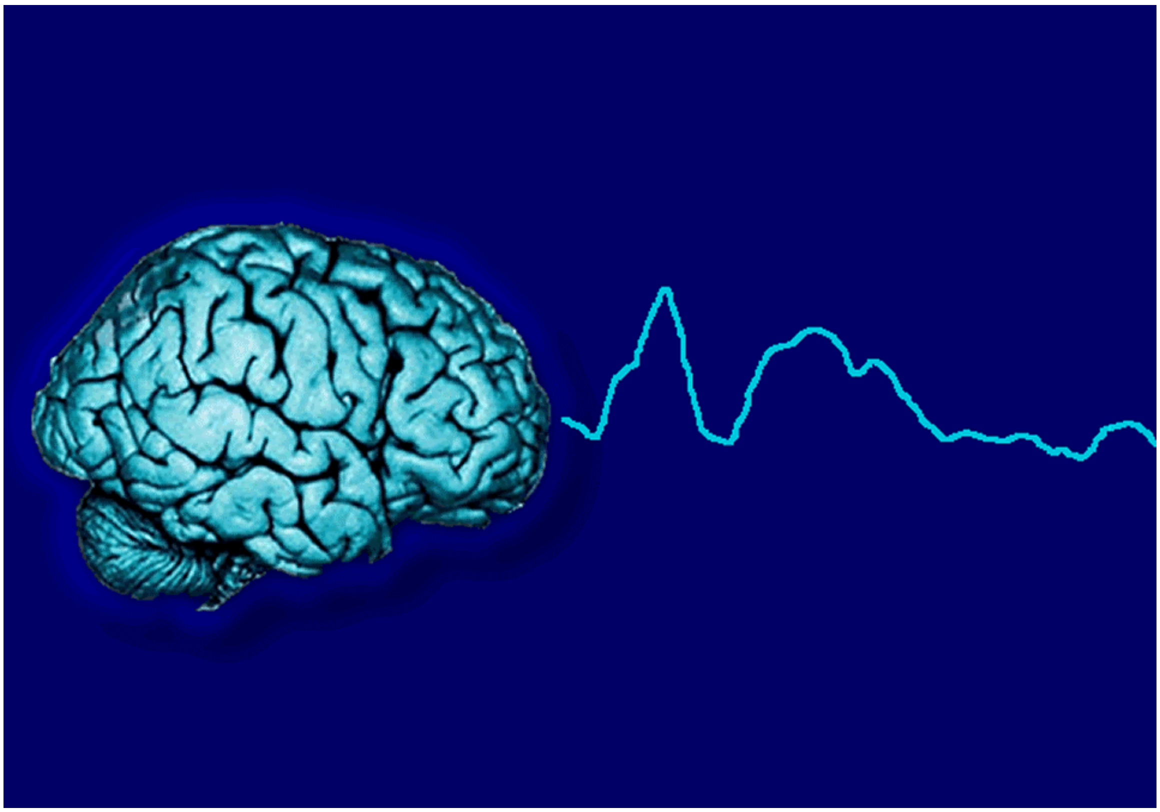
EEG repetition effect to high and low arousal emotional stimuli



N.J. Strekalova

274566

Index

Abstract

In the present EEG study the event-related brain potentials (ERPs) of twenty-four young women were recorded while subjects made old/new recognition judgments about emotionally charged pictures. Pleasant, neutral and unpleasant pictures from the International Affective Picture System (IAPS) were presented twice and differed in emotional intensity (high vs. low arousal). Three time windows were investigated (200-400 ms, 400-600 ms, and 600-100 ms after stimulus onset). Compared to neutral pictures ERP positivity was greater in the early stadium (200-400 ms) for pleasant and unpleased stimuli. Also the positive amplitude of ERPs increased with the intensity of emotional stimuli (i.e. arousal) in all three time ranges and was most pronounced at centro-parietal electrode position with the presence of left hemisphere trend. The old/new effect had a fronto-central bilateral distribution (more present for negative pictures) during 400-600 ms after the stimulus onset and a right anterior distribution in the time window of 600-1000 ms after the stimulus onset for both positive and negative stimuli.

1. Introduction

Emotions are the indispensable component of human life. Like fuel for the car, emotions serve the movement of body and mind. Emotions are a rapid response system, a kind of radar, which allow us to make quick appraisal of the situation, to prepare the reaction on it and to act instantly (for review see Cole, Marthin, & Dennis, 2004.). Physiological reactions mediated by emotional expression have been studied very extensively. The changes in facial muscle reactions, the hart rate, the skin conductance, the startle blink reflex and the brain activation are narrowly connected with utterances of two opponent motivational systems, appetitive and aversive/defensive, which can vary in terms of activation or arousal (Lang, Bradley, & Cuthbert, 1998).

The brain reactivity on emotional stimuli is the aim of this study. Concerning the nature of emotions two main parts of emotional processing were examined in this research: affective valence (appetitive or aversive components) and arousal (intensity of activation).

Valence refers to a continuum from pleasant or positive to unpleasant or negative stimuli with neutral stimuli in the middle. Most pleasant effects are held to be associated with the brain's appetitive/approach motivational system, whereas unpleasant affects with aversive/defensive motivational system (Cuthbert, Schupp, et al., 2000). In a series of experiments, Davidson et al. (1992, 1997, 1998, and 1999) found hemispheric specialization for both affective and cognitive processing. Stimuli which differ in affective valence systematically activate the frontal brain areas, while verbal and visuospatial tasks produce activity in parietal and temporal lobes (Davidson, 1988). For example, during exposure of short film clips to induce approach-related positive emotion and withdrawn-related negative emotions, Davidson recorded the brain electrical activity from different leads. He discovered a hemisphere-valence interaction and a pattern of left-sided activation during positive scenes, and right-sided activation during negative actions. The same pattern of hemispheric asymmetry was found in different studies of infants. Even 10-month old children produce clear left frontal and parietal brain activation while looking at a videotape of an actress displaying laughter; whereas the opposite pattern of right-side activation was shown while watching an actress displaying distress. Data from another study with infants (criers versus noncriers) showed a relationship between the asymmetric activation during baseline measurement and the cry behavior. Infants with greater right-sided baseline activation cried subsequently more in response to the absence of their mothers than children with greater left-sided baseline activation. Davidson claimed the existence of temperamental differences in frontal asymmetry as predictor of the affective reactivity (Davidson, 1998). Frontal asymmetry as a predisposition for emotional processing was found in the EEG study of Pauli (2005). Panic patients exhibited a clear frontal asymmetry with reduced right-frontal alpha power under rest condition and much more while confronted with anxiety-relevant stimuli, compared with anxiety- irrelevant stimuli (Pauli et al., 2005).

These results form the basis of the valence hypothesis. According to the valence hypothesis, the left hemisphere is more activated with positive emotional stimuli, associated with experience of approach-related emotions, whereas the right hemisphere is more involved in processing of negative emotional stimuli, associated with withdrawn-related emotions (Cacioppo, 2004). The empirical evidence for this hypothesis was found in neuropsychological studies. Subjects' resting anterior brain electrical activity was measured in a series of EEG recordings in the study of Sutton and Davidson (1997). After the removal of electrodes, each participant had to fill in self-report inventories of Behaviour Approach and Inhibition System (BAS and BIS). Results showed that subjects with greater baseline left prefrontal activation (i.e. reduced alpha power), reported higher level of BAS strength, whereas the subjects with greater baseline right prefrontal activation, reported higher level of BIS strength. The explanation given was that a certain biological predisposition exists in approach and withdrawn (or inhibitory) motivational tendencies. Individuals with tonically active left prefrontal regions are more likely to guide their behavior toward the desired goals and to experience a positive effect. On the other hand, the tonically active right prefrontal regions may organize the inhibiting behaviour and experience of negative affect (Sutton &Davidson, 1997).

