Attention to the periphery attenuates the EPN and LPP

Elmeri Syrjänen

Handledare: Stefan Wiens
PSYKOLOGI III, 30 POÄNG, 2011

STOCKHOLMS UNIVERSITET
PSYKOLOGISKA INSTITUTIONEN

ATTENTION TO THE PERIPHERY ATTENUATES THE EPN AND LPP

Elmeri Syrjänen

Current research shows that emotions have an important role in guiding attention and cognitions especially when the emotional stimuli are affective. Load theory proposes that when the perceptual load on attention is sufficiently high, irrelevant emotional stimuli is no longer attended to and thus will not produce a distracting effect. In this study 18 participants performed two discrimination tasks where their attention was manipulated spatially. To investigate the effect of spatial attention on ERP components, emotional pictures in 14 different semantic categories were shown while EEG was recorded. The results indicate that a successful perceptual load was achieved, reflected in the behavioral data that show there was a clear difference in performance between tasks. Further the results indicate that a strong effect was achieved in the mean amplitudes of both EPN and LPP corresponding to the semantic categories of pictures. Critically directing the attention to the periphery while emotionally salient pictures were presented attenuated the mean amplitude of both EPN and LPP.

Today, humans are constantly bombarded with information. As the brain has limited capacity for attending more than a few simultaneous stimuli, much of this information is ignored (Lavie, 2010). To bring forward important information to attention, emotions play a critical role in guiding both attention and cognitions (Vuilleumier & Huang, 2009). Recent research in behavioral studies has shown that emotional stimuli can direct attention, especially to negative stimuli as this type of information has survival relevance for the individual (Schupp, Junghöfer, Weike & Hamm, 2004).

There are several ways to investigate the underlying mechanisms of attention and survival relevant information. Functional magnetic resonance imaging (fMRI) can show which parts of the brain are activated by certain stimuli but one of the drawbacks of fMRI is that the temporal resolution is very low (several seconds). Event-related potentials (ERP) on the other hand has a very good temporal resolution measured in milliseconds but only reflects general trends in cerebral cortical processes. Because emotional stimuli give a clear psychophysiological response that can be measured with ERP it is well suited for investigating how emotional stimuli modulates ERP components (Foti, Hajcak & Dien, 2009; Olofsson, Nordin, Sequeira & Polich, 2007).

Some research indicates that emotional stimuli may distract attention and thus impair performance in a task (Vuilleumier & Huang, 2009). This shortcut for bringing fast attention to survival significant information could rely on increased sensory responses in early cortical pathways in frontal and parietal areas (LeDoux, 2000). Another source of emotional reactions in the brain is the amygdala where fMRI studies have demonstrated that there are neural pathways that facilitate emotional content especially fear, social and socially related content. These neural pathways may act

independently or enhance emotional reactions to survival relevant stimuli (Vuilleumier, 2005; Vuilleumier & Huang, 2009). These modulations may operate partly independent from top-down attentional systems (Vuilleumier, 2005). However, fMRI studies have shown that to get an amygdala response for emotional content some attentional resources have to be available, thus unattended emotional content can be filtered out completely (Pessoa, 2005; Pessoa, Kastner & Ungerleider, 2003). Behavioral evidence also suggests that there must be attentional resources available for emotionally affective stimuli to influence automatic reactions (Okon-Singer, Tzelgov & Henik, 2007).

Whether unattended stimuli are filtered out early or late has been debated. An early selection would mean that unattended stimuli are filtered out without any processing in the brain. A late selection means that all stimuli are processed in the brain and then only the attended stimuli or survival related stimuli are brought to attention. The Load theory proposes a combination of both early and late selection (Lavie, 2005). When an individual is busy with a task that captures all of their perceptual resources, distracting stimuli are no longer processed. This also means that when the load on the perceptual resources is low, other non-attended stimuli can distract. This theory proposes that this effect should be true even for distracting emotional stimuli; that is, if the main task is sufficiently demanding on the perceptual resources, emotional distractors are ignored. Load theory also predicts that the more demanding a task on higher cognitive functions is (e.g. working memory), the more distracting are the distractors (Lavie, 2005).

