Measuring attentional allocation: What is the appropriate baseline? An event-related potential study

Bachelor thesis

Sarah Winkler

s1133969

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First supervisor: Dr. Rob H. J. van der Lubbe

Second supervisor: MSc. Suzanne M. Vosslamber

Contents

Summary

Electroencephalographical (EEG) measurements have played an important role regarding the understanding of the processes involved in directing, shifting and dividing attention. Several studies indeed employed EEG in the Posner endogenous cueing paradigm to examine these processes. In this study, a variant of this paradigm was used, in which cues were always 100% valid, i.e., cues pointed to the left or the right side where a to be discriminated target was presented. As baseline conditions, two types of trials were used. For one of the trials, a double arrow cue was used that pointed outwards to both sides, whereas for the second type of trials, the arrows pointed inwards. The major goal of this study was to determine whether the type of baseline trial (outward or inward cues) had any effect, as one might argue, that with the outward cue, attention is divided over the relevant sides, while this seems not to be the case for inward cues. EEG was measured from twenty participants that took part in our experiment. Afterwards, behavioral data and EEG data were analyzed. Most important, within the analysis no main differences were found between the baseline condition cues (outward and inward) and the valid cues. According to this, the conclusion was drawn that, based on statistical analysis of behavioral measurement and EEG measurement, the chosen baseline is appropriate.

Samenvatting

Elektroencefalografische (EEG) metingen hebben een belangrijke rol gespeeld voor het begrijpen van de processen die bij het richten, verschuiven en verdelen van aandacht betrokken zijn. Enkele studies hebben EEG binnen het Posner cueing paradigma gebruikt om deze processen te onderzoeken. In dit onderzoek werd een variatie van het paradigma gebruikt. 100% valide cues werden gebruikt om tot de rechter of linker kant te wijzen en de target locatie precies aan te geven. Twee verschillende soorten trials werden als baseline conditie gekozen. Ten eerste werden trials gebruikt die naar buiten gerichte cues inhouden, die naar beide kanten wijzen. Ten tweede werden trials met naar binnen gerichte cues gebruikt, die naar het midden wijzen en de target locatie dus niet voorspellen. Doel van dit onderzoek was te bepalen of de gebruikte baselines effect hadden en geschikt waren. Het is beredeneerd dat uitwaarts gerichte cues verdeelde aandacht induceren, terwijl dit bij inwaarts gerichte cues niet het geval zou kunnen zijn. EEG werd gemeten van twintig proefpersonen. De gedragsdata en EEG data werden geanalyseerd. De meest belangrijke bevinding is dat er binnen de analyse geen verschillen gevonden zijn tussen de naar buiten en binnen gerichte cues uit de baseline conditie. Met betrekking tot deze resultaten kon geconcludeerd worden dat de gekozen baseline geschikt was.

1. Introduction

Over the past decades, the analysis of electroencephalographical (EEG) measurements has played an important role regarding the understanding of attention and the processes involved in directing attention. Several EEG studies used the Posner endogenous cueing paradigm (Posner, 1980) to examine the allocation of spatial attention (e.g. Eckstein, Shimozaki & Abbey, 2002; Talsma, Slagter, Nieuwenhuis, Hage & Kok, 2005; Albares, Criaud, Wardak, Nguyen, Hamed & Boulinguez, 2011; Van der Lubbe & Utzerath, 2013). An effective way to address this is measuring participants EEG during the paradigm to compute event-related potentials (ERPs) afterwards (Hayward & Ristic, 2013).

According to the analysis of the data, it is important to assess an adequate baseline. That is, to choose a condition within the paradigm that serves as a baseline for the other conditions. This condition can be handled as a neutral control, including trials with cues that do not point to a side that should be attended (Albares et al., 2011).

In this study, the major goal is to prove whether the type of baseline trial (outward or inward pointing cues) had any effect and is therefore appropriate. That is, two baselines that contain either outward or inward cues are compared with a valid trial condition. To address the question if the chosen baseline is appropriate, first the various aspects of the cueing paradigm and the used variant of the paradigm are described. Then, the most relevant findings for the question of interest are detailed. Finally, it is explained why this question is examined and how it is appropriate to the used variant of the Posner endogenous cueing paradigm.

In this paradigm, a given visual cue, often an arrow-like symbol, indicates at what side a target is likely to occur. It is then possible to assess participants' ability to carry out an attentional shift (Talsma et al., 2005; Gould, Rushworth & Nobre, 2011). Participants were asked to fixate a dot in front of them. A cue replacing the dot indicates with a variable probability at which side the target is going to occur. Participants are then asked to respond to the target at the moment they notice it by pressing a determined key. This trial is repeated for a predetermined time. Furthermore, there is a difference between valid and invalid cues. Valid cues are those that indicate the target location correctly (e.g. with a validity of 80%). Invalid cues on the other hand are those that do not indicate the target location correctly (e.g. with a validity of 20%).

