The influence of predictive value of cues in the endogenous orienting paradigm examined with event-related lateralizations

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Abstract

The Posner paradigm has often been used to examine the allocation of attention. Van der Heijden (1992) reasoned that participants may use a probability matching when cue validity is less than 100%. In this study, a cue validity of 66% and 100% was used to examine how participants allocate their attention with different cue validities. This was examined with event related lateralizations (ERL). A comparison of the validly cued trials showed no differences in reaction times and percentages of correct responses between the two conditions. However, ERL analyses revealed an effects above an occipito-parietal site. The latter results suggest that participants may indeed use a probability matching strategy.

Introduction

Since the 1950's a lot of research has been carried out in the field of attention. Attention has the critical function of selecting the most important and critical information from a constant stream of sensory input. One of the first empirical demonstrations of the influence of attention on visual processing was reported by Posner (1980). He revealed that when attention was shifted to a location while the eyes were kept at a central fixation point, this resulted in faster and more accurate processing of stimuli presented at attended as compared to unattended locations (Posner, 1980). Several studies have examined attention with the Posner paradigm with various cue validities. However, most studies do not use a cue validity of 100%. This study compares a cue validity of 100% with one less than 100%.

An important distinction in the field of spatial attention is between covert and overt attention. Overt attention is attending to a location or item by moving the eyes to the location or item. Covert attention is shifting the attention without moving the eyes. In the experiment of Posner, participants were seated in front of a computer screen and looked at a fixation point at the middle of the screen. A cue indicated where the target was likely to appear with a validity of 80%, which implies that the target occurred at the cued location on 80% of the trials. The main reason that this validity was chosen is to be able to compute costs and benefits of attentional allocation. In that case also neutrally cued trials are needed. Costs can be computed as the difference in reaction time between invalidly cued and neutrally cued trials cues. Benefits can be computed as the difference in reaction time between validly cued and neutrally cued trials. The common assumption in this paradigm is that participants always focus their attention on the cued side. But what would happen if participants do not follow this instruction on all trials and even less so when cue validity is low? According to Van der Heijden (1992) it is far from clear how a task is executed when the cue validity is less than 100%. Thus those participants allocate their attention differently with a cue validity of 100% compared to less than 100%.

Attentional orienting in the Posner paradigm has often been researched with electroencephalography (EEG). Through EEG event related potentials (ERP) are measured (e.g., Eimer, Van Velzen & Driver, 2002; Green & McDonald, 2006; Hopf & Mangnum, 2000; Van Velzen & Eimer, 2003). In the current study the focus is on lateralized event related potentials. In several studies, event related lateralizations (ERL) were used to examine spatial attention. When a specific process is more carried out in one hemisphere this activity can be extracted from EEG with ERL. The evoked activity that is linked to the focus of attention can be subtracted from the activity that is not linked to this focus using a double subtraction technique (Van der Lubbe & Utzerath, 2013). By using this technique the index becomes highly specific for changes in spatial attention (e.g., Eimer, Van Velzen & Driver, 2002; Green & McDonald, 2006; Hopf & Mangnum, 2000; Van Velzen & Eimer, 2003). Three distinct ERL components are commonly reported; the early direction attention negativity (EDAN), the anterior direction attention negativity (ADAN) and the late direction anterior positivity (LDAP).

The first component, the EDAN, arises above posterior areas starting from about 200 ms after cue onset, and has been interpreted as the selection of the relevant side of the cue (Van Velzen & Eimer, 2003; Praamstra & Kourtis, 2010). The EDAN is not evoked by the induced attention shift, but only during shifts of visual spatial attention trough the physical difference of the cues (in most cases, a left and right arrow) causing the lateralization of an early visual response to the cue and partly the selection of the attended side, given by the cue (Van Velzen & Eimer, 2003; Van der Lubbe & Uterath, 2013).

The second component, ADAN, arises at frontal sites from about 400 ms after cue onset and is thought to reflect activity in the pre-motor cortex (Eimer, Van Velzen & Driver 2002; Van der Lubbe & Utzerath, 2003).

The third component arises above the posterior areas and starts from about 500 ms after cue onset and has been denoted as the late direction anterior positivity (LDAP) (Hopf & Mangnum, 2000; Van der Lubbe &Utzerath 2013).