However, there is some debate about whether emotional distractors can be ignored. One approach has used ERP to study this question. When participants view emotional and neutral pictures, they show an early posterior negativity (EPN) and a late positive potential (LPP) to the emotional vs neutral pictures (Schupp et al., 2006). A common interpretation of these ERP components is that these indexes signal motivated attention i.e. that emotional pictures capture the attention compared to neutral pictures (Olofsson, Nordin, Sequeira & Polich, 2007). In one ERP study on whether emotional pictures can be ignored, participants who feared spiders showed a greater LPP to pictures of spiders than mushrooms compared to a non-fearful control group. The elevated effect on LPP was maintained even during high perceptual load (Norberg, Peira & Wiens, 2010). Other studies suggest that participants high in trait anxiety have a smaller reduction of automatic responses under high load as there are fewer resources left for maintaining a control of attention (Holmes, Kragh Nielsen, Tipper & Green, 2009). Some studies suggest that emotional content is processed automatically without conscious awareness and can impair performance in a task (Okon-Singer, Tzelgov & Henik, 2007). Other studies have not been able to replicate this effect on performance but found an automatic emotional reaction to negative pictures with EEG (Wiens, Sand, Norberg & Andersson, 2011).

Several studies have shown EPN and LPP reactions (negative compared to neutral) to task relevant stimuli at fixation. LPP to task irrelevant pictures at fixation (negative compared to neutral) was reduced when attention was directed to the periphery of the pictures. However, EPN reaction remained unaffected, i.e. emotionally salient content was processed even when it was unattended and task irrelevant and cognitive load did not seem to affect either EPN or LPP (Holmes, Kiss & Eimer, 2006; Wiens, Sand, Norberg & Andersson, 2011).

To further problematize the present understanding of automatic appraisal of affective stimulus, a recent study found that directing the attention to non-arousing areas of emotionally salient pictures gave LPP reactions comparable to neutral pictures (Dunning & Hajcak, 2009). Some studies have shown that context influences the LPP amplitude. When participants were informed that the unpleasant pictures they were viewing were real a clear LPP reaction was measured but when the participants were instructed that the pictures were fictitious the LPP was reduced compared to neutral pictures (Mocaiber et al., 2010). Both of these studies indicate that there are top-down control mechanisms for emotional content.

A common visual stimuli used in ERP research is the IAPS picture set. This large set of pictures contains color photographs in a wide range of topics. These pictures are normatively rated on affective valence and arousal (Lang, Bradley, Cuthbert, 2008). A common method in the research of emotionally motivated attention has been to use these normative ratings to categorize pictures in positive, neutral and negative categories (Olofsson, Nordin, Sequeira & Polich, 2007). However a recent study indicated that this categorization has some drawbacks (Weinberg & Hajcak, 2010). In this study ERP components were compared with regards for both semantic category and categorizes that has been used traditionally (i.e. positive, neutral and negative). The findings indicated that the psychophysiological and normative ratings differed considerably for LPP e.g. the semantic category for exiting with a positive normative rating was comparable with neutral when psychophysiological measures were used. These findings suggest that there is a need to revisit the thinking in current ERP research methods.

An assumption in this research is that the more emotional the pictures are, the more they should resist manipulations of attention. However, according to Load theory, if attentional resources are limited, then processing of emotional pictures should be reduced. As a result, pictures that draw more attention and thus elicit strong EPN (i.e., more negative EPN) and strong LPP (i.e., more positive LPP) when they are attended should show reduced amplitudes when unattended.

The aim of the present study was to test this idea. The novel approach in this study is that instead of being limited to only 3 broad categories (e.g. positive, neutral and negative) use pictures from 14 semantic categories that should reflect emotionally motivated attention more closely. On each trial, a picture was shown in the middle of the screen together with a row of letters above and below the picture. In one task, participants attended the pictures and in the other task, they attended the letters. The EPN and LPP responses when pictures were attended were used to order the semantic categories according to size of the EPN and LPP responses. The prediction was that there would be clear linear trends (i.e., EPN and LPP amplitudes would increase). Then, these responses were compared with the EPN and LPP responses when participants attended the letters. According to Load theory, strong EPN and LPP responses when pictures were attended would be attenuated when letters were attended. Therefore, the hypothesis was that there would be a difference in the linear trends over picture categories between picture and letter task: The linear trend during the picture task would decrease during the letter task.