In this study, a probability of 100% valid cues is chosen. These cues were chosen, because the chance of probability matching is not likely to occur within 100% valid cue trials. That is, reducing the risk to not exactly know what participants in fact are doing (Van der Heijden,

1992). Concerning 100% valid cues, there are two different types of cues used: cues that point to both sides as the side to be attended (outward) and cues that point to no side as the to be attended side (inward). In all of the studies found, only outward cues were used for assessing the appropriateness of a baseline. Concerning outwards pointing cues, participants have to divide their attention on both sides to be able to detect the target correctly, what in turn could lead to an underestimation of the attentional effect (Robin & Rizzo, 1989; Wright, Geffen & Geffen, 1995). However, as Van der Heijden (1992) stated, it is expected that using inward cues is a better way of assessing a baseline, because of the fact that this is not a dividing attention cue, as an outward pointing cue is.

In several studies, a result commonly found is that participants perform better and faster in valid trials than in invalid trials, the so-called cue validity effect (Petersen & Posner, 1990; Eckstein, Pham & Shimozaki, 2003; Giessing, Thiel, Stephan, Rösler & Fink, 2004). The reaction time increased within conditions that handle valid cues (Gould et al., 2011). However, this can also be the result of non-attentional processes, like automatic motor responses. It is further stated, that there are more mechanisms involved in the reaction time, than the simple orienting of attention (Albares et al. 2011). Top-down processes, particularly the knowledge of position gained due to prior trials, modulates the reaction of the participants in a way that they tend to react automatically without really directing or shifting attention (Giessing, Thiel, Rösler & Fink, 2006). Further, an effect commonly found is early ERP activity in the occipital lobe contralateral to the given cue. That is, a cue in the right visual field eliciting an ERP activity on the left side of the occipital lobe and the other way round. This early occurring event is referred to as the first stage of attentional allocation (Eimer, van Velzen & Driver, 2002; McDonald & Green, 2008; Van der Lubbe et al., 2013).

To show that the baseline condition is appropriate, it seems necessary to compare conditions with predictive cues and conditions without these cues. That is, the baseline condition containing cues that do not indicate the target location correctly is compared to the validly cued condition (Talsma et al. 2005). In other words, we need to compare a condition with attention-directing cues to a baseline that is non-informative, thus neutral. According to Gottlob (2004) the possibility of using a neutral cue condition as a baseline is rejected because of methodological problems. However, as he states further, there is one exception, that is using non-informative cues. Then, possible differences between valid cues and baseline cues (non-informative about target location) can be assessed.

According to Bashinski and Bacharach (1980) using valid cues, participants can allocate their attention to a single side of the screen rather than divide their attention to both sides of

the screen at the same time. Eckstein et al. (2002) stated, that participants ignore the irrelevant side of the cue as well as the uncued side, as a result of cues being correctly in 100% of the trials. In this study, participants also had to divide their attention when both sides were cued as the side that has to be attended (outward cues). Thus, using those cues, it is not just a matter of shifting attention, but also a matter of dividing attention, when it comes to outwards pointing cues. The obvious consequence can be that the effect of attention gets underestimated. In this study, cues pointing to the center of the screen (inwards) were used as baselines in addition to the outwards pointing cues to measure differences between valid and baseline cues and to discover if cues pointing inwards were more appropriate than outward cues.

The motivation of running this study is to address the question whether the use of outward and inward cues as a baseline is appropriate. Because of the risk of underestimating the attentional effect by using outward cues, it is expected that using inward cues could compose a better baseline. However, if both baselines are appropriate, there is no difference between outward and inward cues expected. If there is no difference found, than the used baselines were capable. A difference in behavioral data between valid cued trials and baseline-cued trials are however expected. With regard to already existing studies, it is relevant to examine the used baseline conditions, because so far there is no study found concerning the problem of a baseline condition, consisting of inward cues in a 100% valid trial. Therefore, behavioral measures like reaction time (RT) and correct given responses (PC) were used in addition to examining ERPs. Then the possible differences between the conditions are addressed, because by using ERP analysis a broader impression of cue processing is gained.

2. Method

2.1 Participants

Twenty-one participants took part in the experiment. One participant was removed from the data analysis, as he did not follow the given instructions. That is, the participant made too many eye-movements during the crucial cue target interval and he frequently did not reacted at all. From the remaining twenty participants twelve were female and eight male. Eighteen participants were right handed, one was left handed and one was ambidextrous, which was assessed with Annett's Handedness Inventory (Annet, 1970). None of the participants was colorblind, which we checked with the Ishihara color blindness test (Reitzel, 1976). All participants had normal or corrected to normal vision (glasses or lenses) and none of them had a neurological or psychiatric history or used any medication. All were students of the University of Twente.