In this study, we made a comparison between conditions with different cue validities. Gould et al. (2011) also examined the allocation of attention with different cue validities by focusing on lateralized alpha band activity, but they did not examine ERL components. Activity in the alpha band is thought to reflect the allocation of selective attention. Higher alpha band activity may reflect a larger attentional shift, resulting in a greater effect of attention on behavioral performance. This indicates that when there is a higher alpha band activity more attention is shifted to a location.

In most studies with the Posner paradigm the cue validity varies between 60% and 80%. The main reason that this validity at behavioral level was chosen is because of the benefit from knowing where the stimulus will occur and the costs that the stimulus appears on a location it was not cued for (Posner, 1980). Therefore, it can be measured what the effect is of orienting your attention. With the neutral cues the costs of orienting attention can be measured by the difference between invalid and neutral cues. The benefits can be measured through the difference of valid and neutral cue trials. For the EEG, this is not needed as the probably less-involved hemisphere can be used as a comparison. Like stated before, Van der Heijden (1992) argues that it is not clear how a task is executed when the cue validity is less than 100%. Van der Heijden (1989) observed that with a cue validity of 70% participants made use of an overmatching strategy and with a validity of 30% of an undermatching strategy. When the observed cost-benefit difference is smaller than the predicted difference undermatching occurs. When the observed difference is larger overmatching takes place (Van der Heijden, 1989). These strategic changes may be referred to as probability matching. Likewise, Van der Heijden (1992) explained that probability matching means that when a cue is 80% valid participants may only focus their attention on 80% of the trials on the cued side and for the other 20% on the uncued side, regardless of the direction of the cue. The observations of Gould et al. (2011) seem in line with the ideas of Van der Heijden. Gould et al. (2011) found differences with alpha band activity comparing a cue validity of 100% with one lower than 100%. These differences reflect less efficient attentional allocation in the case of less predictive cues, which supports the probability matching hypothesis..

The focus of this research lies on differences in ERL components between the two different cue validities, to see whether the components specific for focusing attention will be different between the two conditions. The experiment consists of one block having a cue validity of 66% and one of 100%. Because the participants are aware that the cue always points in the right direction, it may be expected that the reaction time in the case of 100% validity is less than in the condition of 66%. Several studies claim that when attention is directed to a specific location, there is a faster and more accurate detection of the target then unattended ones (Luck, Hillyard, Mouloua & Hawkins, 1996); Prinzmetal, McCool & Park, 2005).

In line with the research of Gould et al. (2011) the components sensitive for the selection of attention should show more activity with a higher validity cue than with a lower validity cue. Also, the participants can focus their attention fully on the cued side because they can be sure that the target will appear there. Because the participants can focus their attention on one side, the component responsible for the focus of attention, thus the LDAP, will be more active in this task. Besides that, the alpha band activity seems to resemble an LDAP. Thus it will be examined if the LDAP varies as a function of cue validity.

In the research of Van der Lubbe and Utzerath (2013) it was suggested to use an longer cue target interval which can help to make a better separation of induced and evoked activities. It is expected that it reveals additional ERL components..

In this study, we examined whether there is a difference in attentional allocation with different cue validities. It is expected that with a 100% valid cue response rate is higher. To see whether there is a difference between a cue validity of 100% and less, the ERL component assumed to be most specific for the direction of attention will be examined. Previous findings suggest that the LDAP is most specific for the directing of attention (Hopf & Mangnum, 2000). Thus the question is whether there is a more pronounced LDAP in the 100% condition. In line with the research of Gould et al. (2011) it is expected that there is more activity at the LDAP in the 100% condition.

Method

Participants

Twenty-one participants took part in this study. They were students of the University of Twente. One participant was removed from the analysis due to too many eye movements during the critical intervals (between cue onset and target). Twelve of these participants were male and eight were female. Eighteen were right handed, one left handed and one ambidexter, this was measured with Annet Handedness Inventory (Annet, 1970). None of the participants had color blindness; this was tested with ten Ishihara plates (Ishihara, 1976). All participants had normal or corrected-to-normal eye vision and had no history of psychiatric or neurological conditions. The participants got course credits for participating in the study. Before the start of the study they signed an informed consent. The study lasted between 3 – 4 hours of which the experiment was 1.5 – 2 hours. The study was approved by the ethical commission of the Faculty of behavioral science.

