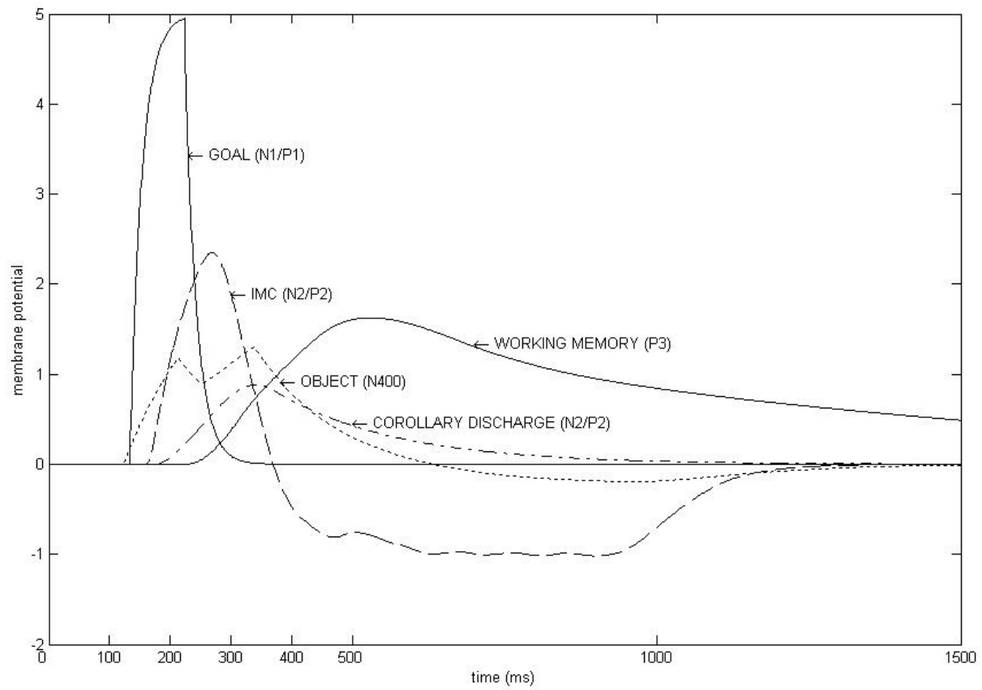
AB Architecture: monitor achieves damage limitation in IMC



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 at180-240ms?
- WMcd signal = ‘echo’ of attention move command signal

7. RELATIONS 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***