UNIVERSITEIT TWENTE.

The influence of spatial attention on the somatosensory processing of pain

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Enschede, 28-09-2012

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Summary

Several studies have shown that distraction modulates the processing of painful stimuli (Blom, Wiering & Van der Lubbe, in press; Van der Lubbe, Buitenweg, Boschkler, Gerdes & Jongsma, 2011). These studies used either sustained distraction (Blom et al., in press) or transient distraction (Van der Lubbe et al., 2011). Due to the differences in procedures used, it remains problematic to compare the results. The current study will try to resolve this problem by combining both sustained and transient distraction. The current study will also investigate whether people who participate for the first time in a research design during which they receive painful stimulation are more anxious than participants that have experienced painful stimulation before and whether anxiety influences their performance on the task.

During the experiment, participants received high or low intensity stimuli to either their right or left arm. The participants were expected to hit a footpedal when they received a relevant stimulus, relevance was determined by the intensity and the side of stimulation.

Results revealed an attenuated amplitude of the N1 component during spatial distraction compared to attention. This indicates that distraction already has an attenuating effect on the processing of pain in the somatosensory cortex. No significant difference between transient and sustained distraction was found on the N1 component. It can be argued whether it is relevant to discriminate between transient and sustained attention since they appear to result in the same process. Furthermore, no significant effect was found of the number of times participated in a similar research design before on the anxiety level. It appears that participants that participated for the first time do not experience a higher level of anxiety than participants that have participated in a similar research design before. Finally, no significant effect of the anxiety level on the false alarm rates was found. However, the anxiety scores ranged very limitedly which made it hard to draw conclusions.

Samenvatting

Verschillende studies hebben aangetoond dat afleiding de verwerking van pijnlijke stimuli beïnvloedt (Blom, Wiering & Van der Lubbe, ter perse; Van der Lubbe, Buitenweg, Boschkler, Gerdes & Jongsma, 2011). Deze studies gebruikten echter óf “sustained” afleiding (Blom et al., ter perse) of “transient” afleiding.(Van der Lubbe et al. 2011). Door het gebruik van verschillende procedures is het problematisch om de resultaten te vergelijken. De huidige studie zal proberen dit probleem op te lossen door “sustained” en “transient” afleiding te combineren. Ook zal er onderzocht worden of respondenten die voor het eerst deelnemen aan een onderzoek waarin zij worden blootgesteld aan pijnlijke stimulatie meer angst ervaren dan respondenten die dit al eerder ervaren hebben en of angst een invloed heeft op het uitvoeren van de taak.

Tijdens het experiment ontvingen respondenten stimuli van hoge en lage intensiteit aan hun linker- of rechterarm. Er werd van de respondenten verwacht dat zij op een voetpedaal drukten wanneer zij een relevante stimulus ontvingen. Relevantie werd bepaald door de intensiteit en de kant van stimulatie.

De resultaten lieten een verzwakte amplitude van het N1 component zien tijdens spatiële afleiding in vergelijking tot aandacht. Dit wijst erop dat afleiding al een verzwakkende werking heeft op de verwerking van pijn in de somatosensorische cortex. Er is geen significant verschil gevonden tussen “sustained” en “transient” afleiding in het N1 component. Dit roept de vraag op of het wel relevant is om onderscheid te maken tussen “sustained” en “transient” afleiding. Ook is er geen significant verschil gevonden tussen de angstniveau’s tussen de respondenten. Tot slot is er geen significant verschil gevonden tussen het angstniveau en de “false alarm” ratio’s. De angstniveau’s varieerden echter zo beperkt dat het moeilijk is hier conclusies over te trekken.

Introduction

Pain can be described as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” (International Association for the Study of Pain Task Force on Taxonomy, 1994). Based on a study by Bekkering et al. (2011), eighteen percent of the Dutch population is estimated to suffer from chronic pain, which is a pain that lasts longer than three months (Morrison & Bennett, 2010). This high prevalence makes research regarding this topic of great importance since chronic pain can have a huge influence on the patient’s quality of life by influencing their daily routine (not being able to go to work or participate in social activities for example). It is of great importance to achieve a better understanding of factors that influence the experience of pain, since factors that decrease the perception of pain could be used in the development of therapy that can help patients to cope better with their pain. One such factor, attention, has been proven to modulate the perception of pain in several studies (McCaul & Haugtvedt, 1982; Rémy, Frankenstein, Mincic, Tomanek & Stroman, 2003; Blom, Wiering & Van der Lubbe, in press; Van der Lubbe, Buitenweg, Boschkler, Gerdes & Jongsma, 2011) . These studies used either a form of attention whereby the locus of attention remained constant over a period of time, so called sustained attention (Blom et al., in press) or a form of attention whereby the locus of attention shifted, transient attention (Van der Lubbe et al., 2011). Due to the differences in procedures used, it remains problematic to compare the results the studies that used either sustained of transient attention. The current study will try to resolve this problem by combining both types of attention in one experiment. Furthermore, a more general concern regarding experiments that include painful stimulation, is anxiety. The anticipation of pain induces anxiety in people (Carlsson, Andersson, Petrovic, Petersson, Öhman & Ingmar, 2006). It can therefore be expected that participants, participating in a study whereby they are going to receive painful stimuli, experience some anxiousness. This anxiety might negatively influence their current performance. However, repeated exposure to a painful stimulus can reduce this anxiety. It is therefore possible that participants that participated in a similar research design before are less anxious than participants that participate for the first time, since they are familiar with the painful stimuli (Bouton, 1988). In addition to resolving the comparability issue regarding studies focusing on transient or sustained attention, the current study will investigate whether participants that haven't participated in a similar study before experience more anxiety and whether a higher anxiety level results in a decreased performance.

