Bachelorthese

EEG representation of emotion evoking pictures

Department: CPE

Tutor: Dr. Rob van der Lubbe

Second Tutor: Caro Wiering

Student: Mike Walpuski (s0123919)

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Enschede, Universiteit Twente – Faculteit Gedragswetenschappen

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Abstract

The present study examined induced emotions via emotiogenic pictures (from the International Affective Picture System) in a spectral analysis of electroencephalographic (EEG) data. Evidence contributing to theories which link prefrontal right sided activity to negative emotion and left sided activity to positive emotions could be found in form of alpha2 (10-13Hz) desynchronization as well as tendencies for alpha1 (8-10Hz), delta (1-4Hz) and theta1 (4-6Hz) asynchronies only. Increasing beta1 (13-20Hz) activity in both hemisphere over parietal areas and increasing left sided gamma (30-50Hz) activity over parietotemporal areas also significantly distinguished emotional states but not in line with introduced theory.

Introduction

Emotion has become an important part of neuroscience and understandings of the brain mechanisms that underlie emotional processing are crucial for further comprehension of human cognition and neural processes associated with psychopathology and pain perception (Jackson, Meltzoff & Decety, 2005; Ogino et al., 2007; Spielberg et al., 2008). EEG signals however have a weak spatial resolution and cannot be traced back in a straightforward manner (Schutter et al., 2006). Assuming activity of electrodes or groups of electrodes to corresponding brain structures below is in spite of the inferential problems a common heuristic. Studies using electroencephalography (EEG) regularly found activation over the right prefrontal cortex (PFC) for negative or pain related stimuli and activation over left PFC for positive stimuli (Aftanas et al., 2001a,b,2002; Davidson et al., 1990; DePascalis et al., 1998; Harmon-Jones & Allen, 1998; Tomarken, Davidson&Henriques, 1990).

These findings are quite consistent with studies using other measures like functional magnetic resonance imaging (fMRI) (Ogino et al., 2007). There are several theories trying to explain PFC activation in emotional states.

Theories according to emotional valence argue that areas of the right PFC become activated with negative emotions and left PFC areas with positive emotions. Heller (1993) proposed a circumplex model of emotion that also integrated findings of posterior activations. Right parietotemporal areas showed increased activation in arousal states, so her model suggests that arousing stimuli activate this particular area independently of valence, while left PFC activity shows positive and right PFC activity shows unpleasant valence.

Valence models however have become criticized by researchers in the field of motivation. They argued that previous research used stimuli for negative emotions that are also associated with withdrawal behavior and positive stimuli that are also associated with approach behavior (Davidson et al., 1990). Therefore they proposed that found activations of left PFC are associated with approach behavior and right PFC activations with withdrawal behavior regardless of stimulus valence. Further research supported their view especially in the case of the emotion anger, which was supposed to be negative in valence but associated with approach behavior. Valence models would predict right side PFC activity because of negative valence, but anger in fact tended to elicit more left sided PFC activity in favor for approach-withdrawal models (Harmon-Jones & Allen, 1998, as reported in Spielberg et al. 2008).

Basing on these foundations the present study wants to analyze emotions elicited from pain and pleasure related pictures.

Several studies about the perception and processing of pain showed comparable results to that of negative and withdrawal related emotion (Chen et al., 1989; Cheng et al., 2008; Jackson, Meltzoff & Decety, 2005). Using fMRI, Ogino et al. (2007) showed that viewing others in painful conditions also activates the cortical structures that are associated with nociperception, mainly areas in the right anterior cingulate cortex and right posterior parietal cortex, what supports the arousal dimension associated with those areas.

However, most studies about emotion and spectral analysis mostly focused on several frequencies like alpha and theta band and were limited to prefrontal areas. Studies involving distinct emotions and covering the full frequency spectrum and the whole scalp are still quite rare (Aftanas et al., 2006).

The present study therefore tries to contribute to this field. Conducting a spectral analysis, the main question of this study is whether there are significant changes in the frequency powers between evoked emotional conditions.

A common method to evoke distinct emotions is to present subjects pictures with corresponding content (Aftanas et al., 2001a,b,2002; Müller, Gruber & Keil, 2000, Müller et al. 1999; Ogino et al., 2007). The International Affective Picture System (IAPS) by Lang et al. (1999) provides a gathering of emotion evoking (emotiogenic) pictures, which were assessed and validated with the Self-Assessment Manikin (SAM) questionaire (Bradley&Lang, 1994).

Findings and definitions about the known frequency bands associated with brain activity are not equivocal and differ somewhat over the studied literature. Niedermeyer (2005), in a classical book about electroencephalographic studies introduces the bandwidths of brain frequencies in Hertz (Hz) as follows. Delta (0.1-3.5), Theta (4-7.5), Alpha (8-13), Beta (14-30), Gamma (all above 30). Also sub-division of bandwidths into theta1,2 or alpha1,2,3 f.e. are common (Crawford, Clarke&Kitner-Triolo, 1996; Klimesch, 1999). These bandwidths are quite stable, but still differ up to several Hz in their outer limits throughout the literature, also accounting for recent findings that support inter- and even intraindividual differences for the occurring frequencies (Aftanas et al. 2002, Doppelmayr et al. 1998, Klimesch, Schimke&Pfurtscheller, 1993).

A short summary of similar studies is given in Tabel 1.1 and a summary of findings from other studies regarding the different frequencies can be found in tabel 1.2.