Before starting the experiment, the participants signed informed consent. The used procedures to complete the experiment as well as the experiment itself were evaluated by the ethical committee of the University of Twente.

2.2 Procedure and apparatus

After signing informed consent and completing the handedness and Ishihara color-vision test, the participants were asked to sit down in front of a computer screen, placing the indexes at the control keys on a standard QWERTY keyboard. The EEG signal was monitored with Brain Vision Recorder.

2.3 Task and stimuli

During the experiment, a variation of the Posner endogenous cuing task (Posner, 1980) was used. Two tasks were used, including either 66% or 100% valid cues. All of the participants had to run one block with cues pointing to the target with a validity of 66% and equally with a validity of 100%.

For the following analysis, only the 100% condition was relevant. In this condition, three different kinds of cues were used. First, there were "valid" cues, in which the target always occurred at the to be attended side (either left or right). Second, the outward cues, which pointed to both sides in the relevant color as the to be attended side. Last, the inward cues, which pointed inwards to the fixation point, excluding the relevant color.

The relevant color indicating the target location was predetermined for each of the participants. These were divided in two groups with each focusing to one color: yellow or blue. The relevant color per participant did not change over the whole experiment.

The utilized cues were all presented at a black screen in a darkened room. In the center of the screen a white fixation point was placed. This point got enlarged after 700 ms to allude the participant that a cue was going to be presented. In the valid cued trials, the cue itself was shaped as a rhombus, consisting of two triangular sides, with each side of the triangle colored different (blue and yellow with one of these labeled relevant). Outward cues were colored only in the relevant color and inward cues were colored only in the irrelevant color. Participants were instructed to direct their attention to the relevant side (dependent on the color they had to focus on). Two circles were placed at each side. Participants were asked to press a determined button as fast as possible if they saw either horizontal or vertical lines in the directed circle, before being covered by a mask after either 44 ms or 176 ms and without making any eye movements. Participants had to press the left control key in the case of horizontal lines and the right control key in the case of vertical lines. A mask covered these targets (lines) after either 44 ms or 176 ms as presented in Figure 1. If participants had no idea of what they actually saw, they were instructed to press the space bar. By handling a "no idea" response, the risk of gambling was reduced. The construction of the experiment demanded an as accurate as possible reaction as well as it was used to assess attention, rather than the ability of gambling.

On the average, each participant made 673 trials in total, divided into two blocks.