Pain and attention

Painful stimuli are, among other cortices, processed by the somatosensory cortex. This cortex consists of the primary- en secondary somatosensory cortex. The primary somatosensory cortex processes touch sensations and information from muscle-stretch receptors and joint receptors (Kalat, 2007). The role of the secondary somatosensory cortex is still a matter of debate. However, there is evidence suggesting that it takes part in multisensory integration (Menzel & Barth, 2005). Multisensory integration means that the information from the different senses is combined to compose a coherent whole. When you're eating an egg for example, you can taste the egg, see it and smell it. These different sensations are perceived as a whole. Painful stimuli are processed first in the primary somatosensory cortex (S1), after which they are transmitted to the second somatosensory area (S2), the somatosensory regions in posterior parietal cortex (Pons, 1992) and the anterior cingulate cortex (Becerra, Chang, Bishop & Borsook, 2010). The activity in these brain regions can be recorded, using electrodes attached to a cap placed on the subject's scalp (Chen, 2001). This recording method is called electroencephalography (EEG). A way to analyze EEG signals is by analyzing the small voltage fluctuations associated with a stimulus (event-related potentials

(ERP)). ERP refers to the mean brain activity in response to an event. In response to painful stimulation, a negative peak is observable (N1) in the ERP after approximately 140 ms from stimulation onset. This peak is thought to represent activity in the secondary somatosensory cortex, as it is maximal contralateral to the stimulated body part (Frot, Rambaud, Guénot & Maugière, 1999). Then, after approximately 250 ms after stimulus onset, a positive peak is commonly visible (P2). The anterior cingulate cortex is suggested to be the source for this peak and it visualizes an orienting respons, an attention shift to novel stimuli. This means that attention is directed to novel stimuli in respons to changes in the environment. With the help of EEG, changes in brain activity can be recorded and observed.

Studies regarding the influence of attention on the N1 component have resulted in some conflicting results. Yamasaki et al. (2000) used electrocutaneous stimuli, which means that the participants were connected to a stimulator which provided them with electrical pulses. These stimuli were presented to the right index finger of the participant. During the experiment, the participant performed an attention and two distraction tasks. The results of this study showed that the peak-to-peak difference between the N1 and P2 components was attenuated during the distraction task. The difference between the negative N1 peak and the positive P2 peak was, thus, attenuated during distraction. This result indicates that there was a decrease in the processing of pain during distraction. However, no individual attenuation effects were found for the N1 en P2 peaks, which means that the influence of distraction was found but not for the N1 component individually.

A similar study by Blom et al. (in press) tried to resolve the discrepancies regarding the influence of attention on the N1 component. They presented participants with electrocutaneous stimuli at the left forearm. The experiment consisted of two distraction, and one attention task. The results of the study by Blom et al. (in press) revealed that the amplitude of the N1 component was attenuated during both distraction tasks. Thus both

Yamasaki (2000) and Blom et al. (in press) found an attenuating effect of distraction on the processing of pain. Blom et al. (in press), however, also found a result regarding the N1 component. The N1 peak is suggested to represent activity in the secondary somatosensory cortex. Therefore the attenuating effect of distraction found in the N1 component could mean that the processing of pain is already attenuated in the somatosensory cortex due to distraction.

The majority of the experiments conducted to investigate the influence of attention on somatosensory processing focused on sustained attention (McCaul & Haugtvedt, 1982; Rémy, Frankenstein, Mincic, Tomanek & Stroman, 2003; Blom, Wiering & Van der Lubbe, in press; Van der Lubbe, Buitenweg, Boschkler, Gerdes & Jongsma, 2011), whereby the locus of attention remains constant over a period of time. However, transient attention, whereby the locus of attention varies over a period of time, is completely overlooked. This poses a problem to the validity of the research. In response to this lack of research regarding transient attention, Van der Lubbe et al. (2011) conducted an experiment that included transient attention. During the experiment participants received electrocutaneous stimuli to either their left or right index finger. The researchers used spatial attention to manipulate attention i.e. participants were expected to attend to either their right or left hand. Their study revealed a decrease in the amplitude of the N1 component during distraction. There remains a problem, however, regarding the comparability of the results obtained by the different studies described above. Since all studies used either a sustained attention approach or a transient attention approach it is impossible to correctly compare the individual results. The current study tries to reduce these problems by conducting an experiment which includes transient as well as sustained attention in conditions that are comparable. This will make it possible to investigate whether the two different attentional approaches result in different somatosensory processing which will contribute to a better understanding of how these two different kinds of distraction relate to each other. This results in the following research question:

"Does the effect of spatial attention on the early processing of painful, electrocutaneous stimuli differ for sustained and transient attention?"