Reference	Stimuli	Delta	Theta	Alpha	Beta	Gamma
Ahern & Schwartz, 1985	Questions	↑ F; R; fear ↓ F; R; happiness		↓ F; R ; fear ↑ F; R ; happiness		
Aftanas et al, 2001a,b	IAPS pictures	na	↑ AT; R; negative ↑ P,PT,O; b.h., positive + negative	↑ AT; L; negative, time dependent (800-1200ms)		
Aftanas et al, 2002	IAPS pictures	na	↑ P,PT,O; R; high+moderate arousal ↑ AT, F; L; arousing positive+ negative	↑ AT, F; L; high arousal time dependent (800-1200ms)		
Aftanas et al., 2006	Film clips	↑ overall, happiness	↑ AT, F, L; joy ↑ AT, F, P,PT; L; disgust (theta2, 4-6Hz)	↓PT; R; disgust (alpha2 10-12Hz)	↓ F; b.h.; happiness ↓PT; R; disgust (beta1, 12-18Hz)	
Krause et al., 2000	Film clips	Na	↑ F, b.h., aggressive	↓P,PT,O, b.h., aggressive+ neutral		
Müller et al., 1999	IAPS pictures	Na	Na	Na	↑ F; L; positive+ negative	↑ F; R; positive+ negative ↑ AT,PT; R; positive ↑ AT,PT; L; negative
Tomarken, Davidson & Henriques, 1990	Film clips	Na	Na	↓ F; R; negative ↓ F; L; positive		
De Pascalis, Ray & D'Amico, 1998	Hypnotical induced emotions	Na	↑ F; R ; pleasant	↓ AT, F; R ; negative	↑ AT, PT; R ; positive	Na
↑ relatively more activity ↓=relatively diminishing activity Syntax: activity, caudality, hemisphere, emotional cond.			L= left hemisphere, R= right hemisphere, b.h. = both hemispheres; AT = anteriortemporal, F = frontal, C=central, P = parietal, PT = parietotemporal, O = occipital			

Tabel 1.1. Summary of effects found in previous studies

Delta	Theta	Alpha	Beta	Gamma
prone to be confounded with eye blink artifacts (Cheng et al., 2006; Chen & Rappelsberger, 1994)	associated with hedonic pleasure, disappointment and frustration (Niedermeyer, 2005)	inverse related to neurocortical activity (Shagass, 1972).	Frontal activity is integral part of consciousness (Niedermeyer 2005)	occurs in sensory, cognitive and motor processing (Niedermeyer, 2005; Müller, Gruber & Keil, 2000)
linked to attention and mental processing (Harmony et al., 1996)	associated with encoding and retrieval processes of working memory, orienting and alertness (Schacter, 1977)	slow alpha1 (8-10 Hz) correlates with attentional processes (Niedermeyer, 2005; Klimesch 1999)	useful measure of emotional processes (Ray&Cole, 1985; Crawford, Clarke & Kitner-Triolo, 1996)	associated with processes of binding sensory information and sensomotoric integration (Niedermeyer 2005, Müller,Gruber & Keil, 2000)
raised activity in painful conditions (Bromm&Lorenz,1998)	associated with feelings of bliss and thoughtless awareness (Aftanas & Golocheikine, 2001)	fast alpha2 (10-13Hz) is associated with sensory-semantical processes and long term memory (Niedermeyer, 2005; Klimesch, 1999)	increased activity in right parietal areas correlated with more avoidant response to angry faces (Schutter, 2002)	associated with arousal (Aftanas&Golosheykin, 2005)
	increased activity in left prefrontal areas to positive mood (Schutter et al., 2001)	less alpha1 in right parietal areas for negative emotions (Crawford, Clarke & Kitner-Triolo, 1996; Sarlo et al., 2005)	increased activity in right frontal and left central areas for negative emotions (Crawford, Clarke & Kitner-Triolo, 1996)	increased activity over anterior cortical sites while watching aversive stimuli (Aftanas&Golosheykin, 2005)
	increased activity in right hemisphere in painful condition (Chen et al., 1989)	global decrease in alpha rhythm for painful conditions (Bromm&Lorenz, 1989)	increased activity for perception of actual pain (Bromm&Lorenz, 1998)	increased activity in right frontal electrodes for emotional stimuli (Müller et al., 1999)
	slow theta1 (4-6Hz) activity in right parietal areas associated with positive emotions, inactivity and drowsiness (Crawford, Clarke & Kitner-Triolo, 1996)	can be confounded with *rolandic mu* rhythm which - is prominent in motor cortex - can be blocked by movement of contralateral limbs (Niedermeyer, 2005)		increased activity in left temporal sites for negative stimuli and increased activity in right temporal sites for positive stimuli (Müller et al., 1999)
	fast theta2 (6-8Hz) activity associated with cognitive activity involving active inhibition processes (Crawford, Clarke & Kitner-Triolo, 1996)	suppression of central and posterial mu rhythm by visual stimuli depicting human body parts in painful conditions (Cheng et al 2008)		related to actual pain perception over central electrodes (De Pascalis & Cacace, 2005)

Tabel 1.2 Summary of findings regarding frequency bands

With regards to the introduced literature the present study hopes to find differentiation of frequency bands for the emotional condition. A rise in power will be regarded as sign of increased underlying cortical activity for all frequency bands, with exception to the alpha bands, for which less power will be regarded as rising cortical activity (Shagass, 1972). Stimuli related to pleasure contain partially arousing (erotic) content and are all supposed to be approach associated. Therefore a left frontal activation as well as overall increased right posterial activation is expected for the pleasure condition versus neutral stimuli.

Pain related stimuli are supposed to trigger EEG dynamics associated with withdrawal and raised arousal. Pictures showing people in painful conditions were already used in studies of ‘disgust’ as emotion (Müller et a.,1999; Ogino et al. 2007; Jackson, Meltzoff & Decety, 2005; Sarlo et al., 2005). Therefore in comparison to the neutral condition enhanced activation over right prefrontal and right posterior areas are expected for the pain condition, as well as greater central activation for high beta2 and gamma bands.

Methods

Participants

Nine female and 7 male students between age 19 and 25 (mean 22) of the University of Twente, participated in the study for study relevant credit points.