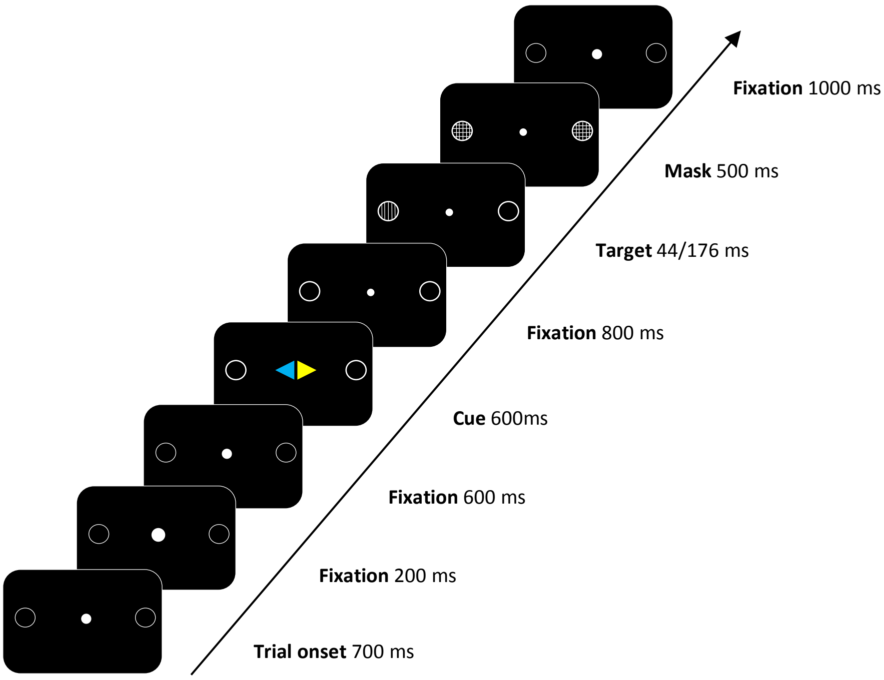

Figure 1
An example of the stimuli and their order. Two types of targets were used; they either had vertical or horizontal lines. Left or right control button presses depend on the orientation of the lines.

Task and Stimuli

The task was similar to the experiment of Van der Lubbe and Utzerath. (2013), which was based on the Posner (1980) cueing task, except that there was no use of an auditory warning stimuli. Stimuli were presented on a computer screen with a black background. Each trial began with a slight enlargement of a white dot that was centered in the middle of the screen for 200 ms. Participants were instructed to look at the fixation point. After showing the default display for 600 ms the cue would appear. The cue consisted of a diamond shape form, consisting of two colored triangles (yellow and blue, with one color relevant depending on the condition) pointing to the left and right circles, this screen was displayed for 600 ms. The cue was replaced with the default display for 800 ms and then the target would appear for 44 or 176 ms. This was either a horizontally or vertically striped target. Responses were to be made as fast and accurately as possible. After the 44 or 176 ms target display a masked display would appear for 500 ms and then the default display for 1000 ms, until a new trial began. The experiments consisted of two tasks which each consisted of 7 blocks with 48 trials and each task begun with 24 practice trials, so a total of 672 experimental trials. The two tasks differ in cue validity, one with a validity of 100% and the other of 66%. The sequence of the tasks and the relevant color was counterbalanced between the participants.

Apparatus and EEG recordings

The participant sat approximately 60 cm from the screen in an office chair in a darkened chamber. The task was controlled by using Presentation software (Neurobehavioral Systems, Inc., 2012) installed and executed on an experimental computer. For the task left, right and middle button presses were required with the left and index finger and left ring finger. The buttons pressed were the left or right "Ctrl" key and "spacebar" on a standard QWERTY keyboard.

