Bachelor Thesis

Consciousness and Attention: To what extent individual differences in consciousness are predictable by evoked lateralized EEG activity

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Content

Appendix

Summary

Previous studies showed that attention is likely to play an important role in consciousness. To build further on this, we were interested in whether we could determine individual differences in visual consciousness, and to which extent these differences could be predicted by evoked lateralizations. To address these questions, an endogenous visuospatial attention task was conducted in which participants had to respond to stimuli at either the left or right visual field. To map individual differences in consciousness, these stimuli were masked after a varying time interval by backward masking. A recently developed method for analyzing EEG, the lateralized power spectra (LPS), was applied on event-related potentials to map evoked activity. Results showed that individuals differ to what extent they were able to consciously perceive stimuli. However, these differences could not be predicted by evoked lateralizations. Additionally, our study determined a small but significant role for evoked activity in explaining the role of neuronal activity underlying the attentional orienting to visuospatial stimuli.

Samenvatting

Uit eerdere onderzoeken is gebleken dat aandacht een belangrijke rol speelt in bewustzijn. Hierop voortbouwend waren wij geïnteresseerd of er verschillen zijn tussen respondenten in visueel bewustzijn. Het tweede doel van de studie was het achterhalen of het mogelijk is om voorspellingen over deze eventueel individuele prestatieverschillen te maken op basis van evoked lateralizatie. Om deze vraag te beantwoorden werd er een endogene, visueelspatiele aandachtstaak ontwikkeld waarin respondenten moesten reageren op een stimulus die links of rechts in het visuele veld werden aangeboden. Om individuele verschillen in bewustzijn in kaart te brengen werden deze stimuli na een varierend tijdsinterval onzichtbaar gemaakt door backward maskering. Een nieuw ontwikkelde EEG analysemethode, de lateralizied power spectra (LPS) werd toegepast op event-related potentialen om zo evoked activiteit in kaart te brengen dat gebaseerd is op power. Uit de resultaten bleek dat hoewel er wel individuele prestatieverschillen waren, deze niet voorspeld konden worden op basis van evoked lateralizatie. Tevens bleek dat evoked activiteit voor een klein maar significant deel verantwoordelijk is voor neurale activiteit die ter grondslag licht bij het richten van aandacht naar visuele stimuli.

Introduction

Understanding neuronal mechanisms behind consciousness and attention is a major challenge for cognitive neuroscience. In a study of Mathewson et al. (2009) it has been suggested that because participants often fail to see something that is at other times readily detectable, these changes could be due to variability in conscious awareness. Their study showed that increased alpha oscillations in a visuospatial attentional task are representing an inhibition of cortical activity, which demonstrated that visual consciousness is correlated to changes in the brain at various attentional orienting phases. Additonaly, van Velzen & Eimer (2003) were also able to distinquish brain activities at various attentional orienting phases. More specifically, they found contralateral negativity mainly above occipital-parietal sites at approximately the first 200-400 ms of attentional orienting. However, the method for analyzing EEGs used in this study has got shortcomings, which will be discussed later on. In the current paper, we were interested in to what extent individuals differ in visual consciousness at a task based on visuospatial attention. We limited the characteristics of consciousness similar to the definition as proposed by Tsuchiya, Block & Koch (2005). They stated that one aspect of consciousness, also referred to as phenomenal consciousness, is ‘’the case where qualitative experiences, such as simple sensations, are presents’’

In a study of Mathewson (2009), stimuli were replaced by junk material by a method referred to as backward masking. Because this method prevents an afterimage of the briefly presented stimulus to occur, it is more reliable to bring variation in time of the stimulus presentation (also referred to as stimulus onset asynchrony, or SOA). As a result, it has been stated that this method is useful to influence the participant’s ability to detect stimuli (Breitmeyer, 2014). Recently, backward masking has often been used for finding differences in cognition across individuals in visual tasks (e.g. Kaltwasser et al., 2014; Zhang et al., 2012). Importantly, it has been showed that attention plays an important role in the effectiveness of visual masking (e.g Ramachandran & Cobb, 1995; Boyer & Ro, 2007). Therefore, it could be suggested that it is very likely that visuospatial attention plays an important role in one’s ability to consciously perceive stimuli. However, the precise correlation between consciousness and attention still remains largely unknown.

This correlation between attention and consciousness was also discussed in a paper of Dehaene et al. (2006). They suggested that when participants actively attended a stimuli (top-down attention) various long-distance loops were activated, thereby increasing the ability for to report the presence of the stimuli. However, as they and others suggested, there has been an ongoing discussion about the precise role of attentional processes. It is has often been stated that attention to changes in the visual field is the result of top-down control signals that bias the sensory system (Corbetta & Shulman, 2002; Hopfinger et al., 2000). To be more precise, it has been suggested that attention reduces external or internal noise, thereby inhibiting distracting, non-relevant information (Klimesch, 2011; Kastner & Ungeleider, 2001; Lu & Dosher, 1998). An alternative explanation is that attention occurs as a result of an inhibition of neural activity, thereby providing an ability to regulate the ongoing flow of visual information processing (e.g., Gould, Rushworth & Nobre, 2011; Rihs, Michel & Thut, 2009).

In the past, various paradigms have been used to examine attentional processes. In particular, a paradigm that is often been used to examine visuospatial attention is the Posner cueing paradigm (Posner, 1980). Within this paradigm, endogenous attention is often used, which is attention that occurs as a result of the goals and expectations of an observer (Smith & Kosslyn; 2007; Hopfinger & West, 2006). The Posner endogenous cueing paradigm is therefore useful when the goal is to examine effects of top-down attention. In past studies, this method has been combined with EEG measurements to examine neuronal mechanisms underlying the allocation of visuospatialspatial attention by looking at the correlation of brain areas and top-down attentional processes that occur prior to the presentation of the expected stimulus (e.g., Albares et al., 2011; Hayward & Ristic, 2013).

