The difference between transient and sustained attention on painful electrocutaneous stimulus evoked potentials.

Bachelorthesis Psychology

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Summary

This study investigated the differences between sustained and transient attention in comparable conditions on electrocutaneous pain stimuli, using the P3a component of ERPs. The study was needed because of the absence of a good comparison between sustained and transient attention on pain. Blom and Van der Lubbe (in prep) and Blom, Wiering and Van der Lubbe (submitted) researched respectively transient and sustained attention concerning pain. They suggested a possible difference between sustained and transient attention, but both studies can't be compared because of the differences in study designs.

Participants carried out two types of tasks; a sustained and a transient attention task, both based on the Posner task. In both tasks electrocutaneous stimuli were presented to the right and left forearm of the participant. In the sustained attention task the participants had to focus their attention towards the same side (left or right forearm) the whole block. This in contrast to the transient condition, at which the participants were cued to focus their attention towards both sides randomly. To investigate possible differences on the effect of both ways of attention on the orienting response, the P3a component of ERPs was measured.

Our study reveals no differences of the orienting response towards sustained and transient attention on pain perception. With these results we have overcome the obscurities that existed on the possible differences between sustained and transient attention on pain. The findings that orienting responses towards attended stimuli are significantly lower than towards unattended stimuli, corresponds with earlier studies.

Samenvatting

Deze studie heeft de verschillen tussen *sustained* en *transient* aandacht bij elektrische pijn prikkels in vergelijkbare condities onderzocht, kijkend naar de P3a component van ERP's. De studie was noodzakelijk door de absentie van een degelijke vergelijking tussen sustained en transient aandacht bij pijn. Blom en Van der Lubbe (in prep) en Blom Wiering en Van der Lubbe (ingediend) hebben respectievelijk de rol van transient en sustained aandacht bij pijn onderzocht. Zij suggereerden een mogelijk verschil tussen sustained en transient aandacht, echter was een goede vergelijking tussen beide onderzoeken niet mogelijk door het verschil in onderzoeksopzetten.

Proefpersonen hebben twee typen taken uitgevoerd; een sustained en een transient aandacht taak, beiden gebaseerd op de Posner taak. In beide taken worden elektrische pijn prikkels aangeboden op de rechter en linker onderarm. In de sustained aandacht taak moesten de proefpersonen hun aandacht het gehele blok op dezelfde kant (linker of rechter onderarm) richten. Dit in tegenstelling tot de transient conditie, waarbij de participanten willekeurig per trial te zien kregen naar welke kant ze hun aandacht moesten richten. Om mogelijke verschillen in het effect van beide manieren van aandacht op de *orienting response* te onderzoeken, is de P3a component van ERP's gemeten.

De studie laat zien dat er geen verschillen in de orienting response te zien zijn tussen sustained en transient aandacht in pijnverwerking. Met deze resultaten hebben we de bestaande onduidelijkheden die er bestonden over de eventuele verschillen tussen sustained en transient aandacht bij pijn overwonnen. De bevindingen dat de orienting response bij stimuli waar de aandacht op gericht was significant lager is dan wanneer de aandacht naar de andere kant gericht is, correspondeert met de eerdere studies.

Introduction

When a somatic part of a human body is injured, the discomfort or sensation referred to the damaged tissue is known as nociceptive pain. The term nociceptive pain comes from the Latin word noci, which means “to injure”. The nerve endings that are specified in detecting stimuli that are harmful for the organism are nociceptors. The electrical signals from the nociceptors are transferred through the (spinal-) nerves to the brain. Arrived in the brain the signal passes through and is processed by several brain regions, more specific the SI, SII, the anterior cingulated cortex (ACC) and the prefrontal cortex (PFC). Pain experience is the result of processing in all these areas; it follows that changes in processing leads to a different sensation. Within this processing of pain in the brain, several factors play a role on the pain experience of a human. Normally, the intensity of the subjective experience is usually in proportion to the degree and extent of the damage to the tissue (Perl, 2009).

