Master Degree Program in Human Neuroscience

Visual awareness negativity and P3: ERP study of the distinctive neural correlates of conscious vision

University of Turku

LAURA MERCEDES MORENO HERNANDEZ

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Abstract

This research aimed to replicate the previous findings of Koivisto & Grassini (2016). Using event-related potentials (ERPs), we studied the neural correlates of visual consciousness. Specifically, we wanted to study visual awareness negativity, that has been reported as the first ERP correlate of consciousness as its latency seems to be fast enough to be the neural correlate of the phenomenal consciousness, which could be the earliest manifestation of consciousness. We also studied the late positivity, that seems to reflect the cognitive components of the reflective consciousness, as it involves the voluntary operations performed with the object like identify it or recognize it. Surprisingly, and despite the previously reported in literature, in this study we did not observe visual awareness negativity, but found that only late positivity correlated with conscious perception. We conclude that our results do not support the hypothesis about VAN as the correlate of phenomenal consciousness, whilst our observations regarding P3 appear to support the hypothesis about reflective consciousness occurring in this period. We interpret these findings as possibly affected by a different statistical analysis. Also, the fact that phenomenal consciousness can be understood in various ways may lead to contradictory findings. However, more research is necessary to find alternative explanations to our findings as well as other experimental approaches to the study of neural correlates of consciousness.

Keywords: Event related potentials, visual awareness negativity, Late Positivity, Visual perception, visual consciousness, subliminal perception.

Contents

1. Background

Event-related potentials (ERPs) are changes in the brain's electrical activity that occur in response to external or internal stimulation (Luck, 2014). They constitute a technique that enables the study of neural activity with high temporal resolution using electroencephalography (EEG). This technique constitutes a fast, cheap and practical approach in neuroscience research. In this research we used event-related potentials to study the if there was a difference between the amplitude of the electroencephalographic correlates of visual stimulation that have been associated with conscious vision. The two neuronal correlates of consciousness were the visual awareness negativity (VAN), that is defined as a negative difference in the ERP wave and that appears in the first 200 milliseconds after visual stimulation; this is considered one of the first neural correlates of consciousness (NCC) (Koivisto & Grassini, 2016). We were also interested in the positivity that emerges around 300 milliseconds after the visual stimulus presentation, that has been related with visual consciousness also (Salti, Bar-Haim, & Lami, 2012). For the purposes of this research, we considered conscious perception as the ability to report that a stimulus has been seen. It is also necessary to clarify the distinction between phenomenal consciousness, that is the first impression of seeing; and reflective consciousness, which is the ability to declare about what the subject recalls as seen (Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017). For practical matters, in this document phenomenal experience will be referred to as awareness, and the declarative aspect of consciousness will be referred to as consciousness. The aims, questions and hypothesis are presented below.

1.1 Aims

This research aimed to replicate the findings of Koivisto & Grassini (2016), about NCC, regarding visual awareness negativity that, as mentioned before, seems to be the first neural correlate of visual consciousness. It is observed as a negative difference between two ERP waves and is typically registered around the occipital electrodes and appears around 200ms after stimulus presentation. We also wanted to study the positivity that emerges in the 300ms time-window. Our interest was to discover which ERP waves correlate with conscious vision. In that sense, our research question was: Is visual awareness negativity a correlate of conscious vision and will be P3 greater when the participants report that they consciously saw a target stimulus? Our hypothesis was that the presence of VAN would enhance the P3 amplitude, that would be greater for both in the conscious conditions.

The following section will introduce the ERP technique in the study of visual perception, the components related with visual consciousness, and how and why they are important as a matter of research.

2. Visual processing:

In the classic view of the vision as a neurophysiological process, visual perception is a complex process that extends from the very moment when the light hits the retinal cells, until the electrical impulse resulting from that stimulation is understood and named as something in any position in the space (Goldstein, 2009). The visual signals travel through the lateral geniculate nucleus to reach the cortex, and there a series of subprocesses are activated. After reaching the cortex, the visual information spreads to the visual areas in the dorsal and the ventral stream; both of them interrelated and processing different aspects of the visual information. For example, visuomotor functions are supported by parietal areas, where the dorsal stream converges. These areas also serve the egocentric coding of space. On the other hand, the ventral stream projects to the temporal areas, where allocentric spatial relations and visual recognition are performed (Goodale & Milner, 1992). This evidence has led researchers to think that visual consciousness relies primarily on the ventral stream, flowing from the occipital cortex to the anterior temporal cortical areas, involving a bottom up processing of the stimulus (Railo, Koivisto, & Revonsuo, 2011)).

Some formulations regarding visual processing are more concerned with the time in which the contents are available to consciousness. These theories want to address if awareness occurs immediately when the stimulus is processed by the visual cortices or if awareness occurs later in time when properties of the stimulus have been processed by the frontal cortices. The former theory, named as recurrent processing theory, proposed by Lamme (2010) assumes that there is constant interplay between higher and lower visual areas that enable the cognitive processing of visual stimuli, meaning that perception is the result of recurrent interaction between lower and higher areas in charge of visual processing.

The feedforward model proposed by Lamme (2010) is based on the observation that a stimlulus will reach V1 after approximately 40ms, spread to higher extrastriatal areas in approximately 100ms, and in consequence, will trigger a set of recurent processes originating in the area and will spread to the ones reached earlier. Lamme (2010) points out that the early visual treatment of the information coming from V1 is enough for unconscious processes, but not for visual awareness, as it requires an interplay between the higher areas and the visual cortex (Lamme, 2010). In that sense, it is not an isolated area that enables the conscious experience, but the interplay between them. The consious experience emerges from the early interactions in the cortex, as this interplay allows the integration of all the characteristics of the object in a whole (Lamme, 2010). In that sense, for Lamme (2010) the awareness is gained earlier, even if the declarative experience comes after, when the interactions between the declarative networks are also active.

It is here that the debate about the timing of conscious experience starts to arise: while for Lamme (2010) declarative experience is not the same as consciousness, as awareness can be phenomenal, whilst the declaration of seeing would involve other processes. However, Dehaene & Changeux (2011) propose that all that happens before the declarative state of seeing is just preconscious and in that case, is out of voluntary control and recall. In that sense, consciousness would emerge as a late result of the control exerted from the frontoparietal areas to the visual areas. This would mean that consciousness would emerge late after the stimulus is detected. Their claim is that attending to a stimulus is not the same as being conscious about it. According to the authors, as the depth of processing increases, the time increases and the executive system takes control of a task the effect unconscious systems are displaced and thus, their effect on the behavior is less prominent. In other words, the operations we can perform with the objects outside the conscious domain are limited to the time we are exposed to it. Even being able to perform basic responses like orienting towards the object, however, does not make us conscious of the object. The reflective consciousness just appears until the prefrontal cortex registers the object and operates with it. Some of the core characteristics of the executive system include the ability of integrating and monitoring information available; its limited capacity to process the surroundings and its possibility to operate in the feedback level, characteristics that the consciousness shares with the executive system. According to this, the prefrontal, central and parietal areas and their projections operate in loops that allow the interplay between different levels. This has been named the neuronal workspace theory (Dehaene & Changeux, 2011). In that sense, an object only would be understood as consciously perceived when generates the sustained activity of this workspace.

The previously presented issues raise a question regarding the timing of the access of the stimulus to consciousness, as the two presented models (Lamme, 2010; Dehaene & Changeux, 2011) present competing perspectives regarding when an object can be declared as conscious or unconscious. For (Lamme, 2010), it is possible to think about early consciousness; in the perspective of (Dehaene & Changeux, 2011), consciousness is a late process. This difference is illustrated in the figure 1, when the hypothetical timing of the processes is presented. As can be seen, the first model approaches consciousness around 200ms, which is closer to the VAN. Conversely, the second suggests that consciousness arises around the 300ms and later, which is the time-window of P3. Therefore, is possible to understand why conscious study with ERPs has been centred about this time-windows.