All 16 subjects were strictly right handed as assessed by a handedness scale (Annett, 1970) and had no history of head injury or psychopathology. They were further instructed not to take any psychoactive substances like caffeine, nicotine or alcohol just before the experiment. All of them gave their written informed consent after an short explanation of the experimental protocol in the beginning of the study.

Material and stimuli

To induce three distinct emotional conditions 120 pictures were used. Forty pictures evoking pleasure and 40 neutral pictures were taken from the International Affective Picture System (IAPS; Lang, Bradley, Cuthbert, 2005). This system provides a gathering of emotiogenic pictures, which were assessed and validated with the Self-Assessment Manikin (SAM) questionaire (Bradley&Lang, 1994). Forty pain evoking pictures were taken from studies of Ogino et al. (2006) and Jackson, Meltzoff & Decety (2005) who successfully used them to induce affections associated with pain in functional magnetic resonance imaging studies. All stimuli were presented on a computer screen using presentation software.

EEG recording

The EEG recording was performed with 61 EEG Ag/AgCL electrodes which were placed on the scalp according to the international 10–20 system with a special cap and with three additional bipolar electrodes. Two of them were used to check for vertical and horizontal eye movements and the third one was placed above and beneath the clavicle to record the heartbeat. The ground electrode was placed on the forehead. Electrode skin impedance was less than 5 kΩ and regularly checked in the pauses of the experiment, electrodes were referenced to average. Data were collected with a sampling rate of 500 Hz. All data recording and processing (artifact rejection, averaging, FFT) has been done using the BrainVision software.

Procedure

Participants were placed on a chair in front of the computer screen with approximately 50 cm viewing distance. They filled in an informed consent form, Thayer's Activation-Deactivation Adjective Checklist (Thayer, 1986) and a handedness scale (Annett, 1970) to check for strict right handedness. The laboratory room was dark and window shutters were closed to prevent environmental influence on lighting.

Two one minute baseline measures with eyes closed and eyes open were conducted which were not analyzed further in the present study.

A short introductory text appeared on the screen to explain the following procedure to the participants. They were additionally advised to keep the eyes open, and to avoid body movements during the procedure. Before each stimulus picture, a white fixation cross appeared on the black screen for 3 seconds. All pictures were presented for a duration of 6 seconds and afterwards an evaluation screen appeared with a visual analog scale in form of vertical bar which faded from white on the left indicating ‘not pain related’ to red on the right end indicating ‘very pain related’ (see figure 1.). Participants had to choose via a mouse driven cursor on this bar in how far they would judge the last picture as being related to pain. This screen remained until a choice was made. During the experiment participants saw all 120 pictures in complete randomized order in 4 blocks á 30 pictures. After each block a short pause of three minutes was given, while the experimenter checked for electrode skin impedances to stay under 5 kΩ. Afterwards subjects filled in the Thayer scales (Thayer, 1986) for a second time. The data from these questionnaires were also not further analyzed in the scope of the present study.

Fig.1 visual analog scale bar used in this study

Data reduction and analysis

Brainvision software was used to format the raw data and conduct a Fast Fourier Transformation (FFT). At first the EEG stream was chopped into segments of 4096 ms (equaling 2048 pics pixel length), one at each stimulus onset. To gain segments of artifact-free data, artifact rejection was conducted separately for frontal, cenral and posterior areas. For frontal channels (AF3, AF4, AF7, AF8, Afz, F1, F2, F3, F4, F5, F6, F7, F8, Fp1, Fp2, Fpz, Fz) the maximal allowed voltage was set to 200.00 µV, the minimal to -200.00 µV. The low activity criterion was set to 0.10 µV with an interval length of 50.00 ms. Central channels (C1, C2, C3, C4, C5, C6, CP1, CP2, CP3, CP4, CP5, CP6, CPz, Cz, FC1, FC2, FC3, FC4, FC5, FC6, FCz, FT7, FT8, T7, T8, TP7, TP8) were filtered using a maximal allowed voltage step of 150.00 µV and parietal/occipital channels (O1, O2, Oz, P1, P2, P3, P4, P5, P6, P7, P8, PO3, PO4, PO7, PO8, POz, Pz) were just allowed to have a maximal allowed voltage step of 100.00 µV.

In a following step the artifact free segments were blocked according to their corresponding emotion (pain, pleasure and neutral). Averaged over all subjects, 86.48% of all segments remained, leaving 84.38% pain related, 87.66% pleasure related and 85.94% of neutral segments for further analysis. A FFT using a non-overlapping 10 % Hamming Window and 1Hz frequency bins was conducted. Following a procedure introduced by Aftanas (Aftanas et al., 2001a) the power values for individual electrodes were clustered by averaging them into 12 regions, 6 for each hemisphere respectively (see figure 2). The resulting regional means were named according to their spatial positions, anterior temporal (AT), frontal (F), parietotemporal (PT), parietal (P) and occipital (O). Resulting power (μV^2) data was separated into 8 frequency bands with following bandwidths in Hz. Delta (1-4), Theta1 (4-6), Theta2 (6-8), Alpha1 (8-10), Alpha2 (10-13), Beta1(13-20), Beta2(20-30) and Gamma (30-50).