EEG was recorded from Ag/AgCl electrodes mounted in an elastic cap (Braincap, Braindproducts GmbH) according to the extended 10-20 system (Sharbrough et al., 1991) at the following sites on the scalp: Fp1, Fp2, AF8, AF7, AF4, AF3, F8, F7, F6, F5, F4, F3, F2, F1, FT8, FT7, FC6, FC5, FC4, FC3, FC2, FC1, T8, T7, C6, C5, C4, C3, C2, C1, TP8, TP7, CP6, CP5, CP4, CP3, CP2, CP1, P8, P7, P6, P5, P4, P3, P2, P1, PO8, PO7, PO4, PO3, O1, O2, FPz, AFz, Fz, FCz, Cz, CPz, Pz, POz and Oz. vEOG was recorded with electrodes placed above and below the left eye, hEOG was measured with two electrodes that were placed at the outer canthi of both eyes. A ground electrode was located at the stern. Electrode gel was used to improve conductivity; the electrode resistance was kept below 10kΩ. The EEG and EOG and task-related events such as responses were registered with Brain Vision Recorder 2.0 installed on a separate computer.

Data processing

Processing of the data was carried out with Brain Vision Analyzer 2.0. The data was partitioned in segments from -1000 till 4500 ms relative to cue onset, horizontal and vertical movement of the eyes that exceeded - 40 till 40 µV between the cue – target interval were removed. An average of 86.2 % of the trials was left. RT was measured relative to target onset. Responses quicker than 100 ms or slower than 3000 ms and misses were excluded from the analyses. response time (RT), percentage of correct responses (PC) were analyzed with SPSS (version 20) with the factors, valid (for both conditions) and invalid.

EEG analyses of the cue-target interval

EEG was analyzed from -100 till 1400 ms after cue onset with Vision Analyzer 2.0. Trials with artifacts were also removed. Three criteria were used, values below -150 µV or above 150 µV, a gradient criterion of 100 µV per 1 ms and low activity criterion of 0.1 µV for 50 ms. A correction was made for eye movement with the method of Gratton (Gratton, Coles & Donchin, 1983). The double subtraction technique was used to calculate ERLs for the 26 symmetrical electrode pairs. When the cue pointed to the left the activity from the left side was subtracted from the right side (activity at electrode from PO8 - PO7) and when a cue pointed to the right side the activity from the right side was subtracted from the left side (PO7 - PO8). The ERL is both activities divided by two (Van der Lubbe & Utzerath, 2013). ERLs were analyzed in time windows of 50 ms from 200 till 1400 after cue onset which resulted in 24 different time-windows. The electrode pairs F6/F5, FC6/FC5, P4/P3, PO4/PO3, PO8/PO7 and O2/1 were used for further analyses. These electrodes were chosen due to previous findings found in the study of Van der Lubbe and Utzerath (2013; see also Lasaponara, Chica, Lecce, Lupianez, and Doricchi, 2011; Van Velzen and Eimer, 2003; Praamstra & Kourtis, 2010). The average of each electrode in time-windows 200 till 1400 ms after cue onset for each participant was computed. The significant p value for two consecutive time windows was calculated with √0.05/((24-1)x6), were 24 is the total amount of time windows and six the electrodes used for further analyses. The critical p value was set at 0.019. The difference between the different cue validity conditions was calculated with the same six electrodes and a paired sample t-test.

Results

Table 1

Mean RT, PC and SE as function of condition and cue validity

Condition	Cue	RT (in ms) mean	SE	PC (in %) mean	SE
66%	Valid	872	37.7	74.9	3.3
66%	Invalid	922	41.2	60.5	5.6
100%	Valid	858	50.0	63.9	4.5
100%	Neutral	814	48.7	18.6	3.6

***Note*. RT = reaction time. PC = proportion of correct responses. SE = standard errors.**

Behavioral measures

Behavioral measures were analyzed with repeated measures ANOVA. The mean reaction time and proportion of correct response (PC) are displayed in Table 1. RT and PCs in the different cue conditions are averaged across long and short target presentation durations. The sphericity assumption was violated. With a Greenhouse-Geisser ε correction it was determined that mean response time differed between the different conditions, which were 100% valid, 66% valid, 66% invalid and 100% neutral, $F(1.3, 24.6) = 4.2$, $p < 0.041$. The mean response time did not differ between the condition 100% valid and 66% valid, $F(1,19) = 0.17$, $p < 0.68$. The mean response time differed statistically significantly between 66% valid and 66% invalid, $F(1,19) = 9.5$, $p < 0.006$. At last the mean response time differed statistically significantly between the different conditions 100% valid and 100% neutral, $F(1,19) = 10.4$, $p < 0.004$. Premature responses (slower than 3000 ms) were (0.9%) only found in the 100% condition. Responses that were too fast (less than 100 ms) were lower in de 66% condition (0.9%) than in the 100% condition (5.7%).