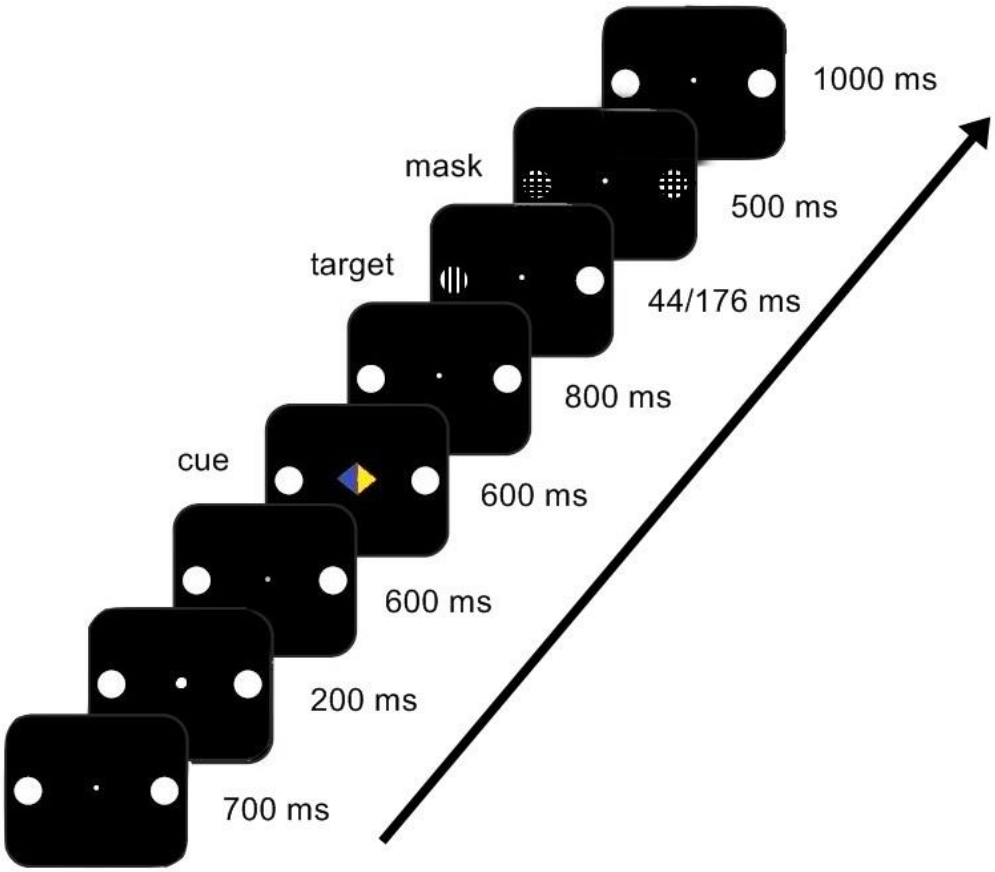

Figure 1. Schematic representation of the setup of a 100% valid cued trial with blue as the relevant color inducing the target location. After 1500 ms the cue set on, resting for 600 ms. After further 800 ms the target occurred resting for either 44 ms or 176 ms, before covered by a mask.

2.4 Recording

The EEG was recorded continuously, from the start until the end of the whole experiment. We also carried out a pre- and post-measurement with a duration of respectively two minutes. EEG was measured from sixty-one electrodes according to the extended 10-20 system (Talsma, Wijers, Klaver & Mulder, 2001), which were located at: Fpz, Fp1, Fp2, AFz, AF3, AF4, AF7, AF8, Fz, F1, F2, F3, F4, F5, F6, F7, F8, FCz, FC1, FC2, FC3, FC4, FC5, FC6, FT7, FT8, Cz, C1, C2, C3, C4, C5, C6, T7, T8, CPz, CP1, CP2, CP3, CP4, CP5, CP6, TP7, TP8, Pz, P1, P2, P3, P4, P5, P6, P7, P8, POz, PO3, PO4, PO7, PO8, Oz, O1 and O2.

Furthermore, the electrooculogram (EOG) was measured to assess participants' eye-movements to exclude trials, in which these were made between cue-onset and reaction, to focus only on attention related EEG data. Four electrodes were therefore placed near the participants' eyes. To measure horizontal eye movements (hEOG) two electrodes were placed

left and right on the outer canthi. To measure vertical eye movements (vEOG) two electrodes were placed above and beyond the left eye. A ground electrode was placed at the stern.

The resistance of the electrodes was kept below 10 kΩ. Signals were filtered with a low pass filter of 100 Hz and sampled at a rate of 500Hz.

2.5 Data analysis

EEG data was analyzed with Brain Vision Analyzer. A lowpass filter of 30 Hz was applied to the data. To be able to make adequate analysis, trials without eye movements were used to be able to conclude, that effects measured, can be ascribes to attention, not to eye-movements. That is, trials with eye movements within the cue-target interval were excluded, showing a value above 40 µV and below -40 µV. Furthermore, trials were excluded when participants made button presses during the cue-target interval that were not relevant for the experiment or when participants did not react at all. On the average 86% of the trials made, were relevant for the analysis.

2.5.1 Behavioral measures

Reaction times (RT) were measured related to target onset. The proportion of correct responses was determined as well (PC). Responses that were faster than 100 ms and responses that were slower than 3000 ms were excluded from further analysis. Paired samples t-tests were addressed to the variables RT and PC for analyzing differences between all the used cues.

2.5.2 EEG measures

EEG data was processed in Brain Vision Analyzer. An interval was chosen from 1000 ms before until 2000 ms after cue onset. A correction to EOG and EEG artifacts was applied. The average amplitudes per participant were determined in windows with a size of respectively 50 ms, ranging from 0 to 1400 ms.
Paired samples t-tests were accomplished, using all the cues used in the experiment.
This analysis included the following electrodes: PO7, PO8 and Oz, as shown in Figure 2. Due to prior studies, these electrodes were expected to provide relevant findings.

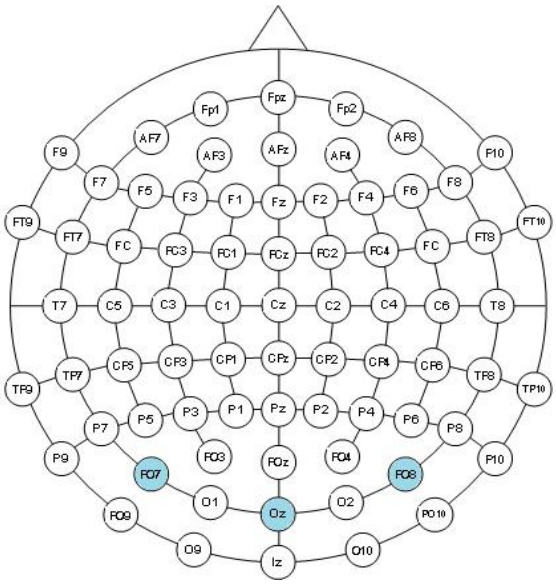

Figure 2. Electrodes included in the statistical analysis are displayed in blue. The current configuration is a standard 64 channels cap with electrode positions according to the extended 10-20 systems.

