PRE-ATTENTIVE CHANGE DETECTION OF EMOTIONAL FACIAL EXPRESSIONS: EFFECTS OF DEPRESSION AND A SHORT PSYCHOLOGICAL INTERVENTION - AN ERP STUDY

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ABSTRACT

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The aim of this study was to examine the pre-attentive change detection of emotional facial expressions by measuring event-related potentials (ERPs) using an electroencephalography (EEG). The ERPs of two groups: depressed and non-depressed were compared. Also the effect of a short psychological intervention to the ERPs was studied. Seven universal expressions were used as stimuli in five experiments. In one experiment all the seven universal expressions were presented with equal probability (p=0.14). The four other experiments used an oddball paradigm i.e. condition in which a neutral expressions was shown as frequent (p= 0.80) and sad or happy expressions as infrequent (p=0.20) stimulus and vice versa were applied. The face specific N170 component was analyzed from 18 depressed and 10 non-depressed participants. The depressed participants were divided into two groups: an initial treatment group and a waitlist control group. The EEG measurement was done for both groups before the initial treatment group's therapy intervention. The second EEG recording was done after the initial treatment group finished their therapy intervention five weeks later. Results of the equal probability condition showed that ERPs of emotional expressions elicit stronger N170 amplitudes than neutral ones. In the odd-ball experiments no differences between sad and neutral expressions were found. When neutral and happy expressions were used, happy expression always elicited stronger amplitudes than neutral expressions regardless of its prevalence (frequent p=0.80, infrequent p=0.20). The non-depressed participants got longer latencies to infrequent happy expressions on the right hemisphere compared to the left but no such hemisphere discrimination was found in the depressed participants. In the frequent happy and infrequent neutral face condition N170 amplitudes of the depressed participants on the right hemisphere were found to be stronger compared to the left, no such discrimination was found among the non-depressed controls. The BDI and SCL-90 inventories predicted 20-29 % of the variation of the emotional ERPs suggesting that depression symptoms might affect the brain's emotional processes. However the therapy intervention was not found to affect the ERPs of the depressed participants in this small sample.

Keywords: depression, electroencephalography (EEG), event-related potentials (ERP), N170 component, universal facial expressions, mismatch negativity (MMN).

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Tämän tutkimuksen tavoitteena oli tutkia aivojen esitietoista muutoksenhavaitsemiskykyä mittaamalla tapahtumasidonnaisia herätevastepotentiaaleja (ERP) elektroenkefalografiassa (EEG), käyttäen ärsykkeenä emotionaalisia kasvonilmeitä. Tutkimuksessa verrattiin kahden ryhmän: masentuneiden sekä ei-masentuneiden - ERP vasteista. Lisäksi tutkimme psykologisen lyhyt intervention vaikutuksia koehenkilöiden ERP vasteisiin. Tutkimuksessa käytettiin ärsykkeinä seitsemään universaalia kasvonilmettä, viidessä eri koeasetelmassa. Yhdessä koeasetelmassa kaikilla seitsemällä kasvonilmeelle oli yhtä suuri todennäköisyys esiintyä (p=0.14). Neljässä muussa koeasetelmassa käytettiin niin sanottua oddball paradigmaa, jossa neutraali kasvonilme esitettiin usein (p=0.80) ja surullinen tai iloinen ilme esitettiin harvoin (p=0.20). Sama asetelma toistettiin myös päinvastaisella ärsykejärjestyksellä. Kasvoherkkää N170 vastetta analysoitiin 18 masentuneelta ja 10 ei-masentuneelta koehenkilöltä. Masentuneet koehenkilöt jaettiin kahteen ryhmään: heti hoidon aloittavaan ryhmään sekä odotuslista eli kontrolliryhmään. EEG tutkimukset toteutettiin kaikilla koehenkilöillä ennen lyhytinterventiota sekä viisi viikkoa myöhemmin. Kontrolliryhmä sai intervention toisen EEG tutkimuksen jälkeen. Kaikilla seitsemällä universaalilla kasvonilmeellä ollessa sama esiintymistodennäköisyys (p=0.14) emotionaaliset kasvonilmeet synnyttivät suurempia N170 vasteen amplitudeja kuin neutraalit kasvonilmeet. Oddball kokeessa eroja ei löytynyt surullisten ja neutraalien kasvonilmeiden välillä kummallakaan ärsykejärjestyksellä. Sen sijaan kun neutraalia ja iloista kasvonilmettä esitettiin, iloinen kasvonilme sai aina aikaa suuremman amplitudin kuin neutraali kasvonilme riippumatta sen esiintymistodennäköisyydestä (p= 0.20 tai p=0.80). Ei-masentuneilla koehenkilöillä latenssit olivat pidempiä oikealla aivopuoliskolla kun iloinen kasvonilme esitettiin harvinaisena (p=0.20) ärsykkeenä, kun taas masentuneilla tällaista puolisuuseroa ei ollut havaittavissa. Vastaavasti kun iloinen kasvonilme esitettiin ärsykkeenä usein (p=0.80) ja neutraali kasvonilme esitettiin harvinaisena (p=0.20) ärsykkeenä, masentuneilla havaittiin suurempia N170 amplitudeja oikealla aivopuoliskolla verrattuna vasempaan. Ei-masentuneilla tällaista puolisuus eroa ei havaittu. BDI ja SCL-90 kyselylomakkeiden mukaan pystyimme ennustamaan 20–29% emotionaalisten kasvonilmeiden synnyttämistä ERP vasteista. Toisin sanoen masennusoireet heijastelevat muutoksia N170-komponentissa kun ärsykkeinä käytetään emotinallisia kasvonilmeitä. Viiden viikon terapia intervention ei kuitenkaan havaittu vaikuttavan masentuneiden koehenkilöiden ERP vasteisiin tässä aineistossa.

Avainsanat: masennus, tapahtumasidonnaiset herätevastepotentiaalit (ERP), elektroenkefalografia (EEG), N170 komponentti, universaalit kasvon ilmeet, poikkeavuusnegatiivisuus (MMN).

CONTRIBUTIONS

Raimo Lappalainen (Prof.) and Piia Astikainen (Ph.D.) were responsible for organizing and supervising the present study. Lappalainen planned the intervention together with Heidi Kyllönen (M. Psych) and instructed the students who gave the psychotherapy intervention. These students with Kyllönen were responsible for gathering and analyzing the survey data. Astikainen planned the EEG experiments and supervised the gathering, analyzing and reporting of the ERP data.

In addition to this master's thesis, the following authors have completed or are preparing their master's theses using the same participant sample, but different data:

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1. INTRODUCTION

Facial expressions represent an important and highly automated part of non-verbal communication in our daily life (Cauquil, Edmonds & Taylor, 2000; Batty & Taylor, 2003). Expressions are a way of communicating with other people telling others the state of mind the person is in (Batty & Taylor, 2003). During the course of evolution facial expressions have made human behavior more adaptive by creating means to understand the attitudes and feelings of other people from a distance. It is important to study the mechanisms behind the facial perception, because expressions are an important part for social behavior.

Depression is the most common mood-disorder in the world. It's prevalence in Finland is about 5% according to the Terveys 2000 –study. Depression causes problems for the individual suffering from it as well as to the general public. The economic burden of depression for the Finnish economy according to KELA is approximately 1.3 billion euros, causing about 4000 people per year to drop out of work (Raitasuo & Maaniemi, 2008).

Facial expressions are linked to depression in many ways. According to a review study made by Bourke, Douglas and Porter (2010) depressed participants seem to have a negative response bias to facial expressions. This bias affects the facial perception, so that positive, neutral or ambiguous facial expressions tend to be evaluated more negatively among the depressed patients compared to normal controls. Furthermore the depressed patients seem to have selective attention toward sad expressions and away from happy expressions. (Bourke, Douglas & Porter, 2010.)

Short therapy interventions like the Acceptance and Commitment therapy (ACT) have been found to improve the quality of life of the people suffering from depression (Smith & Glass, 1977). It seem that therapy interventions are equally affective in curing depression as medication is, but in addition therapies reduce the risk of relapses (DeRubeis et al. 2008). Keeping this in mind in the long run short term therapy interventions might be a better and cheaper cure for depression compared to long lasting therapies or medication.

1.1 The Neural Basis of Facial Perception

Human facial recognition is divided into two systems according to the distributed human neural system for face perception –model created by Haxby, Hoffman and Gobbini (2000) (fig.1). First the core system consists of three brain regions: the inferior occipital gyri, the superior temporal sulcus and the lateral fusiform gyrus. The task of the core system is to code the low-level features of faces, like the eyes and movement. Second the extended system continues the perception process by coding the emotions and personality of the face. The extended system consists of the intraparietal sulcus, amygdala, insula, limbic system and the anterior temporal. (Haxby, Hoffman and Gobbini, 2000; Haxby, Hoffman and Gobbini, 2002.)

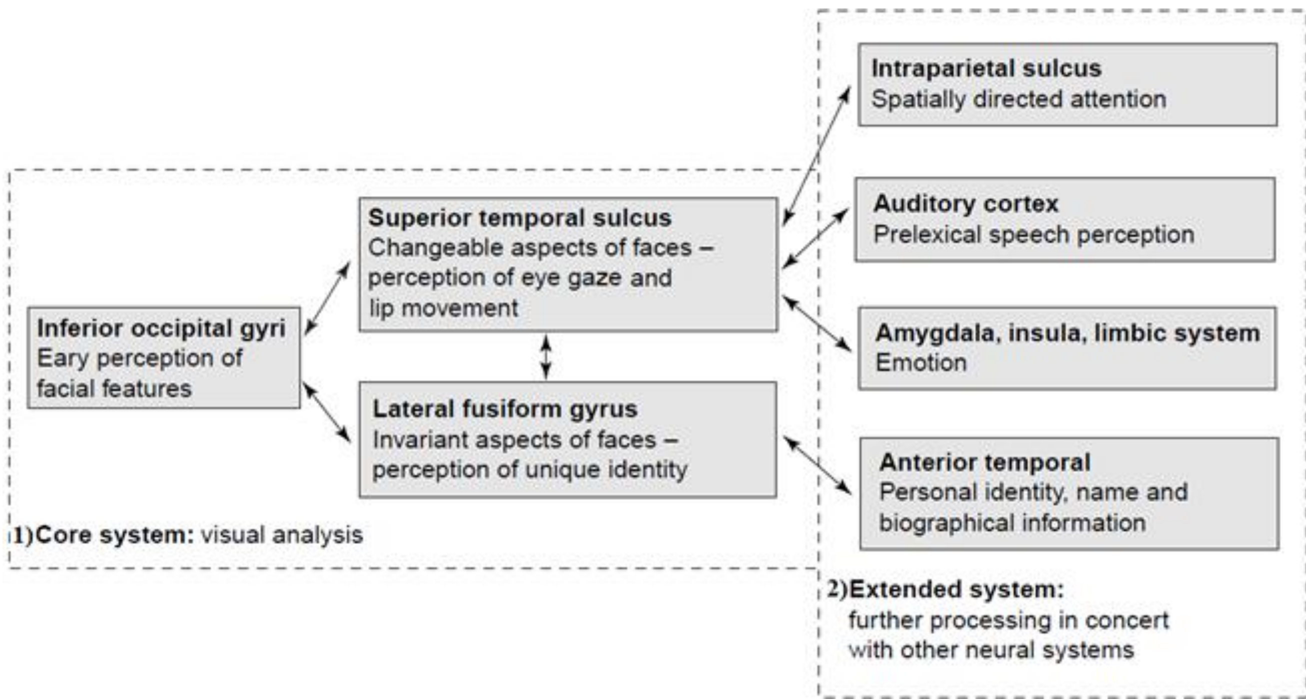

Fig. 1. A model of the distributed human neural systems of face perception –model according to Haxby, Hoffman and Gobbini 2000 and 2002.
1) The core system consists of three brain regions that make the initial visual analysis of the face.
2) The extended system consists of four brain areas taking the processing of facial perception further.