The sphericity assumption was violated. With a Greenhouse-Geisser correction it was determined that proportion of correct responses (PC) differed significantly between the different conditions 100% valid, 66% valid, 66% invalid and 100% neutral, $F(1.3, 25.3) = 4.6$, $p < 0.032$. PCs did not differ between the condition 100% valid and 66% valid, $F(1,19) = 0.01$, $p < 0.970$. PCs differed statistically significantly between 66% valid and 66% invalid, $F(1,19) = 9.4$, $p < 0.009$. At last the PCs differed statistically significantly between the different conditions 100% valid and 100% neutral, $F(1,19) = 16.2$, $p < 0.001$. And between 66% valid and 100% neutral, $F(1,19) = 5.2$, $p < 0.033$.

EEG analyses of the cue-target interval

In Figure 2 and 3 the topographical maps for both conditions at relevant time intervals are displayed. Analyses were performed on 50 ms intervals from 200 to 1400 ms after cue onset for the selected electrodes pairs. A summary of the most relevant findings on the ERLs is presented in Table 2. The presence of the EDAN was confirmed for 250 - 350 ms in the 100% condition, no ADAN seems present at the electrodes that were used for the analysis. An LDAP was present in the 66% condition from 500 till 700 ms at P4, O2, PO8, so more posterior oriented and in the 100% condition from 500 - 850 ms at PO8, PO4, thus also more posterior oriented. The occipital negative activity at 1100 till 1200 ms was attributed to the biasing related negativity (BRN) comparable to the term used in the study from Grent and Woldorff (2007). But the activity in current study was occipito-parietal oriented as seen in Grent and Woldorff (2007). However, due the fact that in this study there was a longer cue-target interval, the activity what is devoted to BRN continued till 1400 ms. This activity seemed larger in the 66% condition but there was no statically support for this.

Table 2

A summary of effects observed on the event-related lateralizations

Condition	Electrode	Window	Component	Condition	t (19)	*p*
66%	P4	500 – 600 ms	LDAP	66%	3.5 - 3.1	$0.003 < p < 0.006$
66%	O2	500 – 700 ms	LDAP	66%	3.7 - 2.7	$0.002 < p < 0.013$
100%	O2	250 – 350 ms	EDAN	100%	4.7 - 3.2	$0.001 < p < 0.005$
100%	PO8	500 – 700 ms	LDAP	100%	4.3 - 3.1	$0.001 < p < 0.007$
100%	PO4	500 – 800 ms	LDAP	100%	4.6 - 2.7	$0.001 < p < 0.013$
100%	PO8	750 – 850 ms	LDAP	100%	3.7 - 3.1	$0.002 < p < 0.006$
100%	FC6	1100 – 1200 ms	BRN	100%	- 3.0	$0.008 < p < 0.009$

***Note*. Effects are described in terms of ipsi-contralateral differences (therefore FC6, P4, etc.) BRP = biasing related positivity. EDAN = early directing attention negativity. ERL = event related lateralization. LDAP = late directing attention positivity.**

Difference between conditions

A significant difference in activity was found at electrode PO4 in the time window 650 - 700 ms what seems to concern the LDAP. t (19) = -2.1, $p < 0.047$. A activity of .21 µV for the 66% condition and .61 µV 100% condition. Thus, a larger activity occurs at the electrode PO4 in the 100% condition. This activity is also visible in the topographical maps (Figure 2 & 3). The activity is larger in the 100% condition till 850 ms and is occipital oriented. As presented in Table 2 there is an EDAN visible in the 100% condition (250 till 350 ms) but not in the 66%. However, when a comparison was made no differences were found between both conditions at these time windows. In the topographical maps there is a negativity above the parietal sites from 250 ms in the 100% which resembles these findings. Also presented in Table 2 is a BRN, which is visible in the 100% condition (1100 - 1200 ms) and not in the 66% condition. However, here no differences were found between both conditions at these time windows.