Results consistent with valence hypothesis were found in a recent neuroimaging study (fMRI). During emotional evaluation of positive, negative and neutral pictures participants in the experiment of Dolcos (2004) showed greater left dorsolateral PFC activation for positive pictures and greater right ventrolateral PFC activity for negative pictures (Dolcos et al., 2004). In a study of Van Strien and Valstar (2004), subjects with a high level anxiety and normal individuals performed the Stroop task with emotional words, which were presented in left or right visual field. For left visual field (i.e. right hemisphere) the emotional Stroop effect was greater for negative than positive words. Participants with high anxiety rating tended to have a larger interference for positive words in the left relative to the right visual field. In spite of failing to demonstrate a left-hemisphere involvement in the processing of positive words, the obtained results are in correspondence with the valence hypothesis (Van Strien & Valsar, 2004). Comparable results were found in functional magnetic resonance imaging studies (fMRI), using emotionally valenced positive and negative pictures (Canli et al., 1998). A significant activation of left middle frontal gyrus, as well as middle and superior temporal gyri, was found in response to positive stimuli. Significant activation in response to negative pictures was mainly seen in the right inferior frontal and gyrus and the gyrus rectus, which is consistent with the valence hypothesis (Canli et al., 1998).

The second component of the brain's emotional motivation system is arousal, which refers to a continuum that varies from calm to excitement and has been found to play an important role in modulating the neural mechanisms of memory formation. Arousing events seem to be better remembered than neutral events. Participants in the experiment of Dolcos et al. (2004) were able to give a more detailed description about arousing pictures than about neutral pictures. Also the recall of emotionally charged stimuli was significantly better, suggesting better encoding of high-arousing than low arousing stimuli. Dolcos proposed that arousing events may not only receive deeper semantic processing but are also more intensely included in the working memory, leading to better retention. Clear topographic differences were found between valence-related and arousal-related components of emotional processing. While the valence effect was activating frontocentral sites and ventromedial PFC, the arousal effect to arousal was sensitive at parietal sites and dorsomedial PFC. The involved regions reflected the self-awareness and appetitive behavior in the case of valence and ventromedial activation, and a general processing of emotional information (arousal and dorsomedial activation) (Dolcos, 2002, 2004; Dolcos & Stiben, 2004).

Because emotions are very rapid and changeable, the best manner to "catch a moment" is to use electro-encephalogram (EEG). This is a non-invasive measure of electrical brain activity with a good time resolution. Changes in the electrical activity of the brain can be recorded in the order of milliseconds (Davidson, 1998). In order to analyse reactions to special selected stimuli, event-related brain potentials (ERPs) are used in the majority of studies. Event-related brain potentials represent time-locked electrical cortical activity associated with different information processing, and provide important information about emotional regulation. A lot of the ERP studies have found the emotion effect - ERPs for emotional stimuli (both pleasant and unpleasant) tend to have more pronounced positive brain waves than ERPs for neutral stimuli in the time window of 300-800 ms after stimuli presentation (Dolcos & Cabeza, 2002).

Several studies have investigated both arousal and valence influences on event-related potential changes. In the experiment of Cuthbert et al. (2000) participants were asked to judge their emotional reactions during watching of pictures containing positive, negative, and neutral slides with low and high arousal ratings. The results showed that viewing emotional pictures provoked a pronounced Late Positive Potential (LPP), occurring from 400 ms after stimulus presentation, which was enhanced with the emotional intensity of the stimuli. There was a significant covariation of late positive potential and the arousal judgment of each subject, which illustrated the relationship between emotional activation and EEG positivity (Cuthbert et al., 2000).

The recruitment of selective attention processes by emotional stimuli was found in the study of Schupp (2000). The emotional pictures from the International Affective Picture System (IAPS) were sorted by arousal rating from low to high subsets. After picture presentations, the subject was asked to rate the each picture as pleasant, unpleasant, and neutral. Again, the results showed that emotional pictures evoked greater late positive event-related potentials than neutral pictures at all recorded electrode sites. High aroused pleasant and unpleasant stimuli elicited larger positive waves (from 400 ms and beyond) than less intensive pleasant and unpleasant pictures. The data showed that the Late Postive Potential (LPP) in reaction to affective pictures is modulated by motivational significance of picture presentation, and was pronounced at frontal, central, and parietal sites (Schupp et al., 2000). In their later study, Schupp et al. (2004) found evidence for the selective processing of affective cues also for briefly presented emotional pictures in two stages: the early negative and the late positive potentials. The early selective processing for positive and negative pictures caused a pronounced negative shift in the ERP waveform over temporo-occipital leads at about 150 ms after picture onset. The late positive potentials were enlarged for emotional compared to neutral images over centro-parietal regions. These data suggest that even a quick glimpse of emotionally relevant stimuli can be sufficient for starting of the selective processing in the brain (Schupp, et al., 2004).

Comparable results were obtained in the research of Amrhein et al (2004), where startle response, skin conductance, and event-related brain potentials were assessed. Participants were instructed to ignore the loud noises that they would hear via head phones during the first part of the experiment when the eye-blink component of the startle-responses, skin conductance, and ERPs activity were measured. The data of skin-conductance and startle-reflex supported the idea of their modulation by arousal and valence respectively. The largest startle blink responses occur in unpleasant context and the smallest in pleasant context. The interpretation of these findings, according to motivational priming hypothesis, is that the startle reaction appears to be a defensive mechanism, protecting the body for possible injury. Thus the defensive startle reflex should be of significantly greater amplitude in negative circumstances when the aversive/defensive motivational system is active (Lang, Bradley & Cuthbert, 1998). As was predicted, the EEG positivity was higher for pleasant and unpleasant than for neutral pictures from 200 to 700 ms after stimuli onset. ERP positivity was pronounced at parietal electrodes and intermediate at central electrodes. However, no hemispheric asymmetry was found for emotional processing of positive or negative pictures, a result that contrasted with the assumptions of the valence hypothesis (Amrhein et al., 2004).

Two concurrent measures of the startle response were used in another study of Cuthbert et al. (1998): the elicited blink reflex and the event-related potentials. The aim of this study was to investigate the impact of directed attention to an acoustic probe on both evoked startle responses. While looking at emotionally evocative pictures (positive, negative, and neutral), participants were exposed to random selected startle stimuli (white noise) and tone stimuli (acoustic signal). Subjects were divided into two groups: an ignore group and an attend group. The participants of the first group was told to pay no attention to the startle and tone stimuli (unattended condition), whereas the other group should perform a choice reaction time task requiring attention to the probes (attended condition). The data suggested that reflective eye blinks varied with the pleasantness of affective pictures (more pronounced for negative stimuli) but were not sensitive for the presence of directed attention. In contrast, the positive wave occurring as a response to an acoustic probe at about 300 ms after stimulus onset (P3 wave), had a smaller amplitude during viewing of emotionally arousing pictures for both startling (noise) and non-startling probe stimuli (tone), but again was similar in both attended and unattended condition. This reduction of secondary probe P300 reflects a greater allocation of attention resources to the visual emotional stimuli. The absence of the influence of directed attention on changes in the P3 amplitude in this experiment reflects the general motivational resistance of appetitive and aversive cues. One explanation given was that in natural environments, the survival mechanisms automatically require the attentional resources, because neither the blink reflex nor the event-related potentials were diminished by attention to the startle probe (Cuthbert et al., 1998).