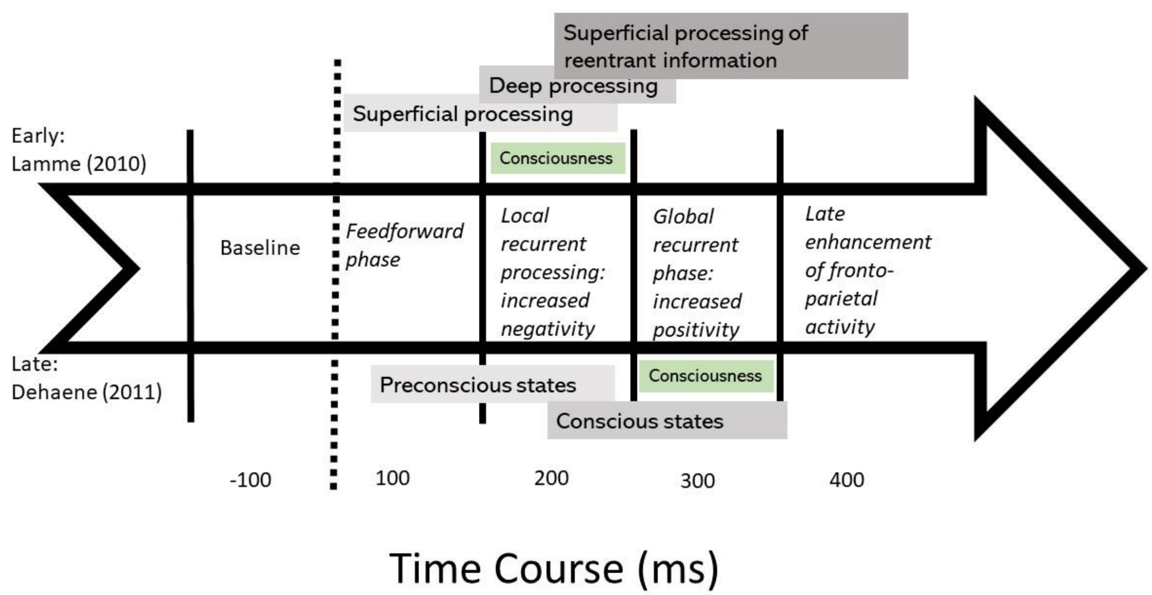

Figure 1. Models of visual consciousness. *Constructed based on Lamme (2010) and Dehaene & Changeaux (2011).*

Lamme's model assumes that early interactions between different levels in the cortex allow the conscious experience. In contrast, the bottom model assumes that the later interactions between the fronto-parietal areas are the ones that enable conscious operations.

Regarding the way visual information is processed, several experiments using event-related potentials have tried to understand how the initial activation spreads, in order to understand the course of events in the brain that are associated with visual experience. For example, Foxe & Simpson (2002) used high-density ERP recordings to study the time course of visual processing using *scalp density analysis,* to establish a time frame of the activation in the ventral and dorsal streams; they also aimed to determine the onset of activation of the frontal areas (Foxe & Simpson, 2002) . They reported faster activation of the dorsal pathway in comparison with the ventral areas and consequently suggested that this timing offers support for the theory of the global working space, as its timing is as early that can favor the multiple interactions between areas and in consequence to activate the processes that are in charge of the long-high detailed processing of the visual stimulus. In that sense, top down processes could control the spreading of this primary signal. However, they also notice that is possible to assume that the frontal activations that were observed were the result of anticipation or attentional predisposition (Foxe & Simpson, 2002).

In conclusion, while the basics of visual perception seem to be well understood, what happens afterwards is still a matter of discussion. Competing models have been proposed as ways of explaining the way brain deals with this information: the top-down theories propose that perception is a process based on cognitive control of the frontal areas, while the bottom-up theories assume that the information processing is dependent on the stimulus (Railo, Koivisto, & Revonsuo, 2011). In that sense, what type of neural activations are requisites for conscious perception, and which neural mechanisms enable posterior stimulus processing, is a matter of considerable research in the area of visual perception in general, and in the area of visual consciousness in particular. The different models about how visual information flows and reaches consciousness have led to different conclusions as they use different methods and concepts to study the process. As a consequence, different electrophysiological correlates have been proposed as the neural bases for visual consciousness. The following section describes in general terms the research using ERPs to try to find the neural correlates of consciousness, including the early phenomenal and the late declarative conscious reports.

3. ERPs in the context of visual research

Event-related potentials constitute a technique derived from electroencephalography, which are used to detect changes in the electrical activity relative to a specific time point (e.g. when visual stimulus is presented). In other words, ERPs are measurements of activity resulting from a specific trigger (called an event) which occurs at a specific time during the registration. The timing of the event allows the researcher to select specific time points in the continuum of the EEG and cut it according to their occurrence. After this segmentation, it is possible to compare the potentials according to the presence/ absence of a specific type of stimulation (Luck, 2014). Event-related potentials allow the tracking of the time course of the average activity in the brain that results from stimulation. In that sense, their aim is to correlate the timing of the processes that could be associated with some cognitive process. In visual cognition, they are used to understand the processing of visual information as well as to understand the complex cognitive processes that take place after it (recognition, location) (Railo, Koivisto, & Revonsuo, 2011). ERPs constitute a useful tool to study vision as they provide high temporal resolution information about what is happening while information is reaching the brain. The time-lock between stimulus and the subsequent neural responses allows us to draw more accurate conclusions about the cognitive (or sensory) processes that are activated under the experimental conditions (Koivisto & Revonsuo, 2010).

A related technique, the evoked potential, has been used widely to study perception in both clinical contexts and research context, within the clinical context, EPs have been useful to establish the sensitivity to stimuli of participants who cannot communicate easily and that therefore cannot produce behavioural responses that are accountable as reactions to specific stimuli. In this context, the auditory, visual and tactile sensitivity modalities can be studied in an objective manner (Daube & Rubin, 2009). The use of event-related potentials for studying visual consciousness thus constitutes a useful tool given the fact that it does not require verbal report from the participant, making the study of non-declarative processes (such as unconscious vision) easier. For example, regarding consciousness, even when the subjects can have some problems recalling if we saw some type of stimuli, the neural response to the stimulation helps us to understand if the stimulus was registered in any way, even when the patient even cannot declare that they saw something.

3.1 Components commonly isolated from visual awareness research

This section will present the components commonly isolated from visual awareness research, as well as the main evidence compiled about them.

Components can be described as the changes in the EEG that appear in specific time points and that seem to reflect the response to stimuli that are presented in contiguity with them. ERP research identifies components according to their timing (known as latency) and the polarity of the resulting deflection, which can be positive or negative (Luck, 2014). However, these are not the only criteria that serve to classify the components: the task type, the modality that evokes and their possible origin are also criteria that can be employed to this end. In the context of event-related potentials of vision, the components mainly found are component 1 (C1), which names the first component appearing after the stimulus; positivity 1 (P1), which would be the first positive deflection observed after the visual stimulation; and negativity 1 (N1), which is the first negativity deflection that appears after stimulus. These components are registered in typical visual tasks that require identification, discrimination, or visualization of stimuli (Luck, 2014). Another set of typical neural correlates of consciousness in visual awareness research is the visual awareness negativity (VAN), which consists in a negative difference in the amplitudes of two ERPs. This negativity is registered around the occipital electrodes and can appear around the 200ms time-window. It sometimes appears simultaneously with N200, that is observed as negative deflection that occurs around 200ms post stimulus (Förster, Koivisto, & Revonsuo, 2020; Railo, Koivisto, & Revonsuo, 2011). Despite their coincidence around the same time-point, these two are different deflections that can be reflecting visual consciousness.

Later in time, a positive deflection, called positivity 300 (P3, P300) or late positivity (LP), which is observed around 300 milliseconds after the stimulus onset, has also been linked to visual consciousness research. Its late appearance suggests that is a cognitive component, which means that it might reflect the result of the access to the information regarding seeing, more than consciousness itself (Railo, Koivisto, & Revonsuo, 2011).

As part of the research aimed to assess the neural correlates of consciousness some experimental paradigms have been used to assess the speed of visual processing, to stablish if it coincides with the timing of the awareness of the stimulus. As a result, different time slots have been proposed as neural correlates of visual consciousness, ranging from the very early visual components observed like C1 (Foxe & Simpson, 2002) or LP (Railo, Revonsuo, & Koivisto, 2015). The causal mechanism that enables the experience of conscious vision is still a matter of debate. However, independent components and conjunctions of them have been proposed as the neurophysiological correlates of conscious vision and consequently visual experience. (Railo, Revonsuo, & Koivisto, 2015; Koivisto & Revonsuo, 2010).