An experiment was conducted which resembles the experiment conducted by Van der Lubbe et al. (2011). The only difference is that sustained attention was added to the task. Based on the results by Blom et al. (in press) can be expected that the current study will demonstrate attenuated amplitude of the N1 component during distraction in comparison to attention. The results of the current study regarding transient attention are expected to be similar to the results obtained by Van der Lubbe et al. (2011) which means a decreased amplitude of the N1 component during transient distraction in comparison to attention. Based on these studies, no difference between the attenuating effects of transient and sustained attention on somatosensory processing can be expected.

Anxiety

As mentioned earlier, the anticipation of pain is known to induce anxiety in humans (Carlsson et al., 2006). It can be expected that participants that have participated in a research design with exposure to painful stimulation before are less anxious than participants that have never experienced painful stimulation during an experiment before, since repeated exposure to a painful stimulus can reduce the anxiety (even till extinction) (Bouton, 1988). Anxiety might impair the performance of participants during the experiment i.e. discerning between relevant and irrelevant stimuli. Hopko, Ashcraft, Gute, Ruggiero and Lewis (1998) demonstrated the effect of anxiety on performance. Their experiment had three reading conditions which were defined by the content (math or non-math) and the type of distractor words (control, math-related, math-unrelated). Participants were assigned to three groups: low-math anxiety, medium-math anxiety and high-math anxiety. The results indicated that high- and medium-anxiety participants needed more time to read the paragraphs which had distractor words embedded. Another example of a study that revealed an effect of anxiety on performance was conducted by Byrne and Eysenck (1995). They used the 'face in the crowd effect' which was found first by Hansen and Hansen (1988). Their experiment demonstrated that anxious individuals were slower to detect the happy face in the crowd of angry faces relative to non-anxious individuals. These results are in line with a meta-analysis of Bar-Haim et al. (2007) which concluded that anxious individuals preferentially attend to threat-related stimuli relative to neutral stimuli, the so-called 'threat-related bias'. Apparently, anxious individuals are less able to inhibit (supress) threat-related stimuli in comparison to low-anxious individuals.

The results by Hopko et al. (1998) and Byrne and Eysenck (1995) can be explained by the attentional control theory and the influence of anxiety by Derekshan and Eysenck (2009). Attentional control theory states that attention is regulated by the central executive, which is a system in the brain that performs complex functions like planning. Attentional control is, according to attentional control theory, regulated by two types of processes (Yantis, 1998). The first process is top-down goal driven, whereby attention is controlled by an individual's goals, knowledge and expectations (Corbetta & Schulman, 2002). The second process is bottom-up stimulus driven, whereby attention is influenced by salient stimuli. According to attentional control theory, anxiety disrupts the balance between these two processes. It enhances bottom-up processes in comparison to top-down processes. A consequence hereof is that the inhibition function is disrupted since this function is related to top-down goal driven processes. In conclusion it can be stated that anxious individuals can experience an impaired inhibition function since anxiety can enhance bottom-up stimulus driven processes in the central executive. This impaired inhibition function results in an impaired ability to suppress irrelevant stimuli. If this impaired inhibition function is present during experiments this could pose a threat to the validity since the performance on the task is negatively influenced by anxiety. The current study will investigate whether this is the case using the following research question:

“Does the anxiety level differ between participants that have participated in an experiment with exposure to painful stimulation before and participants that have never experienced painful stimulation during an experiment before and does the anxiety level influence the false alarm rate?”

The current study uses a questionnaire to determine the anxiety level of the participants. Based on the study by Bouton (1988) it is expected that participants that participate for the first time in an experiment using painful stimulation have higher anxiety levels than participants that participated in such an experiment before. With the questionnaire it can be investigated whether a difference in anxiety level actually exists between the participants. The obtained anxiety levels will be compared with the performance of the participants to determine whether anxiety influenced performance. Since the performance is expected to be impaired due to an impaired inhibition function, performance will be measured using false alarms i.e. responding when presented with an irrelevant stimulus.

Method

Participants

Thirty four students from the Faculty of Behavioral Sciences of the University of Twente participated in the experiment. Their mean age was 23.7 with a standard deviation of 3.3. From the 34 students, 5 were male and 29 were female. Two of the participants were left handed. None of the participants suffered from neurological deficits. The experiment lasted for three hours. The procedures of the study were approved by a medical ethical committee.