However it has been shown that attention has great influence on the subjective pain perception (Melzack, 1993). Although pain interrupts and demands attention (Eccleston & Crombez, 1990). They note that several characteristics related to the environment, such as the difficulty and complexity of tasks, are moderating the interruption of attention by pain. Studies show that when attention is distracted from the pain it has been shown that subjects score a lower pain-rating compared to when they attended the pain (Shimizu, Hatayama & Ohyama, 1990; Hodes, Howland, Lightfoot & Cleeland, 1990). Additionally, other findings indicate that highly demanding tasks might distract attention from pain more than less demanding tasks, resulting in lower pain ratings (Veldhuijzen, Kenemans, de Bruin, Olivier & Volkerts, 2006). Van Ryckeghem, Van Damme, Crombez, Eccleston, Verhoeven & Legrain (2011) conducted two experiments to investigate the role of distraction on pain experience. The first experiment was to determine possible differences on the reaction time of a participant on

attended and unattended stimuli. Visual stimuli, at which the participants directed their attention, were presented just before presentation of painful stimulus, either at the side or at the opposite side. The participant had to press a button at the side of the painful stimulus, which could be the left or the right hand. Significantly faster reaction times were observed when the visual cue was presented at the same location as the painful stimuli, in comparison to the situation where the visual cue was presented at the other side. These results suggest that it takes longer to process a painful stimuli at which someone didn't focused their attention to. The second experiment was designed to investigate the possible effects of this manipulation of the spatial attention on pain perception and pain experience. Participants completed the same task but were now asked to not respond on the location but to give a rating of the intensity of the stimuli, whether attended or not. The results showed that the intensity of the electrocutaneous stimuli was rated significantly higher when a visual stimulus was presented at the same side as the painful stimulus in comparison to the situation where the visual stimulus was presented at the other side. These results demonstrate that directing attention spatially away from a pain stimulus has influence on the experience of pain.

When discussing attention, a clear distinction can be made between voluntarily and automatic attention. When one chooses the direction of their attention voluntarily it is called endogenous attention, so called top down attention. At the other hand when an external object or event grabs attention it is known as exogenous attention, or bottom up attention. Furthermore a distinction can be made between sustained and transient attention. In the case of sustained attention, someone's attention is always focused towards the same location or task. In contrast to sustained attention, with transient attention someone has to focus to several locations randomly, and the locus of attention varies from trial to trial.

One way to investigate the effect of transient and voluntarily or automatic attention on pain is a Posner experiment (Posner, Snyder, & Davidson, 1980). The earlier mentioned study

of Van Ryckeghem et al. (2011) and the study of Eimer and Forster (2003) have used a Posner like experiment to investigate the role of attention on pain perception. The Posner experiment is known as the spatial cueing paradigm and is based on shifts in attention. Originally the task was designed only with visual cues and visual stimuli. Participants are cued to attend to one of two sides where the stimuli should come, whereupon the stimulus appears. In the test there is a difference between compatible and incompatible cues. When the cue is pointing in the direction of the target stimulus, this is called a congruent, or attended, cue. In contrast, when the cue points to a direction, but not the location of orientation, it is an incongruent, or unattended, cue.

Besides effect observed on reaction time, event-related potentials (ERP's) delivered from the electroencephalogram can be useful in visualizing possible effects. One of the most clear effects in the ERP is the positive deflection arising around 300 ms after presentation of a stimulus. P3a is known to be the activation in the brain when an organism has to rapidly deal with a novel stimulus (Picton, 1992; Polich & Kok, 1995). P3a is especially associated with orienting and involuntary shifts to changes in the environment. These changes could be new (never experienced before), unexpected or unpredictable stimuli. The reaction to these changes in the environment is called the orienting response, and is suggested to visualize the amount of attention that is paid to a sudden change in the environment before it is identified. The higher the P3a amplitude, the greater this orienting response. Rosenfeld (1993) reviewed the experimental variables affecting the P3a amplitude and concluded that rare or meaningful items result in a larger P3a.