According to several brain imaging studies multiple brain areas activate within milliseconds after pictures of emotional faces are presented to participants. For example Compton's (2003) findings argue that emotional values of facial stimuli are encoded automatically within the first 100-300ms after the stimuli. The activating brain areas include the amygdala, basal ganglia and the insula. Furthermore the cigulate sulcus and the orbitofrontal areas activate to some emotional facial stimuli. (Adolps, Tranel, Damaslo & Damasio, 1994.)

The neural areas processing emotional facial stimuli usually overlap with multiple cerebral areas activating during the processing of emotional stimuli. For example the amygdala seems to activate during the processing of fearful facial expressions (Phillips et al. 1997) as well as the sad facial expressions (Blair et al. 1999). According to Phillips et al. (1998) happy facial expressions increase the activity of the cingulate sulcus and gyri (Phillips et al. 1998). Blair et al. (1999) found that angry expressions enhance the activity in the orbitofrontal and anterior cingulate cortex. Finally disgust has been found to activate the anterior insula, right putamen and the thalamus (Phillips, 1998). The findings mentioned above point out a difficulty to name one single neural area to be responsible for processing emotional facial expression. Instead it seems that multiple neural areas of the extended system (fig. 1) contribute to the perception of different facial affects.

1.1.1 Event-Related Potentials Measured by Electroencephalography

Electroencephalography (EEG) is a measurement of multiple currents that flow during the synaptic excitations of dendrites. Multiple pyramidal neurons need to activate in the cerebral cortex to make EEG measurements possible. When a stimulus causes neurons to activate, synaptic currents are produced within the dendrites. It is this current that generates an electrical field over the scalp that is then measurable by an EEG-system (Sanei & Chambers, 2007). In other words a large number of action potentials sum up in the brain causing voltage fluctuations that can be measurable by the EEG-system.

Different types of electrodes are used in an EEG recording system. Typically EEG recordings are measured using an electrode caps. The currents measured by electrodes are magnified with an amplifier making analyses of small changes in the current possible when the responses of hundreds of stimuli are summed together and then averaged.

Event-related potentials (ERP) are EEG response’s that measure the electrical response to certain sensory, affective and/or cognitive events. ERP’s are voltage fluctuations in the EEG induced in the brain as a sum of a large number of action potentials. These potentials are time locked to sensory, motor or cognitive events (Sanei & Chambers, 2007).

The ERP waveform can be quantitatively characterized in three main dimensions: amplitude, latency and scalp distribution (Johnson, 1992). First the amplitude provides an index of the magnitude of neural activity i.e. how neural areas responds functionally to the stimulus used in the experiment. Second the latency is a time point where peak amplitude occurs, revealing the timing of the activation. The ERP signals can be either positive (P) such as the P300 or negative (N) such as the N100. The digit after the letter P or N indicates the time of the component in milliseconds after the stimulus. Third scalp distribution provides a pattern of the voltage gradient of a component over the scalp at any time instant. (Sanei & Chambers, 2007.) Our main interests in this study are the amplitudes and latencies of the ERP's. It should also be noted that other more advances methods for EEG analysis have been developed, such as time-frequency analysis or independent component analysis. However these methods have not been applied in this study.

1.1.2 The Face Specific N170 Component

The N170 component is a negative ERP that has a peak at 140 - 170ms after the stimulus reflecting the neural processing of faces (Haxby et al., 2002). Several studies have demonstrated that the N170 elicits to pictures of human faces while other pictures (for example: animal faces, human hands) did not elicit the N170 or its amplitude was significantly smaller. These finding suggests that the N170 is sensitive to human facial detection rather than other general information. (Bentin et al., 1996; Rossion, Joyce, Cottrell & Tarr, 2003; Itier & Taylor, 2004.) Early stages of facial processing indexed by the N170 are automatic and unmodified by selective attention. That is to say they are pre-attentively processed. (Cauquil et al., 2000.)

Facial expressions appear to be encoded within the first 300ms after the stimulus (Balconi & Pozzoli, 2003; Campanella, Gaspard, Debatisse & Bruyer, 2002). Campanella et al. (2002) have reported that ERP components like the negative N170 and the positive P300 to be sensitive to categorizing different facial expressions. According to multiple studies positive and negative emotions evoke earlier N170 component than neutral emotions (Betty & Taylor, 2003; Luo et. al., 2009; Astikainen & Hietanen, 2009) i.e. the latencies of emotionally loaded facial expressions (positive or negative) are shorter than those of the emotionally neutral faces.

The N170 component causes bilaterally observable negative amplitude on both sides of the hemisphere. This negative amplitude was found to be significantly larger in the right hemisphere compared to the left. (Bentin, Allison, Puce, Perez & McCarthy, 1996.)

1.2 Seven Universal Facial Expressions

There are six universal emotional facial expressions in addition to the neutral expression that are recognized in different cultures around the globe (Ekman, 1971; Ekman & Friecen, 1971; Ekman & Friecen, 1976). These six universal expressions are: happy, fearful, sad, disgust, surprise and anger.

Ekman's (1971) studies have pointed out that people can judge pictures of emotions shown to them attentively. Later brain imaging studies have found that facial affects can also be processed pre-attentively (Cauquil et al., 2000). Batty & Taylor (2003) found that happy facial affects are processed faster than negative facial affects. This so called happy face advantage has also been found in other studies (Kirita & Endo, 1995; Leppänen & Hietanen, 2004). Astikainen and Hietanen (2009) showed that happy faces elicits earlier N170 component than negative ones. ERP's of fearful and happy faces have been found to elicit more negative amplitudes in the N170 components than faces with a neutral or surprised expression (Batty & Taylor, 2003). This brings us to the first objective of this study: do the ERP's of seven universal facial expressions produce different amplitudes or latencies in the N170 component when presented with equal probability ($p=0.14$)?

1.3 Change Detection Measured by Mismatch Negativity Paradigm

The mismatch negativity (MMN) component indicates that the brain has detected a change in the background of homogenous events (Sanei & Champers, 2007). The MMN reflects the difference elicited by repetitive frequent (standard) and infrequent (deviant) stimulus in the series of multiple stimuli. It has been established that the MMN is generated by a discriminative process detecting any changes in sequences of stimuli using traces developed by the previous stimulations i.e. it is related to the automatic memory based processing mechanisms (Näätänen & Winkler, 1999). Mismatch negativity is most clearly seen by subtraction of the ERP elicited by the frequent stimulus from the ERP elicited by the infrequent stimulus. MMN can be found for any distinguishable change happening for example in visual or auditory stimulations regardless of the subject's attention or behavioral tasks. (Näätänen, Pakarinen, Rinne & Tekegata 2004.)

MMN is typically recorded in an oddball paradigm, for example in a sequence of auditory stimuli: infrequently occurring deviant sounds are interspersed amongst frequently occurring standard sounds. Meanwhile the subject attention is directed elsewhere, by asking them to carry out for example a visual task like watching a video. (Michie et al., 2000; Näätänen, Gaillard & Mäntysalo, 1977.)

Mismatch negativity can be found in the visual modality as mentioned above. Visual mismatch negativity (vMMN) has been reported for example to changes in color (Czigler, Balazs, & Winkler, 2002), objects' orientation (Astikainen, Lillstrang & Ruusuvirta, 2008) and motion direction changes (PazoAlvarez, Amenedo, & Cadaveira, 2004). Some studies also suggest that vMMN can be found for combinations of features. According to these findings the memory representations involved in the MMN change detection responses encode the infrequently occurring features that differ from the frequently occurring features (Winkler et al., 2005).

VMMN has been found to elicit with complex visual stimuli like facial expressions. Zhao and Li (2006) named this phenomena expression mismatch negativity (eMMN). They presented neutral faces as frequent stimuli and emotional faces (sad and happy) as infrequent stimuli. Both infrequently presented sad and happy emotional faces elicited more negative amplitudes than frequently presented neutral faces. Furthermore the amplitudes elicited by sad faces where more negative than those elicited by happy faces making the vMMN between the neutral and sad expression seem greater than the vMMN between the neutral and happy expression. (Zhao & Li, 2006.) Astikainen and Hietanen (2009) found a vMMN while using Ekman's & Friesen's (1976) neutral faces as frequent stimuli and fearful or happy faces as infrequent stimuli, but in contrary to Zhao and Li (2006) they found no difference between the amplitudes of the two emotional (fearful and happy) expressions. Stefanics et al. (2011) used fearful and happy faces in their odd-ball experiment. They found vMMN to infrequently presented affect (fearful or happy) when compared to frequently presented affect (fearful or happy).

As mentioned above it has been found that the N170 components amplitudes and latencies change in MMN paradigm experiments when frequent and infrequent stimuli are used. Thus it is reasonable to study the changes in the N170 component using an MMN paradigm. We are interested to find out if the N170 component can detect any changes on a sequence of emotionally loaded facial stimuli using traces developed by the previous stimulus. We hypothesize that expression mismatch negativity (eMMN) can be found between frequently (p=0.80) and infrequently (p=0.20) presented neutral, happy and sad facial expressions. The second objective of our study is to find out does an eMMN occur when: 1) neutral affect are presented as frequent (p=0.80) stimuli and emotional sad and happy affects, are presented as infrequent (p=0.20) stimuli? 2) Emotional (sad and happy) affects are presented frequently and the neutral affect is interspersed amongst them?

The third objective of this study is to investigate if the prevalence of the stimuli affects the N170 component? Meaning does the N170 component elicited by ERP's of happy, sad or neutral facial affects differ if the stimuli is presented as: 1) frequent (p=0.80), 2) infrequent (p=0.20) or 3) equal probability (p=0.14) stimuli.

1.4 Depression

Depression is a clinical condition characterized by persistently depressed mood and loss of interest leading patients to distress and social impairment. Patients with diagnosed depression, suffer from despair and hopelessness. According to ICD–10 patients suffering from depression usually experience the following symptoms: lowering mood, reduction of energy and decreases in activity. The person might lose interest and pleasurable feelings reducing the capacity for enjoyment and interest. The persons concentration is reduced and the patient fatigues easily. In addition the sleeping rhythm of the patient usually gets disturbed. Also the appetite of the person decreases usually resulting to weight loss. Self-esteem and self-confidence declines making the patient feel worthlessness and guilt easily. The lowered mood of the patient usually varies only a little from day to day. Depression can lead to psychomotor retardation, agitation and loss of libido. Depending on the severity of the symptoms depression can be divided in to three categories: mild, moderate and severe. (World Health Organization.)

Depression is sometimes evaluated via self-reported psychological test inventories. One of the most popular and best known psychological depression inventory is Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock & Erbaugh, 1961). Extensive research of the BDI has been made supporting the inventory's construct validity and ability to measure symptoms and the severity of depression making it a potential tool in helping diagnose depression (Schotte, Maes, Cluydts, Doncker & Cosyns, 1997). The findings of self-reported psychological test inventories lead us to our fourth hypothesis: can we predict the responses of the N170 component with the BDI scores and three other less known inventories: The Acceptance and Action Questionnaire two (AAQ2), the Depression Anxiety Stress Scale (DASS) and the Symptom Checklist-90 (SCL-90)?