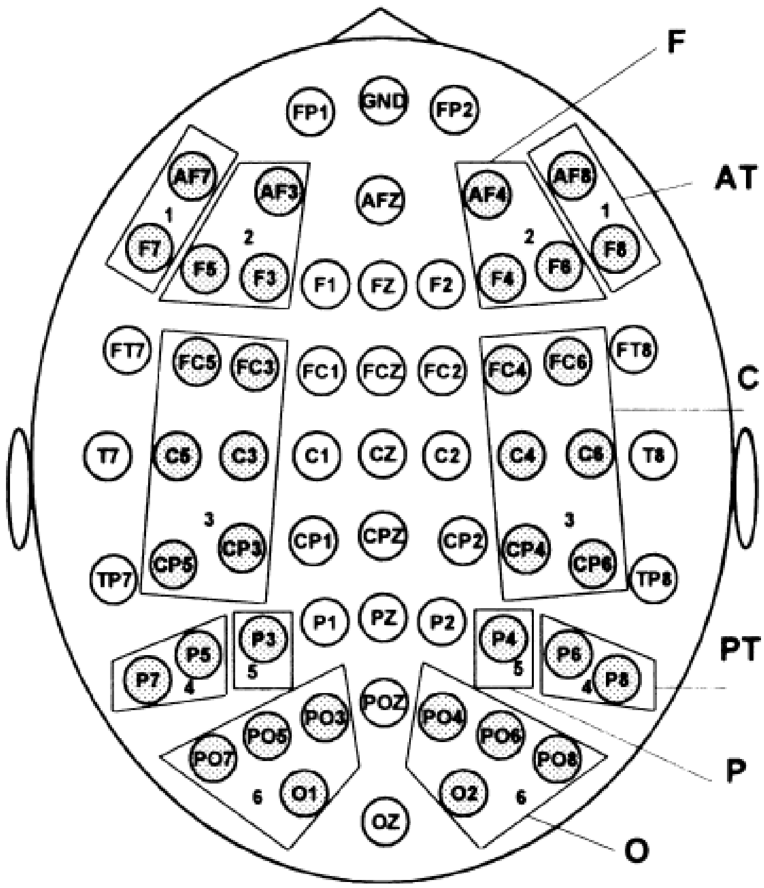

Fig.2. layout of electrode clusters and used shortcuts, see text for details.
[source: modified from Aftanas et al. (2001a)]

A SPSS 15.0 software packet was used to analyze significant differences in frequency band power between the induced emotions. Because hemispherical lateralization for emotional conditions were expected for the specific spatial sites, two-way repeated measures ANOVA's were used for each of the 8 bands at each caudality (AT, F, C, P, PT, O) separately with the factors 'hemisphere' (2 = left or right brain hemisphere) X 'emotion' (3= pain, pleasure, neutral). All effects concerning the emotion condition were reported if they reached a level of $p \leq .2$ for two sided testing.

	Delta	Theta1	Theta2	Alpha1	Alpha2	Beta1	Beta2	Gamma
SUMMARY	Tendency: ↑ AT; R ; negative ↓ P; L; negative ↑ P; L; positive+ neutral	Tendency: ↑ AT, F; R ; Negative + neutral	Tendency: ↑ PT,O; b.h. ; positive	**↓ C; b.h. ; negative** Tendency: ↓ AT; R; negative ↓ F, P; b.h. ; negative	**↓ AT; R; negative** **↓ F ; b.h.; negative**	**↑ P; b.h. positive** Tendency: ↑ F ; L; positive+ negative	Tendency: ↑ O ; R; negative	**↑ PT ; L; negative** Tendency: ↑ P; L ; negative
AT	H*E, F(2,14) = 2.55, p=.114	H*E, F(2,14) = 1.98; p=.176	Ns	E, F(2,14)=1.9; p=.186	**H*E, F(2,14) = 2.79; p=.096***	Ns	Ns	Ns
F	Ns	H*E, F(2,14) = 1.931; p=.182	Ns	E, p=.107	**H*E, F(2,14) = 3.13; p=.075***	H*E, F(2,14) = 2.44; p=.123	Ns	Ns
C	Ns	Ns	Ns	**E, F(2,14) = 2.99; p=.083***	Ns	Ns	Ns	Ns
P	H*E, F(2,14) = 2.25; p=.142	Ns	Ns	E, F(2,14)=2.5; p=.118	Ns	**E, F(2,14) = 3.72; p=.051***	Ns	H*E, F (2,14) = 2.69; P=.102
PT	Ns	Ns	E, F(2,14) =1.81; p=.2	Ns	Ns	Ns	Ns	**H*E, F(2,14)=3.92; P=.045****
O	Ns	ns	E, F(2,14)=2.48; p=.12	ns	ns	Ns	E, F(2,14) = 2.57; P=.112	Ns

↑ relatively more activity ↓relatively diminishing activity ***p<.1; **p<.05**	H*E = interaction hemisphere and emotion E = main effect of emotional condition Syntax: activity, caudality, hemisphere, emotion. cond.	L= left hemisphere, R= right hemisphere, b.h. = both hemispheres; AT = anteriortemporal, F = frontal, C=central, P = parietal, PT = parietotemporal, O = occipital

Tabel 2. Summary of results from the present study according to location and frequency band.

EEG Data

Delta. At anteriortemporal sites pain (vs. pleasure) evoked more activation in the right hemisphere and pleasure (vs. pain) showed more activity on the left hemisphere. But this interaction effect had just a tendency to significance, $F(2,14) = 2.551$, $p = .114$. Interestingly, neutral (vs. both affective) stimuli elicited the most Delta activity in both hemispheres with an advantage of the right side, like negative stimuli.

A further tendency to significance was found over parietal areas $F(2,14) = 2.249$, $p = .142$, showing the opposite pattern for both affective stimuli (pain evoked more activity on the left side and pleasure on the right) but the same for neutral ones (more activity over the right hemisphere). This observation is quite odd but because of the weak statistical power it is also still attributable to chance.

Theta1. An expected right sided lateralization for negative stimuli and a left sided lateralization for positive stimuli over anteriortemporal regions showed only a very weak tendency to significance $F(2,14) = 1.975$, $p = .176$. Further analysis reveal significance of greater right hemisphere pain activation (vs. pleasure) $F(1,15)=4.23$, $p=.058$, respectively less pleasure activity (vs. neutral) $F(1,15)=3.59$, $p=.78$. It is again mentionable that neutral stimuli showed similar power and hemispherical preference as negative stimuli.