3. Results

3.1 Behavioral measures

As it is not seen to be relevant for the analysis the duration of the cue-target interval was mediated for the reaction times and the percentage correct given responses. Therefore, it is focused on the cue position in the visual field and the condition (valid of baseline).

The mean reaction times were significant higher for valid cues with 858 ms than for the baseline cues pointing outward or inward with respectively 920 ms and 912 ms. Significant differences were found between the valid cues and both baseline cues. These differences concerned as well cues placed in the left as the right visual field of participants.
Significant differences were found ranging from t (19) > 2.4, $p < 0.026$, with the greatest difference found between valid cues in the left visual field and inward cues, t (19) = 4.7, $p < 0.0001$.

The largest percentage of correct given responses was as well in the valid cued condition, with 76% correct given responses on the average, while for the baseline conditions the mean percentage correct given responses ranged from 67% to 70%. Again, significant differences were found between the valid cues (left and right visual field) and both baseline cues, ranging from t (19) > 3.5, $p < 0.002$. Greatest difference was found between valid cues placed in the right visual field and inward cues, t (19) = 5.0, $p < 0.0001$.
For neither RT nor PC, a significant difference was found between the baseline cues pointing either outward or inward.

Table 1. *Significant differences found between valid and baseline cues concerning participants reaction time (RT) and percentage correct responses (PC).*

		RT		PC	
Difference	**Position in visual field**	***t* (19)**	***p***	***t* (19)**	***p***
valid - outward	left	3.4	0.003	3.5	0.002
valid - inward	left	4.7	<0.0001	4.6	<0.0001
valid- outward	right	2.4	0.026	4.0	0.001
valid - inward	right	4.3	<0.0001	5.0	<0.0001

3.2 EEG measures

Paired samples t-tests were performed on the data respectively for each of the twenty-eight time windows, ranging from 0 to 1400 ms. Because of the fact that several time windows were explored, a correction was necessary, thereby reducing the possibility of a Type I error. That is, two successive significant effects had to agree with $p<\sqrt{}$ (0.05/27x4x3), thus $p < 0.012$ (for a comparable procedure see Talsma et al., 2001).

The paired samples tests were respectively performed for the three occipital electrodes PO7, PO8 and Oz per time window. According to the major goal of the study, it seems most relevant to focus on the differences measured per electrode between the 100% valid cues and the baseline cues. That is, the differences between 100% valid cues, pointing to the left or right, and both baseline cues, pointing outwards or inwards. Furthermore, the differences between the baseline cues pointing outwards or inwards were analyzed.

First, significant differences were found at PO7 between 100% valid cues presented in the right visual field and the baseline condition handling inward cues. Because of five time windows succeeding, the significance criterion is satisfied. Overall, the differences found ranged from t (19) > 2.8, $p > 0.11$ (Table 2).

Table 2. *Differences measured between 100% valid cues in the right visual field and inward cues, measured at PO7.*

time windows (in ms)	***t* (19)**	***p***
450 – 500 ms	3.0	0.007
500 – 550 ms	4.1	0.001
550 – 600 ms	4.0	0.001
600 – 650 ms	3.4	0.003
650 – 700 ms	2.8	0.011

In the time window ranging from 450 ms – 500 ms it is further found that de 100% valid cue presented in the right visual field, elicited ERPs contralateral to its own position. As presented in Figure 3 the elicited effect is most visible at the occipital electrode PO7, thus contralateral to the presented cue at the right visual field.

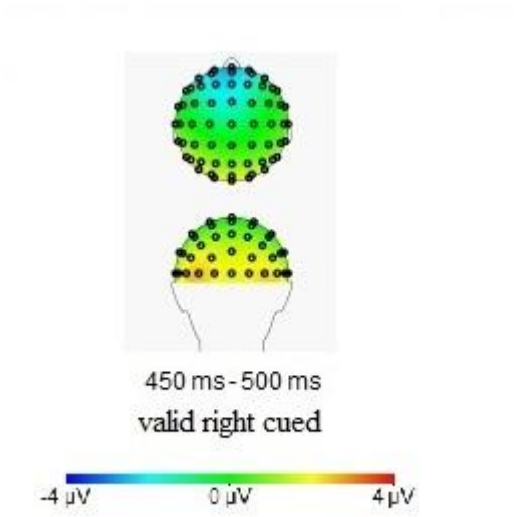

Figure 3. Topographical map of the averaged ERPs elicited by a 100% valid cue, presented in the right visual field in the time window from 450 ms – 500 ms.