Stimuli and procedure

The experiment described in this paper was part of a bigger study. The main purpose of this study was to investigate the effects of ‘mindfulness’ on the processing of electrocutaneous stimuli. Mindfulness can be defined as “an open and receptive awareness towards internal and external present-moment experience and paying attention in a particular way: on purpose, in the present moment and nonjudgmentally” (Craske & Arch, 2010). Sixteen participants participated in a pre-test. The composition of this pre-test is similar to the experiment described in this paper. After the pre-test, 34 participants (including the 16 participants who participated in the pre-test) took part in a nine week mindfulness course. They were expected to keep a diary in which they described how they practiced mindfulness on their own. After completion of the course, all participants took part in the experiment described in this paper, for 16 of the participants this session was a post-test.

During the experiment, participants were seated in a chair, facing a monitor which displayed visual stimuli. Then the right cap size was selected and placed on the participant’s scalp. The electrodes, used to make the EEG, were attached to the cap. They received an explanation regarding the purpose of the study both on the monitor and orally before the start of the experiment and they were asked to fill in Thayer's mood scale before and after the experiment (Blom et al, in press). Thayer's mood scale is a questionnaire using continua to measure a variety of emotions. A score was assigned to an emotion by measuring the distance between the starting point of the continuum and the point added by the participant times ten. This resulted in a range from 0 till 110. During the analysis, the difference between the anxiety score before the start of the experiment and the score after the end of the experiment was used. This was chosen instead of the absolute scores before the start of the experiment because the difference scores indicate the relative difference between the anxiety before participation and after.

The participants were asked to place a headphone over their ears during the actual experiment to prevent distraction from sounds. For the same reason the lights were turned off. On both sides of the participants, a Digitimer DS5 constant current stimulator was placed to deliver the electrocutaneous stimuli. The bipolar concentric electrodes, attached to the Digitimer DS5, were placed on the right en left forearm of the participants over the median nerve.

Participants received two kinds of stimuli during the experiment. The first was a low intensity stimulus which consisted of a pulse train composed of two stimuli, lasting 1 ms each. The high intensity stimulus consisted of a pulse train composed of five stimuli, also lasting for 1 ms each. The stimulus intensities were matched with personal perceptions of sensation. To achieve this, three thresholds were determined during a pre-test wherein participants were exposed to increasing stimulus intensities starting at 0.0 mA and increasing by 0.1 mA until the threshold was reached. The first threshold to be determined is the pain-threshold which is the first intensity level to be experienced as annoying instead of neutral. The second threshold is the sensation-threshold which is the intensity level at which the participant first detects a sensation. Finally, the maximum intensity level participant would allow during the experiment. These thresholds were determined for both arms individually.

After these thresholds were determined, participants were presented with two low intensity stimuli and two high intensity stimuli individually for both arms. Participant were able to rate these stimuli on a continuum ranging from 0-10 which is called the Visual Analogue Scale (VAS). A zero meant ‘no sensation at all’, 5 corresponded with the pain-threshold and 10 meant ‘extremely painful’.

Task

The trial started with the appearance of a white fixation cross displayed on a black background. 1200 ms after onset of the trial, a cue replaces the fixation cross. The cue is composed of two triangles pointing outwards, one red the other green and was displayed for 400 ms. Both colors appeared with equal probability on either the left or right side of the fixation point. The side, at which the triangle with the relevant color pointed, was the side the participant was instructed to attend to. Six hundred ms after onset of the visual cue, the stimulus was presented to either the participant’s left or right arm. Half of these stimuli were of high intensity and half of them were of low intensity. They appeared on either side randomly. Participants were asked to respond only when a relevant stimulus was presented at the cued side (responding meant hitting a footpedal). After the respons, the fixation cross turned grey to confirm that a respons was given. Participants were given a time span of 4000 ms to respond. The participant received no further feedback regarding the accuracy of the respons. The entire trial lasts for 6200 ms (see figure 3).

The actual experiment consisted of four blocks containing 96 trials. As mentioned earlier, participants were expected to respond when a relevant stimulus occurred. A relevant stimulus was determined by the side of stimulation and the intensity. Participants were instructed before the start of the experiment which intensity level was relevant for them. The relevant intensity level remained constant during the entire experiment and was either high or low. The relevant side was determined during the trial using a relevant color. The relevant color was determined at the start of each block and varied between blocks, during two block the relevant color was red and during two it was green, and was counterbalanced over all participants.

The trials were essentially the same during the sustained and transient blocks. During a sustained block, however, the cued side was the same for the first half of a block and switched to the other side the second half of a block en remained the same until the end of the block. In the transient trial the cued side varied randomly.

At the end of each block and before the start of the first block participants were asked to rate four example stimuli on the VAS. They received two high and two low stimuli to either the left or right arm randomly. After each block, participants were granted a two minute break.