However using EEG measurements for research has often been useful; there are a few problems that could occur. A frequently used method for analyzing EEG data, event-related potentials has got major shortcomings. Using event-related potentials makes it possible to measure brain responses that are the direct results of an event by looking at brain responses after the presentation of a stimulus (more specifically, by comparing brain activity after a specific event to a baseline measurement). Thereby, computation of ERPs assumes that all the relevant signal is temporarily bound to a specific event. However, a lot of potentially relevant signal is cancelled out by averaging across a large number of trials (e.g., see Buszaki, 2006; Hermann, Gritusch & Busch, 2005). In other words, only evoked and not induced activity are taken into account at further analysis. It is likely that attentional orienting is varying over trials and between individuals and this variation may be more interesting than pure evoked, event-related activity. In recent studies (van der Lubbe et al. 2014; van der Lubbe & Uzerath, 2013) a wavelet analysis analysis (Basar et al. 2001) was conducted to raw EEG data (also referred to as lateralized power spectra, or LPS), thereby most likely measuring both evoked and induced attention. Another advantage of conducting wavelet analysis is the possibility to measure various frequency bands, which may provide important insights regarding attentional processes and consciousness. Furthermore, van der Lubbe & Uzerath (2013) suggested that hemispherical differences should be taken in account at analyzing EEG data. For this reason, computation of LPS is based on a double-subtraction method which corrects for these hemispherical differences. In recent studies, wavelet analyses were also applied on event-related potentials, also referred to as LPS-ERP (van der Lubbe, 2014; van der Lubbe, 2013). It has been stated that the LPS-ERP is more sensitive compared to other ERP-related methods such as event-related lateralizations (ERL; also used in the previous mentioned study of van Velzen & Eimer (2013)) because it might reveal effects that are not visible in ERLs due to individual differences. Furthermore, other than ERP-related methods such as the ERL, a double-subtraction method is used to correct for hemispherical differences or general biases. Importantly, it is likely that not all the signal that is taken into account at LPS is relevant. Since these signals, which could also be just noise, are not taken into account at the computation of LPS-ERP, the signal-to-noise ratio is higher. To sum up, it is more likely that signals that occur at the LPS-ERP are relevant effects.

As stated earlier, we were interested in building further on studies regarding consciousness using attentional orienting tasks (e.g. van der Lubbe et al. 2014; van der Lubbe & Uzerath, 2013; Mathewson, 2009). As described above, the study of Mathewson et al. (2009) demonstrated a correlation between consciousness and differences in brain activities. Furthermore, it has been suggested that these differences are likely to be related to attentional processes. Unlike the study of Mathewson et al. (2009), we were interested in differences between rather than within individuals. We conducted a visuospatial task based on endogenous cueing and including backward masking and using the LPS-ERP to analyze EEG data. In a recent study of Aldiek (2015), who used LPS to analyze EEG data, a relationship between lateralization and individual differences in consciousness has been demonstrated. However, the current study only takes evoked activity into account. Rippe (2016) performed the same study, but used the

LPS to analyze EEG data rather than the LPS-ERP. Therefore, comparing the current study with the latter might reveal relevant information regarding the evoked and induced nature of attention. In the current study, we first expect individuals to differ to which extent they are able to detect stimuli with different SOAs. Second, we expect that evoked activity is capable at predicting these individual differences in visual consciousness. Additionally, our results are likely to provide important information regarding the evoked and induced nature of attentional orienting.

Method

Participants

Twenty participants, mainly students from the University of Twente and Saxion Enschede, participated in the study. Thirteen participants were male, and seven were female (mean age = 23 years, ranging from 18 to 34). Fourteen participants were right-handed, five were left-handed and one was ambidextrous, which was assessed using the Annett's Handedness Inventory (Annett, 1970). All participants had normal or corrected-to-normal vision, none was color blind, and all had no history of neurological diseases. Prior to the study, all participants gave their written informed consent. The study was approved by the ethics committee of the Faculty of Behavioral, Managament and Social Sciences of the University of Twente.

Task & procedure

A variation of the Posner endogenous cueing task (Posner, 1980) was used. A default display consisted of a centrally presented white fixation point on a black background and two open circles on the left and right side of the screen. Start of a trial was marked by a short enlargement of the fixation point for 200ms. The participants were instructed to direct their eyes towards the fixation point. After presenting the display for another 500ms, a diamond shape-cue (rhomb) appeared which consisted of two colored triangles (blue and yellow) pointing to the right or ride side. One color functioned as a cue of the to-be-attended site. The relevant color was counterbalanced over participants. The rhomb was displayed for 600ms, and afterwards replaced by a fixation point. After a total of 1400ms (600 plus 800), the target was presented at either the left or the right circle. This target consisted of either horizontal or vertical stripes. Participants were instructed to respond by either pressing the left (for horizontal stripes) or right (for vertical stripes) "Ctrl" button. A mask covered the target after varying time intervals (16 ms, 32 ms, 48 ms, 64 ms, 80 ms, 96 ms, 112 ms, 128 ms, 144 ms, 160 ms, 176 ms, 192 ms, 208 ms and 224 ms). The participants were instructed to guess if the target seemed invisible. A graphical representation of the task is shown in figure 1.

The task consisted of 896 experimental trials, which were divided between eight blocks of 224 trials each. Prior to the first block, the participants were instructed to execute a trial block to practice and adjust the eyes to the light-deprived environment. The experiment included a one-minute break between each block. In total, execution of the experiment took approximately 100 minutes.