1.4.1 The Cognitive Dysfunctions in Depression

Mood disorders are usually associated with distinct pattern of cognitive impairment. It is commonly accepted that depression is associated with a diversity of different cognitive deficits like memory and learning problems (Austin, Michell & Goodwin, 2001). Some studies have found depression to impair for example the verbal and visual learning and memory (Austin et al., 2003) as well as the visuospatial memory (Potter, Gallagher, Thompson & Young, 2003).

Other problems found to be caused by depression are problems concerning the attention and executive function (Potter, Gallagher, Thompson & Young, 2003) and the ability to perceive the affective significances of visual, auditory and somatosensory stimuli (Shenal, Harrison, and Demaree, 2003). Depressed patients also make more mistakes in facial affect recognition compared to normal non-depressed control subjects. Depressed patients show overall impairment in multiple functions concerning facial stimulus leading to abnormalities in the processing of emotional information. (Mikhailova et al., 1996.)

1.4.2 Neural Deficits in Depression

Multiple studies have reported a variety of neural deficits that have been found in patients suffering of depression. First of all the depressed patients seem to have a left amygdala hyper arousal when processing unconscious stimuli (Sheline et al., 2001). Studies have found that increased amygdale activity is related to the severity of depression (Drevets et al., 1992), meaning that the more depressed the patient is the more active his amygdale is. This hyper arousal increases the salience of negative stimuli and decreases the salience of positive rewarding stimuli creating a negative bias toward negative information and away from positive information (Disner, Beevers, Haigh & Beck, 2011). Also the Hippocampus is active during the processing of emotional stimulus. Studies have found that together with the amygdala the hippocampus is associated with the biased memory for negative stimulus in depression, triggering a bottom-up regulation of the hippocampus, caudate and the putamen allowing depressive recall without the need to recruit top-down prefrontal regions. In other word depression seems to make negative recall automatic. (Disner, Beevers, Haigh & Beck, 2011.)

Abnormalities in the brain can be found during episodes of major depression. The abnormalities have been found from areas, including the frontal cortex, cingulate gyrus, basal ganglia, and temporal cortex (Lafer, Renshaw & Sachs, 1997). It seems that the depressive symptoms are caused by the dysfunctions of regions of the limbic systems, frontal lobes and the basal ganglia. Reduced blood flow and glucose metabolism is found in depressed patient's prefrontal cortex, anterior cingulate cortex, basal ganglia and the caudate nucleus, resulting to abnormal functions of attention under stress. (Videbech, 2000.)

1.4.3 Mismatch Negativity Paradigm and Depression

Information processing on the pre-attentive levels has been found to be impaired in patients suffering from major depression (MDD). The most common finding in MDD patients is the reduction of auditory P300 amplitudes and increased peak latencies to auditory stimulus (Houston, Bauer & Hasselbrock, 2003; Urretarizcaya, Moreno & Bennlloch, 2003). This increase suggests that acute MDD episodes affect the frontal brain systems, (Kähkönen et al., 2007) this most likely also has an effect on the MMN of depressed patients.

Chang, et al. (2010) found that vMMN decreases in patient suffering of depression. This indicates a dysfunction in the pre-attentive processing of emotional faces. That is most likely a deficit of the higher-level configural processing of expressions rather that lower level perceptual processing (Chang et al., 2010). Gergen and Mille (2000) found that depressed patient's right-posterior functions are compromised in tasks involving positive, neutral and negative faces compared to normal controls. This is in line with the finding made by Chang et al. (2010) that patients suffering from depression produce smaller early vMMN in the right hemisphere compared to healthy controls. The left hemisphere seems to produce an equal response in both the depressed patients and the non-depressed controls (Chang et al., 2010).

The effects of depression on the MMN have been studied earlier in the auditory and visual systems. The deficits of attention and perception in the visual, auditory and somatosensory stimuli of the depressed lead us to our fifth hypothesis: there might be a difference between the N170 component elicited by the depressed participants compared to that of the non-depressed controls.

1.5 Attachment and Commitment Therapy Intervention

Psychotherapy interventions have been found to improve the quality of life of people suffering from depression (Smith & Glass, 1977). According to DeRubeis et al. (2008) cognitive therapy is equally effective in curing depression as antidepressant medication. Furthermore cognitive therapy seems to reduce the risk of relapses in depression. This being said the results of multiple studies addressing acceptance and commitment therapy (ACT) suggest that the effectiveness of ACT appears to be equivalent to that of cognitive therapies, even though the mechanisms used in ACT are different from many other therapies. (Hayes, Luoma, Bond, Masuda, & Lillis, 2005.)

According to the ACT model as people learn language they also acquire complicated connections and causalities between different things and events. These connections can become malfunctional causing for example depression or other mood disorders. ACT is based on the relational frame theory which is a modern behavioral approach to human cognition and language. (Fletcher & Hayes, 2005; Hayes, 2006.)

ACT seems to work across an unusually broad range of problems according to the studies of Hayes (2006). The goal of ACT is to enhance psychological flexibility and enable people to make behavioral changes. Psychological flexibility consists of core processes such as: acceptance, values, being present and committed action. (Hayes, 2006.) In ACT it is important to examine language and thoughts critically and prevent their negative effects on behavior using different mindfulness and acceptance strategies (Fletcher & Hayes, 2005). There are not enough studies yet to conclude that the ACT is generally more effective than other active treatments, but many studies conclude that the methods used in ACT have produced encouraging results for treating a variety of different psychological disorders (Hayes, 2006). In this study the depressed participants received a five weeks intervention of ACT therapy as a treatment to depression.

The last hypothesis of this experiment is to find out does the five weeks ACT therapy intervention have an effect on the ERP's of the depressed participant's i.e. Is there a difference between the N170 component evoked by the visual stimulus of the depressed participants before and after the six session of ACT therapy?

1.6 Objectives of this Study

In this study we attempt to establish whether the face sensitive N170 component differs between the seven universal facial affects. Next we investigate if the N170 component elicited by neutral, sad and happy expressions reflects change detection that can be seen using an expression mismatch negativity (eMMN) paradigm. Furthermore we are concern if depression affects the N170 and the eMMN component. If so then we are interested in finding out can we influence this by giving the patients therapy?

To sum it up the six hypothesis of this study are:

1) Do the ERP's of the seven universal facial expression produce different N170 components?

2) Does the N170 component reflect change detection between frequent (p=0.80) and infrequent (p=0.20) stimuli using the mismatch negativity paradigm?

3) Does the prevalence (frequent p= 0.80, infrequent p= 0.20 or equal probability p= 0.14) of the facial expression (happy, sad, neutral) have an effect on the N170 component?

4) Can self-reported psychological test inventories (BDI, AAQ2, DASS and SCL-90) predict the N170 components evoked by the ERP's of different facial expressions?

5) Is there a difference between the N170 components evoked by the visual stimulus of the depressed participants compared to non-depressed controls?

6) Is there a difference between the N170 evoked by the facial expressions of the depressed participants before and after the 6 session of ACT therapy?

2. METHODS

2.1 Participants

The criterion to become a participant in our study was that the person had to be right handed; they had no previous depression diagnoses or other therapies going on at the moment. In addition the participants had never been diagnosed with other neurological disorders; they had a normal hearing ability and a normal vision or corrected-to-normal vision.

There were three groups of participants (fig. 2): two groups of depressed participants (initial treatment groups and waitlist group) and a non-depressed control group. The participants of the two depressed groups were diagnosed as depressed by a doctor using the criterion of ICD-10 before the EEG measurements. They also filled out four self-reported surveys (BDI, AAQ2, DASS and SCL-90). After the last EEG measurements the doctor diagnosed the two depressed groups again to see if the diagnosis had changed.

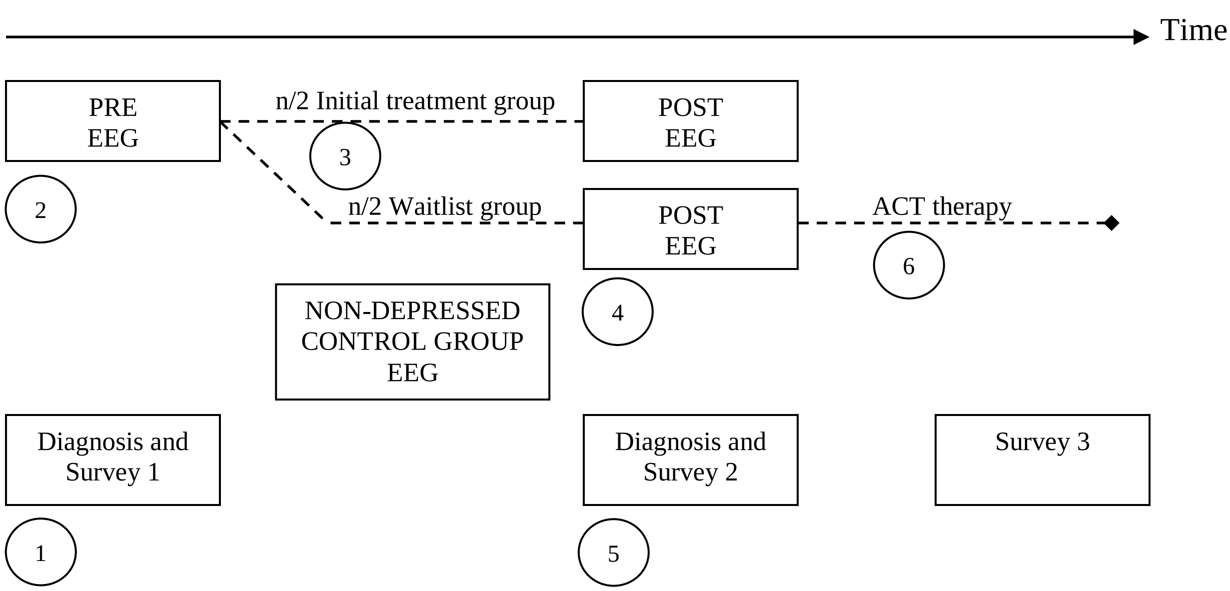

Fig. 2. Experiment procedure.
1) All participants were diagnosed by a doctor and they filled out self-reported surveys.
2) The participants had their first EEG measurement.
3) Participants were divided into the initial treatment group and the waitlist group: the initial treatment group got an ACT therapy intervention and the waitlist group didn't.
4) The depressed participants had their second EEG measurement.
5) The depressed participants had a control diagnosis made by the doctor and they filled out self-reported surveys.
6) The waitlist group got an ACT therapy intervention.

In the initial treatment group the participants got a five week therapy intervention immediately after the first EEG study and the participants in the waitlist group got their therapy intervention five weeks later after the second EEG measurement. The non-depressed control group consisted of people that didn't feel depressed and no evidence of mood declaration was found on the self-reported surveys.

2.2 Demographical information and Survey Data

The mean age of the depressed participants was 51 years and 72% of them were women. In the control group the mean age was 40 years and 80% of the participants were women. The two groups differed from each other statistically on participant age (t (26) = 2.32, p = .028).

As mentioned earlier the participants were asked to fill out four self-reported psychological test inventories before the first EEG measurement and after the last EEG measurement. All the test scores of the depressed participants where significantly higher compared to the scores of the non-depressed control group (table 1): BDI (t (33) = 8.52, p < .001), DASS (t (33) = 6.31, p < .001), AAQ-2 (t (33) = 6.35, p < .001) and SCL-90 (t (33) = 6.28, p < .001).