Besides those already mentioned, another identified NCC is the Selection Negativity (SN), which is observed as a change in the amplitude of negativity in the 200ms time window, a deflection which is understood as an estimation of the time at which some specific characteristics are discriminated and chosen for further processing. However, the timing of this deflection seems to overlap with the VAN and, for that reason, it has been assumed that it could be the same type of neural correlate of consciousness. (Koivisto & Revonsuo, 2010). However, in experiments that involve stimulus masking, VAN seems to appear a bit earlier than SN. Accordingly, it has been suggested that VAN can enhance the SN, which is more the result of the attentional shift to the stimulus. (Koivisto & Revonsuo, 2010). Therefore, the first components of awareness are not dependent on the object itself, but more on other features related with the stimulus (for example, location). On the other hand, the stimuli that cross the "conscious threshold" depends on their specific characteristics, so is object-based attention (Koivisto & Revonsuo, 2010). In that sense, SN could be useful to explain detection, but not awareness. The subject has the sensation of having seen something, the subject is able to point the location of the stimulus, but is unable to specify the stimulus features (Koivisto & Revonsuo, 2010). According to it, SN would reflect attentional orientation, prioritization of cognitive resources to filter the surrounding world and selection of the stimulus that reach awareness, more than awareness itself. In this case, we can think about SN as the first filter to get into awareness, all the stimulus that become conscious require to have pass the attentional selection, but not all the ones that have been selected, become necessarily conscious.

Table 1. Components studied in visual tasks

Name	Peak site	Polarity	Peak time (ms)	Is this NCC?	Reference
C1	Occipital and subsequent dorsolateral frontal cortex	+/-	~50-80	N	(Foxe & Simpson, 2002)
P1		+	~100-140	N	(Railo, Koivisto, & Revonsuo, 2011)
N1		-	100	N	(Koivisto & Revonsuo, 2010)
VAN	Difference in the negativity around the Occipito-temporal electrodes	-	~200		(Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017)
N200	Occipital	-	200	Y	(Koivisto, Revonsuo, & Salminen, 2005)
P300	Frontal	+	300	Y	(Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017)
SN	Temporal	-	200	Y	(Koivisto & Revonsuo, 2010)
LP	Difference in the positivity registered during the P3 window.	+	~300	Y	(Koivisto, Salminen-Vaparanta, Grassini, & Revonsuo, 2016)

Source: *Constructed based on (Foxe & Simpson, 2002;* Koivisto, Revonsuo, & Salminen, 2005; *Railo, Koivisto, & Revonsuo, 2011)*

Summarizing, several components have been linked to visual perception: C1, P1, N2 and P3. Koivisto (2016) links P1 with the prerequisite for visual awareness, VAN could reflect the visual awareness, and P3 could constitute the result of the cognitive treatment of the stimulus (Koivisto, Salminen-Vaparanta, Grassini, & Revonsuo, 2016). Experimental evidence describing the components seems to support this claim. The upcoming section will describe the types of components linked with visual awareness and to describe some of the experimental evidence that is being recollected about this matter.

3.2 ERPs, visual perception and visual consciousness

Visual awareness has been described as the experience of seeing (Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Railo, Koivisto, & Revonsuo, 2011). Accordingly, everything that can be declared is part of that conscious perception. Little doubt about the relationship between the declarative nature of the experience and the consciousness. However, in terms of what is the first neural correlate of the phenomenal experience is under research, and how conscious information is processed in terms of its time-course is still a matter of debate. Event-related potential technique has been widely used to look for the NCCs during the recent years given their good time resolution which allows us to correlate the neural responses that occur in response to visual stimulation. Those recordings can be also correlated with visual awareness behavioural measurements. Therefore, experimental designs usually compare what happens in the brain when the individual is aware of the stimulation and when she is not. Approaches to study this phenomenon have used fast-appearing stimuli, low-contrast stimuli, and attentional changes (Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Railo, Koivisto, & Revonsuo, 2011).

The variety of experimental paradigms has given varied results which has as a consequence, lack of agreement about how visual stimulus are consciously processed. Different conceptualizations of visual awareness lead to different experimental arrangements and measurements, and as a result, the conclusions reflect consciousness as is understood in that specific theoretical framework (Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017). In that sense, for Koivisto et al. (2017), the key to understanding visual awareness is to perform research aimed to separate the phenomenal experience of seeing from the cognitive processes associated with more sophisticated processes as cognitive categorization or identification (Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017). Their claim is that separating phenomenal experience from reflective experience allows us to understand the subsequent neural events as antecedents or consequences of consciousness and so, they can be classified as different components of the conscious process but in their earlier or later stages.

It is necessary then to describe how visual consciousness has been understood and conceptualized. According to Koivisto & Revonsuo (2010), phenomenal consciousness consists in sensation of seeing, something that could be the registration of the object by the sensitive system. For Koivisto y Revonsuo (2010) therefore, phenomenal consciousness can constitute the necessary and sufficient condition for consciousness. However, for other researchers (Dehaene & Changeaux, 2011) the mere registration of the object by the sensitive system and in that sense could be defined as a building block for awareness, although it does not constitute consciousness itself. Visual consciousness seems to originate in extrastriatal visual areas, particularly the ones that are part of the ventral stream (Koivisto & Revonsuo, 2010). On the other hand, reflective consciousness refers to the cognitive component of consciousness, related with all the operations we do with the basic percept: recognize it, categorize it or locate it (Goldstein, 2009). This type of consciousness has its correlate around frontal areas that control attention, memory, and motor output (Koivisto & Revonsuo, 2010; Railo, Koivisto, & Revonsuo, 2011)

Different ERP components can be associated with visual processing, but not all of them are related with consciousness. Regarding this, Koivisto & Grassini (2016), studied the subjective report of the participant with their neural activation in a task that consisted forced-choice report of where the stimulus was located. They found that there was a negative difference in the amplitude of ERP's, the lower awareness evoked more positive waveforms. They also studied the later positive waveform that appeared 300ms after stimulus presentation, and they found a greater positivity which could be associated with the evaluation and voluntary manipulation of the stimulus and in consequence, a reflective consciousness process. Figure 1 displays one example from Koivisto & Grassini (2016), in which the changes in the amplitude of visual awareness negativity in the occipital electrodes are illustrated.

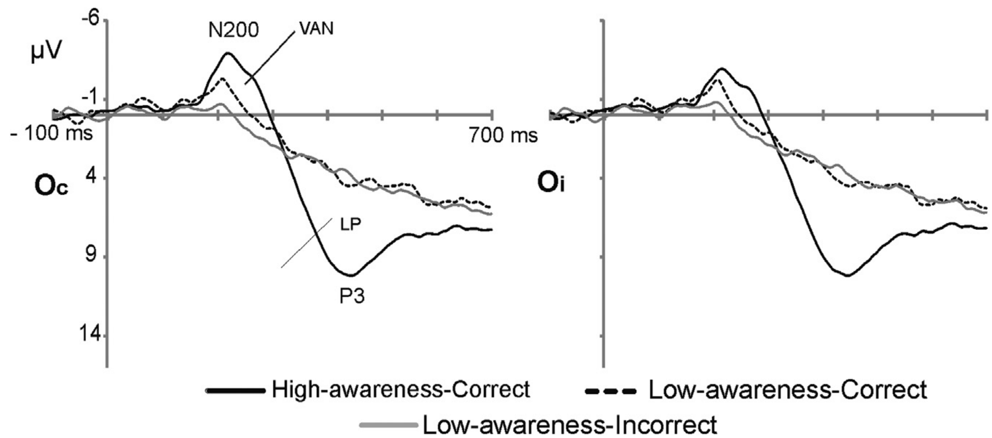

Figure 2. Event related potentials in response to the distinct type of trials in the occipital electrodes. *From: Koivisto & Grassini (2016).*

In other experiment, Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo (2017), aimed to compare the ERP correlates of visual awareness in detection and identification tasks. They expected that there was a dissociation between the ERP correlates of detection and identification that allow to trace the neural correlates of awareness as one or another. The rationale behind it was that detection would be more related with basic registration of the stimulus, while identification would be related with reflective experience. Their hypothesis was that stimulation below the threshold would enhance the difference in the negativity recorded around parietal and occipital electrodes. They also hypothesized that it would be an enhancement of LP when the stimulation was presented over the threshold. Their findings in the detection tasks supported their hypothesis about early negativity, as the stimuli that were detected generated a larger negativity in comparison with undetected stimuli. However, in terms of the identification tasks no difference was observed. They concluded that detection is enough to declare awareness, as there was a difference between the negativity when the target was identified, in consequence they assume that the negativity observed constitute the first correlate of awareness. In contrast with detection tasks, identification might involve more sophisticated cognitive processing that comprise memory and attentional processes. They suggest that the low-level phenomenal experience is enough for being aware of the stimulus, but insufficient for its identification. Accordingly, detection would be the behavioural correlate of awareness (at least in the very basic level of it) and the posterior cognitive processes would lead to the identification, and thus, they would be part of a different level of conscious processing. In that sense, the observed difference in negativity in the 200ms post-stimulus period could constitute the first correlate for awareness, at least in its very basic level.