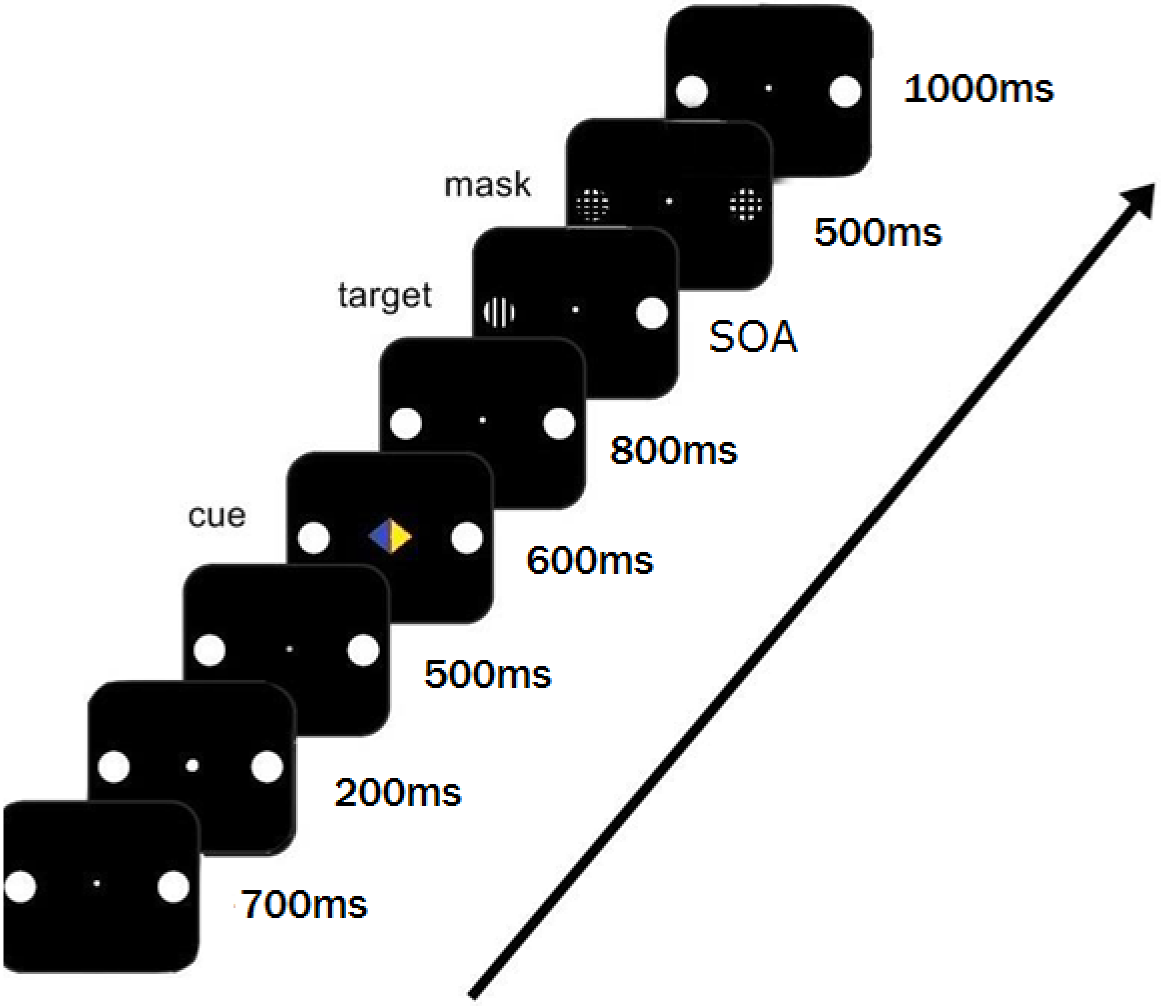

Figure 1. Schematic representation of the sequence of events in one trial. SOAs were 16ms, 32ms, 48ms, 64ms, 80ms, 96ms, 112ms, 128ms, 144ms, 160ms, 175ms, 192ms, 208ms and 224ms, resp.

Apparatus & EEG Recordings

Participants sat approximately 80cm in front of the monitor on a comfortable chair. The stimuli were presented with Presentation Software (Neurobehavioral Systems, Inc., 2012). A standard QWERTY keyboard was used to register the responses. EEG was recorded using Brain Vision Recorder. 30 passive Ag/AgCl ring-electrodes were placed at 30 locations. Four electrodes were placed near the participant's eye to record the electroonculogram (EOG). Vertical EOG (vEOG) was recorded from electrodes placed above and below the left eye, while horizontal EOG(hEOG) was recorded from electrodes placed at the outer canthi of both eyes. 25 electrodes were mounted on the scalp at the following locations: Fpz, Fz, F3, F4, F7, F8, FC5, FC6, Cz, C3, C4, T7, T8, CP5, CP6, Pz, P3, P4, P7, P8, PO3, PO4, PO7, PO8, Oz (see fig. 2). The resistance of the electrodes was kept below 10 kΩ. To enable conduction between the electrodes and the scalp, conductive gel was used. To amplify the EEG and EOG, a 72-channels QuickAMP (Brain Products GmbH) amplifier was used. EEG, EOG as well as task-related events such as stimulus onset and responses were registered with BrainVision Recorder (BrainProducts GmbH), which was installed on a separate computer. Signals were sampled at a rate of 500 Hz with the following online filters: a low-cutoff was set .016 Hz, a high-cutoff was set at 140 Hz and a notch-filter of 50 Hz was used.