The involvement of defensive and appetitive motivational system in emotional reactions, and the interaction between emotion and attention, have been systematically studied over the last few years. For example, in the study of cerebral patterns of attentional habituation to emotional visual stimuli, Carretie et al. (2003) found that emotional stimuli have the lowest level of habituation when compared to neutral stimuli. Habituation, as an adaptive mechanism involves the reduction in the response to repeated stimuli. However, not all stimuli are sensitive to habituation, like signal stimuli which are very important for the individual. Emotional stimuli are by definition the signal stimuli because they are very adaptive and become habituated less and more slowly. In this study participants had to attend to three different pictures types: emotionally positive, negative, and neutral, while event-related potentials were recorded. The chosen way to investigate the habituation was the recording of electrical brain activity, involving neural mechanisms within the first 200 ms after stimulus presentation. The negative wave N1 or N100, which occurs about 100 ms after stimulus onset, represents such activity. N1 is thought to reflect a wide range of attention-related processes. Analysis of the N1 wave showed that the highest resistance to attentional habituation was produced in response to negative stimuli, suggesting the robust involvement of attentional system in emotional processing (Carretie, Hinojosa & Mercado, 2003).

This strong interdependence of cognitive and affective neural mechanisms is a renowned topic of many neuropsychological studies. Influence of emotional connotation of stimuli on memory processing was the main focus in the ERP study of Dietrich et al. (2001). The researchers were interested in how emotional content did change the recognition and recall performance as indexed by event-related potentials. The stimuli for this experiment were words, presented visually in a continuous word recognition paradigm. All words were divided into two categories: target words, which were presented twice and non-target words with one presentation. The participant’s task was to rate the words in both categories concerning their emotional content (positive, negative, and neutral) on a scale ranging from 5 (‘most positive’) to -5 (‘most negative’). Then the words were presented in repetition trials and the subjects had to decide for each word whether it was shown for the first (new) or the second time (old). It was hypothesized that brain responses to repeated and recognized items would be characterized by a more positive waveform. The acquired results supported this hypothesis. Beginning at about 250 ms after stimulus onset (P3 wave), the correct classification of target words (second presentation) elicited the more pronounced positive waveform for all electrode sites. The difference between first and second presentation was much less pronounced for words that were emotionally neutral (Dietrich et al., 2001).

The effect mediated by the repetition of stimuli is known as an ‘old/new effect’ (Rugg, 1995). ‘Old/new effect’ occurs in the time rang of 300-800 ms after stimulus onset when stimuli are correctly identified and presented twice in a single series. This effect can be influenced by different parameters such a stimuli frequency, task difficulty, and seems to reflect the modulation of two main underlying brain electrical activities: a negative wave in the time range of 300-500 ms after stimulus presentation (N4/ N400) is also known as an early negative component, and a late positive component (LPC), which occurs in the time window of 500-800 ms. (Dietrich et al., 2001; Rugg, 1995; Van Strien et al., 2005). According to dual-process theories of recognition, there are two distinct processes responsible for the ability to discriminate between studied (old) and non-studied (new) items: familiarity and recollection. Familiarity is thought to be a result of an assessment of the global familiarity between a test item and all previously learned items in memory. This is a context-insensitive, automatic process of remembering. Recollection is related to the conscious retrieval of specific information about studied items and is sensitive to the context (Van Strien et al, 2005; Curran, Cleary, 2002; Finnigan et al., 2002).

Recent studies have suggested that the early component of ERP ‘old/new effect’, which is called ‘FN400 old/new effect’, may be related to familiarity, whereas the later ERP component of old/new effect is thought to be related to recollection. The ‘FN400 old/new effect’ got this name due to frontal distribution, and the later component is called ‘the parietal old/new effect’, because of predominantly parietal distribution (Dietrich et al., 2001; Van Strien et al., 2005; Curran, Cleary, 2002; Finnigan et al., 2002).

In the study of brain electrical activity during extended continuous word recognition, Van Strien et al. (2005) examined the ERP data from twenty participants. During the experimental continuous word recognition, task subjects were presented sets of frequent words. Each word was repeated ten times in random order, varied with filler words (i.e. new words that were not repeated). Participants were told to press the response button as an indication of the novelty of stimuli (‘new’ or ‘old’ words). The researchers found a clear ‘old/new’ effect for the early component of ERPs at time range of 300-500 ms after a word presentation. The correct recognition of a previously presented word evoked a more positive waveform than the correct identification of a new word. This effect was obtained in the midline parietal brain area. No increased positivity in early ERP component was noticed for the increased repetitions of words. However, across nine presentations, the later ERP (500-800 ms time window) component did exhibit the pronounced positivity. It was proposed that the number of repetitions can influence the strength of the memory trace. These results supported the dual-processing model, where the early component of memory processing is related to an automatic and global mechanism of familiarity, whereas the later component is sensitive to more conscious computing of new information, which is associated with a graded recollection (Van Strien et al., 2005).

At the same time as the interpretation of ERP data has resulted in dual-process models, the alternative memory models claim to provide a new account for episodic recognition. According to the global matching models, the recognition decision criterion is a summed strength of all matches between items and all memory traces in a single global memory system. Proponents of global matching models suggest that strengths above the criterion will result in an old response whereas strength below this criterion will produce a new response. To test this assumption, Finnigan et al. (2002) developed an ERP experiment, in which a list of old and new words were presented to participants in two conditions: ‘weak condition’ (words were presented once), and ‘strong condition’ (words were presented three times). Subjects had to make an old/new recognition judgment for each test words. The obtained results showed that the negative wave occurring at about 400 ms after a word presentation (N400) was of greatest amplitude at the left parietal sides in graded manner (new<weak<strong). This result provided evidence that parietal N400 effect indexed the memory strength. However, the researchers reported the lack of significant differences between ‘weak’ and ‘strong’ conditions in frontal FN400

components. They claimed that FN400 may reflect some specific form of implicit memory, rather than to be related to familiarity (according to dual-process models). The late positive component effects (LPC) was found to be related to recognition decision accuracy. The pronounced LPC wave was seen for correct recognized words, compared to not-corrected recognized words, and had a left and centro-parietal distribution (Finnigan et al., 2002).

Despite the alternative models, most of studies interpret their results in terms of a dual-processing model. Within the context of such theories, the research of Curran (1998) provides an indication of the ERP 'old/new effect' occurring between 400 and 800 ms after stimulus onset. In this study two experiments were composed to compare ERP old/new effects in both lexical decision and recognition tasks. Subjects had to complete study-test blocks with words and pronounceable pseudo words. Half of the blocks were created to test lexical decision and another half to test the word recognition. The researchers found the expected larger positive wave in the time range of 400-800 ms (P600) in recognition tasks, compared to lexical decision tasks. The P600 old/new effect was distinct from an earlier FN400 old/new effect both topographically and functionally. The P600 old/new effect was significant for words but not for pronounceable pseudo words and was distributed over posterior, superior (old>new) and anterior (old<new) regions. The better recognition of words than pseudo words would be consistent with the assertion that words have more detailed encoding and recall than pseudo words, which is consistent with the definition of recollection. On the other hand, the FN400 old/new effect was insensitive to retrieval intention and was similar for both words and pseudo words. The distribution of electrical brain activity of FN400 differed also with the later component P600: the effect was maximal over anterior, superior (old>new), and posterior, inferior (old<new) regions. This finding supported the idea that FN400 old/new effect may be related to familiarity, which is thought to be a global matching between a new item and all previously learned items. The results of this study provide evidence for dual-process models (Curran, 1999).