As can be seen, depending on the timing of the component, and on the approach to consciousness that is assumed, the study of visual consciousness can lead to different conclusions. The following lines will describe in more detail the components that have been approached in the study of consciousness, as well as the type of evidence in support of the different components.

3.3 Visual awareness negativity in conscious vision

In the previous section, it was mentioned that some components have been described as crucial for aware experience: visual awareness negativity or VAN, that could be described as the negative difference resulting from subtracting the aware and unaware conditions that can be superposed with any other component in procedures that involve stimulus masking (Koivisto & Revonsuo, 2010); P300, LP or P3 is a positive deflection that has been related with visual consciousness, its appearance comes around 300ms or later. This deflection is not merely related with consciousness but with cognitive operations also, however in consciousness research has been understood as a NCC (Railo, Koivisto, & Revonsuo, 2011; Polich, 2012).

VAN has been widely related to detection of visual stimuli (Koivisto, Salminen-Vaparanta, Grassini, & Revonsuo, 2016; Koivisto & Grassini, 2016; Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017). It has been described as a reliable neural correlate of awareness and given that it peaks around 200ms after stimulus onset, it has been understood as the earliest activity in the visual cortex that can be used as a marker to signal visual awareness. It has been observed in studies that research visual rivalry, change and attentional blindness, visual masking and contrast manipulation (Koivisto, Revonsuo, & Salminen, 2005) and is centred around the occipitotemporal areas (Koivisto & Grassini, 2016; Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Koivisto, Revonsuo, & Salminen, 2005; Koivisto, Salminen-Vaparanta, Grassini, & Revonsuo, 2016; Salti, Bar-Haim, & Lami, 2012). In an experiment in which the visibility of the stimulus was manipulated in a go-no-go task Railo, Revonsuo & Koivisto (2015) reported that the VAN peaked earlier in the parietal sites than in the frontal sites, suggesting that the visual impulses flow in a bottom-up fashion.

VAN originates in the visual cortices and is described as spreading from there to higher cortical areas. This seems to support a clear separation between the positive deflection that occurs around 300ms after stimulation and the conscious acces to the stimulus. As mentioned before, the phenomenal experience of seeing is different from the operations we execute with the stimulus after experiencing them: we recognize it; we locate it; we are able to describe it, which are further processes that go beyond the conscious basic report and coincide with the timing of P3 more than with VAN (Förster, Koivisto, & Revonsuo, 2020; Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Koivisto & Grassini, 2016). In that sense, visual consciousness as phenomenic experience has its origin in the occipital lobes and does not activate the fronto parietal global network space to operate. In this fashion, they claim that the visual processing that operates in the N200 time window and goes from bottom to upper parts in the brain, would be stimulus-driven and thus would constitute the first neural correlate of conscious vision (Railo, Revonsuo, & Koivisto, 2015; Koivisto & Revonsuo, 2010).

3.4 Late positivity and conscious vision

P3 consists of a positive deflection observed in the ERP wave, that is seen as the greatest peak registered in the ERP waveform occurring in the range between 300 and 650ms after stimulus, is usually registered close to the midline electrodes sites. Mainly this deflection has been observed in cognitive research and then has been linked to attention and memory, particularly updating the information the subject is using to solve current problems, in that sense has been also used to study conscious awareness, as it can be affected by the ongoing stimulation (Polich, 2012). However, whether it constitutes a by-product of awareness, or is instead linked directly to awareness as its prerequisite, is still a matter of debate (Koivisto, Salminen-Vaparanta, Grassini, & Revonsuo, 2016; Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Koivisto, Revonsuo, & Salminen, 2005; Salti, Bar-Haim, & Lami, 2012).

In the context of visual consciousness, it has being reported as showing greater amplitude when subjects are aware of the stimulus, in experiments using masked stimulus, low contrast, or in go-no go tasks (Koivisto, Salminen-Vaparanta, Grassini, & Revonsuo, 2016). However, as part of visual consciousness research, P300 has been more recently understood as a the result post perceptual process linked with higher level cognitive treatment, than as a process at the basis of visual awareness, as it seems to reflect a cognitive component than a neurophysiological correlate of awareness (Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Koivisto, Salminen-Vaparanta, Grassini, & Revonsuo, 2016; Koivisto, Revonsuo, & Salminen, 2005; Polich, 2012). In that sense, it has been suggested that any neural correlate of phenomenal awareness precedes the P300. However, the link between P300 and visual consciousness is that it can be the correlate of reflective consciousness and thus the enabling part of higher operations of consciousness that involve the cognitive manipulation of the stimulus. According to this interpretation, P300 can be understood as a later stage of conscious processing more cognitive and thus more "intentional". For that reason, Railo, Koivisto, & Revonsuo, (2011) warn that it is necessary to separate conscious perception from other processes which allow the operation with the contents of consciousness. (Railo, Koivisto, & Revonsuo, 2011). P300 seems to be enhanced by VAN. Thus, for Railo, Revonsuo and Koivisto (2015) P300 can reflect the conscious processing of the stimulus (memory and attention-wise), and not consciousness itself. P300 can be the result of the cognitive processes that the subject performs to evaluate if they have seen something in the sense they need to operate with the available information to determine if something was presented or not. In that way, this positivity can be the result of attentional or working memory processes, more than with the mere conscious processing. (Koivisto & Revonsuo, 2010; Koivisto & Grassini, 2016; Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Koivisto, Revonsuo, & Salminen, 2005). In that sense, LP would be more a by-product as it constitutes the departure point of other cognitive procesess resulting of the entrance of the stimulus in the cognitive space.

Contrary to the previously presented, Salti, Bar-Haim and Lamy (2012) reported that P300 would be the true NCC, instead of N200. Using a paradigm in which they studied the amplitude of the N200 and P300 and correlated them with the degree of confidence reported by the subjects of seeing a target and with their objective performance in a forced choice location task using masked stimulus, they found that VAN was linearly related with the degree of visibility of the target, whilst P300 had a larger amplitude when the target was seen. In that sense Salti et. al (2012) conclude that this is support for P3 as an NCC, instead of a correlate of confidence evaluation. Also, performance-related P300 was clustered in the frontal cortices. Regarding to VAN and earlier components, those could reflect cognitive processes associated with the process but not awareness itself. For that reason, they conclude that VAN could be related with visibility processes instead consciousness as visibility seems to affect the amplitude of VAN in previous experimental research (Salti, Bar-Haim, & Lami, 2012).

Put together, the main NCCs related to visual awareness are VAN (N200) and P300 (LP) as they seem to reflect the more reliable correlates of phenomenal and reflective experience, respectively. Research conducted in this area seems to support the evidence that VAN could be understood as the first NCC and thus, could constitute the more reliable NCCs of awareness, however, research findings are conflicting in this area and is necessary to continue the research aiming to ensure what are the main NCCs of visual experience.

4. Motivation of research and hypotheses

As it was presented in the precedent sections, the problem remains around which NCC constitutes the very basic awareness response (Koivisto & Grassini, 2016; Salti, Bar-Haim, & Lami, 2012). For Koivisto and Grassini (2016), P300 represents a later stage of conscious processing, instead of the core of awareness. The authors suggest that awareness could be a staged process that involves the basic phenomenal experiences and goes to the full awareness. Between this continuum they assume the negativity around 200ms as a neural correlate of awareness and the positivity around 300ms as the processing part of the experience (Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Koivisto & Grassini, 2016). In that sense, it would be possible to conclude that awareness is a progressive state which evolves from the sensory register to the complex process that leads to recognition, involving higher level cognitive operations.