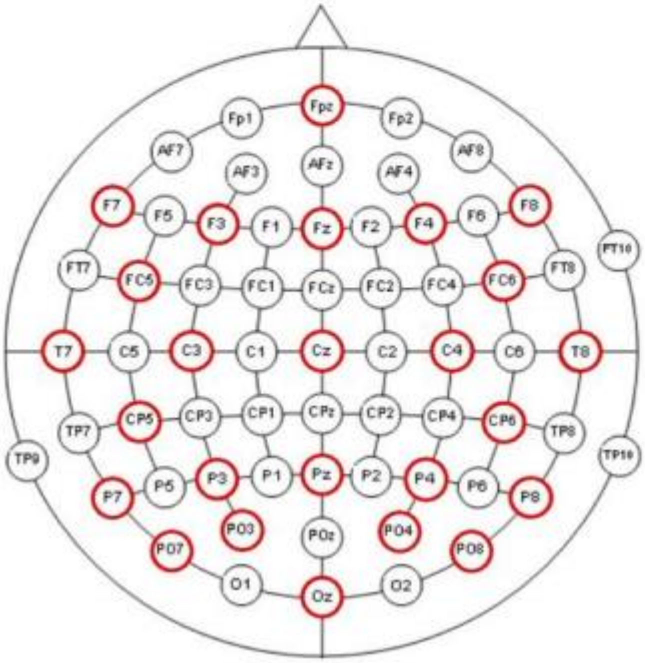

Figure 2. Electrical activies were measured at electrodes marked in red.

Data processing and analysis

Processing of the data was carried out with Brain Vision Analyzer 2.0 (Brain Products GmbH, 2012). The data were first partitioned in segments from -750 to 3400 ms relative to cue onset, with a baseline set from -100 to 0ms. Horizontal and vertical movements of the eyes were marked when amplitudes on the hEOG and vEOG channels exceeded the values of +-40 μV. Earlier studies showed that this value corresponds with eye movements (e.g., see Van der Lubbe & Woestenburg, 1997). This procedure controlled for the possibility that the effects in the cue-target were also related to eye movements.

In the cue-target interval, EEG-segments which contained artifacts were removed. The following criteria were used: a gradient criterion of max. 50 μV, min-max criterion of +/- 150 μV and a low activity criterion of 0.1 μV. After removing trials with eye movements and EEG artifacts, 77% of the trials remained for further analysis. A regression coefficient was measured between EEG and EOG to correct EEG for eye movements.

The activity that was temporarily bound to the cue was averaged across all trials to determine ERPs for each participant. The lateralized activity was determined based on the outcome of a wavelet analysis on ERPs, which was denoted as LPS-ERP (lateralized power spectra on event related potentials). Then a double subtraction was carried out to determine contra-ipsilateral difference waves (see Van der Lubbe & Uzerath, 2013). Therefore, LPS-ERP was calculated according to the following formula:

$$LPS(\omega_p)_t = \left(\left(left\ cues\ \frac{(\omega_p(PO7) - \omega_p(PO8))}{(\omega_p(PO7) + \omega_p(PO8))}\right) + \left(right\ cues\ \frac{(\omega_p(PO8) - \omega_p(PO7))}{(\omega_p(PO7) + \omega_p(PO8))}\right)\right) \times \frac{1}{2}$$

Values of the LPS-ERP vary from -1 to +1. A positive sign indicated that the power within a specific frequency band was larger above the hemisphere ipsilateral to the cued side than contralateral whereas a negative sign indicates the opposite pattern. We decided to explore activity for several electrode pairs (FC5/6, C3/4, CPS5/6, PO3/4, PO7/8, P7.8) as they overlay the potentially relevant brain areas like the frontal eye fields, hand motor areas, parietal areas, occipito-parietal areas and occipito-temporal are. Four bands were analyzed: (i)alpha1 (α_1) ranging from 7.2 to 10.4Hz, (ii) alpha2 (α_2) ranging from 9.4 to 14.0Hz, beta1 (β_1) ranging from 12.2 to 18.4Hz and (iv) beta2 (β_2) ranging from 16 to 24Hz.

The average power was determined for each person for intervals of 40ms after the cue onset, ranging from 200 to 1400ms, which resulted in measuring lateralized activity separated in 30 time windows. t-tests were performed per cue condition to determine whether activity deviated from zero. Due to the high amount of the to-be-performed *t*-tests, a Bonferoni-correction was made to limit the probability of Type-I errors (see Talsma et al. 2001). The formula of the method used in the current study was $p < \surd(.05/((\text{windows}-1)) \times \text{condition} \times \text{electrode pairs} \times \text{band})$. Thereby, the p value for our study was $p < \surd\ (.05/(29x2x10x2) < .00065$. We stated that this p-value had to cross for at least two successive time periods. The tests were performed to make a pre-selection of significant lateralization of alpha synchronization.

To measure to what extent participants were able to consciously perceive stimuli, the proportion of percentage correct (PCs) were determined for each SOA. Only trials without detectable eye movements and button presses in the cue-target interval were used to determine these proportions. Individual averages on PCs were determined as a function of SOA and Target Orientation (horizontal or vertical). After analyzing PC’s on SOA’s, a ranking order was built in based on average percentage corrects and the highest percentages correct of each participant to examine whether there is a correlation between lateralization and performance of the participants. Cumulative ranking orders were used to correlate with lateralizations. Because in the ranking orders two variables of performances were taken into account, we stated stated that this helped to stabilize the data, thereby providing a more suitable method to predict individual differences based on evoked lateralizations.