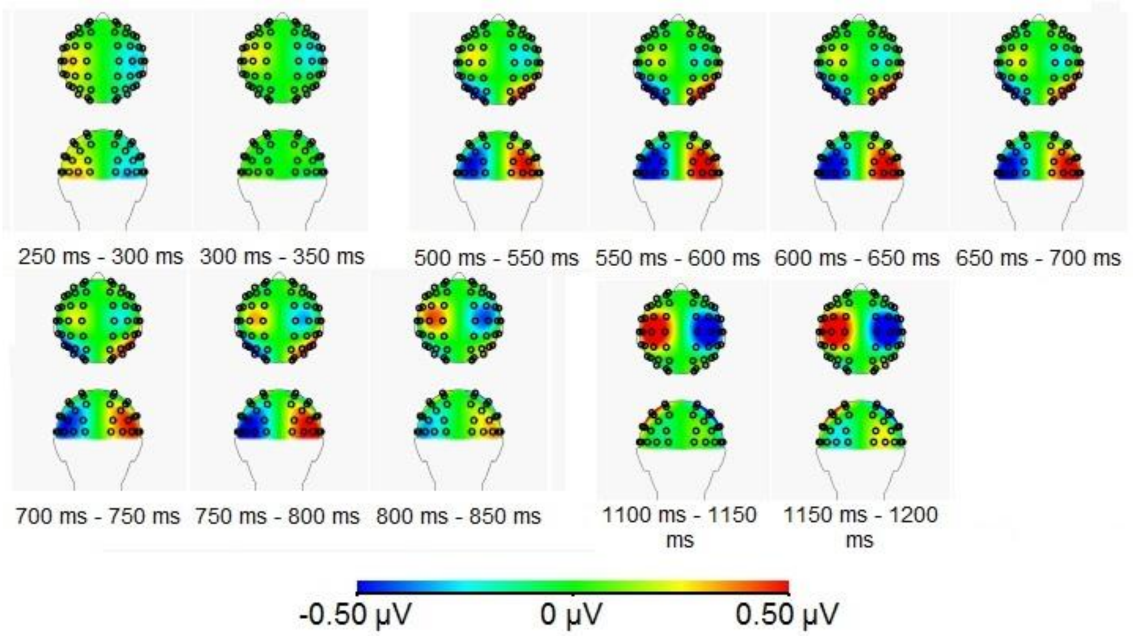

Figure 2. Topographical maps of the event-related lateralization in 50 ms wndow in which significant effects were observed in the 66% condition. In the right hemisphere the ipsi-contralateral difference map is displayed, whereas an inverted contra-contralateral difference map is presented for the right hemisphere.