The same pattern emerged on frontal sides but even weaker $F(2,14) = 1.931$, $p = .182$.

Further expected effects on parietal and parietotemporal electrodes failed to appear.

Theta2. From expected effects only parietotemporal and occipital areas showed a weak tendency to discriminate between emotions. In parietotemporal areas it was very weak $F(2,14) =1.809$, $p = .200$ and emerged as being mainly due to greater left sided activity of positive stimuli – an effect known from other studies to occur with stimuli eliciting disgust (Aftanas et al., 2006) if anterior and frontal electrodes simultaneously show greater left sided activity, what was not the case here ($F(2,14)=.57$, $p=.58$). On occipital electrodes $F(2,14) =2.475$, $p = .12$ again only positive stimuli made a difference with overall more activity in both hemispheres as revealed by Bonferroni comparison, ($p=.036$).

Alpha1. On the alpha1 band, apparently central electrodes discriminated most between emotional conditions $F(2,14) = 2.991$, $p =.083$. The observation based on a significant drop of alpha1 activity in the pain condition (vs. neutral) in both hemispheres ($F(1,15)=6.36$, $p=.023$, see figure 3), although it would have been expected to drop significantly stronger in right hemisphere only.

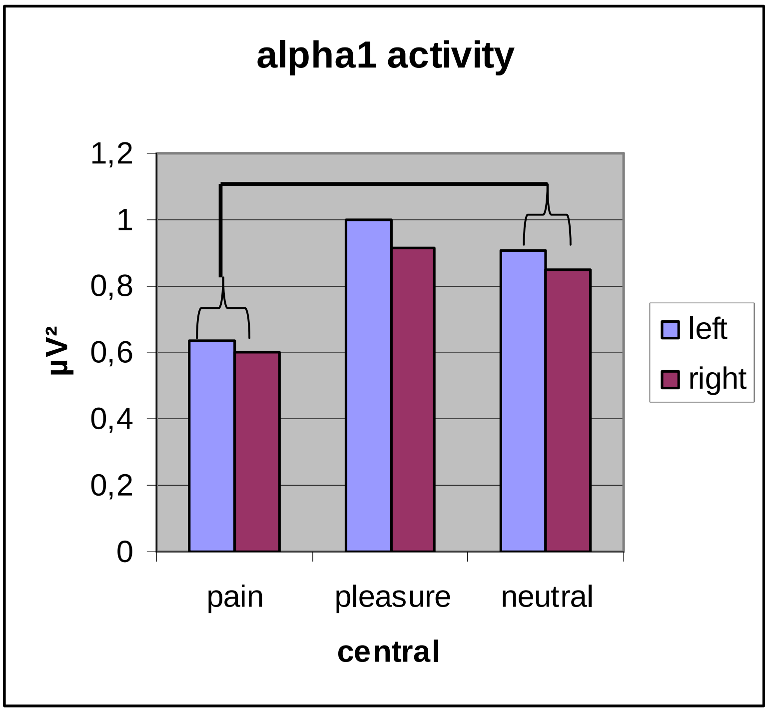

Fig. 3. Significant lower alpha1 activity in pain condition over both hemispheres in central electrodes.

Further hemispherical discrimination of alpha1 power just occurred with tendencies to significance in anteriortemporal (AT), $F(2,14) = 1.903$, $p = .186$, frontal (F), $F(2,14) = 2.636$, $p = .107$ and parietal areas (P), $F(2,14) = 2.499$, $p = .118$.

While Bonferroni tests show the expected greater drop in right hemisphere alpha in the pain condition (vs. neutral) for AT electrodes ($p=.07$), for frontal ($p=.04$) and parietal ($p=.08$) electrodes again a both hemisphere drop in the pain condition (vs. neutral) emerged.

Alpha2. Two significant interaction effects of hemisphere and emotion in anteriortemporal $F(2,14) = 2.788$, $p = .096$, and frontal $F(2,14) = 3.134$, $p = .075$ electrodes occurred. In the AT cluster Bonferroni comparisons show that pain diminishes alpha activity significantly (F(1,15)=6.78, p = .02) in right (M=1.04, SD=.165) in contrast to left hemisphere (M=1.25, SD=.178), while in the frontal cluster, pain again diminishes equal in both hemispheres. The higher alpha2 activity for pleasure (vs. pain) did not reach significance in both clusters (AT: F(1,15)=.36, p=.56; F: F(1,15)=.609, p=.45) presumable due to high standard error.