Table 1

Ranking orders for each participant. Cumulative ranking order was calculated by the formula: (ranking order based on SOAs at the highest PC/ranking order at mean PC)/2

Respondent	Ranking order for SOA on highest PC	Ranking order at mean PC	Cumulative ranking order
1	9	9	9
2	6	5	5,5
3	4	15	8,5
4	15	7	11
5	10	10	10
6	16	19	17,5
7	8	8	8
8	2	2	2
9	12	12	12
10	20	20	20
11	7	6	6,5
12	19	16	17,5
13	10	11	10,5
14	5	4	4,5
15	17	17	17
16	18	18	18
17	2	3	2,5
18	14	13	13,5
19	13	14	13,5
20	1	1	1

Results

Behavioral Measures

The mean percentage correct (PC) at the different stimulus onset asynchrony (SOA) are shown in table 2. The mean PC over all respondents was 82.4% (sd=4). However, as shown in fig. 2, the percentage corrects were unstable over participants as mean PCs were ranging from 68 to 97, lowest scores were ranging from 59.1 to 80.5 and highest scores from 78.3 to 100. On average, a positive effect of SOA on mean PC's has been found; t(19) > 4.9, p<.001. This suggests that participants were better able to consciously perceive visual stimuli at higher SOAs and vice versa for lower SOAs.

Table 2.

Differences of percentages correct and corresponding SOAs of each participant

Ppn	Min. PC	SOA at min PC	Mean PC	Max. PC	SOA at max. PC
1	66.1	16	83.58	92.86	224
2	67.86	16	88.51	97.06	224
3	67.27	32	78.03	84.5	112
4	66.7	64	88.23	100	176;224
5	71.15	48	83.11	91.23	160
6	70.45	64	73.26	84.44	96
7	78.18	48	87.23	94.74	176
8	79.17	16	94.73	100	112;176;192
9	73.77	80	82.20	90.16	160
10	59.1	128	68.19	78.26	144
11	77.19	16	88.39	96.72	176
12	71.4	16	76.35	80.95	176
13	73.59	64	82.77	91.23	208
14	79.03	16	92.70	100	160
15	68.29	48	75.18	83.72	176
16	67.5	48	74.23	82.05	224
17	80.49	48	93.5	100	80;144;224
18	73.47	16	82.03	88.46	208
19	61.22	64	81.03	89.8	160
20	77.59	16	97.12	100	144;160;176;208;224

Note: The effects are described in terms of ipsi-contralateral differences (therefore CP6, PO8, PO4, etc)

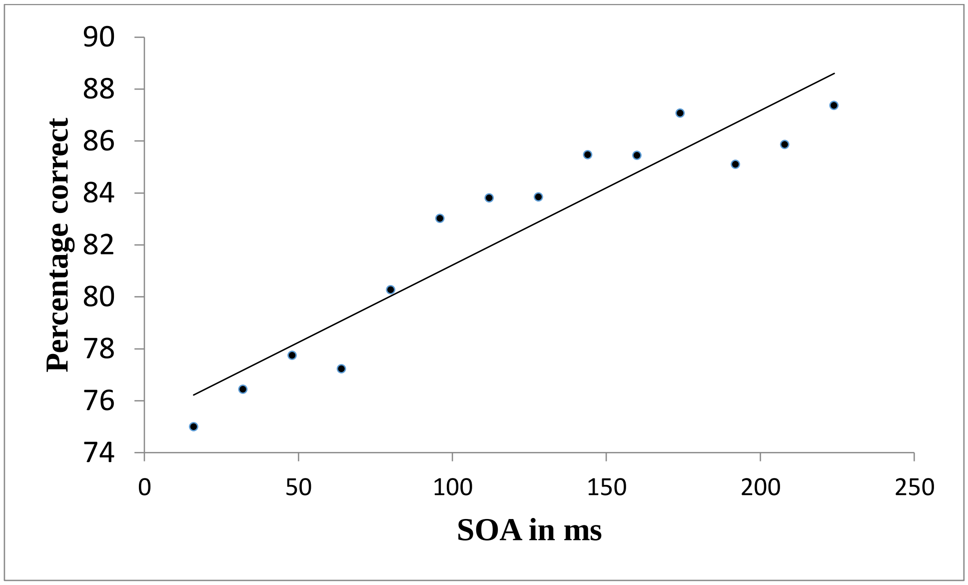

Fig2. Representation of percentages correct answers at each SOA (e.g. at an SOA of approximately 64 ms, partcipants scored approx. 77 percent of the answers corrects on average)

<u>EEG measures</u>

One-sample t-tests were performed to test for ipsi-contralateral differences in the alpha and beta frequency band lateralizations. These statistical analyses showed that only three effects crossed the significance criterion for at least two successive time windows, which are shown in table 3. The most pronounced effect was present at the F8/F7 electrodes (320-360ms, t(19) = 3,9, p<.001), The effects are described in terms of ipsi-contralateral differences; thereby F8 represents activity of the F8 and F7 electrode, PO8 represents FO8 and FO7, PO4 for PO4 and PO3 etcetera

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Table 3

Effects observed for Alpha1 and Alpha2 frequency bands for when the significance criterion was crossed for at least two successive time windows (p < .0065)

Band	window (in ms)	electrode	< p <
Alpha1	280-320	F8	<.001
Alpha2	800-880	PO8	.001 < .002
alpha2	840-880	FC6	.003 < .006

We applied a Spearman's rank correlation to the performance and lateralizations. Effects that crossed the significance criterion for at least two successive time periods were presented in table 4. The most profound effect was present at the PO8/PO7 electrodes for the alpha2 frequency band at the time window from 760-800ms ($p<.0003$, $r_s > -.73$; see figure 3). A graphical representation of the significant results of both lateralizions on each electrode as well as the correlation between lateralizions and individual differences in performances are shown in figure 4.