Method

Recruitment

Eighteen participants were recruited through a bulletin board at the department of Psychology of Stockholm University and through an online ad. The participants were rewarded with course credit or 2 movie vouchers for participating. Participants were informed about the general nature of the experiment before commencement and that the experiment contained some pictures that might be emotionally charged or sexually explicit. The participants were informed that participation was completely voluntary and that they could end the experiment at their choosing without any negative consequences. Participants were also informed that no personal data would be identifiable in the finished article. All participants filled out an informed consent form and a short questionnaire containing questions about sex, age, vision and handedness. At the end of the experiment participants were debriefed and the objective of the study was explained to them. The participants were also given the opportunity to receive the paper via e-mail.

Participants

Twelve of the participants were female and 6 male. Mean age of participants was 29.94 (*SD* 10.04, range 20-49). All participants had normal or corrected to normal vision.

Stimuli

Experimental stimuli consisted of pictures from the International Affective Picture System (IAPS). This large set of pictures contains color photographs in a wide range of topics. These pictures were normatively rated on affective valence (unpleasant to pleasant) where a score of 9 indicate high pleasure and a score of 1 indicates low pleasure. The pictures were also normatively rated according to arousal (aroused to calm) where a score of 9 indicates a picture is highly arousing and a score of 1 indicates the picture is low arousing (Lang, Bradley, Cuthbert, 2008). From the IAPS picture set 375 semantically categorized + 75 target pictures were chosen. Number of pictures and normative ratings of valence and arousal for each category are displayed below in Table1.

Table 1. Number of pictures per semantic category and mean and (*SD*) of IAPS normative ratings of valence and arousal for each category.

Semantic category	N	Normative ratings	
		Valence Mean (<i>SD</i>)	Arousal Mean (<i>SD</i>)
Victim	32	2.85 (.92)	5.19 (.62)
Disgust	25	3.13 (.79)	5.32 (.68)
Threat	30	3.15 (.85)	5.98 (.51)
Mutilation	30	2.22 (.65)	5.98 (.65)
Family	24	7.19 (.49)	4.55 (.63)
Cute	30	7.49 (.62)	4.44 (.55)
Exciting	30	6.54 (.57)	5.49 (.55)
Erotic Couple	30	6.58 (.55)	5.88 (.65)
Erotic Male	15	6.08 (.45)	4.91 (.57)
Erotic Female	15	6.04 (.42)	5.33 (.36)
Object/Flora	30	5.16 (.57)	2.53 (.33)
Animal	28	6.26 (.89)	3.97 (.60)
Human Portrait	18	5.11 (.67)	3.21 (.31)
Human Scene	38	5.21 (.87)	3.52 (.53)

Apparatus

The pictures were shown on a 21" View Sonic p227f CRT-screen with a refresh rate of 100Hz and a resolution of 1280x1024. The distance of approximately 80 cm was maintained with a chinrest. Experimental software was Presentation 10.3 (Neurobehavioral Systems, Inc., Albany, CA).

EEG apparatus was an Active Two Biosemi system (Biosemi, Amsterdam, Netherlands) 128 electrodes (ABC system). Data was sampled in 512Hz. Filters that were used was a low-pass filter at 104 Hz and an offline notch filter at 50 Hz.

Procedure

The experiment consisted of two tasks; picture and letter where (17%) of the images were targets (375 non-targets + 75 targets that require a button press). The 375 IAPS pictures that were non-targets were categorized according to semantic content in 14 categories; victim, disgust, threat, mutilation, family, cute, exciting, erotic couple, erotic male, erotic female, object/flora, animal, human portrait, human scene. In addition to these pictures, 75 suitable but not categorized IAPS pictures were shown for targets (i.e., require button press). In total every participant viewed 450 * 2 tasks = 900 pictures. Each task was divided in 2 ~10 minutes equal parts for an opportunity to rest. Task order was counterbalanced across subjects. Before the main tasks, the participants performed a practice run of the test with 20 pictures that were not presented in the main tasks.

On each trial, a fixation cross appeared for 800 ms then picture stimulus for 200 ms; between trials a random period of (1500, 1600 or 1700 ms) with a blank screen for rest and opportunity to blink.

Both tasks

The picture stimulus consisted of a picture in the middle of screen and 3 letters each above and below the picture (from the set of H, K, M, Z, W, V, N, or X). On target trials the task was to press the space bar, the target pictures were from the set of 75 uncategorized IAPS pictures.