Blom, Wiering and Van der Lubbe (submitted) examined the effects of sustained attention on electrocutaneous stimulus processing. The researchers compared a task in which the participant had full attention towards painful stimuli, with two distraction tasks (Mental-arithmetic and Word-association) in which the participants directed their attention toward the

task at hand. They determined that during the sustained distraction tasks the amplitudes of the N1 and P3a components were attenuated, compared to the situation at which there was full attention towards the stimuli. The attenuation of N1 was seen as a reduction of the somatosensory processing, and P3a attenuation as a reduced orienting response of attention towards the response. Recently Blom and Van der Lubbe (in prep) studied the effect of transient attention on the processing of electrocutaneous stimuli, using a Posner like task with visual cues. The results of that study showed a greater orienting response for initially unattended stimuli, based on the observed enlarged P3a amplitudes. Unattended stimuli are unexpected, because the participant was cued to concentrate at the other side. Because of this more unexpected and unpredictable character of these stimuli, the orienting response was greater. With these findings a difference on the orienting response is suggested between sustained and transient ways of attention. In transient attention condition the stimuli attract attention, so the orienting response will be greater.

Until now a decent comparison between transient and sustained attention on pain hasn't been made. Blom, Wiering and Van der Lubbe (submitted) used distraction tasks to examine the effects of sustained attention on pain processing. Otherwise Blom and Van der Lubbe (in prep) used a Posner task to investigate transient attention. When looking at the results of both these studies, transient attention seems to cause a greater P3a peak than sustained attention. Because of these differences of design and outcomes it is necessary to include sustained and transient attention into one task. This gives the opportunity to make a within subjects comparison on the orienting response of both sustained and transient attention in equal circumstances.

We have chosen to use a Posner like experiment for investigating the differences of sustained and transient attention. Within this experiment both forms of attention can be equally integrated, to make a clear comparison between the two. Instead of the visual stimuli

in the original Posner task, subjects have to discriminate between high and low pain stimuli.. This pain stimuli are delivered to the right and the left forearm. Every trial the participant is cued to focus their attention towards the left or the right arm. When the stimuli is given at this attended side, and is of the before instructed intensity (high or low) which the participant has to look for, a foot pedal has to be pressed. Half of the stimuli will be at the attended side, and the other half will not be. There are four blocks of trials, two with sustained attended stimuli and two with transient attended stimuli. At the sustained attention blocks the attended side will be remain the same the whole time, so the cued side to focus attention to will be the whole block the same. In contrast to the transient attention blocks, at which the attended side is randomly shared between the two sides.

We suggest to find a greater orienting response in a transient than on a sustained condition. When looking at the earlier mentioned research of Blom, Wiering and van der Lubbe (submitted) and Blom and Van der Lubbe (in prep) this difference will be seen in a greater orienting response visible in higher P3a values on the transient condition. This difference implies that painful stimuli on a transient condition are less predictable and newer to the participant, in comparison to a sustained condition, and therefore they will show a greater orienting response. Furthermore, it is expected that our results show a significant difference between the attended and the unattended cued stimuli. Unattended stimuli will induce a greater orienting response, and therefore a greater P3a.

Method

Participants

Seventeen healthy students (3 male and 14 female, age: 20-34 years) participated in the experiment, which lasted for approximately 2,5/3 hours. Sixteen of the participants were right-handed and one left-handed. Every participant was given a detailed explanation of the procedure and signed an informed consent before participating. The experimental procedures were approved by the Medical ethical committee of the MST Enschede.

Stimuli and procedure

Two stimulators were used to deliver the electrocutaneous stimuli. The stimuli were delivered using a stimulation electrode, which was taped over the median nerve at both forearms. The individual sensation thresholds were obtained, measuring when the participant noticed a feeling at all, when the feeling merged into pain and when the feeling became a unpleasant pain. Thresholds were identified by increasing the intensity of a stimulus with steps of 0.1 mA, starting at zero. Participants were instructed to report their pain detection threshold, at which they had to detect the moment where the stimulus merged from just a feeling into an painful feeling. Next, participants had to detect when they felt the stimulus for the first time. And at last they had to mark their maximal threshold, what had to be a clear annoying pain.