However, as Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo (2017) point out that more research is necessary to understand the neural mechanisms that underlie awareness in its purest form, avoiding to get it mistook with other complex cognitive processes that are associated to it (Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017). Also, considering the previous research that reports that stimuli that are perceived produce greater negativity in the N200 time window than those that are not (Koivisto & Revonsuo, 2010) it is important to replicate findings trying to use different methods of analysis which allows us to collect new evidence in favour or against the idea that N200 can be understood as the primary visual NCC, as P3 could reflect other mental operations that the participant uses to establish their level of confidence about seeing or not the target (Koivisto & Grassini, 2016).

In that sense, and regarding the VAN and LP as NCC, it would be useful to establish if these are neural correlates of consciousness, as they could constitute a reliable way to study perception in conditions where the patient reports not seeing anything. Our hypothesis is that stimulus with low visibility would evoke a lower amplitude in the activity visible around the

200ms time-window; the one that correlates (according to Koivisto & Grassini, 2016) with conscious vision. In this context, the determination of the temporal pattern of neural activation in visual experience could allow us to gain precise information about correlations between the observed neural activity and behavioural reports that can be used to understand what are the basic mechanisms of visual experience. To try to replicate these findings and get a better insight regarding the time distribution of the activity linked with conscious vision, we ran mass univariate analyses.

This research could constitute the bases of the approach to visual consciousness, and by studying visual activation, we can understand the basis of seeing, a key step in understanding of other neurological disorders as cortical blindness. A condition in which the subject, even being able to operate with objects in the world is unable to declare that have seen something. By the understanding on how the neural mechanisms of visual consciousness operate, it is possible to get a grasp on how the unconscious vision can also function in these patients.

Because of the previously presented, and according to Koivisto & Grassini (2016), we expect that stimuli with low visibility would evoke a weaker N200 wave in the 200ms time-window. Therefore, our hypothesis is that Gabor patches consciously seen (non-zero visibility ratings) will evoke the visual awareness negativity (VAN) and a stronger P3 wave, compared with those that were not reported as seen.

5. Materials and methods

5.1 Participants

Thirty-four students from the university of Turku (3 males, 3 left-handed; mean age 24.4 years; SD 3.6) without report of neurological disorders, took part in the experiment. All the procedures were developed in accordance with the declaration of Helsinki and were submitted to previous approval by the ethics committee of the Hospital District of Southwest Finland. All the participants declared their agreement to take part in the experiment by written informed consent.

5.2 Apparatus and Stimuli:

The stimuli were delivered using MATLAB (version R2014b), through the Psychophysics Toolbox (Brainard, 1997) and projected on a VIEWPixx/EEG LCD monitor at a 120Hz refresh rate. The stimuli consisted of Gabor patches with a diameter of 6.5° of visual angle and a frequency of 0.7 cycles/degree. Their phase and orientation were varied in a random manner on each trial. The patches were projected on a grey 50% background (45,57 cd/m2). Low-contrast Gabor patches were presented in 2/3 of the trials. Low contrast was assessed for every subject using a QUEST staircase (Watson & Pelli, 1983) adjusted to roughly 50% of subjective detection. High contrast patches were projected in 1/6 of the trials, using a contrast three times higher than the low contrast Gabor patch. All the patches were presented for a period of 2 frames (16.6ms). A blank screen projecting the fixation point and without stimuli was used 1/6 of the times, which served as catch trials.

5.3 Experimental Design

Every trial started with a fixation period that varied from 668ms to 1332ms, to preclude that any observed patterns resulted from learning of a temporal pattern and not from the stimulus properties themselves. 250ms after the interval, either a Gabor patch or a catch trial was displayed on the screen, these patches were displayed 50% of the times in the right side of the screen and 50% in the left side. Immediately afterwards, an arrow pointing left, and right was used as a prompt to ask the participant to identify the position of the patch in the screen. Followingly, a screen displaying the numbers from 0 to 3 was presented, and the participant had to press a key on a number keyboard to indicate their visibility rating. This rating ranged from 0 ("Didn't see any stimulus"), 1 ("Not sure, but possibly saw something"), 2 ("I'm pretty sure I saw something") to 3 ("I saw the stimulus clearly"). To guarantee the differentiation between 0 and 1 this difference was verbally explained to the participant, instructing them that even the lightest suspicion of having seen something should be understood as something. Unconscious visual stimulation was understood as the subjective report of lowest visibility. Every participant went through 10 blocks of 40 trials for a total of 400 trials.

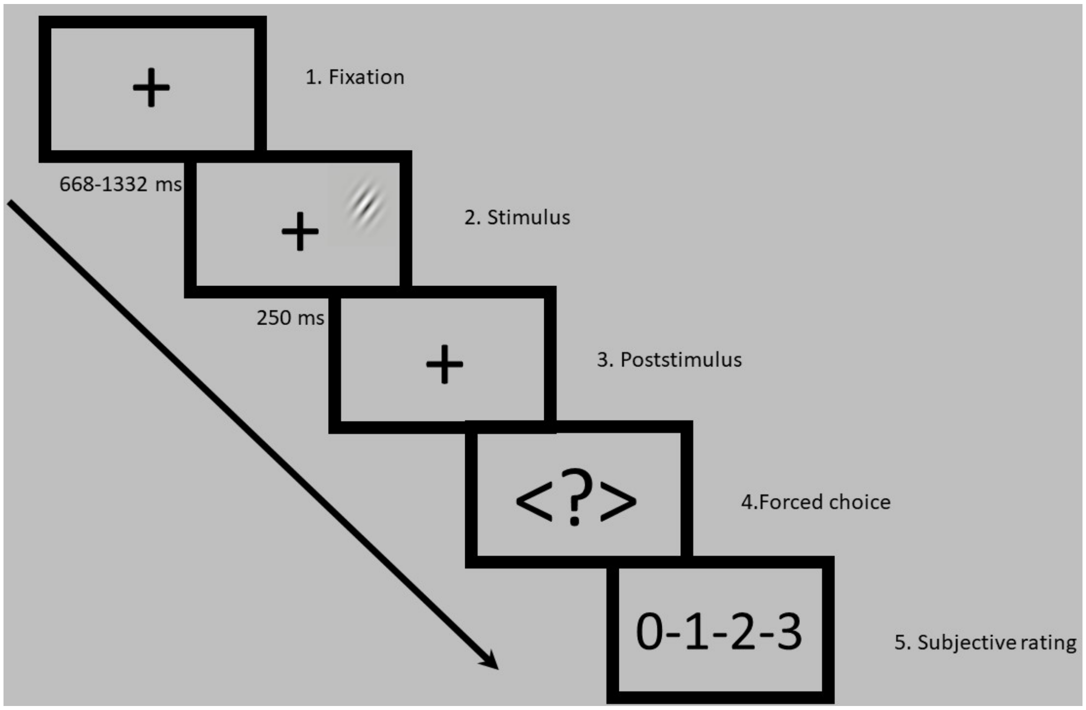

Figure 3. Constructed scheme of a single trial.

Image of the Gabor patch retrieved from: Metropsis Research Edition.
https://www.psychophysics.uk/spatial-contrast-sensitivity/#gabor

5.4 EEG Recording and Pre-processing

The EEG was continuously recorded over 64 channels at a 500Hz sampling rate using a NeurOne Tesla Amplifier. The impedances before the recording were brought close to 5kΩ. Electrooculogram recording was performed using two electrodes adjacent to the participant's left eye. One electrode was one centimetre besides, and the other one centimetre below the participants eye.

The pre-processing was performed using the EEGlab toolbox (version 14.1.1b) with Matlab (version R2016b). The signal for every participant was manually checked and interpolated to identify noisy or unresponsive signals. Once bad channels were identified and interpolated, EEG data was re-referenced to the average of all the electrodes. Two filters were applied to the data (high pass: 0.25 Hz; low pass: 80 Hz). To clean the line noise, the CleanLine EEGlab plugin was used. Afterwards, epoching in the interval -200ms to 800ms after the stimulus onset was performed. Epochs with eye movement recorded from the EOG electrodes were discarded (interval within -500ms to 500ms relative to stimulus onset). As a result, an average 24 trials, with a standard deviation of 37 trials were rejected for each participant. A transposition of electrodes was performed to guarantee that left hemisphere were always ipsilateral relative to the stimulus presentation.