Letter task (attention on both above and below picture, gaze in middle of picture):

Target in this task was to press the space bar when the letters above and below were not identical (e.g. HHH on top and XXX on bottom).

Picture task (attention on picture):

Target pictures in this task were black and white. However, the letters around the pictures were identical e.g. (HHH on top and HHH on bottom).

Data reduction

75 target pictures per task were used to calculate hit rates and reaction time. Also false alarms were calculated, i.e. when the participants pressed the space bar when there wasn't a target. Paired samples t-tests were conducted on hit-rates, RT and false alarms to examine if there was a significant difference between the two tasks.

BESA software (version 5.3.7, MEGIS Software GmbH, Gräfelfing, Germany, www.besa.de) was used for offline processing. Electrodes were placed in the ABC layout where the electrodes are positioned radially equidistant from the vertex across the scalp. Noisy electrodes were interpolated with spherical splines. Eye blinks corrected with a built-in algorithm. Only non-target trials were analyzed. Epochs -100 to 1300 ms. after stimulus onset. Epochs baseline based on 100 ms. before stimulus onset and re-referenced to the arithmetic average of all electrodes. Difference waves across participants were identified by visual inspection of electrode clusters and intervals corresponding to EPN (A10-A15, A26-A28, B07-B11 D31, D32), (Figure 1) corresponding to the left and right occipital sites of the scalp. The LPP was maximal at centro-parietal sites where these electrodes (A01-A04, B01, B02, B20, C01, C02, C23, D01, D02, D14-D16), (Figure 2) were chosen. These electrode clusters were compared to negative and positive (Mutilation and Erotic couple) pictures minus neutral (Human scene) pictures. Across tasks, a greater negativity of amplitude for negative and positive pictures compared to neutral – EPN electrodes was found in the 180-260 ms range after stimulus onset. A greater positivity of amplitude for negative and positive pictures compared to neutral pictures was evident for the cluster of electrodes chosen for LPP was found in the 400-1300 ms range after stimulus onset. The LPP was further segmented in 400-700, 700-1000 and 1000-1300 ms (early, middle and late) to catch potential temporal differences in the amplitude of the LPP wave. For each participant mean amplitude for the relevant electrodes were extracted for each trial. Then amplitudes were averaged separately for each semantic category and task.

Figure 1. Scalp topographies corresponding to an EPN compared to negative and positive (Mutilation and Erotic couple) minus neutral (Human scene) pictures at blue areas on the left and right occipital sites of the scalp.

Figure 2. Scalp topographies corresponding to an LPP compared to negative and positive (Mutilation and Erotic couple) minus neutral (Human scene) pictures at the red areas at centro-parietal sites.

For the behavioral data mean values for target-hits, false alarms and reaction-time was performed. Hit-rates were comparable to d' (d prime) so for clarity hit-rates are reported. Also paired samples t -tests were performed comparing target-hits, false alarms and RT between tasks.

As there was a large discrepancy between the number of female and male participants no analysis was done factoring sex. Mean and standard deviations were calculated for each semantic category for both EPN and LPP. Mean amplitudes of both EPN and LPP were subjected to repeated measures ANOVA to examine main effects of task and semantic categories and interaction. Semantic categories for both EPN and LPP in the three intervals (early, middle and late) were then ordered according to mean amplitude in the picture task and subjected to repeated measures ANOVA with polynomial contrasts to examine linear effect. A subsequent repeated measure ANOVA tested whether the linear increase of EPN and LPP amplitudes during the picture task was reduced during the letter task. LPP showed similar effects for the two first intervals early and middle and none for the third late interval. For clarity only the results of the early interval is presented.

All significance levels, F -scores and η_p^2 were corrected with Greenhouse-Geisser, but degrees of freedom are presented uncorrected for readability. All statistical analyses were considered significant at $< .05$ two-tailed probability level.

Results

Behavioral data

The mean target-hit rate was 98.59% (1.68) for the picture task and 93.93% (5.06) in the letter task. A t-test showed that this difference was significant, $t(17)=4.32$, $p < .001$. The mean false alarm rate was .99% (.86) for the picture task and 4.76% (5.48) for the letter task. A t-test showed that this difference was significant between tasks, $t(17)=-2.97$, $p = .009$. There was also a significant difference in reaction-time between tasks, $t(17)=-10.99$, $p < .001$, with a mean RT of 535.97 ms. (67.33) in the picture task and a mean RT of 661.88 ms. (59.22) in the letter task.