After each block the participant was given a set of stimuli of which the painfulness had to be marked on a visual analogue scale (VAS). VAS is a measurement instrument which measures the subjective characteristics or attitudes. At a continuous line between 0 and 10, participants determine their level of agreement to a statement. In our study the participant was given a stimulus of high and low intensity at both arms. They had to rate the stimulus at the

VAS, with zero as ‘no feeling at all’, ten as a ‘highly painful feeling’, and 5 was marked as the point where a feeling passed into a painful feeling. At the beginning and the end of the experiment a Thayers mood scales-questionnaire was given to the participant to know whether or not the experiment has had an effect on the mood of the participant. During the experiment EEG was measured.

Task

The experiment was divided into 4 blocks, with 96 trials every block. Between each block, there was a short pause of 2 minutes. Before every trial a fixation cross was shown at the screen. After 1200ms a directional cue was presented for 400ms. This cue was composed out of 2 arrows, which pointed to opposite directions, left and right. One of them was red, the other was green. The arrows pointed to the direction where the next stimulus could be expected. At the first and the third block the participant had to look for the same colored arrows, and the second and forth for the other color. The attended color was counterbalanced. The electrical stimulus was presented at either the left or right forearm 600 milliseconds after the appearance of the arrows (see Figure 1). The participant had to press a foot pedal when a high or low stimulus (depending on the attended stimuli intensity) at the attended side. For half of the participants the relevant intensity were the high stimuli the whole task, whereas for the other half the low were the relevant intensity. At two blocks, the side where the attending arrow pointed to was always the same (sustained attention). And at the other two blocks the attending arrow will point randomly to both sides (transient attention). In the sustained attention trials (for example block 1 and 3, counterbalanced across participants) the relevant cue pointed half of the block always to the left and the other half always to the right (counterbalanced across participants). In the transient attention trials, the relevant cue pointed randomly to both sides during the block, and half of the trials towards the stimulation side.

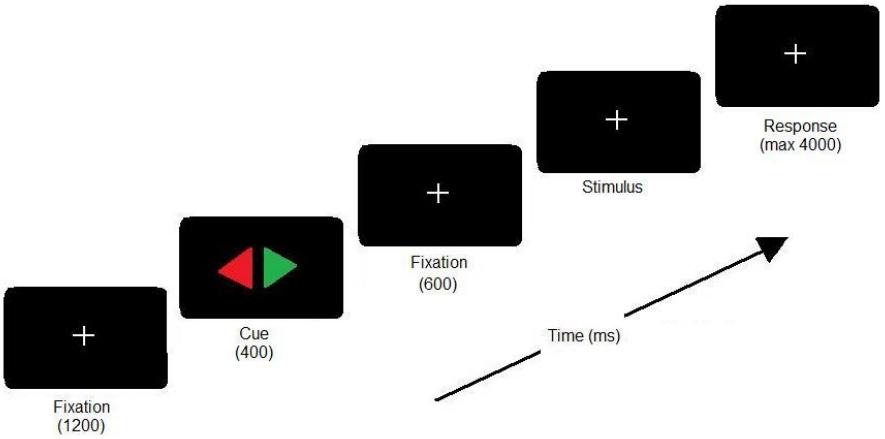


Figure 1: Construction of the sustained-transient task.

Recording

The EEG was recorded from 61 standard channels (extended 10-20 system), using Ag/AgCl electrodes mounted on an electrocap (EasyCap GmbH, Herrsching- Breitbrunn, Germany). All electrode impedances were below 5 kΩ. The ground electrode was placed on the forehead. The vertical and horizontal electrooculogram were measured with bipolar Ag/AgCl electrodes located on the outer sides of the eyes and from above and below the left eye. Signals passed through a QuickAmp amplifier (Brain Products GmbH, Munich, Germany), and were recorded online against an average reference at a sample rate of 500 Hz. Online filtering with a 200 Hz low pass filter and a notch filter of 50 Hz was applied throughout the recording.