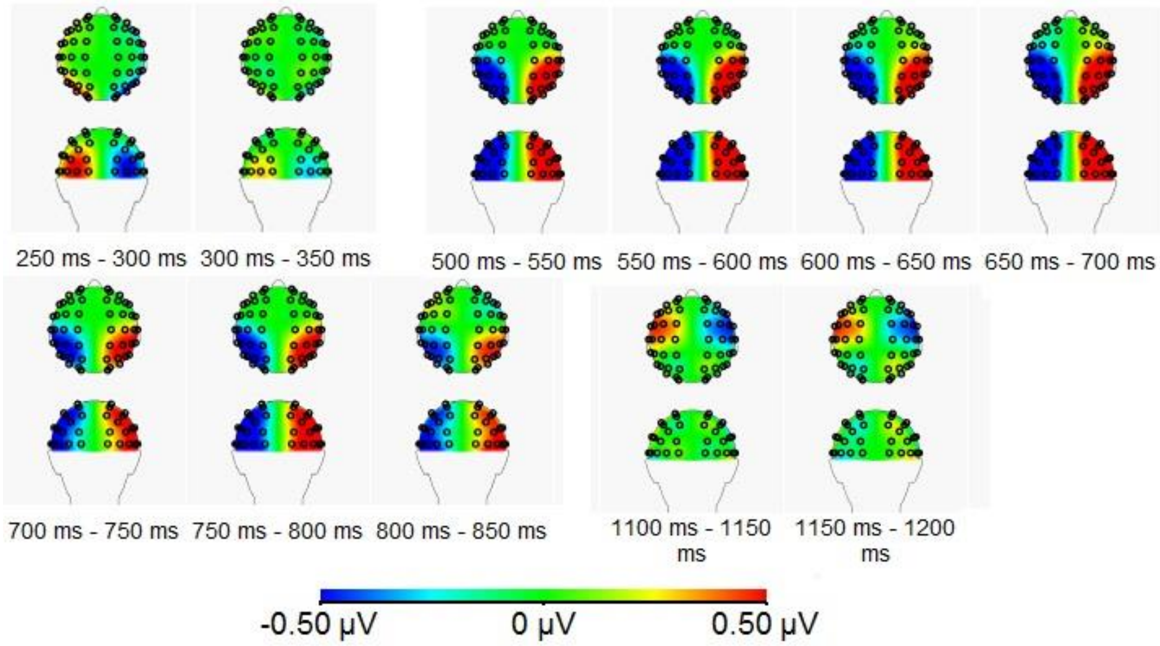

Figure 3. Topographical maps of the event-related lateralization in 50 ms window in which significant effects were observed in the 100% condition. In the right hemisphere the ipsi-contralateral difference map is displayed, whereas an inverted contra-contralateral difference map is presented for the right hemisphere.

Discussion

The Posner paradigm has been used in many studies to examine the allocation of attention. This is mostly measured with a cue validity of less than 100%. However, the question may be raised whether participants allocate their attention efficiently with a cue validity less than 100%. Van der Heijden (1992) suggested that participants do not always focus their attention on the cued side and may make use of a probability matching strategy. The study of Gould (2011) suggests that there is a difference in allocation the attention between a cue validity of 100% and less than 100%. The current study focused on ERL components specific for the focusing of attention: the EDAN, ADAN and especially the LDAP. We also focused on behavioral data and used conditions with cue validities of 66% and 100%.

The behavioral data revealed no difference between the two conditions. It confirmed that there were faster responses for validly cued trials, however no difference was found between validly cued trials in the 100% and 66% cue validity conditions. These data suggest that there is no difference in allocation of attention as function of cue validity. This is not in line with what Van der Heijden proposed.

With the ERLs, different results were found. An EDAN was visible at O2 at the time window 250 - 350 ms (Table 2), being maximal at occipital site in the 66% condition and having a more occipital-parietal distribution in the 100% condition (Figure 2 & 3). However, no ADAN was visible in the ERL results (Table 2). This activity may reflect attentional selection of the relevant part of the cue. It was expected that more activity was shown in the 100% condition due the fact that the participant knows were to focus his attention. However, the activity seems to be larger in the 66% condition (Figure 2 & 3).

The LDAP is clearly present at several electrodes, P4, O2, PO8, PO4 (Table 2) from 500 till 800 ms, which resembles findings from previous studies. In the 66% condition there is a more occipital oriented activity present while in the 100% condition there is a more occipital-parietal focus (Figure 2 & 3).

It was predicted that more components were visible, because of the longer cue-target interval, and this is indeed the case. With the longer cue-target interval, more activity is seen after the usual cutoff at 900 or 1000 ms. As seen in Table 2 there is activity at FC6 from 1100 till 1200 ms in the 100% condition which resembles an BRN as stated before. However, there is also negative activity at the frontal part, that starts at 800 ms till 1400 ms in the 66% condition and in the 100% condition it starts at 950 ms till 1400 ms. The activity seems larger in the 66% condition than in the 100% condition. This activity may reflect frontal eye field (FEF) activity (Van der Lubbe & Utzerath, 2013; Grent et al., 2011). FEF activity seems to be responsible for the non-tracking voluntary eye movements. FEF activity depends thus on which the direction at which attention is focused and the direction to which a saccade, a rapid eye movement, has to be prepared (Van der Lubbe, Neggers, Verleger & Kenemans, 2006). However, the activity that reflects FEF in other studies has been elicited around 200 ms and the activity that is visible here has been elicited at 800 ms (66% condition) or 950 ms (100%c condition) till 1400 ms. This can be due to the fact that this study has a longer cue target interval. Also, the participants are instructed to keep their eyes fixed at the central point on the screen, perhaps towards the end of the cue-target interval this inhibition stops a preparation of a saccade is made. This preparation is the activity of the FEF. But this does not explain why the activity seems to be larger in the 66% condition than in 100% condition. However, all this is interpreted from the topographical maps, because the electrodes used for analysis were mostly occipital oriented whereas the activity what may reflect the FEF is frontal oriented.

