Introduction - ERP Correlates of Visual Consciousness

Two decades of event-related potential (ERP) research have established that the most consistent correlates of the onset of visual consciousness are the early visual awareness negativity (VAN), a negative component in the N2 time range over posterior electrode sites, and the late positivity (LP), a positive component in the P3 time range over fronto-parietal electrode sites. Both are defined as relative differences between the ERPs of aware and unaware conditions.

An earlier review had looked at 39 studies and concluded that the VAN is the earliest and most robust correlate of visual phenomenal consciousness, whereas the LP probably reflects later processes associated with reflective/access consciousness. However, an “early” vs. “late” debate still persists. So when does conscious awareness arise, then?

Methods & Results - The Second Decade

The article is based on an update to that review. 30 ERP and 6 MEG studies that have appeared since 2010 and directly compared ERPs of aware and unaware conditions were considered. The result corroborates the view that VAN is the earliest and most consistent signature of visual phenomenal consciousness, and casts further doubt on the LP as an ERP correlate of consciousness. In particular, LP seems to be associated with post-perceptual processes related to task-relevance, report, etc.

Results - MEG Correlates of Visual Consciousness

Figure 1: Left: the typical time course of ERPs for aware and unaware conditions. Right: VAN and LP visualized as difference waves. (From Ref. 1, p. 923)

Recent studies show that the amplitudes of VAN, and sometimes of LP, correlate linearly with the level of awareness as measured behaviorally with the 4-point Perceptual Awareness Scale (PAS). Whether the ERP correlates of consciousness vary in this graded manner or dichotomously depends on the complexity of the stimulus and task used, the so-called “level of processing” (LoP). Results differ, with LoP sometimes affecting only VAN and sometimes only LP. It is currently unclear how exactly this factor plays out.

Different ERP Correlates for Aware Detection and Identification

One study used (low LoP) detection and (high LoP) identification tasks, and found that only VAN correlates with detection (or “something”) without stimulus identification, while LP correlated with awareness in both detection and identification, as measured by the PAS.

Figure 2: The amplitudes of VAN and LP vary linearly with PAS ratings. (From ref. 3, p. 4)

The Relationship of Consciousness and Attention

Over the past decade, some evidence that visual awareness and attention can be fully dissociated has appeared. In 2010, it was already clear that the VAN can be dissociated from several attention-related components such as the “selection negativity”, but seems to presuppose spatial attention. A recent ERP study tried to investigate the relationship between exogenous, bottom-up attention and consciousness, and suggested that it can be dissociated from visual awareness. It remains currently unclear to what degree VAN depends on exogenous attention.

No-Report Paradigms: Inattentive Blindness Reveals LP Effects Task-Relevance, not Consciousness

Pitts and colleagues have adapted the inattentive blindness (IB) paradigm for ERP research. The challenge here is that conscious reports cannot be obtained after each trial, because drawing attention to the “hidden” stimuli would define elimination of the IB effect. Pitts et al. solved the problem by requiring reports only after entire blocks/phases. They found that the LP component appears only for task-relevant stimuli.

The Role of Expectations and Prior Beliefs

Recent times have seen an interest in the role of expectations in perception, and perception is increasingly seen as an inferential problem. One study investigated the effect of expectation on ERP correlates of visual consciousness. Applying a “ladder” sequence with an ascending and a descending part, the authors presented a stimulus at various contrast levels that were repeated in the descending part. They found that VAN correlated with awareness regardless of the presence of expectations (albeit with lower amplitude in their absence), whereas LP correlated with awareness only in the absence of expectations (during the ascending part of the sequence).

Open Questions

• To what degree are VAN and LP dissociable from exogenous attention?
• How does the “level of processing” influence the neural correlates of consciousness?
• Under which circumstances, and in what sense, are awareness and its correlates graded, and when are they dichotomous?
• How do expectations and prior knowledge influence awareness?
• How do the results reviewed here speak to theories of consciousness, such as Recurrent Processing Theory and Global Neuronal Workspace Theory?
• How do “predictive coding” variables relate to (theories of) consciousness?

Discussion - New Developments in Visual Consciousness

Since 2010, the field of consciousness research has seen exciting new developments. A selection of them is presented here.

Visual Consciousness: Graded, Not Dichotomous

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Dissociable ERP Correlates for Aware Detection and Identification

One study used (low LoP) detection and (high LoP) identification tasks, and found that only VAN correlates with detection (of “something”) without stimulus identification, while LP correlated with awareness in both detection and identification, as measured by the PAS.

Figure 3: Scalp distributions of VAN (left) and LP (right) for detection vs. identification. (From ref. 8, p. 1265)

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