EPN

Mean and std for EPN of the examined categories in the picture task were for Human Scene 8.57 (3.82), Threat 8.38 (3.86), Object/Flora 8.19 (3.28), Exciting 8.19 (3.98), Mutilation 7.95 (4.13), Animal 7.60 (3.50), Human Portrait 7.53 (3.74), Cute 7.12 (3.46), Victim 7.09 (3.80), Family 7.01 (4.00), Disgust 6.77 (4.07), Erotic Male 5.92 (3.68), Erotic Couple 5.44 (4.16) and Erotic Female 4.71 (4.42). Figure 3 shows the mean EPN for the different semantic categories separately for the picture and letter task. The semantic categories are ordered according to the size of the EPN during the picture task.

To determine whether EPN amplitudes varied with semantic category when participants viewed the pictures, a repeated measures ANOVA of picture category showed that there was a significant effect of category on the mean amplitudes of EPN, $F(13, 221) = 13.62$, $p < .001$, $\eta_p^2 = .45$. Further, when the categories were reordered according to their amplitudes a specific polynomial contrast analysis showed a significant linear effect on the mean amplitude of EPN, $F(1, 17) = 88.61$, $p < .001$, $\eta_p^2 = .84$.

After the EPN amplitudes for the various categories during the picture task were ordered according to their size, a subsequent repeated measures ANOVA tested whether the linear increase of EPN amplitudes during the picture task was reduced during the letter task. A repeated measure ANOVA with task (Picture and Letter) and picture category showed a significant main effect of task, $F(1, 17) = 11.42$, $p = .004$, $\eta_p^2 = .40$ and a significant main effect of semantic category, $F(13, 221) = 18.56$, $p < .001$, $\eta_p^2 = .52$. The interaction between task and semantic category did not reach significance, $F(13, 221) = 2.05$, $p = .072$, $\eta_p^2 = .11$. Critically, a specific polynomial contrast analysis showed a significant interaction of task with the the linear effects over the semantic categories, $F(1, 17) = 9.46$, $p = .007$, $\eta_p^2 = .358$.

Figure 3. Scatterplot of mean amplitudes of EPN for the different semantic categories and a regression line that shows the interaction of the linear effects between tasks. Note that the semantic categories are ordered according to their size in the picture task.

LPP

Mean and std for LPP of the examined categories in the picture task were for Human Scene -0.54 (1.64), Object Flora 0.00 (1.40), Human Portrait 0.03 (1.55), Threat 0.21 (1.33), Family 0.34 (1.70), Cute 0.46 (1.53), Animal 0.50 (1.39), Exciting 0.50 (1.58), Victim 0.51 (1.73), Erotic Male 0.58 (1.68), Mutilation 0.69 (1.75), Disgust 0.92 (1.83), Erotic Couple 1.98 (1.62), Erotic Female 2.03 (2.12). Figure 4 shows the mean LPP for the different semantic categories separately for the picture and letter task. The semantic categories are ordered according to the size of the LPP during the picture task.

To determine whether LPP amplitudes varied with semantic category when participants viewed the pictures, a repeated measures ANOVA of picture category showed that there was a significant effect of category on the mean amplitudes of LPP, $F(13, 221) = 7.63, p < .001, \eta_p^2 = .31$. Further, when the categories were reordered according to their amplitudes a specific polynomial contrast analysis showed a significant linear effect between the different semantic categories on the mean amplitude of LPP, $F(1, 17) = 32.38, p < .001, \eta_p^2 = .66$.

After the LPP amplitudes for the various categories during the picture task were ordered according to their size, a subsequent repeated measures ANOVA tested whether the linear increase of LPP amplitudes during the picture task was reduced during the letter task. A repeated measure ANOVA with task (Picture and Letter) and picture category showed a significant main effect of task, $F(1, 17) = 9.20, p = .008, \eta_p^2 = .35$ and a significant main effect of semantic category, $F(13, 221) = 9.20, p < .001, \eta_p^2 = .35$. The interaction between task and semantic category did not reach significance, $F(13, 221) = 1.77, p = .132, \eta_p^2 = .09$. However, a specific polynomial contrast analysis showed a significant linear effect between tasks and the pictures in the different semantic categories, $F(1, 17) = 34.53, p < .001, \eta_p^2 = .67$.