Recording

The EEG was recorded using BrainVision recorder with 61 channels. The Ag/AgCl electrodes were attached to an electrocap. Eye movements were measured using bipolar Ag/AgCl electrodes, which were placed in the outer corner of the eye. Another set of bipolar electrodes was located above and below the left eye. Finally, the ground electrode was placed on the participants' forehead. The impedance of all electrodes was below 10 kΩ. The recorded signals passed through a QuickAmp amplifier.

Data Analysis

Whether the difference scores in anxiety level differed for participants that participated for the first time and participants that participated in a similar study before was tested with an independent samples t-test. To test whether participants that were more anxious performed worse on the task, false alarm rates were used. The false alarm rates were obtained by adding all the false alarms within a block and dividing this number by the number of trials the participant wasn't expected to respond. The false alarm rates were analyzed with ANOVAs using block number as a within-subjects factor (block 1/block 2/block 3/block 4) and the times participated before was the between-subjects factor (first time/ participated before). The false alarm rates were also analyzed with ANOVAs using block number as a within-subjects factor and the anxiety level as a covariate.

The EEG was analyzed using Vision Analyzer 2.0. Around each stimulus a time window of -100 till 500 ms. was chosen. Next, the averages were calculated. The mean activity from -100 till 0 ms from stimulus onset was selected as a baseline. To filter the EEG from artifacts minimum/maximum amplitudes of -250/250 µv prefrontal, -150/150 µv central, -200/200 µv frontal and -100/100 µv parietal were allowed. The different criteria were chosen because ocular movements induce larger amplitudes at prefrontal sites in comparison to parietal sites (Blom et al., in press). By allowing larger amplitudes at the parietal sites in comparison to prefrontal sites, excessive EEG data exclusion was prevented. These ERPs were computed using EEG without artifacts for all electrodes. An ocular correction was applied on the ERPs also. After segmentation according to the different conditions, the averages were calculated again and another baseline correction was applied.

Since the current study is focused on the N1 component the data is analyzed using a time window of 157 to 197 ms. This time window was based on the peak found in the grand averages. This was done to ensure that most individual N1 peaks would be captured in the selected time window. With PASW Statistics 18 the obtained averages were subjected to repeated measures ANOVAs. The within-subjects factors included in the analyses are stimulus electrode (C5/C6), side of stimulation (right/left), intensity (low/high), attention (attended/unattended) and task (sustained/transient). The between-subjects factor was the number of times participated before (first time/participated before).

Results

Behavioral data

ANOVAs of the intensity level showed that there was a significant main effect of intensity on the ratings on the VAS scale ($F(1,30)=127.4$, $p<0.01$), where intensity level 'low' was rated significantly lower than intensity level 'high' with a mean rating of 2.7 for 'low' intensity and a mean rating of 4.4 for 'high' intensity level. In which block the participant rated the stimuli also had a significant effect on the mean ratings ($F(1,30)=11.090$, $p<0.01$). The further along the experiment the participant rated the intensities, the lower the rating became. Respectively 4.0 for block 1, 3.8 for block 2, 3.3 for block 3 and 3.1 for block 4.

An independent t-tests regarding the difference in anxiety level and the number of times participated showed no significant main effect ($F(2,30)=0.783$ $p=0.384$). Also, no significant effect of the number of times participated on the false alarm rate was found using ANOVAs ($F(1,28)=0.473$, $p=0.497$). Finally, no significant effect of anxiety level on the false alarm rate was found ($F(1,28)=0.00$, $p=0.996$).

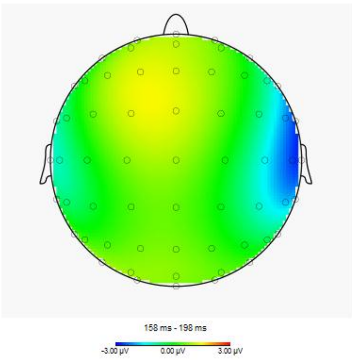
EEG data

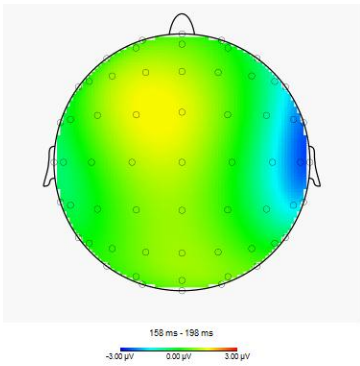
N1 component. There was a significant main effect of attention ($F(1,30)=9.572$, $p=0.004$). The amplitude was more negative during the attention compared to the distraction task, respectively -2.117 during attention and -1.880 during distraction (see figure 1). However, no significant difference between transient, respectively sustained attention was observed ($F(1,30)= 0.896$, $p=0.352$). The stimulus intensity had a significant effect on the amplitude of the N1 component ($F(1,30)=23.710$, $p<0.001$). When stimulus intensity increased, the amplitude of the N1 component was more negative, respectively -1.868 for low level intensity and -2.129 for high level intensity. There was no significant main effect of the number of times participated (F(1, 30)=0.876, p=0.357).