Murray, Nobre & Stokes (2011) found that ADAN and LDAP are not only evoked by visual-spatial orientation but also when attention is directed to the expected location of tactile or auditory events. With a selective visual short-term memory (VSTM) encoding task, the benefit of better item-recall probability was predicted by the preparatory measures of attention. Their results demonstrated that neural mechanisms of preparatory attention selection are beneficial in selective VSTM. Besides that also preparatory EDAN and ADAN activity induces a quicker and more correct response. The response time in the current study was smaller for the valid 66% condition than valid 100% condition, however not significant. As seen in Table 2 and the topographical figures (Figure 2 & 3) an EDAN is present in the 100% condition and not in the 66% condition. However, from the topographical figures an ADAN seems to be present in the 66% condition but this is not seen in the results (Table 2). Thus the results found in Murray et al. (2011) are not found in this study. This can be due to the fact that in the study of Murray et al. (2011) a different kind of experiment was used with targets that could be presented at different locations. Further research is needed to confirm this difference.

In the introduction the question was raised whether there was a stronger LDAP in the 100% condition, because the participant knows that in the 100% condition the attention is always focused on the good side so it is expected that there is more activity because a LDAP is specific for the direction of attention. Besides, it was expected that more activity was seen in all components sensitive for direction attention as in line with Gould et al. (2011). A difference during the LDAP was found between conditions. However, the difference was only for a short time window and only at PO4. Nonetheless the topographical maps seem to show some differences between both conditions. The electrodes used for analysis were mostly occipital oriented and the most difference between the both conditions seems to be frontal and parietal oriented (Figure 2 & 3). Only six electrodes pairs were used for analysis, but a lot more (26) were used during the measurement. By expanding the total amount of the electrodes for further analysis, it may be that there is more difference in activity when a cue is always valid or only 66% of the time. However, according to the topographical maps more research is needed to see whether there really is no difference in allocation attention between the different conditions.

It can be concluded from these results that there is not much difference between activities in the ERL components sensitive for direction attention with different cue validity. This is not in line with what was found earlier in the study of Gould et al. (2011). This can be due the fact that Gould et al. (2011) used different cues and had cue validities of 60%, 80% and 100% which shifted between trials. Depending on the kind of cue, the validity of the cue differed. For example, a star figure had a cue validity of 60%, a triangle of 80 and a square 100%. Therefore, the figures indicated the validity. All the cues could come up during the trials. Because the participants in the study of Gould had different validities during the tasks, the expectation of the cue validity had to shift between trials. In this study the validity differed between the two blocks and was the same during the task.

Van der Heijden discussed that it was not clear how a task is performed when the cue validity is less than 100%, participants could use probability matching or the participants were less prepared for the cued position and what more than minimal for the uncued location. This is due to the fact that no difference was found at the behavioral measures and only one difference with the ERL measurements. It can be said that an experiment with a similar design as in this study does not need to have a 100% cue validity to measure how a task is performed as Van der Heijden stated.

With the Posner paradigm it is assumed that the participants focus all their attention on the cued side. Van der Heijden wondered whether this was a correct assumption. If the results of this study showed that there was a difference between both conditions. Research of the half decade could be questioned due to fact that it was not sure how participants performed the task. In this research one significant differences was found at the LDAP, which is assumed to be specific for foccusing of attention. Also in the study of Gould et al. (2011) difference were found between the two cue validities. As shown in Table 2, difference were found between the both conditions when the LDAP was present. However, not a significant difference appeared, except for PO4. Also in the topographical maps it seems that there are differences between the both conditions. But as stated before the study of Gould used different cue validities and a different setup of the experiment. Besides that Gould looked at the Alpha band activity whereas here the ERLs were of focus.

A shorter cue-target interval may influence the difference between the conditions because less time inhibition of saccades is needed. In the topographical maps an FEF seemed visible at both conditions, but only after 800 ms. Further research is needed with a cue validity of 100% with different cues, central oriented or on a specific location and different figures to see whether the kind of cues also influences the ERL components regarding cue validity. In conclusion, with a longer cue-target interval, a fixed target placement and an arrow as cue no differences were found in cue validity in the behavioral results. In the ERL a difference was found for one time window at the electrode PO4. This minor difference can suggest that there is a difference between cue validities. Van der Heijden suggested that there was a difference in allocation of attention with a cue validity of 100% and less than 100%. The ERL results in this study implicates that the assumption of Van der Heijden was valid.

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