Table 1. The demographic and self-reported survey information from the participants chosen to this study from each group

Group	N	Age		Gender *	BDI**		DASS**		AAQ2**		SLC90**	
		M	SD		M	SD	M	SD	M	SD	M	SD
Initial treatment group	10	52	10.41	70 %	22.50	8.81	41.50	19.42	41.90	10.40	97.40	50.44
Waitlist group	8	50	13.31	46 %	16.88	6.24	28.63	15.48	40.63	11.49	69.25	25.51
Control group	10	40	12.40	80 %	2.20	2.57	6.50	5.80	61.30	5.40	14.00	16.91

* % Female
** Before the first EEG measurement

2.3 Stimulus Types and Procedure

In this study Ekman's and Friesen's seven Pictures of Facial Affect (1976) were used as stimuli. Four different actors were used of which two were male and two were female (female actors NR and PF, male actors EM and JJ). Seven universal expressions from each of the four actors were used i.e. 28 different pictures were used. The pictures were black and white and they were presented against a dark background on a 23' Asus vg 236 series H monitor with a 2ms delay. The resolution of the monitor was 1920 x 1080, the aspect ratio was 16:9 and the refresh rate was 120 Hz. The participants sat approximately one meter away from the screen on a wooden chair. The room was well-lit. The participants were instructed to keep their gaze on the center of the monitor. Then participants were asked not to pay any particular attention to the pictures presented. Instead of paying attention to the pictures the participants were told to keep their attention on the audio book playing Helge Herala's: Elämään sateenkaaren alla –story. The audio book was played with the Philips DVD player DVP3580 through a Yamaha MPS 5 speaker. The experiments where constructed like this because we were interested in the visual task irrelevant change detection of the participants. To be able to measure this, a demanding primary task is needed according to the MMN paradigm. The participants were told that at the end of the experiment a question concerning the story was going to be asked to test that the participant had listened to the story.

The first experiment consisted of the seven universal facial expressions (happy, fearful, sad, disgust, surprise, anger and neutral) found by Ekman (1976). This experiment was named the 7exp experiment. The expressions were presented in random order and the probability of each expression was one in seven (p=0.14). Each picture was shown for 200ms at a time and between each picture a 500ms stimulus onset asynchrony (SOA) (empty black screen) was presented (fig. 3). The time interval was short (200ms) because we were interested in the pre-attentive change detection of the participants. Each of the expressions was shown 80 times (20 times/actor). In total 560 pictures were presented in random order.

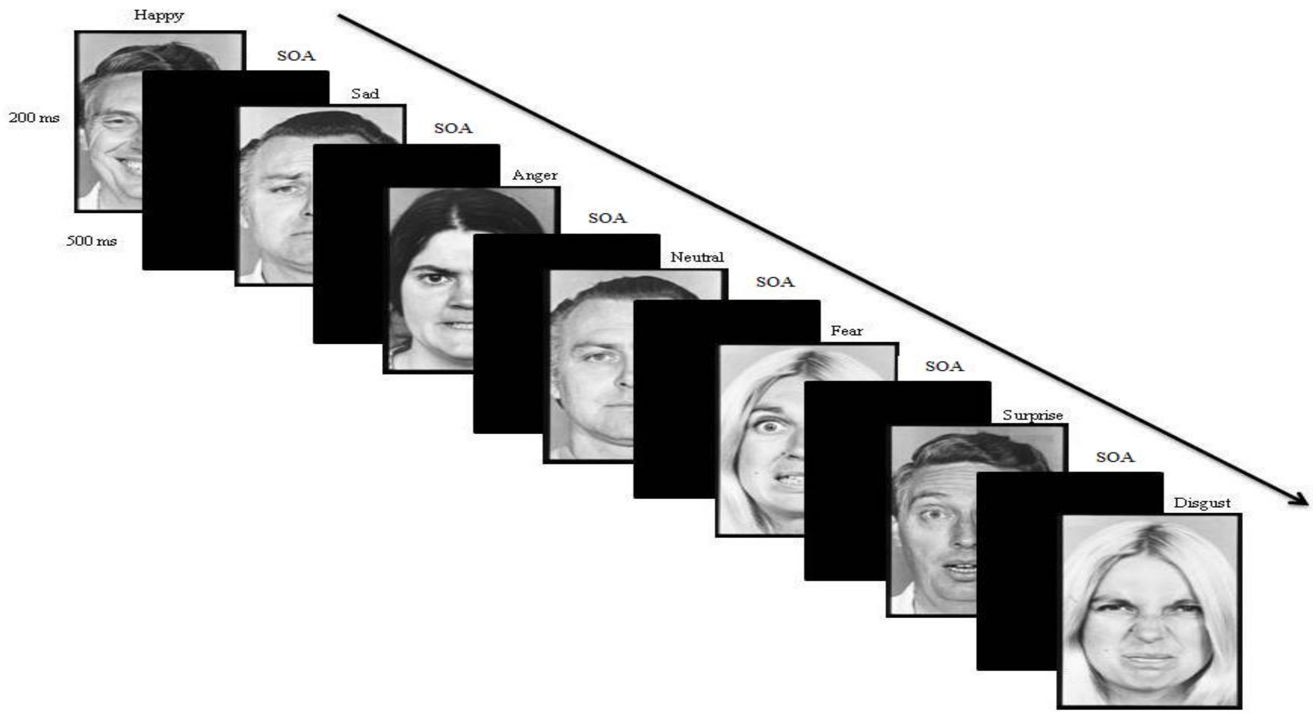

Fig. 3. Experiment one: seven universal facial affects shown in a random order for 200ms at a time with a 500ms stimulus onset asynchrony in between. (Copyright by Ekman, 1976. Reprinted with permission.)

In the other four experiments a so called oddball paradigm was used. In the oddball paradigm frequently presented standard stimuli are randomly replaced by infrequently presented deviant stimuli. The infrequent stimuli differed from the frequent stimuli in one or more ways. In this study the pictures differ from each other for example by sex, personality and the emotional affect presented, making these changes higher level changes that are encoded by the extended system mentioned earlier (fig.1).

The pictures in experiment 2-5 were shown to the participants for 200ms at a time. After every picture a 500ms SOA was shown. The pictures were presented in quasi-random order so that between each infrequent stimulus at least two frequent stimuli were presented (fig. 4). A total of 560 pictures were presented in every experiment so that the frequent stimuli were presented 480 times and the infrequent stimuli were presented 80 times. The probability for a frequent stimulus was 0.80 and the probability for the infrequent stimulus was 0.20. Each experiment lasted for about 8 minutes and after each experiment a short brake was taken, enabling the participants to move and change position.

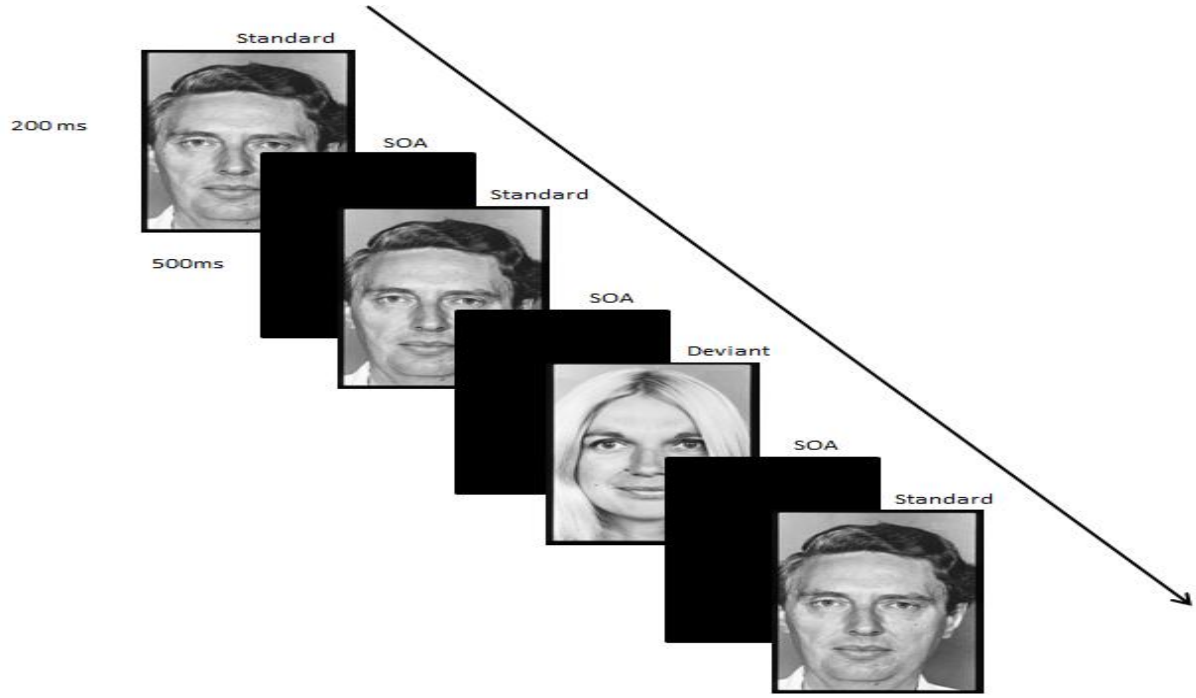

Fig. 4. Experiments 2-5: An infrequently shown expression appears amongst frequently shown expressions. Pictures with different expressions are shown for 200ms and in between each affects a 500ms stimulus onset asynchrony was presented. (Copyright by Ekman, 1976. Reprinted with permission.)

In conclusion the five different experiments used in this study were the following:

1) The first experiment consisted of seven facial expressions occurring with an equal probability (p=0.14). This experiment was thus named here as the 7exp experiment

2) The second experiment consisted of frequently (p=0.80) occurring neutral facial expressions and infrequently (p=0.20) occurring sad facial expressions. This experiment was named $\mathrm{Neu_F Sad_I}$.

3) The third experiment was the opposite of the second one. The sad facial expressions were shown frequently (p=0.80) and neutral expressions was shown infrequently (p=0.20) and it was named $\mathrm{Sad_F Neu_I}$.

4) The fourth experiment was arranged so that neutral facial expressions were frequently (p=0.80) shown and amongst them happy faces were shown infrequently (p=0.20). This experiment was named $\mathrm{Neu_F Hap_I}$.

5) The last experiment was the opposite of the fourth experiment. It consisted of frequently (p=0.80) occurring happy facial expressions and infrequently (p=0.20) occurring neutral facial expressions ($\mathrm{Hap_F Neu_I}$).

All the five experiments were randomized for every participant separately so that the 7exp experiment was always presented as first or last. The other experiments were fully randomized.

2.4 EEG Recordings

Electroencephalography was recorded by Geodesic Sensor Net model HydroCel GSN (HCGSN) (Appendix A). The net consisted of 128 channels (Geodesic Sensory Net, 2007). The amplifier used to amplify the electric activity of the brain was NET AMPS 200.

The impedance of the electrode net was maintained below 80kΩ. The sampling rate was 1000 samples per second. The data was collected using Net Station EEG –software version 4.2.1 on a Mac G5 power Mac. The stimuli were presented with the E-Prime software version 2.0.8.90 with a Dell 5500 computer.

The EEG data was analyzed using Brain Vision Analyzer 2.0-software. The analysis of the data began by deleing all the channels that were not measuring appropriately. Next a 23ms time sift was performed to the markers because the computer playing the stimuli had a graphic card that had a 23ms delay. The ocular correction was made using the Gratton & Coles algorithm (Gratton, Coles & Donchin, 1983). The VEOG method was used in making the ocular correction and the electrode 8 or 25 was used as a reference electrode. Next the raw data inspection was made automatically using the individual cannel mode. The computer marked the gradient as bad if the maximal amplitude step was higher than 100 microvolt's (μV) per millisecond. If this condition was met the program marked the data as bad on a time interval of 150ms before and after the gradient. After this the filters were set to the data using the IIR (infinite impulse response) filter, to reduce the effects of the background noise. The Low cut off frequency was set to 0.1Hz and the high cut off was set to 30 Hz. The slope was set to 24 decibel per octave. The notch filter was set to 50 Hz to erase the effects of the main current.