A significant interaction effect between the electrode and the side of stimulation was found (F(1,30)=46.302, p<0.001. The electrode contralateral to the stimulated side showed significantly higher activation than the electrode ipselateral to the stimulated side (see figure 2). The results revealed a mean amplitude of -2.861 for the right and -1.126 for the left side for C5 and a mean amplitude of -1.181 for the right and -2.826 for the left side for C6.

A) Low Intensity

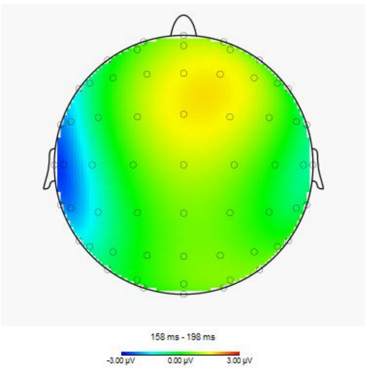
Left

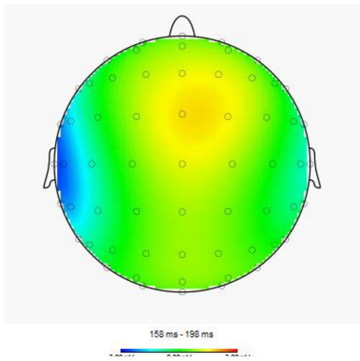




Attended **Unattended**

Right

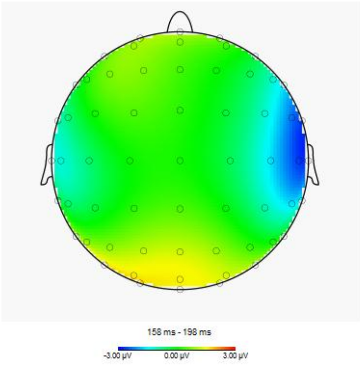


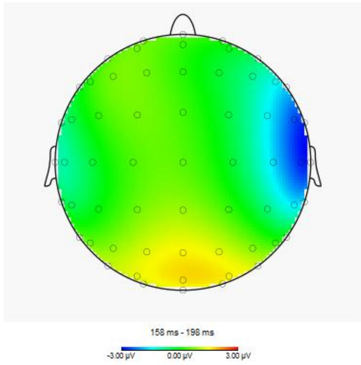


Attended **Unattended**

B) High Intensity

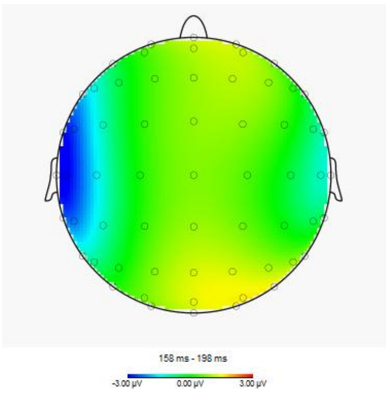
Left

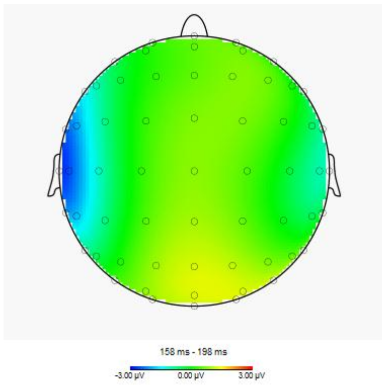




Attended **Unattended**

Right

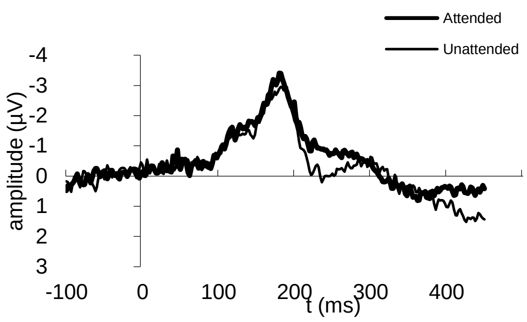




Attended **Unattended**

Figure 1, Topview of isopotential maps of the grand averages for the N1 component as a function of the side of stimulation (left/right) and attention (attended/unattended).

