Progress in the search for the neural correlates of visual awareness

Michael Pitts
Psychology Department
Reed College
Portland, OR, USA
Neural correlates of consciousness (NCC)

“Most of the processing that goes on in your brain is unconscious. Some of the results of that processing, you become conscious of. What’s the difference between the two?”

Francis Crick (1999)

NCC = “The minimal set of neuronal events jointly sufficient for a specific conscious percept”

Theories of consciousness

Sensory Theories
e.g. recurrent processing theory
- phenomenal vs. access
- “rich” awareness
- NCC: early (< 300ms)
- NCC: localized “flicker”
- attention & awareness fully dissociable

Cognitive Theories
e.g. global neuronal workspace theory
- access-only
- “sparse” awareness
- NCC: late (> 300ms)
- NCC: wide-spread “ignition”
- attention necessary for awareness

N. Block  V. Lamme  D. Dennett  S. Dehaene
We See More Than We Can Report: “Cost Free” Color Phenomenality Outside Focal Attention

Zohar Z. Bronfman¹,², Noam Brezis¹, Hilla Jacobson³, and Marius Usher¹,⁴,⁵,⁶
¹School of Psychology, Tel Aviv University; ²The Cohn Institute for the History and Philosophy of Science and Ideas, Tel Aviv University; ³Cognitive and Brain Sciences, Ben-Gurion University of the Negev; ⁴Sagol School of Neuroscience, Tel Aviv University; ⁵Wadham College, University of Oxford; and ⁶Department of Experimental Psychology, University of Oxford

Spotlights

Rich conscious perception outside focal attention

Ned Block
New York University, New York, NY, USA
awareness without attention... really?

Inattentinal Blindness

“Failure to perceive unexpected objects or events because attention is focused on another task”

Mack & Rock (1998); Simons & Chabris (1999)
Methods: single task

Single task (report cued row)

Critical trial (change in color variance)

3-AFC: Which looks most like what you just saw?

Jackson-Nielsen, Cohen, & Pitts (under review)
Methods: dual task (color)

Dual task (cued row + color)

Critical trial (change in size variance)

3-AFC: Which looks most like what you just saw?

Jackson-Nielsen, Cohen, & Pitts (under review)
Methods: dual task (size)

Dual task
(cued row + size)

Letters?
Size?

Jackson-Nielsen, Cohen, & Pitts (under review)
Results

Jackson-Nielsen, Cohen, & Pitts (under review)
**Results Exp 2: low-to-high**

![Bar graph showing the number of letters in working memory across single and dual task conditions.](image)

- Single task: 3.75 letters (84%)
- Dual task color: 3.5 letters (67%)
- Dual task size: 3.5 letters (67%)

**Critical Trial 1**

- Correct choice (high color diversity): 46%
- Incorrect (low color diversity): 33%
- Incorrect (foil; low color div.): 21%

**Critical Trial 2**

- Correct choice (high size diversity): 58%
- Incorrect (low size diversity): 21%
- Incorrect (foil; low size div.): 21%

Jackson-Nielsen, Cohen, & Pitts (under review)
awareness without attention... really?

No

- attention is necessary for awareness (single dissociation)

Why the discrepancy between our results and Bronfman et al.’s?

- subjects learned over 100’s of trials to distribute a small (non-zero) amount of attention to non-cued rows to perceive color diversity
Theories of consciousness

Sensory Theories
e.g. recurrent processing theory
• phenomenal vs. access
• “rich” awareness
• NCC: early (< 300ms)
• NCC: localized “flicker”
• attention & awareness fully dissociable

Cognitive Theories
e.g. global neuronal workspace theory
• access-only
• “sparse” awareness
• NCC: late (> 300ms)
• NCC: wide-spread “ignition”
• attention necessary for awareness

0 1
Theories of consciousness

Sensory Theories
e.g. recurrent processing theory
  • phenomenal vs. access
  • “rich” awareness
  • NCC: early (< 300ms)
  • NCC: localized “flicker”
  • attention & awareness fully dissociable

Cognitive Theories
e.g. global neuronal workspace theory
  • access-only
  • “sparse” awareness
  • NCC: late (> 300ms)
  • NCC: wide-spread “ignition”
  • attention necessary for awareness
The 3 NCC problem

When contrasting “aware” vs. “unaware” conditions, it’s difficult to distinguish...

- Preconscious processing (necessary but not sufficient)
  &
- Postperceptual processing (sufficient but not necessary)
  from...
- NCC-proper (necessary and sufficient)
Paradigm comparison

Backward masking paradigm (at threshold)

Task = after each trial report percept, e.g. did you see a word (Y/N)? can you identify the word?

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Mask</th>
<th>Preconscious processing</th>
<th>Conscious perception</th>
<th>Postperceptual processing</th>
<th>Plan/execute response</th>
<th>Trial type</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADIO</td>
<td></td>
<td>edge detection</td>
<td></td>
<td></td>
<td>decision-making</td>
<td>unaware</td>
</tr>
<tr>
<td></td>
<td></td>
<td>visual word form</td>
<td></td>
<td></td>
<td>pre-motor planning</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>processing</td>
<td></td>
<td></td>
<td>response execution:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>“no, I saw nothing”</td>
<td></td>
</tr>
</tbody>
</table>

| RADIO    |      | edge detection          | visual awareness     | hold item in working      | decision-making       | aware      |
|          |      | visual word form        |                      | memory                    | pre-motor planning    |
|          |      | processing              |                      | access perceptual         | response execution:   |
|          |      |                         |                      | info for report           | “yes, I saw radio”    |            |