Second, significant differences were found at Oz between 100% valid cues presented in the right visual field and the baseline condition handling inward cues. Because of three time windows succeeding, the significance criterion is satisfied. The differences were found to be significant for t (19) > 3.3, $p < 0.004$, with the greatest difference found between 800 ms – 850 ms, with t (19) = 4.2, $p < 0.0001$. Although not the most significant difference found in that time window, the measured difference was most visible in a topographical map of elicited ERPs between 750 ms – 800 ms, as presented in Figure 4.

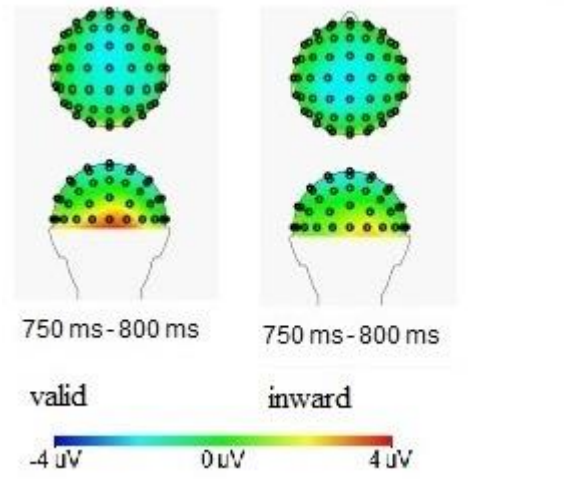

Figure 4. Topographical maps of the averaged ERPs elicited by a 100% valid cue compared with the averaged ERPs elicited by an inward pointing cue, from 750 ms – 800 ms.

Furthermore, the found differences measured at PO7 and Oz were also visible in the averaged curves of elicited ERPs in the analyzed time windows as presented in Figure 5.

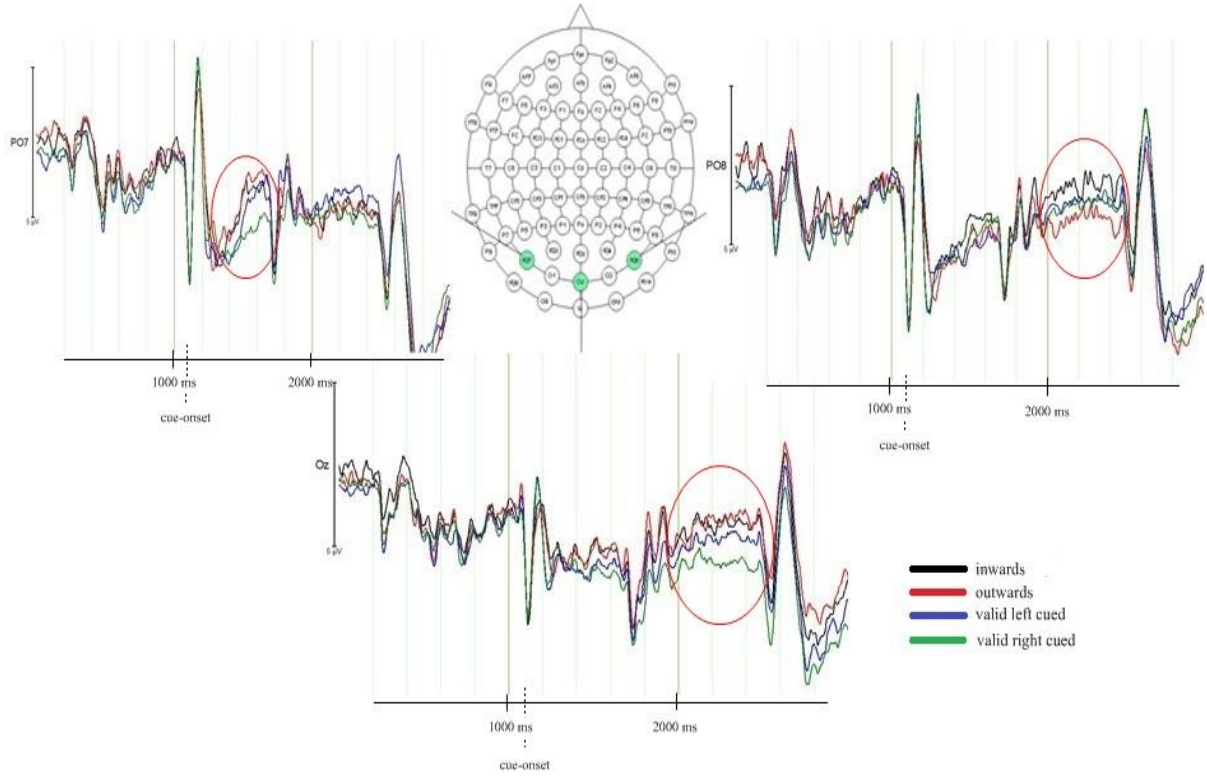

Figure 5. ERPs extracted from the four different cues used in the experiment (outward, inward, 100% valid in the left visual field and 100% valid in the right visual field) at the three relevant occipital electrodes PO7, Oz and PO8.