There is no doubt that emotional cues have the capacity to modulate affective and cognitive processing. To summarize, just after the presentation of an emotional stimulus different neural activities start to arise.

1. At about 100 ms after stimulus onset, a negative wave N1 occurs, which is thought to reflect involuntary attentional processes and is highly resistant to attentional habituation in response to emotional stimuli (especially negative). The analyses have shown that N1 is distributed over two brain regions: frontal and posterior.

2. The second electrical brain activity is presented in the time window of 200-400 ms with the positive peak occurring about 300 ms after stimulus onset, the P3 wave, has been associated with attentional processes for new and meaningful stimuli. The amplitude of P3 becomes more pronounced in response to emotional stimuli and by the correct identification of target stimuli by the second presentation (the ERP old/new effect).

3. A negative wave in the time range of 300-500 ms after stimulus presentation (FN4/N400) is known as early component of old/new effect and may be related to familiarity of new item to all remembered stimuli. The 'FN400 old/new effect' has a frontal distribution, and was maximal over anterior, superior (old>new), and posterior, inferior (old<new) regions.

4. There is some inequality between researchers about the time windows of wide distributed late positive component –LPC– with different brain waves like P3, P600, and late positive potential (LPP). This component is associated with memory retrieval processes and novel learning, and is found to be enhanced with affectivity of stimuli. For the later component of old/new effect the LPC is related to recollection and has a predominantly parietal distribution. In the time window of 400-600 ms the Positive Slow wave occurs (P600), which may indicate the controlled cognitive processing, evaluation en memory storage. The P600 old/new effect for words was distributed over posterior, superior (old>new) and anterior (old<new) regions.

In this study we have restricted the variety of approaches of brain electrical activity to three ERP components: between 200 and 400 ms after picture presentation (P300 wave), between 400 and 600 ms after picture presentation (Positive Slow wave, P600), and between 600 and 1000 ms after picture presentation (Late Positive Complex, LPC).

The goal of the present EEG study was to examine to what extend the ERP old/new effect is modulated by both valence and arousal components of emotion. In this experiment we recorded event-related potentials while offering the pictures from International Picture System (IAPS) (Lang, 1997). Pictures were selected on the ground of the pleasantness or valence (positive, negative, and neutral) and arousal (arousing vs. neutral ratings). We hypothesized that the presentation of emotionally charged pictures (both with positive and negative valence) would result in the increased ERP positivity in frontal regions during the first 400 ms after the stimulus onset with the presence of hemispheric specialization, according to valence hypothesis; whereas the effect of arousal we expected to find especially in parietal regions in all three ERPs components. It was suspected that the second presentation of affective pictures would influence the pronunciation of positive waves mainly in Late Positive ERP Component, which should correspond with the ‘old/new effects’.

2. Method

2.1. Participants

Twenty four young women in the age range between 20 and 30 years (mean age was 23) were participating in a single session of the experiment as volunteers or for study credits. They were all randomly selected Dutch speakers, which had normal or corrected to normal vision and were predominantly right-handed (three of them were left-handed).

Because of the measure failure of the left mastoid site and lack of EEG registration there were data missing of two participants.

2.2. Stimuli and Apparatus

One hundred en sixty pictures were chosen from the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 1999). They were divided into three main categories, selected according to valence and arousal (see tab.1):

- Pleasant pictures within 32 positive high aroused events, and 32 positive low aroused events;
- Unpleasant pictures within 32 unpleasant high aroused events, and 32 unpleasant low aroused events;
- Neutral pictures (32 events).

Each picture was presented twice as color slides in random order. In this way nine conditions were made: positive valence high arousal first presentation (ph1), positive valence low arousal first presentation (pl1), negative valence high arousal first presentation (nh1), negative valence low arousal first presentation (nl1), positive valence high arousal second presentation (ph2), positive valence low arousal second presentation (pl2), negative valence high arousal second presentation (nh2), negative valence low arousal second presentation (nl2), neutral first presentation (nt1), and neutral second presentation (nt2).

The pictures were selected for women, because they tend to be more sensitive for emotional stimuli and show clear brain activation in response to these stimuli (Van Strien et al., 2000; Cuthbert et al., 2000; Dolcos et al., 2004; Lang et al 1998).

Stimuli were presented on a 17inch high resolution PC monitor at a distance of 80 cm from the subject's head.

Before the EEG measurement participants had to fill in three questionnaires:

- "Vragenlijst Handvoorkeur" (Van Strien, 1992) for hand preference (attachment 1),
- "Personal Reaction Inventory" (Grown, and Marlow, 1964) for desirability (attachment 2),
- "Zelf-Beoordelings Vragenlijst" (Van der Ploeg, Defares, and Spielberger 1980) for emotional state (attachment 3).

Tab.1. Valence and arousal mean (m) and standard deviation (sd) of IAPS stimuli for female subjects

Category		Valence*		Arousal*	
		m	(sd)	m	(sd)
positive	high	7.42	(0.45)	6.12	(0.46)
	low	7.3	(0.66)	3.36	(0.41)
negative	high	2.08	(0.40)	6.50	(0.46)
	low	3.57	(0.72)	4.02	(0.48)
neutral		5.07	(0.37)	3.18	(0.68)

* judged according to 9-point scale

2.3. Procedure

The participants were sitting in a comfortable chair in a darkened and sound-attenuated room. They were instructed to relax and to avoid superfluous body movements, concentrating their attention on the monitor. For each pictures the subjects had to decide whether it is shown for the fist (new) or for the second time (old). According to their decision they should press the right button for new photos and left button for old photos.

Each trial consisted of the 400 - 600 ms presentation of a fixation cross in the middle of the screen, the 500 ms presentation of the IAPS picture, followed by the 1000 ms presentation of the fixation xcross. The intertrial interval was 500 ms. During the preparation for EEG recording, participants were asked to fill in three questionnaires. After all electrodes were connected, the base rate of the brain electrical activity was measured in a task with open and closed eyes. Before the experiment began each participant received 20 practice trials (10 new and 10 already once presented) to get used to the procedure.

2.4. EEG Recording

The electroencephalogram (EEG) was recorded with active Ag/AgC1 electrodes from 32 sites according to the International 10-20 System (Fz, FCz, Cz, CPz, Pz, Oz, F3/4, F7/8, FC3/4, FT7/8, C3/4, T7/8, CP3/4, TP7/8, P3/4, P7/8, O1/2, AF3/4) which were set in an elastic cap (BioSemi ActiveTwo System). Mathematically linked mastoids M1 and M2 were used for EEG reference. The ocular correction was made with help of Electro-oculogram (EOG) activity which was recorded from three electrodes placed around the left eye, and from one electrode at the temple of the right eye. Vertical and horizontal eye movements were registered with the same recording parameters as for EEG and then were corrected using the algorithm of Gratton (Gratton et al., 1983).

2.5. Data reduction and analyses

All individual EEG data were analyzed with BrainVision software. High pass filter with cutoff 0.15 Hz and low pass filter with cuttof 30 Hz (24 dB/oct) were used before the continuous EEG file was divided in 320 segments with an interval from 100 ms before to 1200 ms after picture onset for further evaluation. The EEG signals were digitized with a 512 Hz sampling rating (BioSemi ActiveTwo system). After baseline correction with 100ms prestimulus period, artifacts below or above the allowed amplitude of -75 µV/ 75 µV were removed. The averaging for ERP signals took place separately for nine conditions and for each participant.

Trails with correct responses were analyzed in three time windows: between 200 and 400 ms after picture presentation (P300 wave), between 400 and 600 ms after picture presentation (Positive Slow wave, P600), and between 600 and 1000 ms after picture presentation (Late Positive Complex, LPC).

