

Lecture 4: The Neural Correlate of Consciousness (NCC)

Introduction

- What is consciousness?

The physiological basis of subjective awareness remains a genuine scientific mystery (the ‘hard’ problem of consciousness)

Definition of the function of consciousness;

Definition of the ‘NCC’.

- Does visual consciousness equate to awareness of all information encoded in each area?

No, because some neural encodings demonstrably do not reach awareness:-

- Destruction of V1 may leave residual ‘blindsight’ - possibly contingent on LGN output bypassing V1^[1]
- The existence of monocular neurons in V1;
- The phenomenon of ‘change blindness’.

Hence, the NCC concerns those neural encodings/operations that do result in awareness.

NCC may be classified by brain location...

The retina is outside the NCC:

- Hallucinatory perception possible within retinally blindfield (Charles Bonnet syndrome)^[2]

Is area V1 outside the NCC ? YES ! ^[3] (1995)

- YES (?) - Blindsight ‘Riddoch’ syndrome, awareness of motion in the absence of visual sensation proper ^[4]
- YES (?) – Absence of motion vision caused by V5 lesion, despite V1 being intact ^[5]
- NO (?) - TMS to V1 modulates feedback from V5 & motion percept ^[6]
- YES (?) - This is still an active debate (2011)... (awareness v non-awareness fails to modulate V1 activity)^[7]

The feedback hypothesis of NCC

- Theory of recurrent (or re-entrant) processing being the key ingredient of NCC (Lamme, 2006)
 - The time course of the neural activity in V1 correlating with correct detection of a target is consistent with an origin in feedback from higher areas ^[8]

The NCC as an experimental paradigm, or strategy

- Use of bistable percepts , e.g. binocular rivalry (BR)
 - Bistable perceptual phenomena imply neural competition
 - Physiological phenomena correlating with bistable percepts may be part of NCC
 - Eye-switching experiment implies an important component of BR is ‘image rivalry’, in addition to eye rivalry ^[9]

Correlates of rivalry in BOLD signal (fMRI studies of human perception)

- Face v house paradigm reveals focus of activity switching between FFA and PPA ^[10]
- Vertical v horizontal grating reveals rivalrous activity in V1 (use blindspot to resolve ocular-specific activity)^[11]
- Higher resolution scan shows rivalrous activity in LGN, as well as V1^[12]

Correlates of rivalry in single unit activity

- Increasing proportion of bistable modulating neurons through areas V1, V4 and IT cortex; ^[13, 14]
 - Also found in human hippocampal formation ^[15]
 - Note use of ‘flash-suppression’ version of rivalry
 - Single neuron activity recorded in monkey LGN not reported to modulate with rivalry ^[16]
 - Local Field Potential (LFP) signal recorded in V1 also modulates, at ‘gamma’ frequencies ^[17]
 - LFP is more analogous to BOLD signal recorded by fMRI

Synchronisation of neural activity as a hallmark of NCC

- Computational models explore synchrony as a means of sculpting rivalrous, hierarchic neural networks specific for each image, contingent upon dichoptic stimulation of each eye^[18]
- Fluctuations in gamma band of human EEG correlate with rivalrous percepts ^[19]
 - Gamma fluctuations are constrained by slower ‘theta’ band oscillations

General Reading

Consciousness and neuroscience.

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On the neural correlates of visual perception.

Pollen, *Cerebral Cortex*. 9: 4-19 (1999).

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Zeki, *Trends in Cognitive Sciences*. 7: 214-218. (2003).

Psychophysical magic: rendering the visible 'invisible'.

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Towards a true neural stance on consciousness.

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Decoding visual consciousness from human brain signals.

Haynes, *Trends in Cognitive Sciences*. 13: 194-202 (2009).

Neuronal gamma-band synchronization as a fundamental process in cortical computation.

Fries, *Annual Review of Neuroscience*. 32: 209-224 (2009).

Can binocular rivalry reveal neural correlates of consciousness?

Blake *et al.* *Philos Trans R Soc Lond B Biol Sci*. 369: 20130211 (2014).

Neural correlates of consciousness: progress and problems.

Koch *et al.* *Nature Reviews Neuroscience* 17: 307-321 (2016)

Website with abundant practical & theoretical information (& video) all regarding retinal rivalry:

www.jove.com/details.stp?id=2030

Specific Sources

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Schmid *et al.*, **Nature**. **466**: 373-377 (2010).

2. *Visual hallucinations in eye disease.*

ffytche, **Current Opinion in Neurology**. **22**: 28-35 (2009).

3. *Are we aware of neural activity in primary visual cortex?*

Crick and Koch, **Nature**. **375**: 121-123 (1995).

4. *The primary visual cortex, and feedback to it, are not necessary for conscious vision.*

Fytche and Zeki, **Brain**. **134**: 247-257 (2011).

5. *The brain activity related to residual motion vision in a patient with bilateral lesions of V5.*

Shipp *et al.*, **Brain**. **117**: 1023-1038 (1994).

6. *Striate cortex (V1) activity gates awareness of motion.*

Silvanto *et al.*, **Nature Neuroscience**. **8**: 143-144 (2005).

7. *Attention but not awareness modulates the BOLD signal in the human V1 during binocular suppression.*

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8. *Two distinct modes of sensory processing observed in monkey primary visual cortex (V1).*

Super *et al.*, **Nature Neuroscience**. **4**: 304-10. (2001).

9. *What is rivalling during binocular rivalry?*

Logothetis *et al.*, **Nature**. **380**: 621-624 (1996).

10. *Binocular rivalry and visual awareness in human extrastriate cortex.*

Tong *et al.*, **Neuron**. **21**: 753-759 (1998).

11. *Interocular rivalry revealed in the human cortical blind-spot representation.*

Tong and Engel, **Nature**. **411**: 195-199 (2001).

12. *Eye-specific effects of binocular rivalry in the human lateral geniculate nucleus.*

Haynes *et al.*, **Nature**. **438**: 496-499 (2005).

13. *Activity changes in early visual cortex reflect monkeys' percepts during binocular rivalry.*
Leopold and Logothetis, **Nature**. **379**: 549-553 (1996).
14. *The role of temporal cortical areas in perceptual organization.*
Sheinberg and Logothetis, **Proceedings of the National Academy of Sciences of the USA**. **94**: 3408-3413 (1997).
15. *Single-neuron correlates of subjective vision in the human medial temporal lobe.*
Kreiman *et al.*, **Proceedings of the National Academy of Sciences USA**. **99**: 8378-8383 (2002).
16. *No binocular rivalry in the LGN of alert macaque monkeys.*
Lehky and Maunsell, **Vision Research**. **36**: 1225-3124 (1996).
17. *The role of the primary visual cortex in perceptual suppression of salient visual stimuli.*
Keliris *et al.*, **Journal of Neuroscience**. **30**: 12353-12365 (2010).
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19. *Rhythms of consciousness: binocular rivalry reveals large-scale oscillatory network dynamics mediating visual perception.*
Doesburg *et al.*, **PLoS One**. **4**: e6142 (2009).