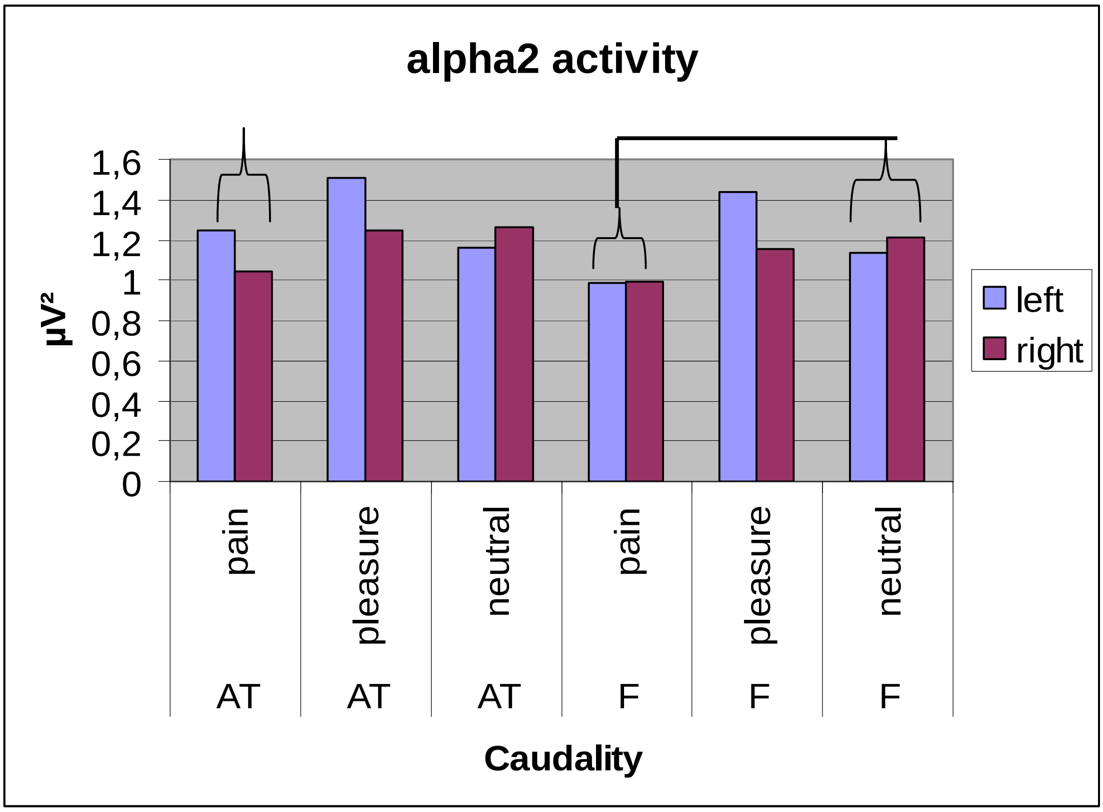

Fig. 4. Alpha2 activity for anteriortemporal (AT) and frontal (F) cluster. In AT right hemisphere pain activity is significantly lower than in left hemisphere; pain in F drops in both hemispheres (vs. neutral).

Beta1. The parietal cluster showed a significant effect of emotion, with F(2,14) = 3.723, p =.051. The effect could be further traced back to a significant higher beta1 activity (F(1,15)=7.96, p = .013) in pleasure (M=.44, SD=.06) vs pain (M=.39, SD=.05) for both hemispheres.

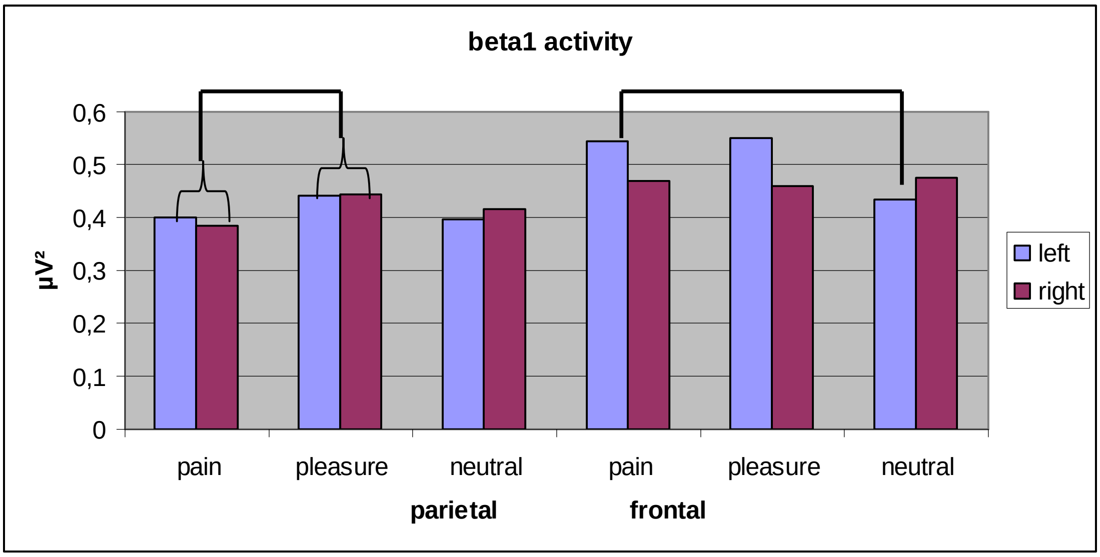

Fig. 5. Beta1 activity in pleasure (vs. pain) condition significantly rises in both hemispheres in parietal electrodes and activity in the pain condition (vs. neutral) rises in left hemisphere in frontal electrodes

Additionally an interaction effect of hemisphere*emotion had a tendency to significance in frontal areas with $F(2,14) = 2.441$, $p = .123$. Further examination revealed that activity significantly rises in the left hemisphere in the pain ($F(1,15) = 3.34$, $p=.09$) and pleasure ($F(1,15=4.17$; $p=.059$) condition (vs. neutral).

Beta2. Reactivity for emotion could only be found with a tendency to significance in occipital leads with $F(2,14) = 2.569$, $p = .112$. Bonferroni tests suggest that right side pain activity for beta2 is higher than in the neutral condition.

Gamma. Activity over parietotemporal and parietal areas were able to discriminate between emotions. A tendency to an interaction effect for hemisphere and emotion in the gamma band over parietal areas with $F(2,14) = 2.694$, $p = .102$ was found, showing more gamma activity for the left hemisphere in pain and pleasure condition (vs. neutral) with ($F(1,15) = 3.53$, $p=.08$) and diminishing activity in the right hemisphere for all conditions.

The same effect reaches significance over parietotemporal areas $F(2,14)=3.919$, $p = .045$ and was traced back to a significant lateralization of gamma on the left hemisphere in the pain condition ($F(1,15)=4.607$, $p=.049$). The observation of gamma to rise in pain conditions on the left hemisphere in overall temporal areas was also found in studies about nociperception (Müller et al. 1999).