A) Low intensity



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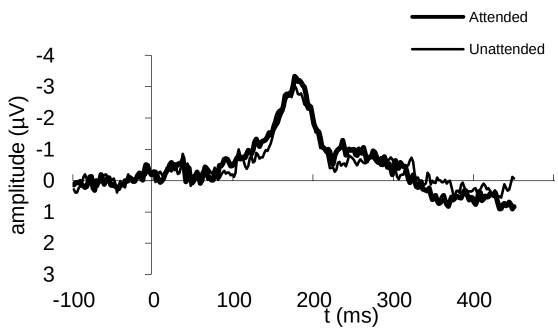
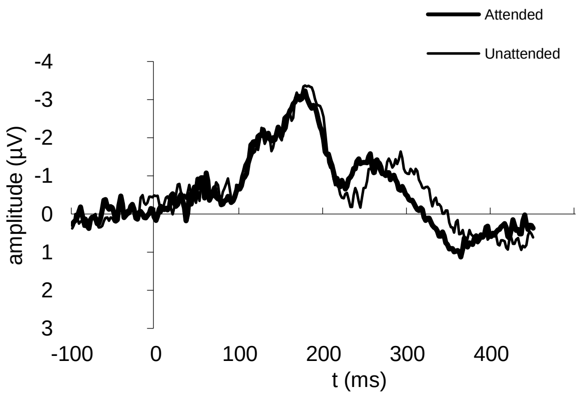


Right

B) High intensity



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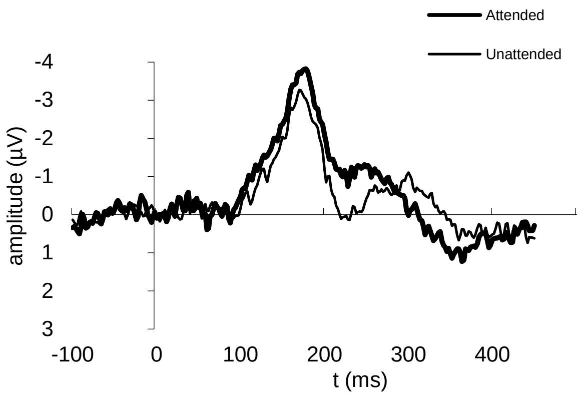

Right

Figure 2, Grand average ERP's for the N1 component as a function of the amplitude in µv and time passed in ms.

Discussion

Pain and attention

The aim of the current study was to resolve the comparability issue regarding the results obtained by several studies caused by different procedures. These studies used either sustained attention (Yamasaki, 2000; Blom et al., in press) or transient attention (Van der Lubbe et al, 2011) and the current study combined both in comparable conditions. It was hypothesized that sustained and transient distraction would both result in an attenuated amplitude of the N1 component in comparison to attention, based on the results obtained by (Yamasaki, 2000; Blom et al., in press; Van der Lubbe, 2011). The results of the current study revealed a significant main effect of distraction on the N1 component compared to attention. The amplitude of the N1 component was attenuated during the unattended trials in comparison to the attended trials for both attentional approaches. This decreased negativity of the amplitude of the N1 component suggests decreased somatosensory processing. This result is in line with the studies by Yamasaki (2000), Blom et al. (in press) and Van der Lubbe et al. (2011). Based on the results of the current study it can be concluded that somatosensory processing declines when spatial attention is directed away from the side of stimulation and that somatosensory processing increased when spatial attention is directed to the side of stimulation. Whether the influence of distraction is attenuating or the influence of attention is amplifying is not clear. This result could be of great importance to chronic pain patients, since distraction could be used to decrease the somatosensory processing of pain in these patients. Decreased somatosensory processing could result in a decreased perception of pain and a decreased perception of pain contributes to the quality of life of chronic pain patients. Future research could investigate whether the attenuating influence of distraction on the processing of pain also applies to chronic pain.

A second hypothesis regarding the influence of attention on the somatosensory processing of pain was that there would be no significant difference between the influence of sustained distraction and transient distraction. The results of the current study did not reveal a significant effect of the kind of distraction on somatosensory processing of pain. This means that the attenuating effect of both kinds of distraction on the N1 component did not differ. This result confirms the hypothesis. One implication of this result is that it can be questioned whether these two different kinds of distraction result in different somatosensory processes since they appear to have the same influence on the amplitude of the N1 component. When this is taken a step further, it can be questioned whether the distinction between transient and sustained distraction is even relevant. Future research should investigate whether the influence of the kind of distraction on the processing of pain also does not differ during later stages of the processing of pain. If this would be the case this would strengthen the hypothesis that sustained and transient distraction result in the same processing of pain and that discriminating between the two kinds of distraction might be irrelevant. The result of the current study regarding the influence of transient and sustained distraction implicates that both kinds of distraction could be used in an attempt to decrease the processing of pain in chronic pain patients.

Anxiety

Another aim of the current study was to investigate whether anxiety influences the performance during the experiment and whether participants that participated in a similar research design before have a lower anxiety level than participants that have never participated in a similar research design before. It was hypothesized that participants that have never participated in a similar research design before experience more anxiety than participants that have participated in a similar research design before since repeated exposure to a stimulus reduces the anxiety (Bouton, 1988). The results did not reveal a significant effect of the number of times participated before and the anxiety level. The hypothesis was, thus, not confirmed. From this result it can be concluded that participants that participated for the first time are not more anxious than participants that have participated in a similar research design before.