2.6. Statistical analyses

The ERP data were analyzed by means of repeated-measures analyses of variance (rmANOVA) for valence, arousal, and electrode position for two stimuli repetitions (old/new) as within subjects. *F* ratios were tested, with The Greenhouse-Geisser correction was applied to all repeated measures with greater than 1 degree of freedom. Significant interactions effects were followed-up by means of topographic voltage maps that were constructed to explore the distribution of effects.

3. Results

3.1. Behavioural data

Mean percentage of correct responses was 96.4.

3.2. Event-related potentials.

3.2.1. ‘Old/new’ effect

The grand-average ERP waveforms during viewing of affective pictures the first and second time are presented in fig. 1. The data from frontal (Fz), central (Cz), and parietal sites (Pz) demonstrate the differences between the first and the second presentation (‘old/new’ effect), which are statistical significant for the area measures of 200-400 ms and 400-600 ms after stimuli onset (see tab. 2 and 3). For the 600-1000 ms time window no significant ‘old/new’ effect was found, $F(1, 21) = 3.66$, $p = .069$.

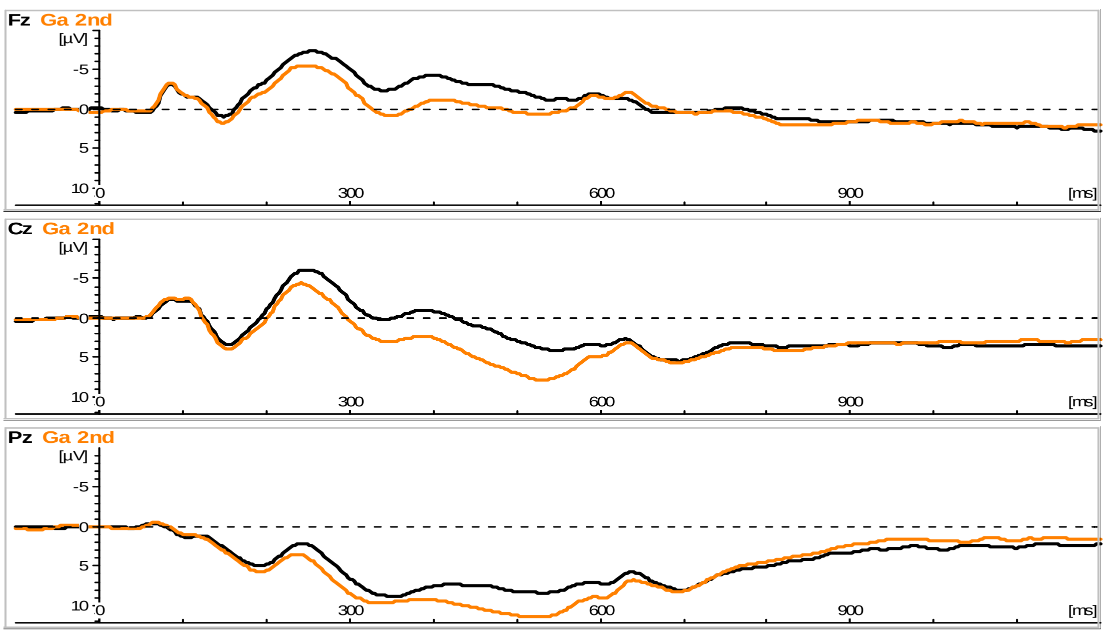


Fig. 1. Grand-average ERP waveform during viewing of affective pictures the first time (= new presentation; black lines) and second time (= ‘old picture’; orange lines) from midline electrodes Fz, Cz, and Pz.

3.2.2. Event-related potentials: Arousal effects.

In all three area measures significant differences were found between event-related potentials for high arousal pictures compared to low-arousal emotional pictures (see tab. 2, 3, and 4).

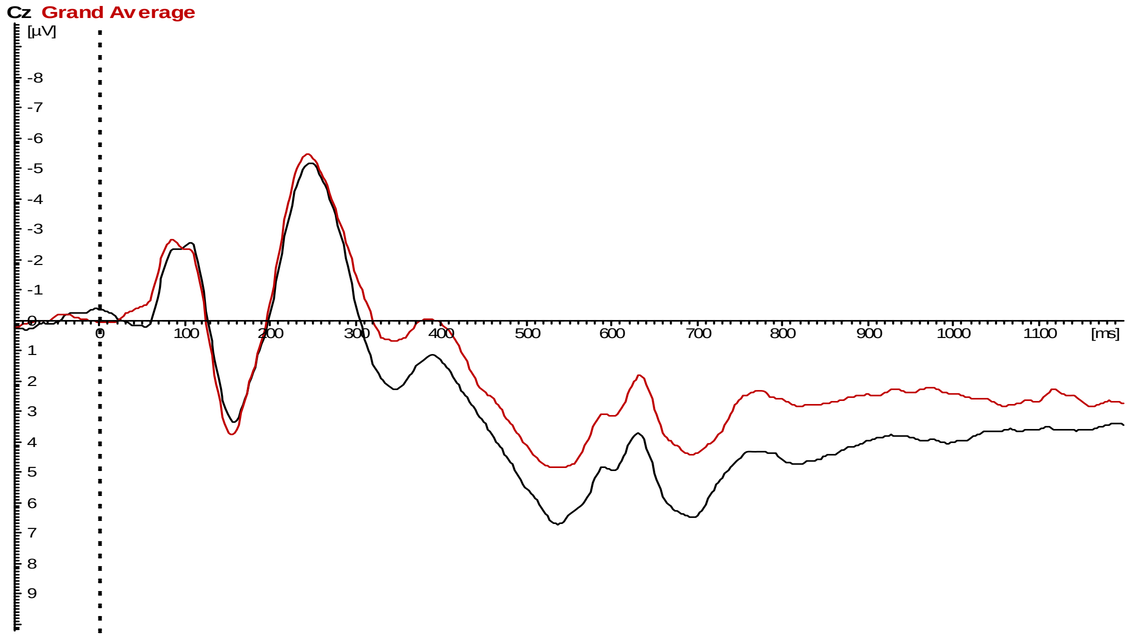


Fig.2. Grand-average ERP waveform during viewing of high- and low-aroused emotional pictures (high arousal stimuli, black lines; and low arousal stimuli; red lines) from the midline electrode Cz.

3.2.3. Event-related potentials: ANOVA results.

Statistical significant results in three time windows (area measures 200-400 ms, 400-600 ms, and 600-1000 ms after stimuli onset) are presented in tables 2 till 4.

3.2.3.1. Area measures 200-400 ms after stimuli onset

As illustrated in Table 2 main significant effects were found for all factors. Positive charged pictures yielded enhanced positivity of ERP as compared to negative charged pictures (factor valence). Also the arousing events elicited more pronounced positivity (factor arousal), compared to stimuli with low arousal. The second presentation (old) of a picture was paired with greater amplitude of the ERP wave, than the first presentation of a picture (new). There were significant distinctions between ERP signals in different brain areas (electrode position).

The repeated measure design (2×2×2 ANOVA) showed the following interaction effect:
in this time window the amplitude of P300 was affected by the valence × old/new effect × electrode position. The figure 3 demonstrates the topographic voltage map of the scalp distribution activity during the repetition of positive and negative charged pictures (factor valence). There is a more distinct enhancement of the positivity of the ERPs waves for the second presentation of the negative stimuli compared to the second presentation of the positive stimuli (fig. 3).