The displayed curves range from 0 ms – 1400 ms, enclosing the duration of a whole trial. On the x-axis the time is described in time windows of 200 ms respectively. On the y-axis the µV is described. Cue-onset is marked at about 1100 ms with a striped line. Further, the analyzed differences between the used cues were encircled in red. There it is visible that the ERPs elicited by the four used cues differ mutually. For PO7 and Oz especially the inward cues differ from the valid cues presented in the right visual field.

A difference at PO8 might be supposed between the baseline condition cues pointing outwards or inwards, based on the in Figure 4 displayed ERPs. The observable difference found in the Figure was not found to be significant in the statistical analysis. That is, neither at PO8 nor at another measured electrode and in none of the twenty-eight time windows, a significant difference was found between the baseline condition cues.

4. Discussion

The major aim of the present study was to determine whether the type of baseline trial (outward or inward cues) had any effect, as one might argue, that with the outward cue, attention is divided over the relevant sides, while this seems not to be the case for inward cues. Therefore, it is investigated if the chosen baselines can be considered as appropriate baselines to assess the effect of spatial attention with 100% valid cues. These were chosen to reduce the risk of probability matching (Van der Heijden, 1992).

To examine if the chosen baselines are appropriate, it is necessary to state statistically that there is no difference between the given baseline cues. That is to state that no differences can be found between outward cues (pointing to both sides as relevant) and inward cues (pointing to the middle of the screen). Judging a zero effect like this is difficult, because of a type II error occurring. That is, actual there is a difference, but this difference could not be found, because of a too low power. In fact, missing actual differences in this study is not ascribed because of low power, because the number of participants in this study is adequate.

As described in the introduction, a result commonly found is, that participants perform better and faster in valid trials than in invalid trials, or baseline trials (Petersen & Posner, 1990; Eckstein et al., 2003; Giessing et al., 2004). Behavioral analysis confirmed that RT was faster in the valid cued conditions, than in the baseline cued condition. This finding is thus in accordance with the commonly found results observed in the Posner cueing paradigm. Further, here it is already found that there is a difference between the valid cues and the baseline cues, as it was expected, but concerning RT and PC no differences between the baseline cues pointing either outwards or inwards could be found. Van der Heijden (1992) stated that inward cues might be a better baseline because these were not dividing attention cues like outward cues. According to the data, this expectation can not be verified yet.

Analysis of EEG data revealed differences between the valid cues and the baseline cues. That is, it is proven that attentional effects in valid cued trials differ from attentional effects elicited through baseline cues, especially between valid and inward cues. Here, again no significant difference between the baseline cues pointing outward and inward was found. That is, in neither the behavioral analysis nor the EEG analysis van der Heijden's expectation could be verified.

However, an effect commonly found in recent studies is early ERP activity in the occipital lobe contralateral to the given cue (Eimer et al., 2002; McDonald et al., 2008; Van der Lubbe et al., 2013). Due to EEG analysis, this effect was also found in the present study. As

presented in Figures 3 and 5, a 100% valid cue in the right visual field, elicited an early EEG activity contralateral to its position after 450 ms. This shows that especially brain regions related to vision, thus maximum posterior, were involved in the processes necessary for the task, thus allocating attention. The differences between the elicited EEG activity by either 100% valid cues or inward cues were also visible in these Figures.

However, the behavioral and EEG analysis revealed clearly results. Based on the differences found between the valid cues and the baseline cues, the conclusion can be drawn that the baselines were appropriate. Using these baselines provides what Giessing et al. (2006) stated: reacting automatically without really directing or shifting attention, due to prior trials. Further, in the present study no reason is found to suppose that the inward cues would serve as a better baseline than the outward cues does. Because of the fact that no significant difference was found between these baselines, they both are seen as appropriate. That is, because no difference could be found between cues giving no relevant information about the target location at all (inward) and those implying the target location at both sides (outward), the baselines worked even efficient. This signifies that it is even contributing using non-informative cues as a baseline to compare other conditions with.

In general, this study was made to examine the appropriateness of a baseline including non-informative inward pointing cues. As already mentioned in the introduction, no study was found that addressed this problem as well. In this study, it is stated that the used baselines including outward and inward directed cues, were even appropriate. Therefore, the study is relevant for all possible future attentional studies that will focus on the processes involved in as well dividing, shifting or holding attention using an attentional paradigm. The used cues can then vary between valid ones, informative ones and non-informative ones. To ensure that the used baselines were even efficient, it would be advisable to run an analysis including all measured electrodes during the experiment in future studies. Even if there is no difference between the baseline cues found here, it could be possible that there were significant effects for other electrodes in other time windows.