5.5 Software and Statistical Analyses

The statistical analyses were run in Matlab (version R2016b). After pre-processing, a two-tailed *mass univariate test* using the averaged ERPs of all the subjects at all the time-points between 0 and 800ms was performed to compare the amplitude of VAN and P3 in the conscious and unconscious essays, including all the 64 electrodes. We used this approach considering that in spite of the decrease in the statistical power, it also decreases the probability of having false discoveries, as it is not restricted to analysing just specific time points or electrodes, but all of them. This effectively increases the reliability of the statistical testing and also allows us to identify any unexpected effects that could be observed outside the time window of interest, in contrast with the t-test that requires a specific time window to perform the estimations, as it takes all the hypothesis as related to each other, instead as independent samples (Groppe, Urbach, & Kuta, 2011). However, as the *mass univariate analysis* performs several hypothesis tests in every time-point and in every electrode, the rate of error is increased as the amount of hypothesis is increased too. In consequence, in order to ensure that the multiple hypothesis testing did not affect the final result, we used the (Benjamini & Yekutieli, 2001) *false discovery rate* correction procedure. FDR is a statistical method that estimates alpha error by fixing a specific rejection zone for all the hypothesis being tested (Storey, 2002) and allows to test the significance of each single t-test with an error of 5%.

6. Results

To get a visual representation of the general picture, we included the grand averages of all the electrodes in the figure 4. This figure illustrates all the electrodes: the left panel presents the conscious trials, in the middle the unconscious essays trials, and the right panel the difference between them.

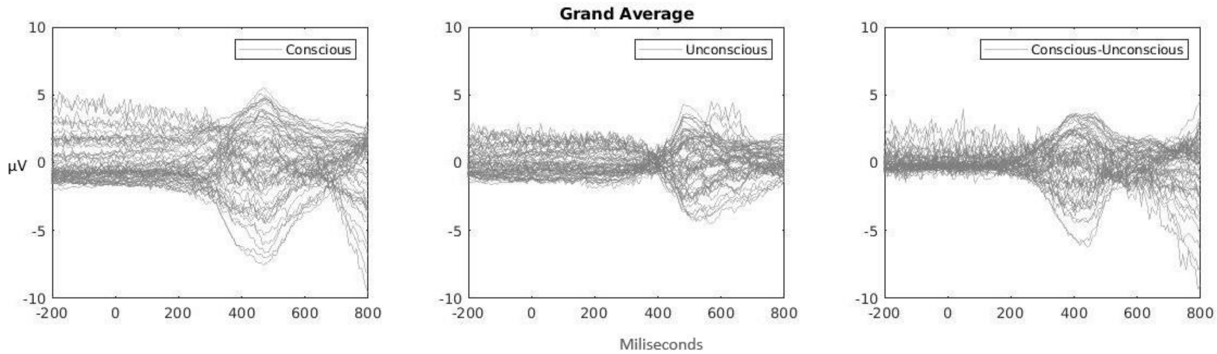

Figure 4. Grand average of ERPs.

The first graph presents the conscious ERP; in the middle panel, the unconscious condition, and on the left, the difference between the two conditions. X axis shows time in milliseconds, Y axis s µVolts.

Figure 4 shows the result of the grand average of the ERPs in the single conditions. By mere visual examination it is possible to notice that the waves start to differentiate each other around the 252ms time-window. It is also possible to see that in the conscious condition the registered amplitudes seem to be greater than in the unconscious essays, in which the waves seem to be smaller and to be more grouped. All the ERP waves seem to be increased in amplitude passing the 400ms. The difference between the two conditions shows a greater positivity that can be seen markedly in the 400ms after stimulus as well as smaller amplitude in the early negativity.

6.1 Mass univariate ERP analysis

After running the *mass univariate analysis and* correcting for *FDR*, we were able to identify effects around the 250ms to nearly 600ms time window, these effects were statistically significant at p = .05 level. The results showed a posterior negativity increasing as well as an increased late positivity in the frontal areas. To estimate the sources of these variations, scalp-maps of the specific time-windows were drawn, the main observed effects are presented in the 252, 300, 400, 450 and 500ms. The observed patterns will be described in detail under the figure of the corresponding timepoint. Figure 5 shows the results of the *mass univariate analysis,* the significative effects can be seen as intense yellow or intense blue, yellow for the positivity and blue for the negativity effects. In the right side, channel number is presented, in the base, the time in milliseconds of the identified effect and in the left, and colour represents the t-value.

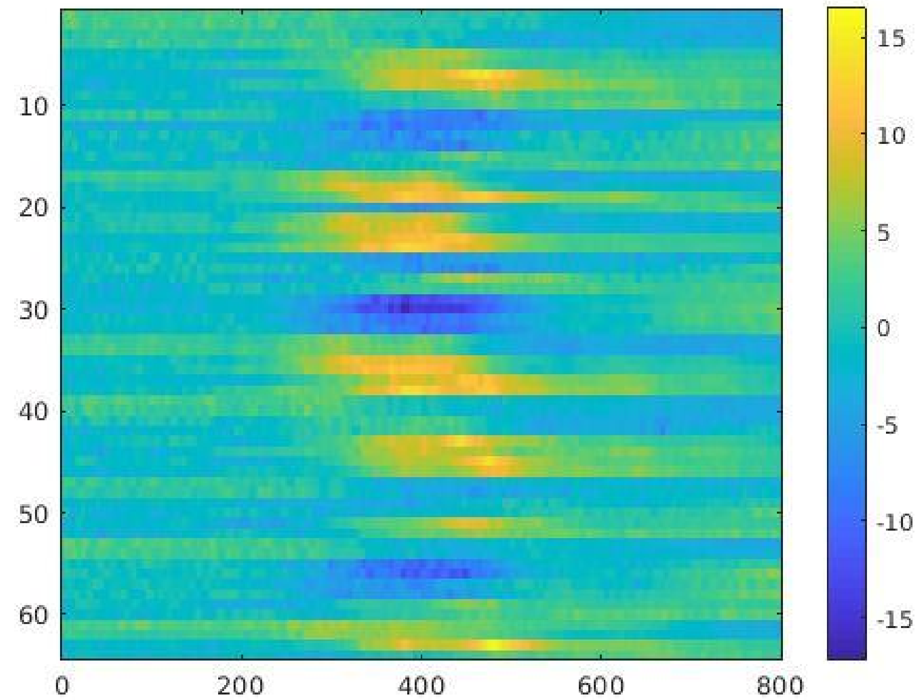

Figure 5. Mass univariate analysis results.
The yellow colour denotes a greater positivity whereas the darkest blue denotes greater negativity. Effects that were statistically significant at p = .05 level after FDR correction, are observed in the more intense colour.

6.2 Scalp-maps

To get an idea of the temporal distribution and an approach to the spatial distribution, we drew scalp-maps in the specific time-points where some effects were identified. Figure 6 presents the 252ms, 300ms, 400ms and 452ms time-windows and allows us to get an idea of the polarity distribution of the effects. The scalp-maps will be discussed individually below.