Table 2
ANOVA main and interaction effects for area measure 200-400 ms

Factors	F	df	p
Valence	7.43	1, 21	0.013
Arousal	13.21	1, 21	0.002
Old/new effect	26.55	1, 21	0.000
Electrode position	35.2	1.72, 36.1	0.000
Valence × Old/new effect × Electrode position	3.04	4.54, 95.37	0.016

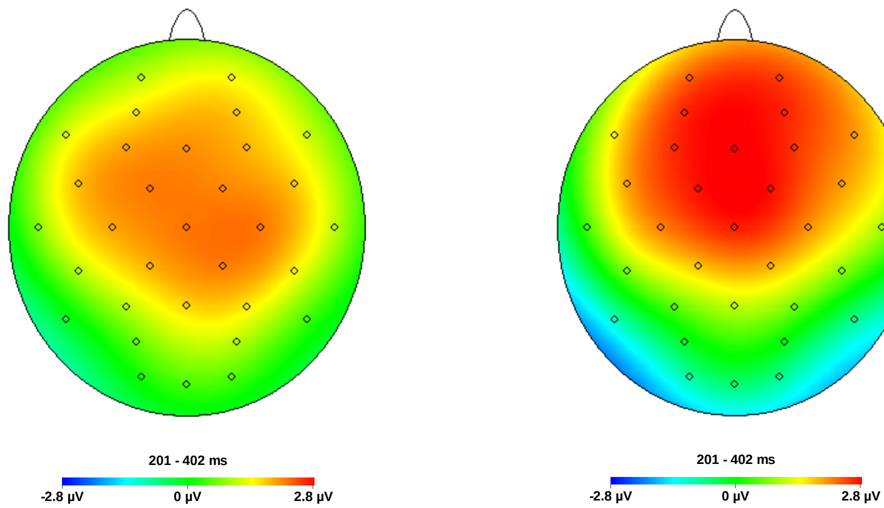


Fig. 3. The left picture shows the differences in scalp distribution of the ERPs between the first presentation (new pictures) and the second presentation (old pictures) during viewing pictures with a positive valence, and the right picture - during viewing pictures with a negative valence.

3.2.3.2. Area measures 400-600 ms after stimuli onset

Significant results are shown in the table 3. There is no effect of valence of the stimuli on the event-related potentials, but the strength of the emotionality (arousal) played a role in the pronouncing of the waveform. Also the old/new effect was clearly present for the second presentation of the pictures. The distribution of the brain activity (electrode position) was significant different between electrode sites.

The significant interactions of old/new effect × electrode position, and valence × arousal × electrode position and the scalp distribution of the electrical activity are shown in the table 3 and in the fig.4 and 5. The enhanced positivity was observed during the second presentation of the pictures. The area of activity on the topographic voltage map is located in the central regions with a right hemisphere trend (fig. 4). Moreover the clear difference exists in ERPs scalp distribution of the positive and negative aroused pictures (fig. 5). For the negative aroused stimuli there is a bilateral activation of fronto-central brain areas.

Table 3
ANOVA main and interaction effects for area measure 400-600 ms

Factors	F	df	p
Arousal	6.76	1, 21	0.017
Old/new effect	39.35	1, 21	0.000
Electrode position	32.45	2.02, 42.39	0.000
Old/new effect× Electrode position	7.69	4.36, 91.5	0.000
Valence × Arousal × Electrode position	3.05	6.83, 143.47	0.005

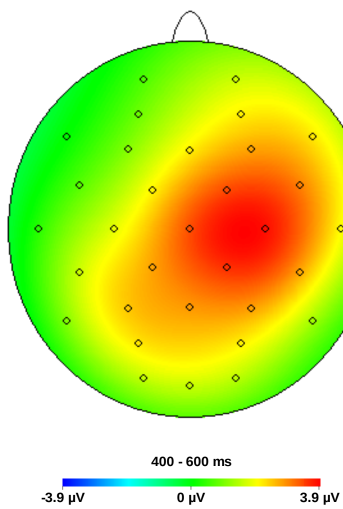


Fig.4. Scalp ERP distribution of the difference between the first and the second presentation of the stimuli (‘old/new’ effect) for the 400- to 600-ms area measure.

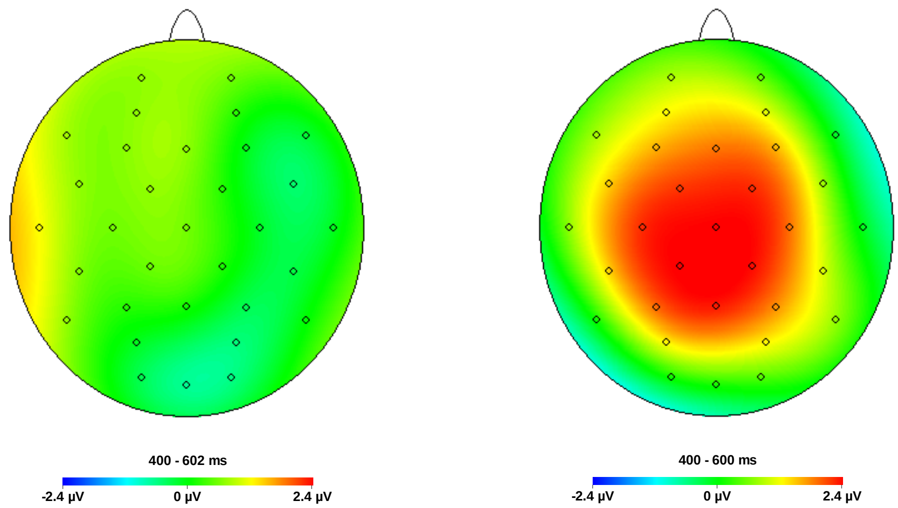


Fig.5. Differences between in scalp distribution of the ERP arousal effect (high minus low) for the positive (left picture) and the negative (right picture) stimuli for the 400- to 600-ms area measure.

3.2.3.3. Area measures 600-1000 ms after stimuli onset (late positive complex)

The Late Positive Complex was accompanied with the generally more pronounced positive shift in response to high arousal pictures compared to low arousal stimuli (tab. 4). However, neither the old/new effect nor the effect of emotionality of the pictures (valence) was significant. Table 4 shows also the interaction effects which influenced the positivity of the LPC: arousal × electrode position, and old/new effect × electrode position. The first interaction is illustrated in the ERPs scalp distribution on the fig. 6. There is a bilateral with left trend activation for aroused pictures (both positive and negative). The ‘old/new’ effect expressed itself in the enhanced right-anterior postivity, which is shown in the fig. 7.

Table 4
ANOVA main and interaction effects for area measure 600-1000 ms

Factors	F	df	p
Arousal	13.19	1, 21	0.002
Electrode position	7.15	2.89, 60.61	0.000
Arousal × Electrode position	4.16	6.01, 126.26	0.001
Old/new effect × Electrode position	5.12	3.37, 70.71	0.002

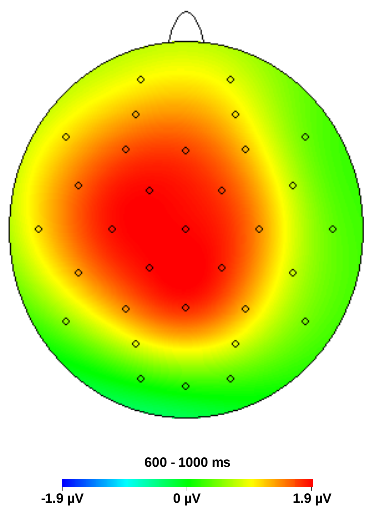


Fig.6. Scalp ERP distribution of the difference between the high and low arousal stimuli for the 600- to 1000-ms area measure.