The current study also investigated whether a higher anxiety level influenced the false alarm rate. No significant effect of anxiety level on the false alarm rate was found. Therefore, the hypothesis that more anxious participants performed less well on the task is not confirmed. The discrepancy between the actual and expected results could be explained by looking at the anxiety levels. The mean anxiety level was 1.8 (SD: 9.6). Since the anxiety level could range from 0 till 110, it can be concluded that none of the participants felt very anxious at all. This makes investigating the influence of the anxiety level on the false alarm rates problematic, since the anxiety levels vary very narrowly. The influence of anxiety on the performance on the task should be tested in an experimental design in the future. In an experimental setting, problems regarding a too limited range of scores are avoided since these levels are manipulated.

In conclusion, spatial distraction resulted in a decreased amplitude of the N1 component compared to attention. This indicates that distraction already has an attenuating effect on the processing of pain in the somatosensory cortex. No significant difference was found between sustained distraction and transient distraction on the N1 component. It can be argued whether it is relevant to discriminate between transient and sustained attention since they appear to result in the same process. Furthermore, no significant effect was found of the number of times participated in a similar research design before on the anxiety level. It appears that participants that participated for the first time do not experience a higher level of anxiety than participants that have participated in a similar research design before. Finally, no significant effect of the anxiety level on the false alarm rates was found. However, the anxiety scores ranged very limitedly which made it hard to draw conclusions.

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Appendix

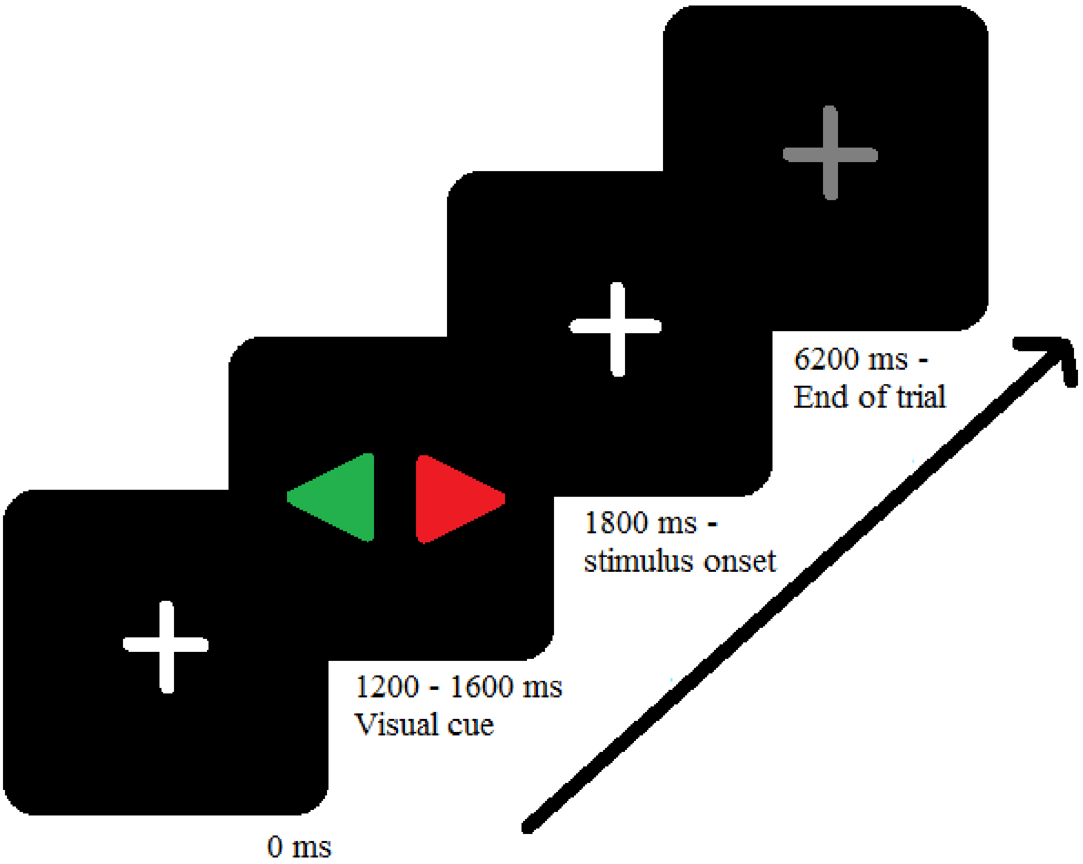

Figure 3, Posner task. The trial starts with the appearance of the fixation cross.Then, 1200 ms after trial onset, the visual cue is displayed. Stimulus onset is at 1800 ms. The participant is granted 4000 ms to respond. After a respons is given, the fixation cross turns grey. Finally, at 6200 ms, the trial ends.