Table 4

Correlations between LPS-ERP and individual differences that crossed the significance criterion for at least two successive time periods.

Band	window (in ms)	electrode	< p <
alpha1	360-440	FC6	.001 < .006
alpha2	720-800	PO4	.003 < .004
alpha2	720-800	PO8	<.00

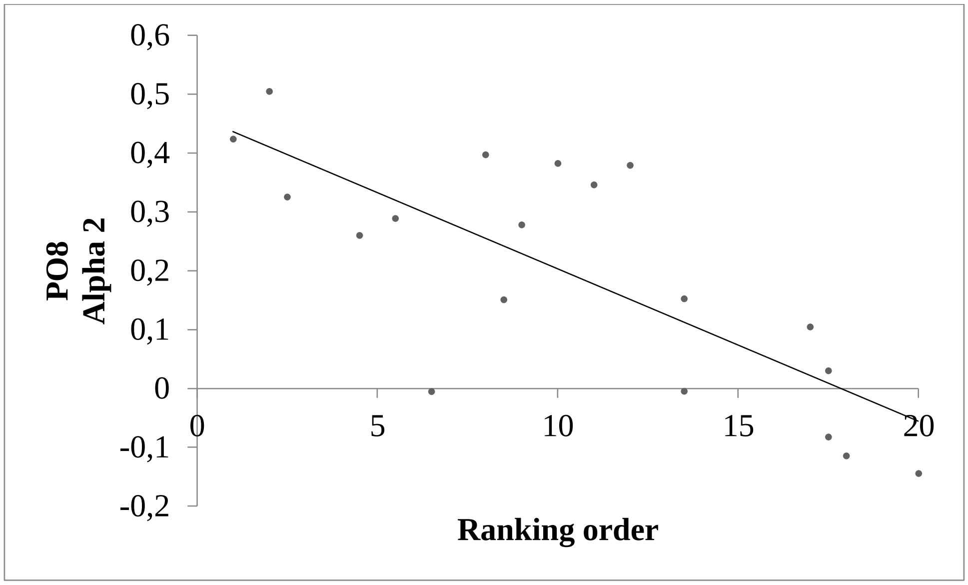

Fig 3. Relation between alpha2 lateralization on the PO8 and PO7 electrodes and performance in the time window with the most significant correlation (760 – 800 ms, $p<.00$, , $r_s > -.73$). Each point represents the lateralizaion and ranking order for each participant.

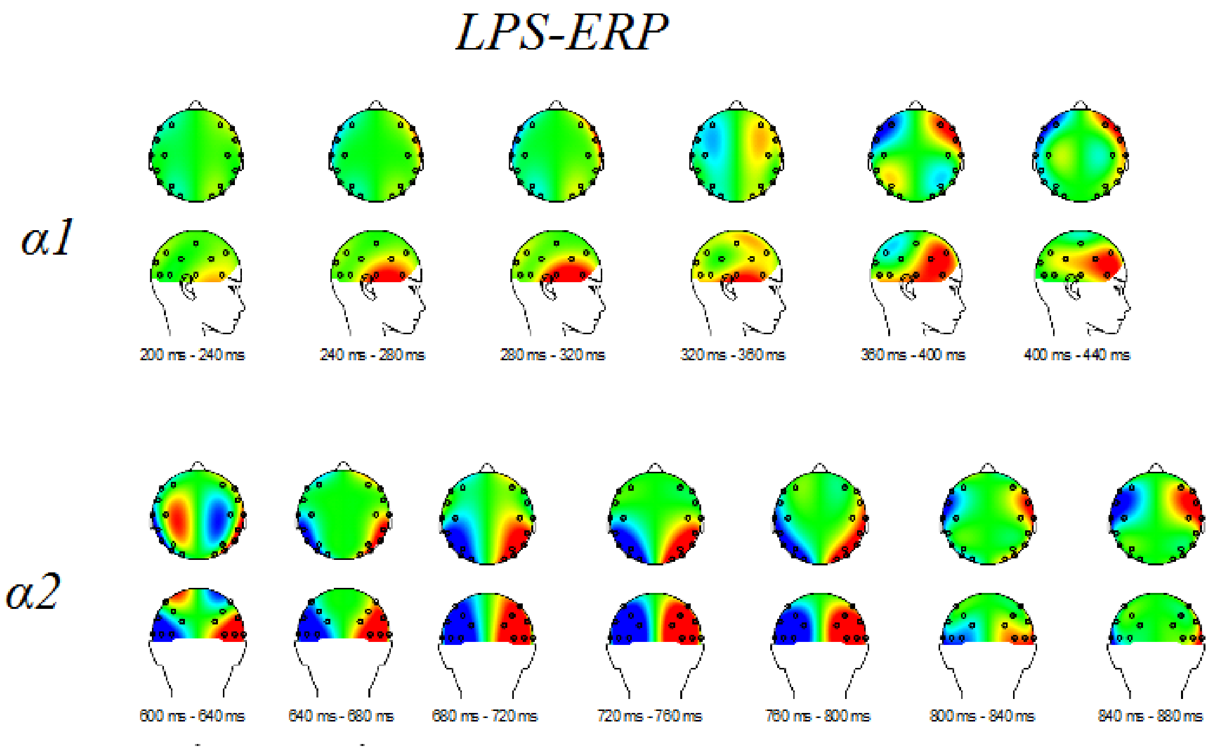

Fig 4. Topographical maps for the α1- frequency band (200-440 ms) and α2-frequency band (600-880 ms) for the time windows where a significant power difference was found. At the 200 to 440ms time window the left hemisphere was presented as contra-ipsilateral power, whereas the right hemisphere reflects the ipsi-contralateral power difference. LPS-ERP = lateralized power spectra on event-related potentials

Discussion

As mentioned in the introduction, several studies have been conducted to examine the correlation between attention and consciousness (e.g. van der Lubbe et al. 2014; van der Lubbe & Uzerath, 2013; Mathewson et al. 2009). In the current study, we wanted to build further on the latter mentioned studies by examining individual differences on performance at a visuospatial task on the endogenous cueing paradigm (see Posner, 1980) and including backward masking (see Breitmeyer, 2014). Importantly, we were interested in whether these individual differences in visual consciousness could be predicted by evoked lateralizaions.