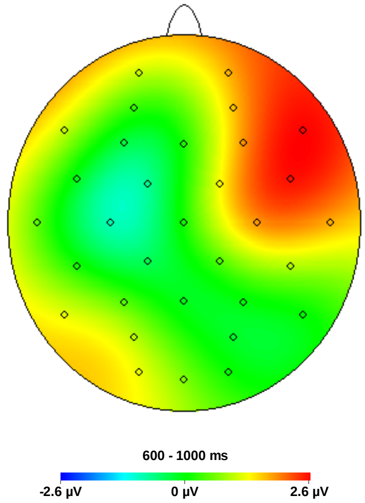


Fig.7. Scalp ERP distribution of the difference between the first and the second presentation of the stimuli (‘old/new’ effect) for the 600- to 1000-ms area measure.

4. Discussion

The obtained results show that emotional pictures evoke pronounced positive brain waves in the three time windows (ERP s components) considered in this study, namely between 200- and 400 ms; between 400- and 600- ms, and between 600- and 100 ms after stimuli onset.

In agreement with the results of previously researchers, the *arousal* level of the emotionality of the stimulus (from calm to excitement) influences the event-related brain potentials (Schupp et al., 2000; Cuthbert et al., 2000). The amplitudes of the ERPs in this study in all three time windows became more positive pronounced according as the pictures were more emotionally charged (high arousal). Especially the last ERP component, so-called Late Positive Complex (LPC) was very sensitive to highly arousing emotional stimuli and was enlarged for high- compared to low-arousal images over centro-parietal regions with a left hemisphere trend. This outcome is in accordance with data of other studies (Schupp, et al., 2004).

Also an effect of *valence* was found in the present study. We found that positive pictures, compared to negative stimuli, enhanced the ERPs positivity in the time range of 200-400ms, but not in the later time measures.

According to the valence hypotheses (Cacioppo, 2004; Sutton &Davidson, 1997), positive stimuli should activate the left hemisphere, whereas the negative stimuli are responsible for the activation of the right hemisphere. In present study we couldn't fine clear brain asymmetry for positive and negative pictures. Perhaps the spatial limitation of the chosen method (EEG) did not allow us to find a precise location of the brain activities.

The third factor we were interested in was the so called *'the old/new' effect*, characteristics of an enhanced positivity of brain waves by the second presentation of the same stimulus.

In the present study we found a clear 'old/new' effect, especially in the later stages after the stimulus onset (400-600 ms and 600-1000 ms). In the time window of *400-600 ms* after the second presentation of the pictures the enhanced postitivity was shown in central sites, whereas in the time range of 600-1000 ms the repetition effect was found in anterior region. Both activations had a trend in a right hemisphere direction. In the present study we made use of emotional charged pictures (IAPS), which were presented twice and probably caused another hemispheric activation than in the study of Curran et al. (1999). He found the opposite pattern of activation for ‘old’ words (the FN400, than words in other researches did old/new’ effect was maximal over anterior, superior regions, whereas the P600 ‘old/new’ effect was maximal over posterior, superior regions). These results were explained in term of dual-process model, what we did not examine in the present study. Comparable results were presented in the Kayser’s study of event-related potentials during auditory and visual word recognition tasks (Kayser et al., 2003). However data demonstrated modality-specific differences in the scalp topography, the broadly distributed ‘old/new’ effect had almost the same time course peaking at 560 ms was in both modalities, with more anterior scalp distribution for visual items.

The most remarkable results were obtained for the combination of such factors as arousal, valence, and ‘old/new’ effect. In several previous studies the interaction of two factors were investigated. For example Cuthbert et al. found that emotional pictures prompted a pronounced late positive potential than did neutral pictures (factor valence). These positive potentials were enhanced for the stimuli which were more emotionally intense (factor arousal). A late positive slow wave was significant larger for affective than for non-affective stimuli (Cuthbert et al., 2000). Using pictures from the International Affective Picture System (IAPS), Schupp found the greater late positive event-related potentials for emotional high aroused photographs compared to neutral pictures with low arousal at all recorded electrode sites (Schupp et al., 2000). In our study we found comparable results, demonstrating greater positivity for emotional pictures with high arousal factor in the time window of 400-600 ms. The spread bilateral activation was larger for negative than for positive high aroused pictures.

Both arousal and valence typify the emotionality of stimuli. From the perspective of the limited attention resources, only those stimuli will be attended which are important for the respondent (Schupp, et al., 2000). In natural circumstances pleasant and unpleasant stimuli indicate how safe or dangerous is the environment, and how the subject should react. The reaction should be very quick, that’s why results of many studies showed that ERP waveform patterns for emotional stimuli differ from neutral stimuli already earlier in the time (around 200 ms). Also the intensity of the stimulus plays a crucial role in the selective attention mechanisms. This is not sensible to ignore silent stimuli because they could be very important or even threatened for the observer. The combination of both factors should recruit the most attention resources to serve for the most optimal survival.

Another interaction we were interested in was that of valence and the ‘old/new’ effect. This interaction was present in the time range of 200-400 ms and was greater for the negative pictures than for positive pictures with a fronto-central bilateral distribution. In the study of event-related potentials of emotional memory, Dolcos found that emotional events also tend to be better remembered than nonemotional events and provoke more positive going ERPs for pleasant and unpleasant than for neutral stimuli. The subsequent memory effect was larger for emotional pictures during the 400-600 ms time range and provided the evidence that emotional stimuli processed faster than neutral stimuli (Dolcos, Cabeza, 2002). We did not investigate the memory effect of conscious recall, but we also find that emotional stimuli (mainly negative) provoked greater positive ERPs during the second presentation of the same picture. There is no doubt that the recognition of a certain stimuli could be influenced not only via the repetition of the same signal but also via affective neural mechanisms (Dietrich et al., 2001). For the second time presented emotional stimuli will be recognised rapidly and will use more attention resources compared to neutral stimuli. Mainly for the negative items it could be very important to pay the full attention, especially when they have occurred once before.

In summary, the present study shows that pleasant and unpleased pictures (factor valence) increase the ERP positivity in the early stadium after the stimulus onset (200-400 ms). However there is no clear hemispheric specialisation for the processing of emotional pictures, what was supposed in the valence hypothesis. As was hypothesised the positive amplitude of ERPs increased with the intensity of emotional stimuli (i.e. arousal) in all three ERPs components. The obtained results support the previous findings of centro-parietal hemispheric involvement in the processing of aroused stimuli, with the presence of left hemisphere trend in this activation. We also found that the second presentation of affective pictures enhances the pronunciation of positive going wave in both 400-600 ms and Late Positive ERP components (600-1000 ms after the stimulus onset). For the first time window there was fronto-central bilateral distribution which was more pronounced for negative than for positive pictures. The late component had more right anterior distribution, and did not differ between the negative and positive stimuli.

We suggest that positive slow event-related potentials indicate the selective attention processing of emotional stimuli. The present results show that the brain's response increases with the emotionality of the stimuli (both arousal and valence), and with the repetition of the same emotional stimuli.

Some important limitations in our study should be considered. The chosen method of electro-encephalogram registration of brain activity had a good time resolution, however the spatial resolution was not good enough to determine the underlying area's of the brain activity precisely. The best solution for the future research would be using both EEG and fMRI methods to investigate temporal as well spatial processes.

5. References

Aftanas, L.I., Golocheikine, S.A. (2001). Human anterior and frontal midline theta and lower alpha reflect emotionally positive state and internalized attention: high-resolution EEG investigation of meditation. *Neuroscience Letters, 310,* 57-60.