The segmentation of the 7exp experiment was created using the marker positions of each expression. To ensure that every expression was divided into a separate segment a time window of -200ms to 500ms was used. Overlaps were made possible. In other words seven different segments were created. Next a baseline correction was made from -200ms to 0ms before the stimulus to make the calculation of the mean possible. The mean was calculated for every expression separately. The mean values that contained over 56 segments (70%) were chosen for further analysis. Finally the peak detection was made for all the seven means. Analyzer 2.0 made an automatic peak detection searching for the global maxima in the interval during 100-200ms after the stimulus to make sure that the N170 component was found. The search was made separately for every chosen cannel: from the left hemisphere the electrodes: 56, 57, 59, 63 and 64 and from the right hemisphere the electrodes 95, 96, 99, 100 and 107 were chosen.

The segments for experiments 2-5 (oddball) were created using the marker positions. Makers in the data consisted of frequent standard stimuli and infrequent deviant stimuli. The segmentation of the data was made in 4 steps. In the first segmentation the infrequent and frequent stimuli were divided into their own segments using the time window of -200ms to 1600ms. This ensured that all stimuli marked as infrequent stimuli (groups of three) were separated from all the rest of the frequent stimuli. Each infrequent stimuli group now consisted of the following stimulus lining: frequent-infrequent-frequent –stimuli (fig. 5 Step 1). During the second segmentation all the infrequent stimuli groups were segmented using the time window of -200ms to 500ms to ensure that each segment had one frequent stimulus and one infrequent stimulus, overlaps were made possible (fig. 5 Step 2). Next a baseline correction was made -200ms to 0ms before the stimulus to make the calculation of the mean possible. Two mean values were then calculated using the even-odd model (even = infrequent and odd = frequent) of analyzer to calculate a mean to both the frequent stimuli and the infrequent stimuli. Mean values that contained over 56 segments (70%) were chosen for further analysis (fig. 5 Step 3). In the final step of segmentation a peak detection was made for the two means: frequent and infrequent. Analyzer 2.0 made an automatic peak detection searching for the global maxima in the interval during 100-200ms after the stimulus to ensure that the N170 component was found. The search was made separately for every chosen cannel: from the left hemisphere the electrodes: 56, 57, 59, 63 and 64 and from the right hemisphere the electrodes 95, 96, 99, 100 and 107 were chosen (fig.5 Step 4). These electrodes were chosen because there grand averages showed these areas to have most activity during the experiments.

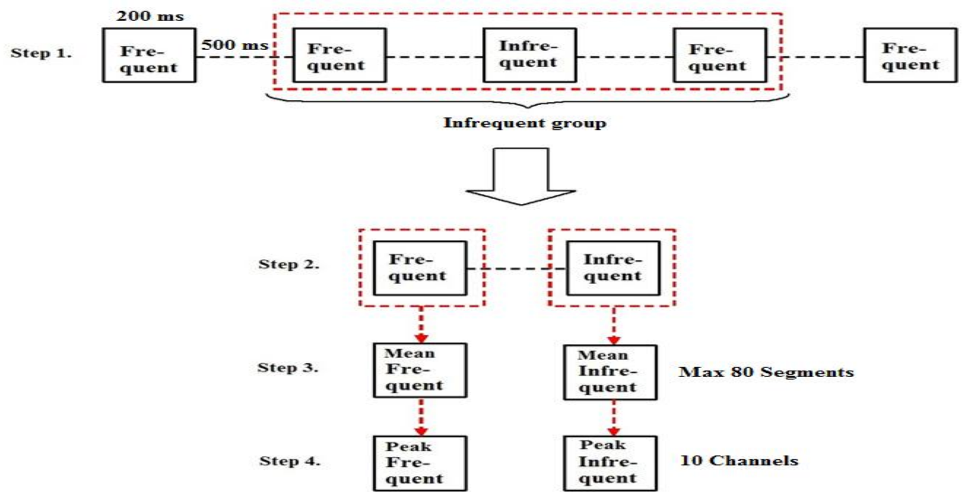

Fig. 5. Four steps of data segmentation.
Step 1. Separation of frequent and infrequent stimulus. Lining them up to rows containing 3 stimuli (frequent-infrequent-frequent).
Step 2. Separating the lining of the stimuli so 1 frequent and 1 infrequent stimulus remained.
Step 3. Calculating the mean values for both remaining stimuli.
Step 4. Peak detection was done separately for each chosen channel.

2.5 Statistical Analysis

The peak values (latencies and voltages) of the N170 component from 10 electrodes (five electrodes from both hemispheres) were transported from analyzer 2.0 to IBM SPSS 19.0 (Statistical Package for Social Sciences for Windows). The peak values were transported as five separate files each containing one of the used experiments. In this study we only report statistically significant findings ($p < 0.05$) or findings containing trends ($p< 0.08$).

The variables were tested with multivariate analyses of variance (MANOVA).Whenever a significant interaction or trend was found post hoc tests were performed using the independent samples t-test or the paired samples t-test for different groups to specify the nature of the interaction.

Three-way ANOVA was used to find differences in responses between depressed and non-depressed subjects. The within-subject factors were stimulus type (frequent, infrequent) and hemisphere (left, right). The between-subject factor was the group (depressed, non-depressed).

To compare the survey data scores and the N170 component a Pearson’s correlation analysis was made. Whenever a significant interaction was found a regression analysis was performed to specify the nature of the interaction. Time of measurement (before therapy, after therapy) was an additional between-subject factor in the three-way ANOVA.

3. RESULTS

3.1 Seven Universal Facial Expressions and the N170 Component

The amplitudes and latencies of the N170 component in the 7exp experiment where all the universal facial expressions had an equal probability to be shown is reported in this section. The statistical reliability of the amplitudes and latencies of the ERP's in the equal probability situation were tested using the repeated measures MANOVA. The within-subjects factors where: stimulus type (neutral, happy, sad, fearful, disgust, surprise and angry) and hemisphere (left, right).

A main effect was found on the stimulus type for the amplitudes of the N170 (F (6, 26) = 10.43, p = .001). Post-hoc tests after the Bonferroni correction revealed that almost all the emotionally loaded faces (happy, fearful, disgust, surprise and angry) had amplitudes that were more negative than that of the neutral faces (table 2).

Table 2. ERP's of emotionally loaded faces elicited in most cases (excluding the sad face) more negative amplitudes than neutral faces. Also the ERP's elicited by the surprised facial expression have statistically more negative amplitudes than sad faces

Expression		t	Sig *
Neutral vs.	Sad	2.59	0.186
	Disgust	3.25	**0.033****
	Anger	3.51	**0.023****
	Happy	4.24	**0.001****
	Fear	5.00	**0.000****
	Surprise	5.83	**0.000****
Surprise vs.	Sad	3.53	**0.048****

* After Bonferroni correction
** T-test is significant at the 0.05 level (2-tailed)

The strongest amplitudes were elicited by the following facial expressions: surprise (M -4.37µV, SD 4.13), fear (M -4.09, SD 4.13) and happy (M -4.02µV, SD 4.47). Then again the weakest amplitudes were elicited by neutral (M -3.00µV, SD 4.28) and sad (M -3.54µV, SD 4.02) expressions (Fig. 6). These results confirm our first hypothesis that the ERP's of the seven universal facial expression produce different amplitudes in the N170 component. No differences in the latencies of the N170 component were found.

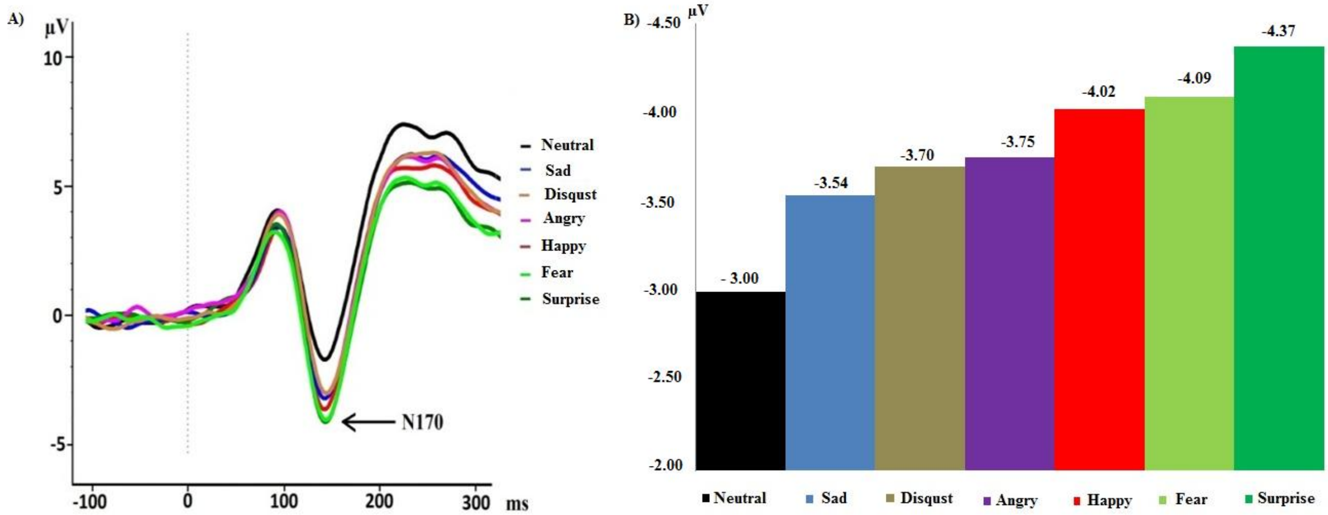

Fig.6. The N170 components of seven universal expressions and their amplitudes.
A) Event-related potentials of seven universal expressions elicit different N170 components
B) Voltages of the amplitudes elicit by event-related potentials of the seven universal expressions

3.2 Change Detection Measured by Mismatch Negativity

In this section change detection was measured from ERP's elicited by emotional facial stimuli using the mismatch negativity paradigm. Results from four experimental settings: 1) $\mathrm{Neu_F Sad_I}$, 2) $\mathrm{Sad_F Neu_I}$, 3) $\mathrm{Neu_F Hap_I}$ and 4) $\mathrm{Hap_F Neu_I}$ are reported. A three-way ANOVA was used to test these arrangements. The within-subject factors were stimulus type (frequent, infrequent) and hemisphere (right, left) and the between-subject factor was the state of depression (depressed, non-depressed).

3.2.1 Change Detection between Neutral and Sad Affects

The experiment where frequent neutral and infrequent sad ($\mathrm{Neu_F Sad_I}$) facial affects were shown the hemisphere (left, right) was found to have a main effect on the amplitudes of the stimuli (F (1, 22) =

4.71, *p* = .041). The paired samples t-test showed that the responses were higher on the right hemisphere compared to the left (*t* (23) = 2.332, *p* = .029). The mean amplitude on the right hemisphere was -4.98 µV and its SD was 4.50 (fig. 7A). The mean amplitude on the left hemisphere was -4.12 µV with a SD 3.59. In the vice versa experiment where sad facial affects were frequent and neutral affects infrequent (Sad_FNeu_I) no significances were found (fig 7B). These findings reveal that the N170 component doesn't detect the changes between the frequent and infrequent stimuli i.e. change detection using the MMN paradigm in these situations was not found.