Behavioral data of our experiment suggested that participants' ability to consciously perceive visual stimuli increased as SOAs got higher and vice versa when SOAs lowered, which suggests that using backward masking in our experiments was successful for altering participant's ability to report the visibility of the stimuli. Moreover, we linked the average performances on the task to evoked lateralizions. Mathewson (2009) demonstrated that variability in participant's ability to consciously perceive stimuli and brain activities were correlated and that these correlations are likely to be due to differences in attentional orienting. Apparently, some relevant things were not present in our study since we found significant activity at only three (early) time intervals. Two of the significant effects were at frontal areas and one effect represented activity at occipital areas, which is not compatible with the study of van Velzen & Eimar (2013) as they found more profound effects at early attentional directing at occipito-parietal sites. As the latter mentioned study was based on ERLs, comparing our study with the latter might suggest that either too much signal is included in ERLs (therefore being not sensitive enough) or too little signal is included in the LPS-ERP (therefore suggesting that the latter analyzing method is too sensitive). However, the presence of lateralizations at the LPS-ERP at the PO8 electrode suggests that evoked activity is likely to be of importance at occipital areas. Additionaly, as mentioned in the introduction, Rippe (2016) used LPS instead of LPS-ERP to analyze performances on the task. In the latter study, more significant effects were found, including effects for parietal areas and effects at later time intervals (also, as shown in the current study as well, including the activity at frontal areas), suggesting that induced rather than evoked attention is important at visuospatial tasks. Since LPS-ERP has a high signal-to-noise ratio (as discussed in the introduction), it could be suggested that either LPS-ERP is too sensitive or that LPS takes too much signal into account. In conclusion, no clear correlation between brain activity and attention to visuospatial stimuli has been found in our study. As the LPS-ERP is relatively sensitive, our results are pointing out to the possibility that some of the neuronal activities that are found in other studies (e.g., van Velzen, 2013; Rippe, 2016) might be irrelevant to what is actually happening at attentional orienting to visual stimuli. Importantly, our results demonstrate that small but significant amount aspects of attentional orienting have a clear evoked component.

As mentioned earlier, the main interest of our study was to examine individual differences in participants' ability to perceive stimuli and whether it is possible to make predictions regarding these differences based on evoked lateralizations. Similar as in the study of Aldiek (2015), behavioral measures showed that respondents differed strongly in their capacity to detect stimuli. A ranking order of each participant was calculated (based on average PCs and SOAs at highest

PCs) and after that correlated with evoked lateralizions. Significant correlations were found at frontal areas for early time intervals and occipital areas time intervals ranging from 720 to 800 ms. This little amount of significant effects suggest that there is no clear evidence that it is possible to predict individual differences based on evoked lateralizions. This point out to the suggestion that induced rather than evoked attention is capable of predicting individual differences. The recent study of Aldiek (2015) found that individual differences could be predicted by the LPS, which includes both induced as well as evoked activity. This suggests that induced activity is indeed important at predicting individual differences in consciousness. In contrast, Rippe (2016), who also used LPS to analyse EEG data, found significant effects at only four time intervals, which is not sufficient to make a clear distinction between the LPS-ERP and LPS. Therefore, based on these studies, the distinction between evoked and induced activity is not yet clear. However, the presence of significant correlations at occipital areas in our study suggests that evoked activity is likely to be of importance at this brain area.

Since both activities at the LPS at the study of Rippe (2016) and the LPS-ERP at our study were not sufficient to predict individual differences, it is likely that some shortcomings could be explained by the setup of our study. Behavioral data showed that participants were better at perceiving stimuli than we expected, showing PCs corrects of higher than 80% at SOAs as low as 16ms. Since the experiment consisted of 8 blocks, these high performances might be partly due to learning effects. To examine the influence of learning effects, it is interesting for future studies to perform an analysis on each block (e.g. to examine whether the ability to perceive the stimuli increased over the blocks). Additionaly, another methodological problem is to distinguish eye movements from neuronal activity at frontal areas. The presence of significant effects at frontal areas at various analyses, as well as at other studies (e.g., Rippe, 2016; Aldiek, 2015; van der Lubbe, 2014), points out that this problem is relevant. Since EEG measures electrical signals that arise from both neuronal activity as well as from muscle movements (for example, the eyes), it is very hard, if not impossible, to distinguish completely between those two variables. A possibility to further examine this problem is to conduct a similar study and use a method to analyze brain activity that is not related to electrical activity, for example fMRI (e.g., see Huettel, Song & McCarthy, 2009) or psychophysiological methods.