Aftanas, L.I., Varlamov, A.A., Pavlov, S.V., Marhnev, V.P., Reva, N.V. (2001). Affective picture processing: event-related synchronization within individually defined human theta band is modulated by valence dimension. *Neuroscience Letters, 303,* 115-118.

Amrhein, Chr., Muhlberger, A., Pauli, P.,Wiedemann, G. (2004). Modulation of event-related brain potentials during affective picture processing: a complement to startle reflex and skin conductance response? *International Journal of Psychophysiology, 54,* 231-240

Arcos de, F.A., Verdejo-Garcia, A., Peralta-Ramirez, M.I., Sanchez-Barrera, M., Perez-Garcia, M. (2004). Experience of emotions in substance abusers exposed to images containing neutral, positive, and negative stimuli. *Drug and Alcohol Dependence, 78,* 159-167.

Cacioppo, J.T. (2004). Feelings and emotions: roles for electrophysiological markers. *Biological Psychology, 67,* 235-243.

Canli, T., Desmond, J.E., Zhao, Z., Glover, G., & Gabrieli, J.D.E. (1998). Hemispheric asymmetry for emotional stimuli detected with fMRI. *NeuroReport, 9,* 3233-3239.

Carretie, L., Hinojosa, J.A., Mercado, F., (2003). Cerebral patterns of attentional habituation to emotional visual stimuli. *Psychophysiology, 40,* 381-388.

Codispoti, M., Bradley, M.M., Lang, P.J (2001). Affective reactions to briefly presented pictures. *Psychophysiology, 38,* 474-478.

Cole, P.M., Marthin, S.E., & Dennis, T.A. (2004). Emotion regulation as a scientific construct: methodological challenges and directions for child development research. *Child Development, 75,* 317-333.

Crown, D.P., & Marlow, D. (1964). *The approval motive: Studies in evaluate dependence.* NY: Wiley.

Curran, T. (1999). The electrophysiology of incidental and intentional retrieval: ERP old/new effects in lexical decision and recognition memory. *Neuropsychologia, 37,* 771-785.

Curran, T., Cleary, A.M. (2002). Using ERPs to dissociate recollection from familiarity in picture recognition. *Cognitive Brain Research, 15,* 191-205.

Cuthbert, B.N., Schupp, H.T., Bradley, M.M., Birbaumer, N., & Lang, P.J. (2000). Brain potentials in affective picture processing: covariation with autonomic arousal and affective report. *Biological Psychology, 52*, 95-111.

Cuthbert, B.N., Schupp, H.T., Bradley, M.M., McManis, M., Lang, P.J. (1998). Probing affective pictures: attended startle and tone probes. *Psychophysiology, 35*, 344-347.

Davidson, R.J. (1988). EEG measures of cerebral asymmetry: conceptual and methodological issues. *Neuroscience, 39,* 71-89.

Davidson, R.J. (1992). Anterior asymmetry and the nature of emotion. *Brain and Cognition, 20,* 125-151.

Dietrich, D.E., Waller, C., Johannes, S., Wieringa, B.M., Emrich,H.M., & Münte, T.F. (2001). Differential effects of emotional content on event-related potentials in word recognition memory. Neuropsychobiology, 43, 96-101.

Dolcos, F., LaBar, K.S., & Cabeza, R. (2004). Dissociable effects of arousal and valence on prefrontal activity indexing emotional evaluation and subsequent memory. *NeuroImage, 23,* 64-74.

Dolcos, F., & Cabeza, R. (2002). Event-related potentials of emotional memory: Encoding pleasant, unpleasant, and neutral pictures. *Cognitive, Affective, & Behavioral Neutoscience, 2(3),* 252-263.

Finnigan, S., Humphreys, M.S., Dennis, S., Geffen, G. (2002). ERP ‘old/new’ effects: memory strength and decisional factor(s). *Neuropsychologia, 40,* 2288-2304.

Gratton, G., Coles, M.G., & Donchin, E. (1983). A new method for off-line removal of ocular artefact. *Electroencephalography and Clinical Neurophysiology, 55,* 468-484.

Junghofer, M., Bradley, M.M., Elbert, Th.R., Lang, P.J. (2001). Fleeting images: a new look at early emotion discrimination. *Psychophysiology, 38,* 175-178.

Kayser, J., Fong, R., Tenke, C.E., Bruder, G.E. (2003). Event-related potentials during auditory and visual word recognition memory tasks. *Cognitive Brain Research, 16,* 11-25.

Lang, P.J., Bradley, M.M., & Cuthbert, B.N. (1998). Emotion, motivation, and anxiety: brain mechanisms and psychophysiology. *Biological Psychiatry, 44,* 1248-1263.

Lewis, M.D., & Stieben, J. (2004), Emotion regulation in the brain: conceptual issues and directions foe development research. *Child Development, 75,* 371-376.

McPherson, W.B., Holcomb, P.J. (1999). An electrophysiological investigation of semantic priming with pictures of real objects. *Psychophysiology, 36,* 53-65.

Northoff, G., Richter, A., Gessner, M., Schlagenhauf, F., Fell, J., Baumgart, F., Kaulisch, Th., Kötter, R., Stephan, K.E., Leschinger, A., Hagner, T., Bargel, B., Witzel, Th., Hinrichs, H., Bogerts, B., Scheich, H., & Heinze, H.-J. (2000). Functional dissociation between medial and lateral prefrontal cortical spatiotemporal activation in negative and positive emotions: a combined fMRI/MEG study. *Cerebral Cortex, 1,* 93-107.

Pauli, P., Wiedemann, G., Dengler, W., Kostorz, S., Amrhein, C., Muhlberger, A., Weik, A., & Grzbiela, A. (2005). *Emotions: fear, phobias and panic*. Internetsite of Institute of Medical Psychology and Behavioral Neurobiology Emotions.

Pause, B.M., Raack, N., Sojka,B., Goeder,R., Aldenhoff, J.B., & Ferstl, R. (2003).Convergent and divergent effects of odors and emotions in depression. *Psychophysiology, 40,* 209-225.

Schupp, H.T., Cuthbert, B.N., Bradley, M.M., Cacioppo, J.T, Ito, T., Lang, P.J (2000). Affective pictures processing: the late potential is modulated by motivational relevance. *Psychophysiology, 37,* 257-261.

Schupp, H.T, Junghofer, M., Wielke, A.I., Hamm, A.O. (2004). The selective processing of briefly presented affective pictures: an ERP analysis. *Psychophysiology, 37,* 257.

Sutton, S.K., & Davidson, R.J. (1997). Prefrontal brain asymmetry: a biological sustrate of the behavioural approach and inhibition systems. *Psychological Science, 3,* 204-210.

Van Strien, J.W, & Valsar, L.H. (2004). The lateralized emotional Stroop task: left visual filed interference in women. *Emotion, 4.*

Van Strien, J.W, Van Beek, S. (2000). Rating of emotions in laterally presented faces: sex and handedness effects. *Brain and Cognition, 44,* 645-652.

Van Strien, J.W., Hagenbeek, R.E., Stam, J.C., Rombouts, S.A.R.B., & Barkhof, F. (2005). Changes in brain electrical activity during extended continuous word recognition. *NeuroImage, 1,* 26 (3), 952-9

Van Strien, J.W. (1992). Classificatie van link – en rechtshandige proefpersonen. *Nederlandse Tijdschift voor de Psychologie, 47,* 88-92.

Van der Ploeg, H.M., Defares, P.B., & Spielberger, C.D. (1980*). Zelf-beoordelings vragenlijst.* Lisse: Swets& Zeitlinger B.V.