Figure 4. Scatterplot of mean amplitudes of LPP for the different semantic categories and a regression line that shows the interaction of the linear effects between tasks. Note that the semantic categories are ordered according to their size in the picture task.

Discussion

The aim of the study was to investigate if the attenuation of emotional processing when pictures are unattended would be stronger for affective compared to neutral pictures. The hypothesis of this study was that there would be a difference in the linear trends over picture categories between picture and letter task: The linear trend during the picture task would decrease during the letter task.

The results showed that there was a clear difference in performance when the participants performed the two tasks. The amount of correct responses decreased when the participants attended the letters instead of the pictures. Also reaction time was higher for participants in the letter task.

Further when the participants attended the pictures there was a substantial difference in the mean amplitudes of both EPN and LPP for the semantic categories of pictures. When the mean amplitudes were reordered according to strength a strong linear effect was found. When both tasks were taken into consideration the strong effect on EPN and LPP of semantic category remained, further a significant interaction was found between task and category for EPN but not for LPP. Critically there was a significant linear effect between tasks and the pictures in the different semantic categories.

The high count of target hits in the picture task indicates that the participants attended the pictures. The same applies to the letter task, which point to that the participants followed instructions and attended the letters, thus indicating a successful manipulation of attention. The difference in performance across tasks indicates that the letter task was harder and thus reflects a higher cognitive and perceptual load. These behavioral data matches previous research that has shown that spatial attention and task difficulty increases both the amount of mistakes and reaction time (Okon-Singer, 2007).

As previous research indicates emotional pictures modulate both EPN and LPP (Foti, Hajcak & Dien, 2009; Schupp, Cuthbert, Bradley, Cacioppo, Ito & Lang, 2000; Peyk, Schupp, Keil, Elbert & Junghöfer, 2009). These effects are robust even when the pictures are shown very briefly (Schupp, Junghöfer, Weike & Hamm, 2004). The findings in the present study support these findings of a decrease in amplitude of EPN for negative and positive pictures compared to neutral. As with previous research similarly the LPP was higher for negative and positive pictures than neutral.

As recent research has demonstrated there are pitfalls in using the IAPS normative ratings as self reported and psychophysiological data may differ in several cases, especially when using coarse categorization in positive, neutral and negative picture categories (Weinberg & Hajcak, 2010). In the present study a novel approach was applied where the picture stimulus was divided in several semantic categories while spatial attention was manipulated. These considerations resulted in a data driven analysis instead of theoretically motivated. However this raises the question why use semantic categories at all. Why not just sort the pictures by mean amplitude and measure the linear trend between the picture and letter task? Although categorizing the pictures in semantic categories means that some statistical power is lost the added benefit of these categories are the ease of translating the meaning of the results to existing theoretical models.

ERP as a method is although reaching maturity still having some limitations. One of these is the limited spatial information, which results in that it's not possible to draw conclusions where the different ERP components are originating. For the present study this does not present a problem as the research subject is about automatic processes and emotionally motivated attention. However the present study contains some limitations as a result from the ERP method. An obvious limitation is a result of the need to present the stimulus many times in order to average out noise and unrelated brain activity. As movements add a great deal of noise into an EEG-recording which means that target pictures that requires participant response are excluded from the analysis. In the present study this translated into a problem because of the need to have as many pictures in each semantic category meant that target pictures were not semantically categorized. This limits the usefulness of behavioral data to only reflect a control of participant's compliance in the experiment.

The main result of this study was that for both EPN and LPP, the linear trend over categories was stronger during the picture task than the letter task. These results indicate that the stronger the EPN and LPP amplitudes during the picture task, the more attenuated the amplitudes were during the letter task. These findings do not support the idea that pictures that are more emotional and receive more attention (i.e., greater EPN and LPP) are more resistant to manipulations of attention. Instead, when letters were attended, pictures that elicited greater EPN and LPP during the picture task showed the greatest reduction in EPN and LPP amplitudes. These findings give support to the Load theory (Lavie, 2005). As it predicts with sufficient perceptual load the distracting effect of salient emotional stimuli should decrease. A real life application of these findings indicates that in order to reduce anxiety in a distressing situation could be achieved by increasing the perceptual load. This could be achieved with a portable videogame for example (Lavie, 2010).