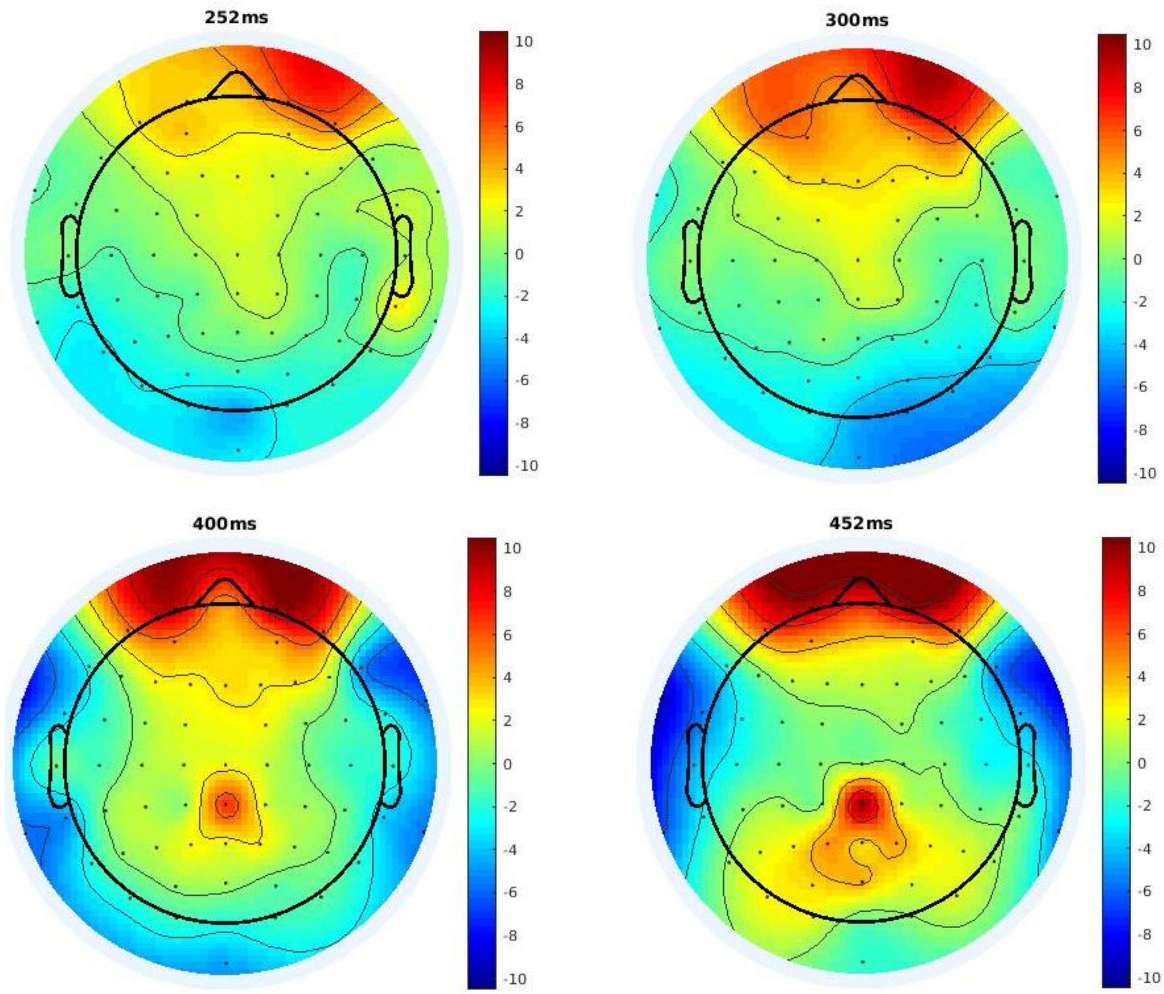

Figure 6. Scalp-maps at 252, 300, 400- and 452-time windows. *The upper panels display the polarity distribution in the 252 and 300 time-window, the lower show the polarity at 400ms and 452ms time-windows.*

252ms

This early time window shows a slight increase in the negativity in the electrodes located around the occipital areas as well as a small increase in the positivity grouped around the frontal areas.

300ms

In this period, the scalp-map shows a marked increase in positivity around frontal areas and a slight increase in posterior negativity.

400ms

An inspection of the scalp-map at this time-window indicates that there is an increased positivity in the frontal electrodes, as well as a centro-parietal increased positivity starting to appear.

452ms

A late positive peak appears in the 452ms time-window for the conscious condition, whereas in the unconscious condition a small negative variation is observed. The scalp-map is coherent with the positivity observed in the ERP waves, the distribution of this positivity has a frontal and centro-parietal distribution. Channels 7-8 and 63 show a similar activation pattern in terms of the peak in amplitude for the conscious condition.

6.3 Isolated ERPs

In the same way, we selected some electrodes that showed differential ERPs that were consistent with the temporal pattern observed in the scalp-maps and the result of the *mass univariate analysis*. Figure 6 shows the channel 7 (P3, parietal, left hemisphere), which illustrates the difference of the two conditions that starts to emerge in the 252ms, in this time period it is possible to see that the amplitude of the non-conscious condition is smaller than in the conscious condition and the increases in the amplitude seem to appear later in time, compared with the conscious condition.

In the right upper panel, the channel 63 (FPz, fronto parietal, center) shows a difference in amplitude that starts to be stronger around 300ms and its increase in positivity in the conscious condition. This positivity peaks around 450ms. The unconscious condition shows a smaller amplitude as well as a positive peak 450ms, however smaller than in the conscious condition.

The ERP wave registered in the channel 36 (F2, frontal, right hemisphere) shows a marked difference in the positivity of the waves for the conscious condition in comparison with the unconscious condition. The positivity peak for the conscious condition occurs in this time window in comparison with the unconscious conditions that has a positivity later peak around 450ms.

Putting altogether, these findings allow us to establish that conscious and unconscious conditions show a different amplitude. The conscious condition shows a greater amplitude as expected; however, the time of the components seems to differ from the previously presented by Koivisto & Grassini (2016).

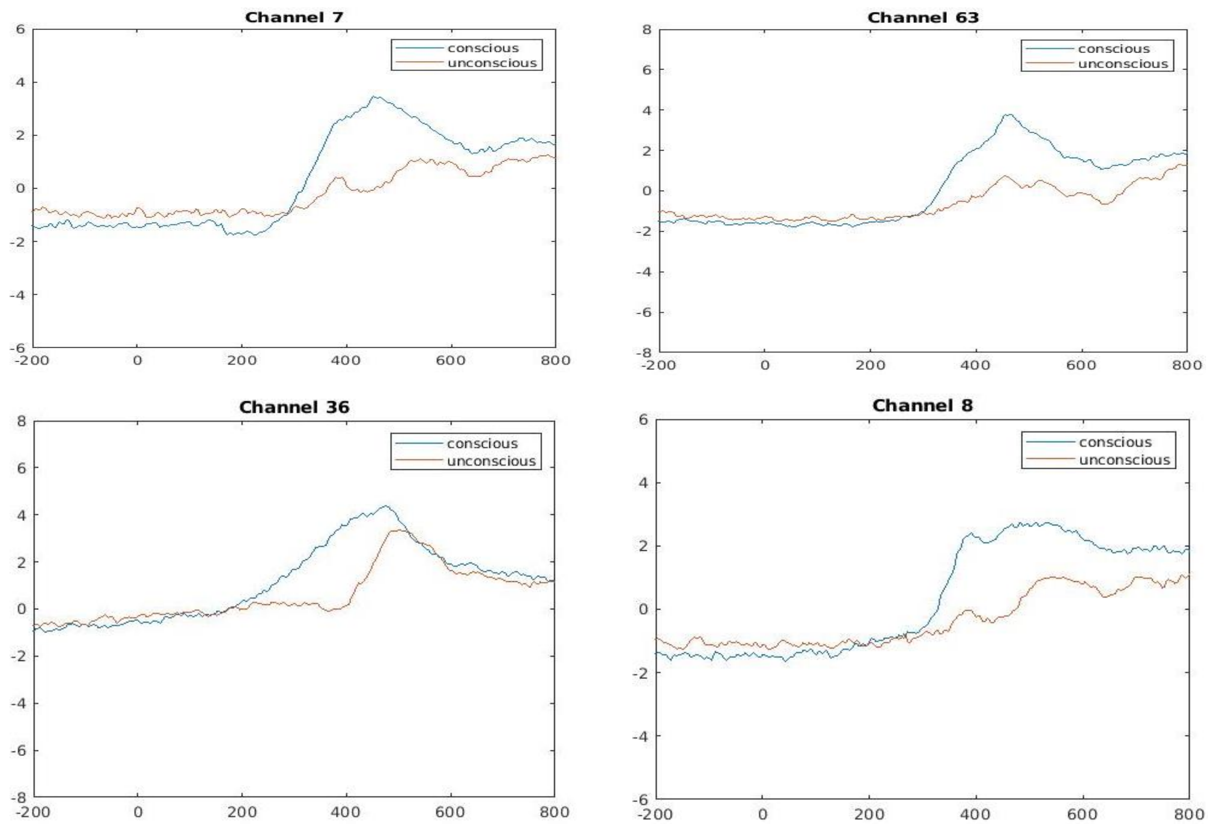

Figure 7. Examples of ERPs at 252, 300, 400- and 452-time windows*. The upper panels show the ERP waves in 252 and 300 time-window, channels 7 and 63, the lower panel show the polarity at 400ms and 452ms time-windows.*

7. Discussion

This research aimed to study the changes in the amplitude of early negativity and late positivity in conscious and unconscious stimulation conditions. We used *mass univariate analysis* to assess the difference in amplitude of two specific deflections. Our findings suggest that conscious condition evokes a greater amplitude in both, early visual negativity, and late positivity, which is coherent with our hypothesis. The scalp-maps indicated spatial distribution that coincides with previous research (Koivisto & Grassini, 2016).