Data analysis

EEG was analyzed by using Vision Analyzer 2. First, a time window around each electrocutaneous stimulus from –100 to 500 ms was selected. The mean amplitude from -100 to 0 ms before stimulus onset served as a baseline. ERP's were computed for all electrodes by averaging EEG for trials without artifacts. The allowed amplitudes were +/- 250, 200, 150 and 100 µV, for prefrontal, frontal, central and parietal electrodes, respectively. EOG artifacts were excluded from EEG data because they induce larger amplitudes at frontal than at parietal sites. ERPs were computed for all electrodes by averaging EEG for trials without artifacts.

Based on the observations of the ERPs and topographic maps, the large time window for the P3a component (300-400 ms) at electrode Cz was chosen. To make a decent comparison of both peaks, a time window which includes both peaks was necessary (see Figure 2).

The VAS-scores were analyzed with a repeated measures ANOVA, using the factors 'block' (before block 1, after block 1, 2, 3 and 4) , 'stimulation side' (right or left forearm) and 'intensity' (high or low stimulus intensity).

Results

Behavioral data

Repeated measures ANOVAs of the VAS, at which the participants rated the intensities of the stimuli before block 1 and after block 1, 2, 3 and 4, revealed a significant main effect of the stimulus intensity ($F(1,16) = 126.6$, $p < 0.001$). The mean of the VAS-ratings of the low intensity stimuli was 3.2 compared to 4.8 of the high intensity stimuli. Also the differences between the blocks were significant ($F(4,64) = 20.1$, $p < 0.001$). The means of