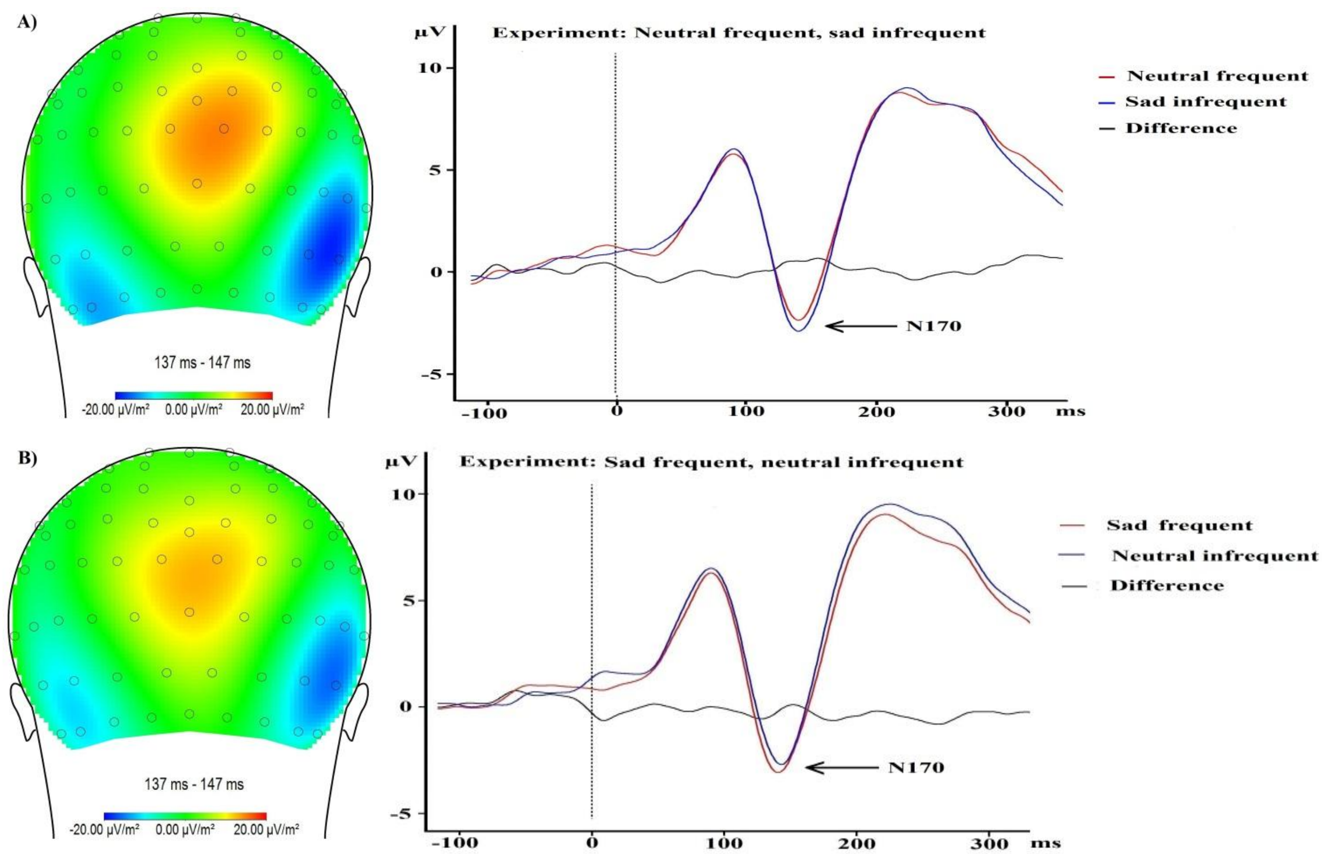

Fig. 7. Current source densities and grand averages of ERPs elicited by frequent (red) and infrequent (blue) stimuli (neutral or sad) in experiments 2 & 3. The difference wave (black) is calculated by subtracting the frequent wave from the infrequent wave.

A) Significantly larger amplitudes were found in the right hemisphere compared to the left in experiment Neu_FSad_I.

A) & B) No eMMN in the N170 component was found in the two experiments Neu_FSad_I & Sad_FNeu_I

3.2.2 Change Detection between Neutral and Happy Affects

In the experiment where neutral facial affects were shown frequently and happy facial affects were shown infrequently ($Neu_F Hap_I$) the stimulus type (frequent, infrequent) had a main effect on both the amplitudes (F (1, 26) = 6.49, p = .017) and the latencies (F (1, 26) = 5.60, p = .026). Post-hoc analyses revealed that happy faces generated larger amplitudes (M = -5.15 µV, SD = 3.84) than neutral faces (M = -4.23 µV, SD = 3.54) (t (27) = 2.75, p = .011). Also the latencies were longer to happy faces compared to neutral faces (t (27) = -2.26, p = .032) (fig. 8C). The mean latency to happy faces was 142.67ms and the SD was 14.81. The mean latency to neutral faces was 140.98ms with the SD of 13.67.

The previously mentioned experiment had also an interaction effect on stimulus type × hemisphere on both the amplitudes (F (1, 26) = 4.94, p = .035) and the latencies (F (1, 26) = 6.02, p = .021). Post-hoc tests indicated that happy faces had stronger amplitudes on the right hemisphere compared to the left (t (27) = 2.23, p = .034) (fig. 8C). On the right hemisphere happy faces had a mean amplitude of -5.66 µV with a SD 4.45 and on the left hemisphere the mean was -4.63 µV with a SD 3.54. Happy faces also had longer latencies on the right hemisphere compared to the left (t (27) = -2.75, p = .011). The latency on the right hemisphere had a mean of 144.14ms and SD of 15.32 and on the left the mean was 141.20ms and the SD was 14.83.

In the experiment where happy faces were shown frequently and neutral faces infrequently ($Hap_F Neu_I$) the stimulus type (frequent, infrequent) had a main effect on the amplitudes (F (1, 26) = 5.49, p = .027) and a strong trend on the latencies (F (1, 26) = 4.144, p = .052). Alike the $Neu_F Hap_I$ experiment the post-hoc test (paired samples t-test) revealed a strong trend: the happy faces generated stronger amplitudes compared to neutral faces (t (27) = -2.03, p = .052) (fig. 8D). The mean amplitude to happy faces was -5.08 µV and the SD was 3.66. On the other hand neutral face generated a mean amplitude of -4.58 µV with the SD of 3.63. Contrary to the $Neu_F Hap_I$ experiment the neutral faces composed longer latencies compared to the happy faces (t (27) = - 2.63, p = .014) (fig. 8D). Neutral faces had a mean latency of 141.63 with SD of 12.93 and the mean for happy faces was 138.95 with the SD of 13.32.

In the same experiment the hemisphere had a main effect on the amplitudes (*F* (1, 26) = 9.77, *p* = .004). According to the post-hoc test the amplitudes on the right hemisphere were stronger compared to the amplitudes on the left (*t* (27) = -2.19, *p* = .037) (fig. 8D).

A trend was also found on the interaction effect of the latencies: stimulus × hemisphere (*F* (1, 26) =3.95, *p* = .057). The paired samples t-test (*t* (27) = -2.496, *p* = .020) revealed that the latencies on the right (M 142.66, SD 11.74) hemisphere were longer compared to the latencies on the left (M 140.61, SD 14.37).

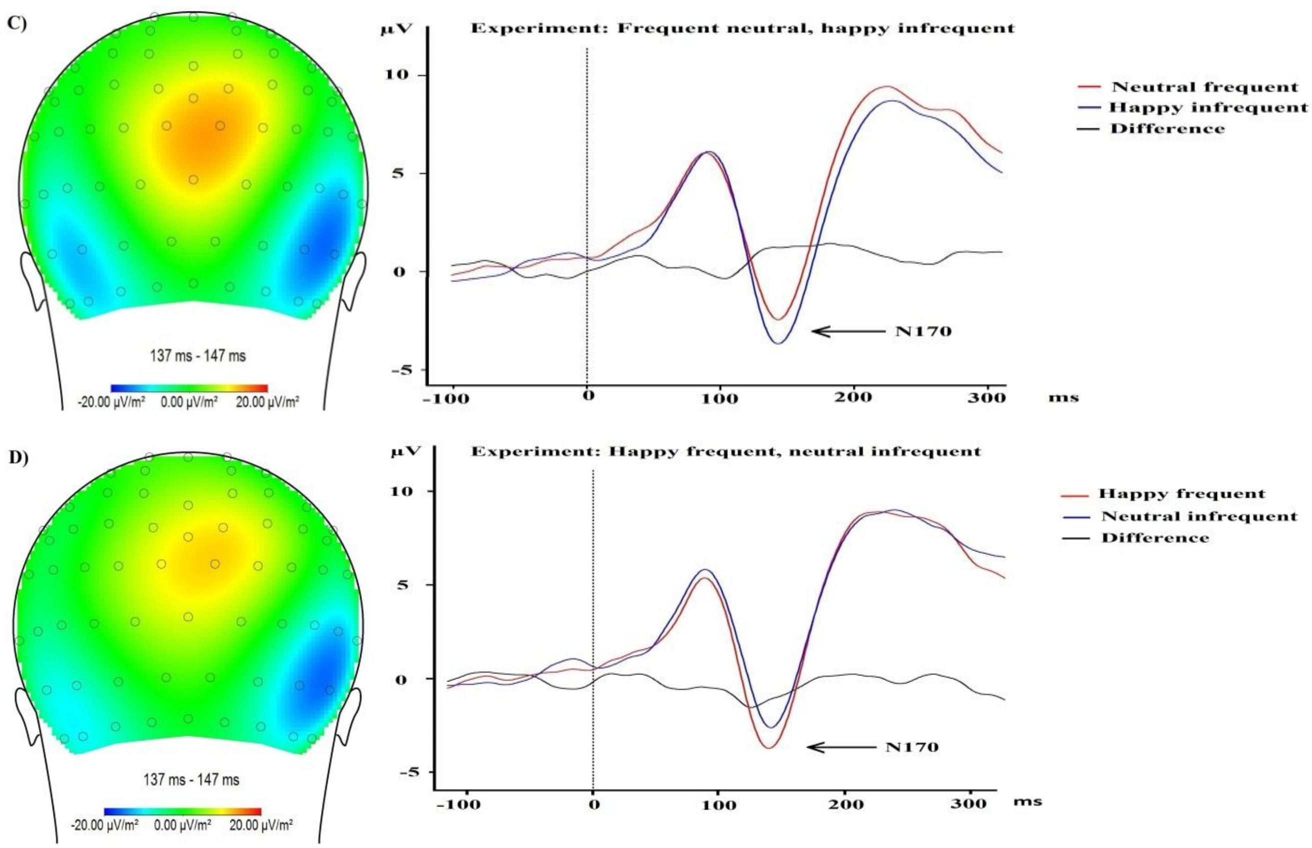

Fig. 8. Current source densities and grand averages of ERPs elicited by frequent (red) and infrequent (blue) stimuli (neutral, happy) in experiments 4 & 5. The difference wave (black) is calculated by subtracting the frequent wave from the infrequent wave.

C) Amplitudes and latencies where stronger to happy facial affects and seemed to be generated more strongly on the right hemisphere compared to the left. An eMMN effect can be found in the experiment Neu_FHap_I.

D) Amplitudes to happy faces were stronger compared to neutral faces. Neutral faces had longer latencies than happy faces.

C) & D) Notice that the amplitudes to happy faces are always stronger compared to the amplitudes of the neutral faces. It seems that this is not a traditional MMN.