References

- Dunning, J. P., & Hajcak, G. (2009). See no evil: Directing visual attention within unpleasant images modulates the electrocortical response. *Psychophysiology* 46, 28-33.
- Foti D., Hajcak, G., & Dien, J. (2009). Differentiating neural responses to emotional pictures: Evidence from temporal-spatial PCA. *Psychophysiology*, 46, 521-530.
- Holmes, A., Kiss, M., & Eimer, M. (2006). Attention modulates the processing of emotional expression triggered by foveal faces. *Neuroscience Letters*, 394, 48-52.
- Holmes, A., Kragh Nielsen, M., Tipper, S., & Green, S. (2009). An electrophysiological investigation into the automaticity of emotional face processing in high versus low trait anxious individuals. *Cognitive, Affective, & Behavioral Neuroscience*, 9, 323-334.
- Lang, P., Bradley, M., & Cuthbert, B. (2008). International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Technical Report A-8. University of Florida, Gainesville, FL, 2008.
- Lavie, N., (2005). Distracted and confused?: Selective attention under load. *Trends In Cognitive Sciences*, 9, 75-82.
- Lavie, N., (2010). Attention, Distraction, and Cognitive Control Under Load. *Current Directions in Psychological Science*, 19, 143-148.
- LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review Neuroscience*, 23, 155–184.
- Mocaiber, I., Garcia Perreira, M., Smith Erthal, F., Machado-Pinheiro, W., David, J. A., & Cagy, M., et al. (2010). Fact or fiction? An event-related potential study of implicit emotion regulation. *Neuroscience Letters*, 476, 84–88
- Norberg, J., Peira, N., & Wiens, S. (2010). Never mind the spider: Late positive potentials to phobic threat at fixation are unaffected by perceptual load. *Psychophysiology*, 47, 1151-1158.
- Olofsson, J., Nordin, S., Sequeira, H., & Polich, J., (2007) Affective picture processing: An integrative review of ERP findings. *Biological Psychology*, 77, 247–265.
- Okon-Singer H., Tzelgov, J., & Henik, A. (2007). Distinguishing Between Automaticity and Attention in the Processing of Emotionally Significant Stimuli, *Emotion*, 7, 147-157
- Pessoa, L. (2005). To what extent are emotional visual stimuli processed without attention and awareness? *Current Opinion in Neurobiology*, 15, 188–196.
- Pessoa, L., Kastner, S., & Ungerleider, L. G. (2003). Neuroimaging Studies of Attention: From Modulation of Sensory Processing to Top-Down Control. *The Journal of Neuroscience*, 23, 3990–3998.
- Peyk, P., Schupp, H. T., Keil, H., Elbert, T., & Junghöfer, M. (2009). Parallel processing of affective visual stimuli. *Psychophysiology*, 46, 200–208
- Sand, A., & Wiens, S. (2011). Processing of unattended, simple negative pictures resists perceptual load. *Neuroreport*, 22, 348–352
- Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Ito, T., & Lang, P. J. (2000). Affective picture processing: The late positive potential is modulated by motivational relevance. *Psychophysiology*, 37, 257–261.
- Schupp, H. T., Junghöfer, M., A. Weike, A. I., & Hamm, A. O. (2004). The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology*, 41, 441–449.

Vuilleumier, P. (2005). How brains beware: neural mechanisms of emotional attention, *Trends in Cognitive Sciences*, 9, 585-594.

Vuilleumier, P., & Huang, Y., (2009) Emotional Attention: Uncovering the Mechanisms of Affective Biases in Perception, *Current Directions in Psychology*. 18, 148-152.

Weinberg, A., & Hajcak, G., (2010) Beyond Good and Evil: The Time-Course of Neural Activity Elicited by Specific Picture Content. *Emotion*, 10, 767-782.

Wiens, S., Sand, A., Norberg, J., & Andersson, P. (2011) Emotional event-related potentials are reduced if negative pictures presented at fixation are unattended. *Neuroscience Letters*, 495, 178-182.