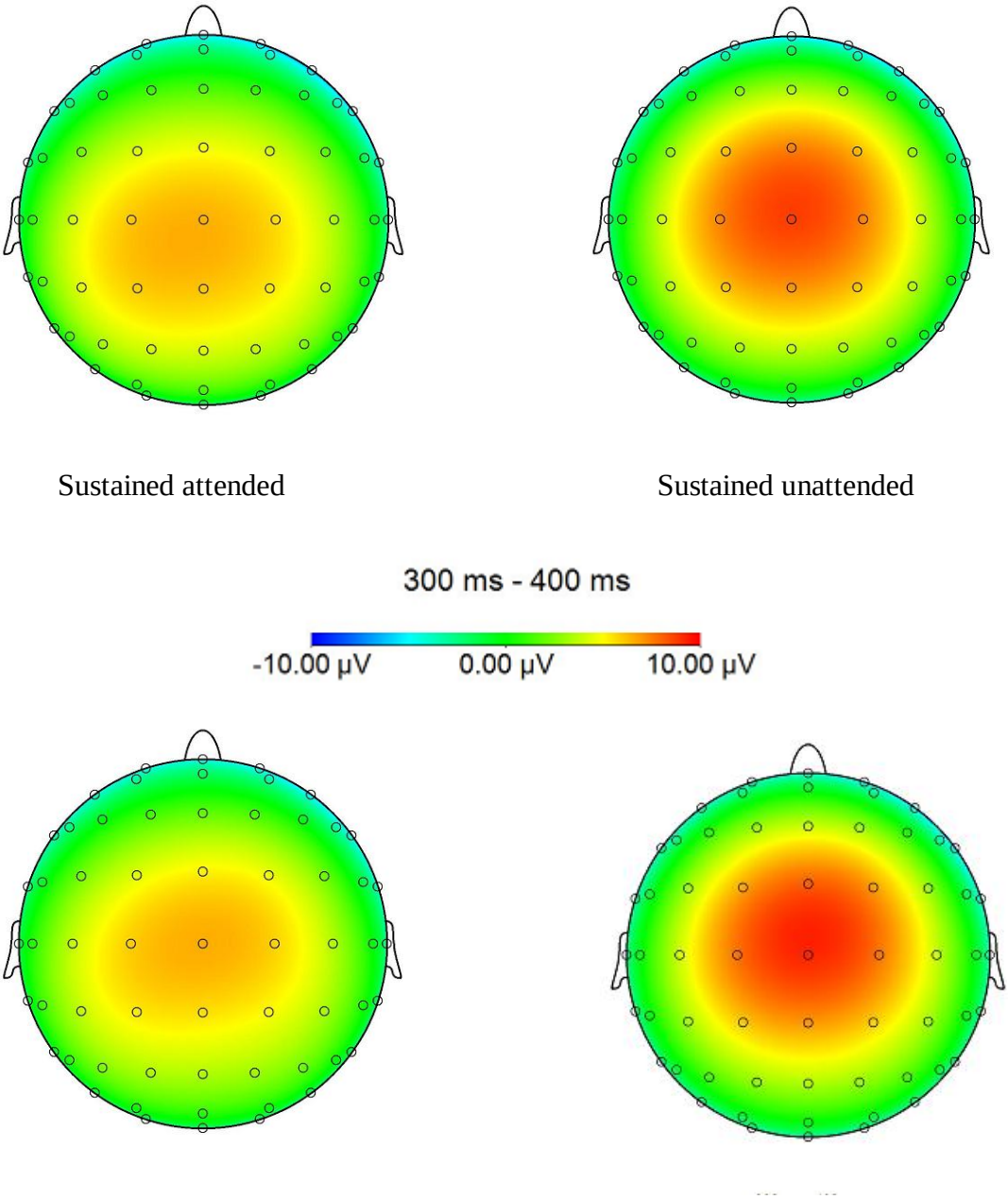
the ratings of the stimuli that were given before block 1 and after block 1, 2, 3 and 4 are respectively 4.9; 4.2; 4.1; 3.4 and 3.5. The ratings decreased almost every block, which shows that the participants experienced the stimuli less painful during the test. Stimulation side showed no significant effect ($F(1.16) = 0.7$, $p = 0.406$). The mean ratings for left and right side were respectively 39 and 42.

Analysis of the Thayers mood scale, which every participant completed before and after the experiment, show especially significant differences on tiredness, at which the participants scored lower before ($\mu = 42.3$) than after the test($\mu = 58.7$, $p < 0.003$) and energetic, which was lower after ($\mu = 45,5$) than before ($\mu = 62.5$) the test ($p < 0.001$).

Analysis of the accuracy data of the experiment show a hit percentage of .79 and a miss percentage of .21. Furthermore .91 was rejected correct, against .09 of false hits. So in 20 percent of the trials at which the participant had to react to the stimuli, the participants did not press the foot pedal. And in 10 percent of the trials at which the participants did not had to respond, they pressed to foot pedal. This suggests that the participants well understood the experiment. The 0.09 false hits and .21 miss percentage show that the trials were difficult enough to keep the focus of the participant.

EEG Data

Grand average ERPs for the 4 conditions (attended sustained, attended transient, unattended sustained, unattended transient) are presented in Figure 3. The electrocutaneous stimuli elicited a maximal P3a component at electrode Cz. The topographical map at Figure 1 shows that the P3a component was maximal at Cz.



Sustained attended

Sustained unattended

Transient attended

Transient unattended

Figure 1: Topographic maps of the Grand Average activation at 300 – 400 ms.

Sustained/Transient No significant difference was found on the amplitudes of the P3a component ($\underline{F}(1,16) = 0.2$, $p = 0.669$) between the sustained and transient tasks. The P3a peak of the sustained condition was 7,9 µV and the peak of the transient condition was 8,1 µV.

Attended/unattended There was a significant main effect ($\underline{F}(1,16) = 23.8$, $p < 0.001$) in that the amplitude of the P3a component was more positive when the stimulus was unattended, in comparison to the P3a when the stimulus was attended. The P3a peak of the attended cued stimuli was 6,7 µV, and the peak of unattended was 9.2 µV.

