ERP and MEG Correlates of Visual Consciousness: The Second Decade

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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.

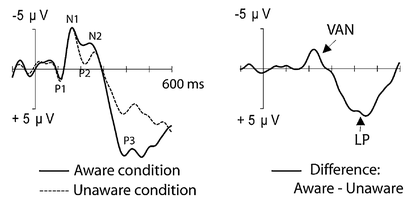

Figure 1. Left: the typical time course of ERPs for aware and unaware conditions. Right: VAN and LP, visualized as difference waves. (From Ref. 1, p. 923)

An earlier review[1] had looked at 39 studies and concluded that the VAN is the earliest and most reliable 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[2] this poster is based on provides 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.

Table 1
Results of the Review of ERP Studies for VAN (N2 range) and LP (P3 range).

Manipulation	Study	Enhanced early negativity (N2 range)	Enhanced late positivity (P3 range)
Contrast	Chica et al. (2010)		Yes
	Eklund and Wiens (2018)	Yes/Yes	Yes/Yes
	Koivisto et al. (2016)	Yes/Yes	Yes/Attenuated
	Koivisto and Grassini (2016)	Yes	Yes
	Koivisto et al. (2017)	Yes/No	Yes/Yes
	Koivisto et al. (2018)	Yes/Yes/Yes	Yes/Yes/Attenuated
	Melloni et al. (2011)	Yes/Yes	Yes/No
	Rutiku et al. (2016)	Yes/No*	Yes/Yes*
	Tagliabue et al. (2016)	Yes**	Yes**
	Ye and Lyu (2019)	Yes/Yes	Yes/Attenuated
	Ye et al. (2019)	Yes/Yes	Yes/Attenuated
Masking	Babiloni et al. (2016)	No/No/Yes	Attenuated/No/No
	Davoodi et al. (2015)	No/No	Yes/Attenuated
	Del Zotto and Pegna (2015)	Yes/Yes	Yes/Attenuated
	Derda et al. (2019)	Yes**	No**
	Fu et al. (2017)	Yes**	Yes**
	Jimenez et al. (2018)	Yes**	Yes**
	Pitts, Metzler, et al. (2014)	Yes/Yes	Yes/No
	Railo et al. (2015)	Yes	Yes
	Rutiku et al. (2015)	Yes/Yes	Yes/Yes
	Salti et al. (2012)	No	Yes
Inattentional Blindness	Pitts et al. (2011)	Yes/Yes	Yes/No
	Schelonka et al. (2017)	Yes/Yes	Yes/No
	Shafto and Pitts (2015)	Yes/Yes	Yes/No
	Harris et al. (forthcoming)	Yes	
Attentional Blink	Batterink et al. (2012)	No/No	No/Yes
	Weller et al. (2019)		
Change Blindness	Scrivener et al. (2019)	No/No	Yes/Yes
Other	Boncompte and Cosmelli (2018)	No	Yes
	Pitts, Padwal, et al. (2014)	Yes/Yes/Yes/Yes	Yes/No/Yes/Attenuated

Table 1. Of 30 reviewed studies, 20 found VAN, and 13 found LP in all tested aware conditions. From ref. 2 (see review article for complete legend).

Results - MEG Correlates of Visual Consciousness

Table 2
Results of the Review of MEG Studies for VAN (N2 range) and LP (P3 range).

Manipulation	Study	Enhanced early negativity (N2 range)	Enhanced late positivity (P3 range)
Contrast	Liu et al. (2012)	Yes	No
Masking	Andersen et al. (2016)*	Yes/Yes/Yes*	No/No/No*
	Wyart et al. (2012)	?	?
Threshold duration	Sekar et al. (2013)	Yes/Yes	Yes/Attenuated
Bistable perception	Sandberg et al. (2013)	Yes	Attenuated
	Sandberg et al. (2014)	Yes	Attenuated

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 Is Graded, Not Dichotomous

Recent studies[3] 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).[4] Whether the ERP correlates of consciousness vary in this graded manner or dichotomously seems to depend on the complexity of the stimulus and task used, the so-called "level of processing" (LoP).[5,6] Results differ, with LoP sometimes affecting only VAN,[5] and sometimes only LP.[6] It is currently unclear how exactly this factor plays out.[7]

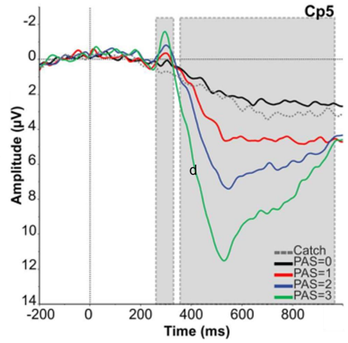

Figure 2. The amplitudes of VAN and LP vary linearly with PAS ratings. (From ref. 3, p. 4)

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 (of „something") without stimulus identification, while LP correlated with awareness in both detection and identification, as measured by the PAS.[8]

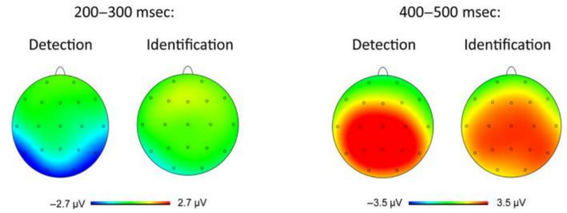

Figure 3. Scalp distributions of VAN (left) and LP (right) for detection vs. identification. (From ref. 8, p. 1625)

The Relationship of Consciousness and Attention

Over the past decade, some evidence that visual awareness and attention can be fully dissociated has appeared.[9] 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.[1] A recent ERP study tried to investigate the relationship between exogenous, bottom-up attention and consciousness, and suggests that it can be dissociated from visual awareness.[10] It remains currently unclear to what degree VAN is independent of exogenous attention.

No-Report Paradigms: Inattentional Blindness Reveals LP Reflects Task-Relevance, not Consciousness

Pitts and colleagues[11] have adapted the inattentional 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 by definition eliminate 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.

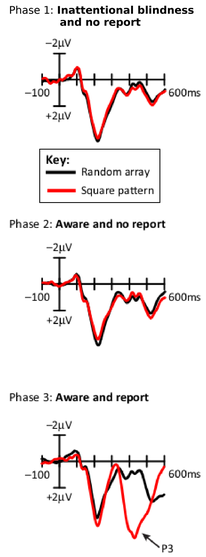

Figure 4. LP/P3 is related to Task-relevance and conscious reports, not to phenomenal awareness. (Adapted from ref. 12, p. 766)

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[13] investigated the effect of expectancy 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 foundthat 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.)

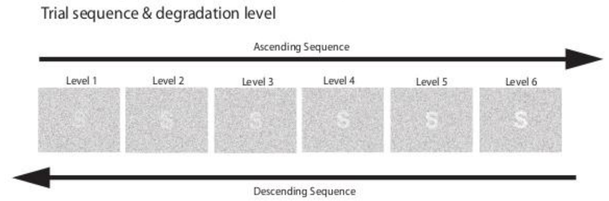

Figure 5. The stimulus increased in contrast over trials, then decreased again. By the time the descending part began, the participant had built up strong expectations about the stimulus. (From ref. 13, p. 1387)

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" accounts relate to (theories of) consciousness?[14]

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