0ms Time 600ms
Inattentional Blindness (IB) paradigm

Video example of stimuli:

https://youtu.be/FONlOaZXzEg
Inattentional Blindness (IB) paradigm

Words (22.5%)
Consonants (22.5%)
Scrambled (45%)
Animal Words (10%)

Scrambled
600-800ms

300ms

600-800ms

Time-lock ERPs
Procedure

Phase 1: Distracter Task (unaware)

Phase 2: Distracter Task (aware)

Phase 3: Word Recognition Task (aware + relevant)

Awareness Assessment

Awareness Assessment

# of stimuli per phase:
- Words: 180
- Consonants: 180
- Scrambled: 360
- Animal Words: 80

• IB to shapes: Pitts, Martinez, & Hillyard (2012) *JoCN*
• IB to faces: Shafto & Pitts (in press) *JNeurosci*
Inattentinal blindness paradigm

Tasks: phase 1 & 2 = detect bright green-disc targets; phase 3 = detect animal words

<table>
<thead>
<tr>
<th>Phase</th>
<th>Stimulus</th>
<th>Preconscious processing</th>
<th>Conscious perception</th>
<th>Postperceptual processing</th>
<th>Plan/execute response</th>
<th>Trial type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RADIO</td>
<td>edge detection</td>
<td></td>
<td></td>
<td></td>
<td>unaware,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>visual word form</td>
<td></td>
<td></td>
<td></td>
<td>task-irrelevant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>processing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>RADIO</td>
<td>edge detection</td>
<td>visual awareness</td>
<td></td>
<td></td>
<td>aware,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>visual word form</td>
<td></td>
<td></td>
<td></td>
<td>task-irrelevant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>processing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>RADIO</td>
<td>edge detection</td>
<td>visual awareness</td>
<td>if it’s a word,</td>
<td>response selection:</td>
<td>aware,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>visual word form</td>
<td></td>
<td>compare to animal</td>
<td>“don’t respond,</td>
<td>task-relevant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>processing</td>
<td></td>
<td>words in memory</td>
<td>the word is not</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>an animal”</td>
<td></td>
</tr>
</tbody>
</table>

0ms — 600ms

Time
Main Questions:

• N250 and N400 during inattentional blindness (Phase 1)?
  (Appelbaum et al., 2009; Luck, Vogel, & Shapiro, 1996)

• P3b when subjects are aware of words (Phase 2) or only when words must be reported (Phase 3)?
  (Dehaene & Changeux, 2011)

• ERPs uniquely associated with awareness (Phase 2 vs. Phase 1), e.g. visual awareness negativity (VAN)?
  (Railo, Koivisto, & Revonsuo, 2011)
Phase 1 (unaware, task irrelevant)
Phase 1 (unaware, task irrelevant)
Phase 2 (aware, task irrelevant)
Phase 3 (aware, task relevant)
Phase 3 (aware, task relevant)
Summary

- **N250 and N400** *regardless* of whether subjects are aware of the word forms.
  - All phases (incl. unaware, task-irrelevant)

- **VAN** (and word vs. consonant ERP difference) *only when* subjects are aware of the word forms.
  - Phase 2 (aware, task-irrelevant)
  - Phase 3 (aware, task-relevant)

- **SP, SN, and P3b** *only when* words must be reported.
  - Phase 3 (aware, task-relevant)
Summary

Results consistent with our previous IB experiments: shapes

Pitts, Martinez, & Hillyard (2012) *JoCN*
Summary

Results consistent with our previous IB experiments: faces

Shafto & Pitts (in press) JNeurosci
Summary

Overall pattern of results (shapes, faces, words)

- extensive preconscious processing during IB
- late, wide-spread “ignition” related to reporting one’s awareness
- early, more localized “flicker” related to awareness per se

VAN ~200-300ms
# Theories of consciousness

<table>
<thead>
<tr>
<th>Sensory Theories</th>
<th>Cognitive Theories</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. recurrent processing theory</td>
<td>e.g. global neuronal workspace theory</td>
</tr>
<tr>
<td>• phenomenal vs. access</td>
<td>• access-only</td>
</tr>
<tr>
<td>• “rich” awareness</td>
<td>• “sparse” awareness</td>
</tr>
<tr>
<td>• NCC: early (&lt; 300ms)</td>
<td>• NCC: late (&gt; 300ms)</td>
</tr>
<tr>
<td>• NCC: localized “flicker”</td>
<td>• NCC: wide-spread “ignition”</td>
</tr>
<tr>
<td>• attention &amp; awareness fully dissociable</td>
<td>• attention necessary for awareness</td>
</tr>
</tbody>
</table>
Alternative theories?

Attention Schema Theory

- *perceptual* theory of awareness (vs. sensory or cognitive)
- awareness is a perceptual model of attention
- specific computation = “person X is attending to Y”
  - X can be oneself or someone else (hence the “social” part)
  - Y can be a sensory stimulus or a thought, emotion, memory, etc.
- predicts: single dissociation btw attention & awareness √
- predicts: mid-latency, non-global NCC √

Is VAN a signature of this awareness computation?

Graziano & Kastner (2011) *CogNeurosci*  
Graziano (2013) *Consciousness and the Social Brain*
Thank you for your attention and awareness!

Collaborators:
- Steve Hillyard
- Antígona Martínez
- Enriqueta Canseco-Gonzalez
- Kathryn Schelonka
- Chris Graulty
- Juliet Shafto
- Jennifer Padwal
- Daniel Fennelly
- Stephen Metzler

Funding:
- KIBM
- NIMH
- NSF
- Reed College

www.reed.edu/psychology/scalp