Sustained/trainsient vs. Attended/unattended No significant effect ($\underline{F}(1,16)=0.8$, $p = 0,378$) of the sustained or transient condition on the attended or unattended stimuli was found.

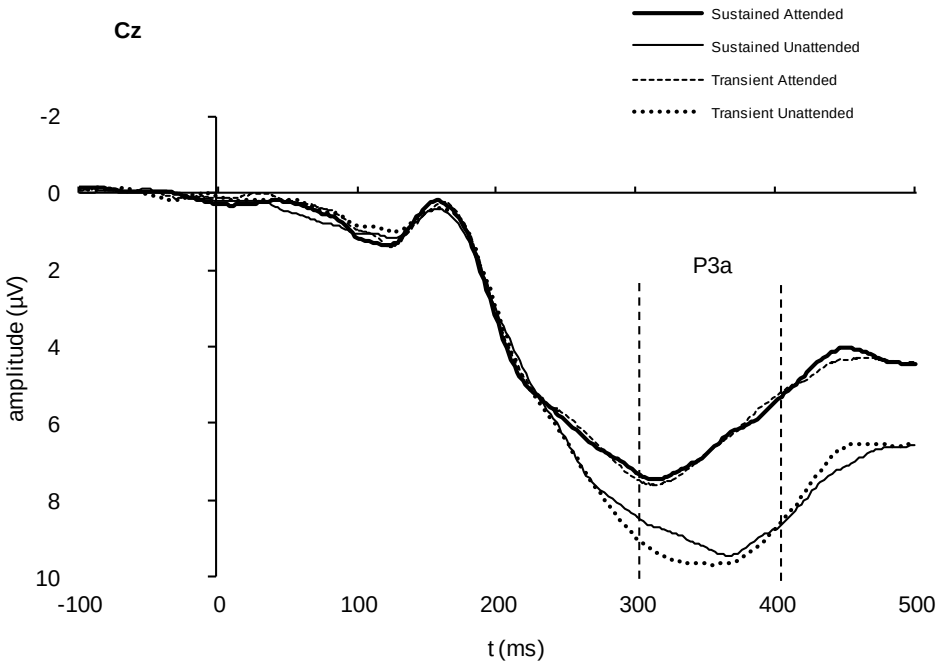


Figure 2: ERP showing the P3a component measured at the Cz electrode with the corresponding window used for analysis.

Discussion

Our study investigated the differences between sustained and transient attention in comparable conditions on electrocutaneous pain stimuli, using the P3a component of ERPs. This study was needed because of the absence of a good comparison between sustained and transient attention on pain. Blom and Van der Lubbe (in prep) and Blom, Wiering and Van der Lubbe (submitted) researched respectively transient and sustained attention concerning pain. They suggested a possible difference between sustained and transient attention.

In our study, participants carried out two types of tasks; a sustained and a transient attention task, both based on the Posner task. In both tasks electrocutaneous stimuli were presented to the right and left forearm of the participant. In the sustained attention task the participants had to focus their attention towards the same side (left or right forearm) the whole block. This in contrast to the transient condition, at which the participants were cued to focus their attention towards both sides randomly. To investigate possible differences on the effect of both ways of attention on the orienting response, the P3a component of ERP's was measured. This P3a component was most prominent at the vertes (Cz). In line with the suggestion that P3a is generated by the ACC, there is chosen for Cz to be the electrode for the data of this study. Figure 2 gives a clear view of the activation on the centre of the scull.