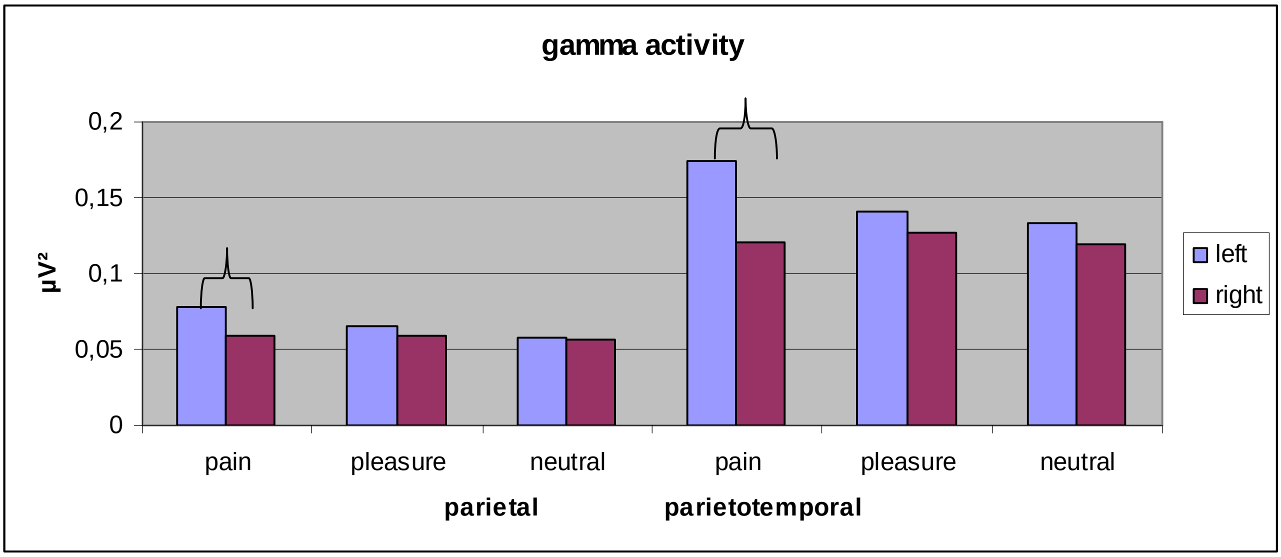

Fig. 6. Gamma activity in parietal and parietotemporal areas show significant left hemisphere power gains for the pain condition.

Discussion

Interestingly, although differences between pain and pleasure condition seem much stronger than those in comparison to the neutral condition, seldom significant effects emerge. Statistically this is due to high variation and resulting standard error of the pleasure condition data. Methodological this can also be interpreted as an overlap between non-arousing and arousing emotional stimuli, especially for some pictures containing sexual content (Aftanas et al., 2002; Tucker & Dawson, 1984). The setup of this study did not account for this discrimination and stimuli were chosen to be pleasurable, regardless of arousal level.

Delta activity showed just statistical weak associations with emotional conditions. But the found activation patterns in anteriortemporal leads showed conformity with the expected outcome, pointing to more cortical activity on the right hemisphere for negative and in special painful conditions (Bromm&Lorenz, 1998). In parietal leads however the left sided dominance for the pleasure condition was not expected. For arousing (affective vs. neutral) stimuli right sided posterior activation would have been more likely. The great power values and weak statistical relevance seem to suggest that delta activity might still be confounded with eye blink artifacts even after rejection procedures (Chen, Liu,Wang & Arendt-Nielsen, 2006; Chen & Rappelsberger, 1994).

Slow theta1 activity also had a strong overall power and only two weak tendencies to discriminate between emotions. But here also, activation confirmed expected anteriorfrontal and frontal right hemisphere dominance for negative stimuli. Interestingly however, this time pain related and neutral stimuli evoked more activation than pleasure related stimuli. Neutral stimuli tended to display the same activation as pain related stimuli, pointing to some unknown relation of both categories. From previous findings on slow theta1 activity a rise in right parietal areas for positive or neutral condition (resembling inactivity) would also have been expected (Crawford, Clarke & Kitner-Triolo, 1996). Missing effects and low statistical distinctiveness could here still also be due to confounding with unfiltered slow eye blinks.

Fast theta2 band tendency to rise in positive (vs. neutral) conditions over both hemispheres in posterior areas are not an expected finding. Previous research contributed evidence that theta2 activity is related to processes associated with active inhibition (Crawford, Clarke & Kitner-Triolo, 1996) what would have been more reasonable for negative stimuli, but not for positive. On the other hand pleasant stimuli depicting sexual content could well have triggered avoidance related behavior like looking away that has to be actively inhibited. Expected increased activity in right hemisphere for both theta bands in painful condition (Chen et al 1989) omitted, as well as increased activity in left prefrontal areas in positive conditions as discovered by Schutter et al. (2001). The parietotemporal finding however was only extremely weak and the occipital finding was also above the reasonable threshold for significancy ($p=.12 > .1$) so all discussed issues could also be attributed to chance.

Alpha1 was the first band that significantly discriminated between emotional conditions. But although a significant drop in alpha activity for the pain condition occurred, it did not show the right hemisphere dominance that has been predicted. Although studies of nociperception found global decrease in alpha rhythm for painful conditions (Bromm&Lorenz, 1989) it would have been more characteristic for alpha activity to drop significantly stronger in right hemisphere with arousing negative stimuli in the current setting (Aftanas 2001a,b; Crawford, Clarke & Kitner-Triolo, 1996; Davidson et al., 1990; Heller, 1993; Sarlo et al., 2005). Alpha1 band has also been found to be related with attentional processes (Niedermeyer, 2005; Klimesch 1999) but the here found activation over central areas could also be associated with rolandic mu rhythm, which emerges from out the motor cortex. Due to the fact that subjects had to evaluate a given stimulus afterwards as being associated with pain or not with a mouse driven cursor on a visual analog scale, anticipation of right hand movement would be capable to produce rolandic mu desynchronizatin on left hemisphere (Cheng et al., 2008; Niedermeyer, 2005). Because of painful stimuli are clearly and fast judged as being related to pain in contrast to neutral stimuli, the aforementioned process seems realistic in this setting. Perhaps this effect is also responsible for the significant both hemisphere drop of alpha activity found on frontal regions for alpha2 and the corresponding tendencies for frontal and parietal alpha1 activity. Other studies assessed stimulus valence in a pretest via SAM scales (Bradley&Lang, 1994) which have several dimensions, so that a distinct body movement associations should not occur.