To sum it up when neutral and happy facial expressions were presented as stimuli, happy facial expressions had stronger amplitudes regardless of the presentation prevalence (infrequent p=0.20 or frequent p=0.80). In other words the N170 components amplitudes seem to reflect change detection between the expressions: neutral and happy, rather than the prevalence of the stimulus: frequent or infrequent. This is not a usual mismatch negativity effect. Also the amplitudes were higher on the right hemisphere in experiments $\mathrm{Neu_F Hap_I}$, $\mathrm{Hap_F Neu_I}$ and $\mathrm{Neu_F Sad_I}$ meaning that processing of facial expressions took place more in the right hemisphere. When happy faces where presented infrequently they had longer latencies than neutral faces. On the contrary when happy faces were presented frequently they had shorter latencies than neutral faces. All in all, our second hypothesis was partly confirmed. The two experimental settings where sad faces were used as stimuli the N170-components didn't reflect change detection. When happy faces were used as stimuli change detection was found, but only in one experimental setting ($\mathrm{Neu_F Hap_I}$) the finding was as predicted by the mismatch negativity paradigm.

3.3 The effect of stimulus prevalence on the N170 component

In this section we report if the prevalence of the stimulus (frequent 0.80, infrequent 0.20 or equal probability 0.14) has an effect on the N170 component elicited by the event-related potentials of facial expressions. The pattern was tested using a three-way ANOVA. The within-subject factors were stimulus type (frequent, infrequent or equal probability) and hemisphere (left, right).

A main effect was found for stimulus type on the amplitudes (F (2, 18) = 8.43, p = .003). When the prevalence of sad facial stimuli in three different conditions (frequent 0.80, infrequent 0.20 and equal probability 0.14) was compared. Two post-hoc tests were performed. The first post-hoc test was performed between the sad expression as an infrequent stimuli and the sad expression as an equal probability stimuli. It revealed that sad faces as infrequent stimuli generate stronger amplitudes compared to the equal probability situation (t (20) = - 3.25, p = .004). The mean amplitude for the sad affect presented as an infrequent stimulus was -5.17μV with SD of 3.88. In the equal probability situation the mean amplitude was -4.17μV with a SD 3.70. The second post-hoc test was carried out between the sad facial affect as a frequent and sad facial affect as an equal probability stimuli. It revealed that as well as the sad infrequent stimuli, the sad frequent stimuli generated stronger amplitudes (M -5.42, SD

5.09) than the sad stimuli in the equal probability situation (M -4.17µV, SD 3.70) (t (20) = -2.91, p = .009).

For the neutral faces the main effect of stimulus type on the amplitudes was significant (F (2, 16) = 7.32, p = .006). That is to say that neutral faces presented frequently elicited larger amplitudes (M -4.83, SD 3.9) than neutral faces presented as stimuli in the equal probability situation amongst the universal expressions (M -3.93, SD 4.29) (t (18) = -3.37, p = .013). No significances where found when happy facial affects were compared.

All in all these finding reveal that when sad faces are presented as frequent (p=0.80) or infrequent (p=0.20) stimuli in an oddball paradigm they generate more negative amplitudes than when they are presented in the equal probability (p=0.14) situation. Correspondingly to the sad faces when neutral faces are presented as frequent stimuli they elicit more negative amplitudes compared to the equal probability situation. On the contrary when happy faces are presented as frequent or infrequent stimuli they elicit practically identical amplitudes and latencies than they did in the equal probability situation. This is to say that the third hypothesis became true: the prevalence (0.80, 0.20 and 0.14) of the facial expressions had an effect on the N170 component with the sad and neutral faces, but not with the happy faces.

3.4 Self-reported Survey Data Correlated with Event-Related Potentials

The participants filled out several psychological tests. In this section the psychological test scores from the BDI, AAQ2, DASS and SCL-90 are correlated to the depressed participants (both the initial treatment group and the waitlist group) first EEG recordings in all the five different experimental settings.

In the experiment where frequent (p=0.80) sad facial affects and infrequent (p=0.20) neutral affects ($\mathrm{Sad_F Neu_I}$), were used a significant correlation was found between the BDI score and the amplitudes of the sad faces in the right hemisphere (table 3B) (r = - .568, p = .022). This stimulus was a statistically significant predictor of the BDI score when a linear regression model was used (β = .368, p = .022). The coefficient of determination showed (R^2 = .275) that 27.5% of the variation in the BDI scores can be explained by the amplitudes of the infrequent sad affects from the right hemisphere (fig. 9A). As can be seen in table 3A unlike the experiment $\mathrm{Sad_F Neu_I}$, the experiment where frequent neutral and infrequent sad ($\mathrm{Neu_F Sad_I}$) stimuli were used no significant correlations was found.

In the experiment where the neutral affects were shown frequently and happy facial affect were shown infrequently ($\mathrm{Neu_F Hap_I}$) the BDI score correlated with the amplitudes of the infrequent happy faces from the right hemisphere (r = - .543, p = .020) (table 3C). When the BDI score was predicted using a linear regression model the amplitudes of happy faces on the right hemisphere were a statistically significant predictor (β = .369, p = .020) of the scores as seen in figure 9B. Nevertheless the coefficient of determination was low (R^2 = .251).

The experiment where frequent happy faces and infrequent neutral faces ($\mathrm{Hap_F Neu_I}$) were used the amplitudes of the frequent happy faces from the right hemisphere correlated with the BDI score (r = - .504, p = .039) (table 3D). When the BDI score was predicted using a linear regression model the happy frequent stimulus was a statistically significant predictor (β = .444, p = .039). Anyhow the explanation power was poor because the coefficient of determination was low (R^2= .204) meaning that 20.4 % of the variation of the BDI score can be explained by the amplitudes of happy frequent faces on the right hemisphere.

Table 3. Amplitudes of N170 component correlated to 4 self-reported psychological test inventories (BDI, AAQ2, DASS and SCL-90)

A)	Left		Right	
	Neutral Frequent	Sad Infrequent	Neutral Frequent	Sad Infrequent
BDI	-0.285	-0.252	-0.272	-0.331
AAQ2	-0.222	-0.205	0.016	-0.032
DASS	-0.198	-0.138	-0.140	-0.191
SCL-90	-0.094	-0.035	-0.124	-0.111

B)	Left		Right	
	Sad Frequent	Neutral Infrequent	Sad Frequent	Neutral Infrequent
BDI	-0.477	-0.417	**-.568***	-0.477
AAQ2	-0.052	-0.136	0.259	0.397
DASS	-0.414	-0.405	-0.440	-0.325
SCL-90	-0.204	-0.162	-0.331	-0.268

C)	Left		Right	
	Neutral Frequent	Happy Infrequent	Neutral Frequent	Happy Infrequent
BDI	-0.380	-0.412	-0.467	**-.543***
AAQ2	-0.189	-0.177	0.188	0.167
DASS	-0.295	-0.334	-0.301	-0.384
SCL-90	-0.093	-0.133	-0.194	-0.326

D)	Left		Right	
	Happy Frequent	Neutral Infrequent	Happy Frequent	Neutral Infrequent
BDI	-0.338	-0.348	**-.504***	-0.391
AAQ2	-0.057	-0.021	0.229	0.227
DASS	-0.165	-0.137	-0.324	-0.248
SCL-90	-0.058	-0.112	-0.265	-0.270

*. Correlation is significant at the 0.05 level (2-tailed).

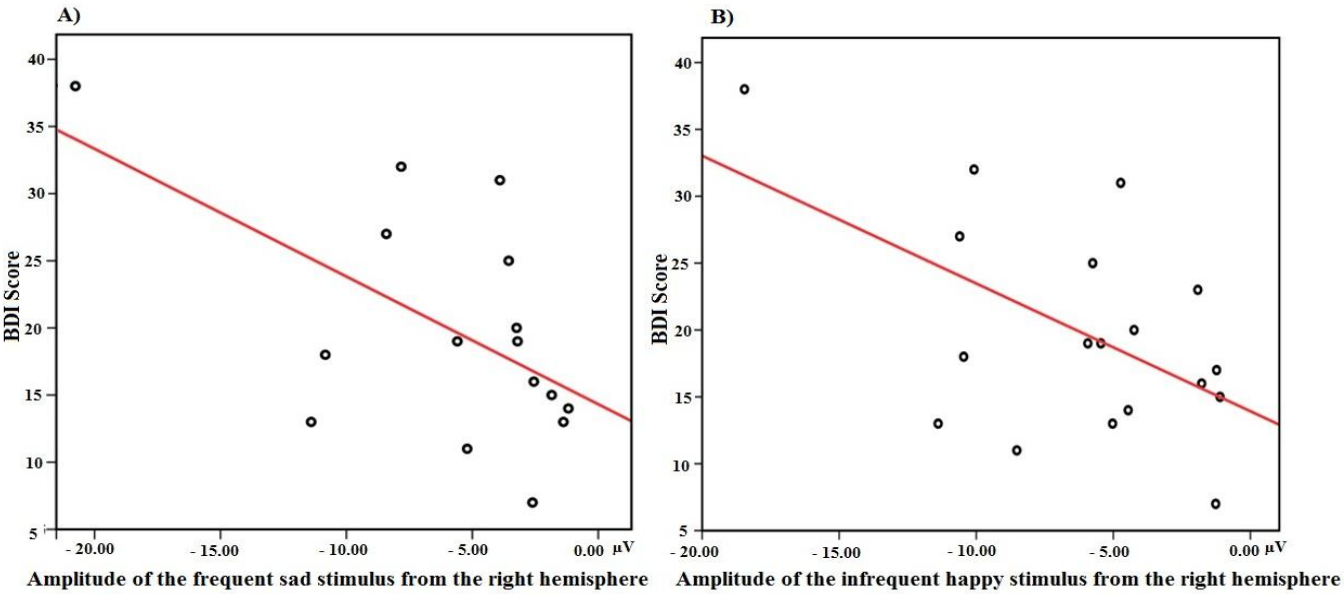

Fig. 9. Regression models of BDI scores with the amplitudes of frequent sad and infrequent happy expressions.
A) Linear regression model of BDI scores and the frequent sad stimuli. It can be seen that when the BDI score decreases the amplitude for sad frequent stimulus weaken.
B) Linear regression model of BDI scores and the infrequent happy stimuli. When the BDI score decreases the amplitudes for happy infrequent stimulus weaken

In the experiment where the seven universal facial expression were presented with an equal probability (p=0.14) latencies of all facial expressions correlate or at least show a trend with the SCL-90 score (table 4). When stepwise regression analysis was used to predict the SCL-90 score the latencies of sad expressions from the right hemisphere were the only stimuli left on the model (β = .590, p = .011). The coefficient of determination was low (R^2= .285). Hence 28.5 % of the variation of the SCL-90 inventory's score can be explained by the latencies of sad expressions. On the other hand no correlations are found between the amplitudes elicited by the universal expressions and survey data.

Table 4. Latencies of seven universal facial affect correlated to four self-reported psychological test inventories (BDI, AAQ2, DASS, SCL-90)

	FEAR	ANGER	DISGUST	HAPPY	SAD	NEUTRAL	SUPRISE
BDI	-,106	-,151	-,234	-,189	-,277	-,192	-,140
AAQ2	,275	,265	,266	,257	,292	,272	,282
DASS	-,092	-,125	-,234	-,146	-,217	-,166	-,139
SCL-90	-,412	-,409	**-,450***	**-,450***	**-,487***	**-,433***	-,413

*. Correlation is significant at the 0.05 level (2-tailed).