Our findings clearly demonstrate that there is a difference in orienting response between attended and unattended stimuli. The P3a amplitude of the attended stimuli is significantly lower than the peak of the unattended. Which suggests that, with sustained attention, attended cued stimuli appear to induce a less stronger orienting effect than unattended stimuli. As earlier mentioned, the P3a peak can be seen as the orienting response of the brain towards a new or unexpected stimuli. So when a stimuli is presented at the side where the participant doesn't expect the stimuli, a higher P3a peak was seen, probably

because it is an unexpected event. The higher P3a peak on the unattended side can be seen as the first reaction to the sudden unexpected event or change, in our case the painful stimulation at the side where the participant did not expected it to come. Van der Lubbe et al. (2011) found similar results on their study their study on the effect of transient attention on pain processing, and suggested that unattended stimuli induced a "call for attention". This can also be seen in the reaction time towards stimuli. Van Ryckeghem et al. (2011) concluded that the response to painful stimuli slows down when attention is directed away from the location of the stimuli, which means that it took the respondent longer to process the unattended stimuli. Based on the oddball paradigm, in which participants has to look for target stimuli that are hidden as rare stimuli amongst a series of more common stimuli, our findings were expected. The oddball paradigm expects a greater orienting response on the target stimuli, in our case the unattended stimuli. However, it has to be taken in consideration that in most oddball tasks the target stimuli are more rare than the unattended stimuli in our study. It can be concluded that the orienting effect on painful stimuli is greater when the stimulus is given to an unexpected place. This is in accordance with the results of the studies on pain and attention of Blom and Van der Lubbe (in prep) and Van der Lubbe et al. (2011), as well as with the findings on similar studies using visual and aural stimuli instead of painful stimuli.

In contrast to the effects of attended and unattended stimuli, no difference was found on the P3a component when comparing sustained and transient attention. Therefore, it can be concluded that there are no differences in the processing of electrocutaneous stimuli between a condition in which a subject expects the stimulus at the same place every trial, and a condition where the attention has to be switched between two places each trial. Furthermore, no effect of the sustained or transient condition on the attended or unattended stimuli was found. The attended and unattended stimuli were not processed different on the sustained or transient condition, which also leads to the suggestion that there is no difference between

sustained and transient attention on pain processing. This because for example the attended stimuli were not processed different when they were cued to the same time the whole time in comparison to when this side varied between right and left. Blom and Van der Lubbe (in prep) suggested a possible difference between sustained and transient attention on pain in their study on transient attention and pain. It is clear that the findings of our research are in contradiction with this suggestion. Based on our findings it can be concluded that transient shifts of attention have no other effect on the orienting response towards the electrocutaneous stimuli than sustained attention. A possible explanation for this difference between their suggestion and our outcomes could be found in the sustained condition of our study. There is a possibility that it took the respondents a while to figure out that, in the sustained condition, all the cues they had to look for were always at the same side. If this was the case, the sustained stimuli in the first block(s) were not very different from the transient stimuli, because the respondents processed every trial apart. To possibly rule this out in further research, the analysis of the data could include only the last parts of the blocks. This way it is more likely to assume that the participant has become aware of the fact that the cued side remains the same over the block.

The behavioral data showed a significant difference between the high and low stimulus intensities. This difference was necessary for the task, because the participants had to discriminate between high and low intensity stimuli. Also important for the study was that the participants felt no significant difference in intensities between the left and the right stimulation side. The participants didn't rate the left and the right stimuli intensities significantly different. Furthermore a significant difference between the intensity ratings of the blocks was found. An explanation for this difference could be the habituation of the stimuli over time, because the ratings of the stimuli declined over time. It is known that with repetition of the same or similar stimuli, a neuronal network is formed and those stimuli no

longer evoke the same orienting response (Solokov, 1990). Effects of fatigue could not be completely ruled out, but the two minutes rest between every block were meant to give the participant the time to repose from the task. Although, the Thayers mood scale shows that the participants were significantly more exhausted after the experiment.

In conclusion, our current study reveals no differences of the orienting response towards sustained and transient attention on pain perception. With these results we have overcome the obscurities that existed on the possible differences between sustained and transient attention on pain. The findings that orienting responses towards attended stimuli are significantly lower than towards unattended stimuli, corresponds with earlier studies.

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