However, our observed effects are surprisingly stronger in the late positivity, in comparison with the previously reported by Koivisto & Grassini, who found VAN as the strongest effect. It is possible that as we employed a *mass univariate analysis* the effect had to be stronger to be taken on account as this method analyses all the time-points as well as all the electrodes and is more sensitive to identify this so-called “unexpected” effects. On the other hand, it could also increase the risk of false negatives, given that this test uses a grouped rejection zone for alpha values. In spite of this, the test allows for the identification of the stronger effects and diminishes the risk of false positives.

When studying the isolated ERPs of conscious and unconscious essays it is possible to notice that there is a greater amplitude in the conscious components, for both negativity and positivity (Förster, Koivisto, & Revonsuo, 2020; Koivisto & Grassini, 2016; Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Koivisto, Salminen-Vaparanta, Grassini, & Revonsuo, 2016; Koivisto & Revonsuo, 2010). However, VAN was not observed in the current set of results, in that sense, it goes in contradiction by previous reports from Koivisto, Revonsuo, & Salminen (2005); Koivisto & Grassini, (2016). This is particularly interesting as these reports declare VAN as the first NCC and as the neural correlate of phenomenal experience. In the other hand, the difference in P3 observed in this study can lead us to the conclusion that declarative access to consciousness is effectively computed in this period.

The present findings should be crossed with the behavioural performance in accuracy as well as with the reaction times, as the reaction times can allow us to draw conclusions about the approximate time the subject was indeed aware of the stimulation and also how this was reflected in their ability to tell the location of the stimulus. As this research aimed to replicate the results of Koivisto and Grassini (2016), would be possible to compare if the timing of the responses and the precision effectively can be inferred by the nature of the task. In the same way, as we can locate the time of the response, we can also trace the possible timing of the registration of the stimulus, trying to place the behavioural response in the same time line as the neural activation, it can happen that somehow the timing of this task had generated any delay in the general processing of the task or that the required response was as fast that did not allow the subject to reflect on their phenomenal experience.

However, we can see that the present results are apparently in line with the reported by (Salti, Bar-Haim, & Lami (2012), as the difference between conscious and unconscious perception is registered in the P3 time window. The difference in the amplitude seen in the conscious and unconscious essays suggest that is possible to depict when the stimulus was somehow entering into the cognitive space which is to say, when the subject was able to perform operations to decide if the stimulus was registered or not. However, the behavioural data can confirm this assertion, by now, it can be declared as a plausible explanation based on the ERPs obtained here.

Accordingly, if we reflect on timing of the registered ERPs here, and we reflect on the proposed models of the visual processing as early (Lamme, 2010) or late (Dehaene & Changeux, 2011), we can notice that this results are more consistent with a late processing, instead of the early response proposed by (Lamme, 2010), as the observed effects start to appear in the 252ms time-window or later. In the same sense, the amplitude of the P3 in the unconscious condition can be interpreted as cognitive manipulation of the stimulus and as a consequence, top down processing instead of stimulus driven activity, which could involve that conscious activity just appears when the subject intentionally tries to retrieve the object on their memory (Dehaene & Changeux, 2011).

According to our results it is hard to ensure that VAN can be interpreted as a reliable first neural correlate of awareness, as we did not find it. It is hard to assume that this type of activity could reflect awareness of the stimulus (Förster, Koivisto, & Revonsuo, 2020; Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Koivisto & Grassini, 2016), It is possible instead, that as has been previously reported, this type of activity could reflect an attentional shift more than awareness itself (Salti, Bar-Haim, & Lami, 2012). On the other hand, the fact that the late positivity in the conscious essays showed a greater amplitude this can be understood as the continuous processing of the information until its final processing. In that sense could be the maintenance of the stimulus in the working memory until its final use (Polich, 2012). Conversely, in the unconscious trials the observed difference in the amplitude could be understood as the result of the cognitive effort of voluntarily trying to recover if the stimulus were consciously perceived or not. In other words, as the stimulus did not have direct access to the consciousness and in consequence is not recognized as present in the phenomenal space, requires further operations in the memory and attention systems, demanding more cognitive resources and a deliberate effort for the recovery, increasing in the activity in this time-window (Railo, Revonsuo, & Koivisto, 2015; Railo, Koivisto, & Revonsuo, 2011; Polich, 2012).

Our results do not replicate the findings of Koivisto & Grassini (2016), who report that the early awareness appears somewhere in the 100-200ms time-window, and the conscious reflective access as a positivity that tends to emerge around 300ms (Förster, Koivisto, & Revonsuo, 2020; Koivisto & Grassini, 2016; Koivisto & Revonsuo, 2010). However, it was possible to see that conscious activity evokes greater amplitudes, which allows to infer that the experimental procedure effectively was discriminating between conscious and unconscious perception. In consequence our inability to replicate the results does not depend on any error related with the design but can reflect a difference with the analysis of the data or the interpretation of the response. More research in this area using the same paradigm can lead us to a clearer explanation of the observed effects.

The present results may lead us to think about consciousness as a system depending on a sensitive threshold that allows some information to reach phenomenal space, instead of being a system that registers everything that is close to the threshold. In that sense, consciousness would be an independent system of attention as (Koivisto, Revonsuo, & Salminen, 2005) proposed earlier, however, we can see that our ERP waves have a different tendency. The observed difference can be based on the task itself and therefore can reflect that the way in which awareness and consciousness are defined lead us to different interpretations of how consciousness is measured, and in consequence to the way it is registered (Salti, Bar-Haim, & Lami, 2012; Koivisto, Revonsuo, & Salminen, 2005; Koivisto & Grassini, 2016). Regarding the unconsciously perceived stimulus, it can be possible that as the stimulus that is near the threshold has not being identified as “something” in the cognitive space, when the subject is questioned about properties of the stimulus, they need to perform more cognitive *voluntary* activity to operate with the object in the mental space (trying to remember if something was seen, and where). This could be the reason why the ERP in the unconscious condition peak around the 400ms, as the subjects are uncertain about what they saw they perform conscious operations to get any retrieval of their visual experience, they are reviewing their memory to determine if they had or had not seen something (Koivisto, Grassini, Salminen-Vaparanta, & Revonsuo, 2017; Koivisto & Grassini, 2016; Railo, Koivisto, & Revonsuo, 2011). Nevertheless, it is important to take on account that the different types of paradigms and models assume different designs making harder to be sure that we are, in fact measuring the same processes. Additionally, trying to assess phenomenal experience in an objective way constitutes a challenge as we do not have third confirmation methods to confirm the participant's report. According to it, it is easier to follow the declarative/ reflective access to consciousness as this type of consciousness seems to be dependent on voluntary cognitive operations that can be inferred through other means, in contrast to the phenomenal consciousness, as the "sensation of seeing", results until now, inaccessible for an external observer. The problem to approach constructs in this way is related with the fact of the sensory system as a limited system that narrows the attentional resources to specific aspects of the environment, in specific time-points, any interruption in the attentional stream can affect the sensation of seeing or even can create the idea of seeing even in absence of stimulus. This problem affects the declaration of the subject, and at the same time raise the question about how much can a subject rely on what they say when they are not even sure of seeing or not? Of course this type of discussion is beyond the scope of this study, but calls attention to the fact that measuring this type of processes requires a complex theoretical and experimental work to ensure that the constructs of interest are going to be registered properly.

7.1 Further developments

As possible developments of this research, it would be to study if there is a relationship between the amplitude of the components and the behavioural performance, as well as if accuracy tasks seem to reflect a relation with VAN and P3. This would enable us to assess the possibility of preconscious treatment of information that was proposed by (Salti, Bar-Haim, & Lami, 2012). Also, it would be interesting to study if the greater amplitudes are also related with higher precision and with higher evaluation of subjective certainty of seeing the stimulus.

Given that the cortical sources of ERPs are not great in spatial distribution, but that we observed some early frontal activations, it would be interesting to study how this frontal activity is involved in this type of tasks. Using TMS to temporally inactivate frontal areas in this time-windows and see if the behavioural and declarative report are affected by this temporal inactivation should allow to draw some conclusions about the contributions of this areas to vision.

7.2 Conclusion

The increased amplitude of P3 seems to support the hypothesis that the search for the conscious experience requires a deliberative effort than a mere registration of the stimulus. That could explain the observed difference in amplitude of P3 component. That could mean that subjects were unaware of what was happening with them until they were questioned about their experience. Therefore, the declarative system had to play a role trying to uncover if the subject was or not presented with the stimulus. Further research including the behavioural results can help in the clarification of the present results.

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