In spite of these findings for central, parietal and frontal areas, anteriortemporal areas of alpha1 and alpha2 band showed predicted desynchronizations in activity for negative stimuli over right hemisphere. Although alpha2 band also showed confounding with mu rhythm as already discussed, these findings clearly indicate that experimental conditions did induce emotional states as being intended. Further contributing to this, parietal and parietotemporal gamma activity rose in left hemisphere in the pain condition. This is not in line with the posterial-right-assumption of valence models for arousing stimuli (Heller, 1993) but compromises with more specific findings concerning emotiogenic pictures and gamma activity (Müller et al., 1999). These researchers also found increased gamma activity in left temporal sites for negative valenced pictures originating from the IAPS. On the other side these researchers also stated that emotional processing enhanced gamma band power at right frontal electrodes regardless of the particular valence as compared to processing neutral pictures, what was not be replicated in this study.

Additionally rising gamma activity is associated with arousal (Aftanas&Golosheykin, 2005) and processes of binding sensory information and sensomotoric integration (Niedermeyer, 2005; Müller,Gruber & Keil, 2000). Therefore the rising activity could perhaps be attributed to associating the painful situation depicted in chosen negative stimuli on the own body.

Finally also beta activity contributed to the reactivity of brainwaves to distinct emotion. On parietal areas higher beta1 activity in pleasure vs pain for both hemispheres emerged. But this finding is not to find back in the literature and even contradicts partially results from other studies that suggest increased beta activity in right parietal areas with greater withdrawal (Schutter, 2001) or perception of actual pain (Bromm&Lorenz, 1998). Expected activity in right frontal and left central areas for negative emotions (Crawford, Clarke & Kitner-Triolo, 1996) did not occur. Instead frontal leads showed rising beta1 activity for affective stimuli (vs. neutral) in the left hemisphere while on occipital areas more beta2 was found for right hemisphere in the pain condition. The last finding partially contributes to the stated activity of right posterior sites in higher arousal level. But because pleasure related stimuli were supposed to be also arousing, both affective conditions should have evoked this activity.

Methodological implications and limitations. The present study found a couple of results referring to emotion for each frequency band. From a statistical point of view looking for hemispherical asymmetries at 8 frequencies over 6 caudalities implicates a good possibility to find relevant findings by chance. Although found results are in most instances in line with previous studies, the statistical power of the found results is too weak to endure an appropriate adjustment to confidently cancel out chancemarketing.

There are two main differences to similar studies (Aftanas et al., 2001a,b, 2002, Müller et al., 1999), that could account for the somewhat different findings discovered here. Subjects in the present study did not pre-evaluate the chosen stimuli by SAM scales themselves. This could be a critical point, because in evaluating a stimulus picture as belonging to a distinct category of emotional valence subjects were more likely to generate the corresponding affection in the test trials. With the already discussed possibility that the presented visual analog scale might produce confounding mu rhythm, future studies should involve the SAM method to evaluate the valence of stimuli.

Another point of interest is the choice of electrode reference. Previous similar studies referenced to the tip of the nose (Aftanas et al., 2001a,b,2002,2006) or Cz (Müller et al., 1999). The presented study used a common average reference, but some researchers suggest this reference to be suboptimal for tracing asymmetries in frequency analyses (Junghöfer, Elbert, Tucker & Braun, 1999; Yao et al., 2005).

Recent literature also suggests that the processing and cortical representation of emotiogenic stimuli can be modulated by corresponding individual traits (Harmon-Jones, 2007; Tomarken et al., 1990). If the 'affective style' of individuals is an important factor in how far they react to emotional stimuli, then controlling for that trait is crucible to analyze data properly.

Some researchers suggested to present negative stimuli always after positive ones, for negative effects tend to persist for longer timer periods than positive (Davidson et al.,1990). The presentation of the emotiogenic stimuli in a complete randomized order could therefore also have been suboptimal to evoke the wished emotions. Previous studies using IAPS pictures however reported no problems regarding this procedure (Aftanas et al., 2001a,b; Müller et al., 1999; Ogino et al., 2006).

To gain better interindividual comparability the FFT data could have been 'normalized' and individual alpha frequencies (IAF) as supposed by Doppelmayret al. (1998) could have been assessed as in other similar studies (Klimesch, Schimke&Pfurtscheller, 1993; Aftanas et al., 2001).

In summary the presented study found significant differences in cortical representations of distinct emotional conditions as induced by IAPS pictures. Evidence contributing to theories which link prefrontal right sided activity to negative emotion and left sided activity to positive emotions could be found in form of alpha desynchronization and tendencies for Delta and theta1 asynchronies only. Beta and gamma band also significantly distinguished emotional states but not in line with introduced theory. Effects and tendencies to effects were found through all frequency bands and scalp areas suggesting emotional processing to be represented in wide spread cortical network. A found drop in alpha activity over central and frontal areas was attributed to rolandic mu rhythm assumingly originating from anticipation of right hand movement, suggesting to abandon ongoing use of digital visual analog scales in EEG measures for further research.

Future studies are necessary to discover the underlying processes of widespread cortical activation and integrate the different frequency band dynamics to a consisting framework.

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