To sum up, our results showed that participants were better at consciously perceiving stimuli in a visuospatial task when SOAs got higher. The LPS-ERP seemed not to be sufficient to explain differences in attentional orienting in terms of evoked lateralization except for a limited amount of occipital areas at early time intervals. These findings suggest that some parts of attention that are not taken into account in methods based on event-related potentals, such as individual differences, are in fact important at attentional orienting. Morover, as some parts of induced attention could be just general biases, it is important to further clarify the precise nature of induced attention at future studies. Behavioral measures confirmed that individuals differed at the extent to which they were consciously able to perceive stimuli. However, we were not able to predict these differences from analyses based on evoked activities. We suggest adjusting methodological changes in future studies, since our study points out that this is likely providing more insight in this area. Moreover, our study showed that evoked activities are, however in small amounts, significantly present at attentional orienting in visuospatial tasks. Since measuring evoked lateralizations has some major advantages over methods that include both evoked as well as induced activity, we suggest taking evoked activity into account at the conduction of future EEG studies regarding visuospatial attentional tasks.

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Apendix A

Toestemmingsverklaringformulier

Titel onderzoek: EEG analyse bij endogene aandachtstaak
Verantwoordelijke onderzoeker: Dr.R.H.J. van der Lubbe (r.h.j.vanderlubbe@utwente.nl)

In te vullen door de deelnemer

Ik verklaar op een voor mij duidelijke wijze te zijn ingelicht over de aard, methode, doel en mogelijke belasting van het onderzoek. Ik ben op de hoogte van het belang van het experiment en zal de aan mij gestelde vragen naar waarheid te beantwoorden. Ik weet dat de gegevens en resultaten van het onderzoek alleen anoniem en vertrouwelijk aan derden bekend gemaakt zullen worden.Ik stem geheel vrijwillig in met deelname aan dit onderzoek. Ik behoud me daarbij het recht voor om op elk moment zonder opgave van redenen mijn deelname aan dit onderzoek te beëindigen. Als ik nog verdere informatie over het onderzoek zou willen krijgen, nu of in de toekomst, kan ik me wenden tot Johanna Rippe (j.rippe-1@student.utwente.de) of Geert Hesselink (g.hesselink@student.utwente.nl).
Naam deelnemer: ....

Datum: .... Handtekening deelnemer: ....

In te vullen door de uitvoerende onderzoeker

Ik heb een mondelinge en schriftelijke toelichting gegeven op het onderzoek. Ik zal resterende vragen over het onderzoek naar vermogen beantwoorden. De deelnemer zal bij een eventuele voortijdige beëindiging van deelname aan dit onderzoek geen nadelige gevolgen ondervinden.

Naam onderzoeker: ....

Datum: .... Handtekening onderzoeker: ....

Apendix B

Informatie Deelnemer

Titel onderzoek: EEG analyse bij endogene aandachtstaak
Verantwoordelijke onderzoeker: Dr.R.H.J. van der Lubbe (r.h.j.vanderlubbe@utwente.nl)

Naam	Studentennummer
Leeftijd	Geslacht man O vrouw O
Heeft u al eerder aan een EEG onderzoek deelgenomen? ja O nee O	
Heeft u in het verleden neurologische aandoeningen (zoals epilepsie) gehad? ja O nee O	
Bent u kleurenblind ? ja O nee O	

De aangegeven informatie wordt vertrouwelijk behandeld.
Hiermee bevestig ik alle gegevens met waarheid ingevuld te hebben.

Datum: .... Handtekening deelnemer: ....

Apendix C

Informatieblad

Titel onderzoek: EEG analyse bij endogene aandachtstaak
Verantwoordelijke onderzoeker: Dr.R.H.J. van der Lubbe (r.h.j.vanderlubbe@utwente.nl)

Bedankt voor uw medewerking aan ons onderzoek. Hieronder staat beschreven wat het experiment precies inhoudt en wat u kunt verwachten. Mocht u na deze uitleg nog vragen hebben, kunt u deze uiteraard aan ons stellen.

In dit experiment gaat u een endogene aandachtstaak uitoefenen. Ondertussen wordt er door middel van EEG hersenactiviteit gemeten met behulp van kleine electrodes die op het hoofd worden geplaatst. Het aanbrengen van de electroden aan het hoofd kan onwennig aanvoelen, deze methode is echter pijnloos en ongevaarlijk.
In het begin van het experiment verschijnt er op het scherm een wit fixatiepunt waarop u uw ogen dient te richten. Vervolgens verschijnt er een gele of een blauwe driehoek. Deze blauwe/gele driehoek geeft de richting aan waar de relevante stimulus zal verschijnen. Vervolgens is het de taak te beoordelen of de relevante stimuli links danwel rechts verschijnt. Het is belangrijk dat u uw ogen hierbij op het fixatiepunt blijft richten. Indien er een cirkel met horizontale lijnen wordt getoond moet u de rechter CTRL toets indrukken. Voor de verticale lijnen geldt het tegenovergestelde; hierbij moet de linker CTRL toets ingedrukt worden.
Het zal af en toe zo zijn dat de stimulus zo snel wordt getoond dat u hem niet kunt waarnemen. Als u de antwoord niet weet, gok dan gewoon.

Ik heb de informatie op dit informatieblad begrepen en mijn vragen zijn naar tevredenheid beantwoord.

Datum: .... Handtekening deelnemer: ....

Apendix D

Annett Handedness Inventory

	Always left	Mostly left	No preference	Mostly right	Always right
Writing a letter					
Throw a ball to hit a target					
To play a racket in tennis, squash, etc.					
What hand is up to handle a broom removing dust from the floor					
What hand is up to manipulate a shovel					
Lighting matches					
Scissors when cutting paper					
To hold a wire to move it through the eye of a needle					
To distribute playing cards					
To hit a nail on the head					
To hold your toothbrush					
To remove the cover from a jar					
	-2	-1	0	+1	+2

-24 to -9	left handed
-8 to +8	ambidexter
+9 to +24	right handed

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