5. References

Albares, M., Criaud, M., Wardak, C., Nguyen, S. C. T., Hamed, S. B. & Boulinguez, P. (2011). Attention to baseline: does orienting visuospatial attention really facilitate target detection? *Journal of Neurophysiology, 106*, 809-816. Doi:10.1152/jn.00206.2011

Annet, M. (1970). Annet Handedness Inventory. A classification of hand preference by association analysis. *British Journal of Psychology, 61*, 303-321.

Bashinski, H. S. & Bacharach, V. R. (1980). Enhancement of perceptual sensitivity as the result of selectively attending to spatial locations. *Perception & Psychophysics, 28*, 241-248.

Eckstein, M. P., Pham, B. T. & Shimozaki, S. S. (2004). The footprints of visual attention during search with 100% valid and 100% invalid cues. *Vision Research, 44*, 1193-1207. Doi: 10.1016/j.visres.2003.10.026

Eckstein, M. P., Shimozaki, S. S. & Abbey, C. K. (2002). The footprints of visual attention in the Posner cueing paradigm revealed by classification images. *Journal of Vision, 2*, 25-45. Doi: 10:1167/2.1.3

Eimer, M., van Velzen, J. & Driver, J. (2002). Cross-modal interactions between audition, touch, and vision in endogenous spatial attention: ERP evidence on preparatory states and sensory modulations. *Journal of Cognitive Neuroscience, 14*(2), 254-271.

Giessing, C., Thiel, C. M., Rösler, F. & Fink, G. R. (2006). The modulatory effects of nicotine on parietal cortex activity in a cued target detection task depend on cue reliability. *Neuroscience, 137*, 853-864. Doi: 10.1016/j.neuroscience.2005.10.005

Giessing, C., Thiel, C. M. Stephan, K. E., Rösler, F. & Fink, G. R. (2004). Visuospatial attention: how to measure effects of infrequent, unattended events in a blocked stimulus design. *NeuroImage, 23*, 1370-1381. Doi:10.1016/j.neuroimage.2004.08.008

Gottlob, L. R. (2004). Location cuing and response time distributions in visual attention. *Perception & Psychophysics, 66*(8), 1293-1302.

Gould, I. C., Rushworth, M. F. & Nobre, A. C. (2011). Indexing the graded allocation of visuospatial attention using anticipatory alpha oscillations. *Journal of Neurophysiology, 105*, 1318-1326. Doi: 10.1152/jn.00653.2010

Hayward, D. A. & Ristic, J. (2013). Measuring attention using the Posner cuing paradigm: the role of across and within trial target probabilities. *Frontiers in Human Neuroscience, 7*, 1-11. Doi: 10.3389/fnhum.2013.00205

Luck, S. J., Woodman, G. F. & Vogel, E. K. (2000). Event-related potential studies of attention. *Trends in Cognitive Sciences, 4*(11), 432-440.

McDonald, J. J. & Green, J. J. (2008). Isolating event-related potential components associated with voluntary control of visuo-spatial attention. *Brain Research, 1227*, 96-109. Doi: 10.1016/j.brainres.2008.06.034

Petersen, S. & Posner, M. 1990. The attention system of the human brain. *Annual Review of Neuroscience, 13*, 25-42.

Posner, M. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25.

Reitzel, C. A. (1976). Tests for colour blindness – 38 plates edition by S. Ishihara

Robin, D. A. & Rizzo, M. (1989). The Effect of Focal Cerebral Lesions on Intramodal and Cross-modal Orienting of Attention. Chapter 7, 61-74.

Talsma, D., Slagter, H. A., Nieuwenhuis, S., Hage, J. & Kok, A. (2005). The orienting of visuospatial attention: An event-related brain potential study. *Cognitive Brain Research, 25*, 117-129. Doi: 10.1016/j.cogbrainres.2005.04.013

Talsma, D., Wijers, A. A., Klaver, P. & Mulder, G. (2001). Working memory processes show different degree of lateralization: Evidence from event-related potentials. *Psychophysiology, 38*, 425-439.

Van der Heijden, A. H. C. (1992). *Selective Attention in Vision, 1*(192-197). London: Routledge.

Van der Lubbe, R. H. J. & Utzerath, C. (2013). Lateralized power spectra of the EEG as an index of visuospatial attention. *Advances In Cognitive Psychology, 9*(4), A-R. Doi: 10.2478/v10053-008-0144-7

Wright, M. J., Geffen, G. M. & Geffen, L. B. (1995). Event related potentials during covert orientation of visual attention: effects of cue validity and directionality. *Biological Psychology, 41*, 183-202.