In conclusion BDI and SCL-90 inventories can be used to predict 20-29 % of the variation of the N170 component. The BDI scores were found to correlate with the amplitudes of sad and happy facial affects i.e. with the emotional facial affects but not with the neutral facial affects. On the other hand SCL-90 scores were found to correlate with the latencies of the universal facial expressions. Thus the fourth hypothesis was shown to be true when using BDI and SCL-90 scores as predictors, but no predictions can be made by the DASS and AAQ2 inventories.

3.5 Comparing the ERP's of the Depressed and Non-Depressed

The purpose of this section is to report the differences in the ERP's of the depressed participants and the non-depressed participants from the first EEG recordings. The analysis was made via a three-way ANOVA. The within-subjects factors were stimulus type (frequent p=0.80, infrequent p=0.20) and hemisphere (left, right). The between-subject factor was diagnosis (depressed, non-depressed).

In the neutral frequent, happy infrequent ($Neu_F Hap_I$) experiment an interaction effect was found between: stimulus type × hemisphere × group on the latencies (F (1, 26) = 6.02, p = .021). The post-hoc test revealed that non-depressed control participants showed longer latencies on the right hemisphere (M = 142.02, SD = 17.18) compared to the left (M = 137.80, SD = 16.13) on happy faces (t (9) = -2.40, p = .040). No such finding was made amongst the depressed participants.

In the $Hap_F Neu_I$ experiment an interaction effect was found between: hemisphere × group on the amplitudes (F (1, 26) = 7.57, p = 0.11). A trend was revealed in the post-hoc test of the depressed group (t (17) = 1.96, p = .066). The depressed participants generated greater amplitudes on the right (M -6.08µV, SD 4.30) hemisphere compared to the left (M -5.09µV, SD 3.45). In the control group no statistically significant differences were found between the hemispheres neither on the amplitudes nor the latencies. While the experiments $Neu_F Sad_I$ and $Sad_F Neu_I$ showed no statistically significant effects.

To sum it up when the happy stimuli was exceptional (infrequent) the normal controls processed it for a longer time on the right hemisphere compared to the left. In the experiment where happy expressions were shown as frequent stimuli the depressed participants reacted with bigger right hemisphere amplitudes compared to the left hemisphere. In experiments where happy faces

($\mathrm{Neu_F Hap_I}$ and $\mathrm{Hap_F Neu_I}$) were presented the fourth hypothesis as stated became true. In the experiments where sad faces were presented ($\mathrm{Neu_F Sad_I}$ and $\mathrm{Sad_F Neu_I}$) the fourth hypothesis was not met.

3.6 The Effects of Attachment and Commitment Therapy -Intervention

We investigated the effects of the Attachment and Commitment –therapy (ACT) intervention to the participants ERP's elicited by the facial affects in all the five different experimental settings. According to survey data the therapy intervention improved the wellbeing of the participants. BDI scores were significantly lower after the treatment (M 14.60, SD 10.24) compared to the beginning (M 22.50, SD 8.81) (t (9) = 2.97, p = .016). Also the DASS inventory's scores decreased during the therapy interventions (t (9) = 3.59, p = .006). The mean points in the DASS inventory were 41.50 before therapy with a SD of 19.42 and after the therapy the mean scores were 29.00 and the SD was 17.35. The waitlist group didn't show any improvement during this period.

The main effect of the attachment and commitment therapy (ACT) -intervention to the ERP's and thus the N170 component was analyzed using three-way ANOVA. The within-subject factors were: stimulus type (frequent p=0.80, infrequent p=0.20) and the hemisphere (left, right). The between-subject factor was the therapy intervention (before therapy, after therapy).

The only significant interaction effect was found in the latencies between stimulus type × therapy effect in the $\mathrm{Neu_F Hap_I}$ experiment (F (1, 14) = 5.53, p = .034). In spite of this the post-hoc test revealed no differences before and after therapy. There was no significant difference in experiments $\mathrm{Neu_F Sad_I}$, $\mathrm{Sad_F Neu_I}$ and $\mathrm{Hap_F Neu_I}$ before and after the therapy interventions. Also no effects were found in the experiment where the seven universal facial affects were presented with equal probability (p=0.14). In other words the sixth hypothesis was not met. When the initial treatment groups' and the waitlist groups' ERP's from the second EEG recordings were compared no statistically significant differences were found.

4. DISCUSSION

This study was carried out in attempt to establish whether pre-attentive change detection of emotional facial expressions can be seen in the face sensitive N170 component i.e. do the N170 components amplitudes and latencies differ depending on the presented expressions. The second part of the study investigated does the N170 component reflect change detection between frequent (p=0.80) and infrequent (p=0.20) neutral, sad and happy facial stimuli using the MMN paradigm. Furthermore it was investigated can self-reported survey data predict changes in the N170 component. The last part of the study assessed the questions can depression affects the N170 component and can we influence this deviation by the means of therapy.

As expected the event-related potentials of visual facial stimuli elicited an N170 component. This result is consistent with several earlier findings that suggest the N170 component to be specialized to human face detection rather than other general information (Bentin et al., 1996; Rossion et al., 2003; Itier & Taylor, 2004). As noted these responses generate more negative amplitudes on emotionally loaded faces (disgust, anger, happy, fearful and surprise) than neutral faces. Unlike Batty & Taylor (2003) we did not find any differences in the latencies of the N170 component when different expressions were presented with equal probability (p=0.14).

Moreover in previous studies (Bentin et al., 1996) the N170 component caused bilaterally observable amplitudes on both sides of the hemisphere. These negative amplitudes where found to be significantly larger in the right hemisphere compared to the left especially on sad and happy faces in oddball paradigm experiments. These observations are in line with the findings in several earlier studies (Batty & Taylor, 2003; Rossignol et al., 2004; Blau et al., 2007).

The differences in the N170 components make sense when perceived from the neural level, because several brain areas have activation when emotional faces are presented to participants (Adoplps, 1994). Furthermore the face recognition is divided into two subsystems: the core system that processes low-level features like aspects of the face and the extended system that processes general-level features like emotions (Haxby, Hoffman and Gobbini, 2000). Not to forget that different emotions are processed in different neural regions (Blair et al., 1999; Phillips, 1999). The complexity of the facial recognition system could have an effect on N170 component.

It seemed that in the experiments where the oddball paradigm was used the ERP's of happy faces always elicited stronger amplitudes in the N170 component than neutral expressions regardless of its prevalence: frequent (p=0.80) or infrequent (p=0.20). In the experiments where sad and neutral faces were presented as stimulus no significant differences between the expressions could be found. This brings us to the conclusion that change detection was not made based on the memory trace created by the frequent stimuli. Rather the change detection was made based on the emotional content of the stimuli. In other words this was not a usual eMMN where infrequent stimuli interspersed amongst frequent stimuli cause bigger neural reactions.

The answer to this exceptional phenomenon might be found in the results of the experiment where all the seven universal facial expressions were presented with an equal probability (p=0.14). It seems that the neutral faces evoke smaller N170 amplitudes than happy faces found in our results as well as in Batty & Taylors (2003) results. But no discrimination between sad and neutral facial expressions was found because amplitudes of these expressions were almost the same (table 2). Consequently, if an oddball paradigm design is created so that the frequently presented stimuli evoke smaller N170 amplitudes than the infrequently presented stimuli a false eMMN can be perceived.

There is evidence that vMMN evokes when changes in lower-level features happen in the stimulus for example the colors, shape (Czigler, Balazs, & Winkler, 2002) or objects orientation changes (Astikainen, Lillstrang & Ruusuvirta, 2008). When schematic faces (Chang et al., 2010), single persons feature's (Susac et al., 2004; Zhao & Li, 2006) or low-level features (Ashley et al., 2003) of faces are used as a stimulus we can argue that the experiment doesn't measure emotional content per se but merely structural low-level feature changes in the face.

As mentioned previously change detection exists to low-level feature of facial perception. This change detection seems to follow the pattern of traditional MMN where infrequently presented stimuli disturb the memory trace created by frequent stimuli (Näätänen & Winkler, 1999). But the condition changes when the stimulus becomes more abundant in information. In our study the stimuli had different personalities, gender as well as emotions i.e. they were more complex. Because so many low-level features of the faces change between every presented picture it seems that the brain doesn't create a memory trace based on these features. Instead the change detection mechanisms catch the changes in the general level features (i.e. emotions) and make the comparisons based on that information. The general level features seem to be so complex that the mismatch negativity mechanisms don't cache these changes. A similar study was made by Astikainen and Hietanen (2009), who used neutral faces as frequent stimuli and happy and fearful faces as infrequent stimuli. They found a vMMN component, but we argue that it might be due the same reason as the results in our experiments with happy and neutral faces mentioned earlier. Our conclusion is that when more complex general-level stimuli are used participants don't make the comparison based on the low-level change they detect, but instead they make the comparison based on the more complex general-level features like the emotional content of the stimulus.

According to our results the prevalence of the stimuli effects the N170 component. Neutral facial expressions have stronger amplitudes when presented as frequent stimulus (p=0.80) compared to the situation where they are presented as an equal probability stimulus (p=0.14) amongst the seven universal expressions. The reason for this might lie in the findings that emotions like fear and disgust have more meaningful information coded in them making responses to these expressions more important compared to that of the neutral expressions (Plutchik, 1980; Ekman & Wriesen, 1975).

On the other hand when the prevalence of the sad faces is frequent (p=0.80) or infrequent (p=0.20) they evoke stronger amplitudes compared to the equal probability situation (p=0.14). The reason for this might be found in the fact that sad faces don't signal immediate threat or engaging behavior. Instead sad faces as well as neutral faces signal a withdrawing behavior that usually doesn't need our urgent attention.

Unlike neutral and sad expressions, happy facial expressions have practically the same N170 component regardless of the prevalence. An assumption of engaging behavior can be made from the happy facial expression. Engaging behavior is important to recognize in all different contexts and situations because this kind of behavior usually leads to situations where some kind of response is compulsory. Not to forget the happy face advantage that has been reported in multiple studies (Batty & Taylor, 2003; Kirita & Endo, 1995; Leppänen & Hietanen, 2004). It might be that the happy expression is usually more distinguishable than other expressions, making it more recognizable.

It was discovered that BDI scores correlated with ERP's of emotionally loaded expressions in oddball experiments. The level of depression might affect the way the person reacts to the emotionally loaded stimuli. Even though BDI scores decreased between the first (before therapy) and second (after therapy) EEG-recordings the N170 components amplitudes and latencies didn't change. This might be due to the fact that a five weeks' time period is too short to bring forth observable changes in neural levels.

Scores of SCL-90 correlated with emotionally loaded faces in the seven universal expression experiment. The correlation is especially strong for the latencies of sad faces on the right hemisphere. Participants, who evaluated their symptoms high, had shorter latencies to sad faces i.e. they responded more rapidly to sad faces compared to participants who reported less symptoms. Participants who reported high scores on the SCL-90 might have a negative bias towards sad faces. Even though SCL-90 scores decreased after the five week therapy intervention there was no sign of change in the N170 components amplitudes or latencies.

The depressed and the non-depressed control group differed in the experiments where happy faces were used. When the happy facial stimulus was shown infrequently normal controls processed it for a longer time on the right hemisphere compared to the left. The depressed participants didn't have this kind of hemisphere discrimination. This finding is in line with Chang et al. (2010) and Gergen & Mille (2000) findings. On the other hand when happy face where presented as a frequent stimulus and neutral stimulus was presented infrequently the depressed participants generated stronger amplitudes to the expressions in the right hemisphere compared to the left i.e. their neural reactions on the right hemisphere were bigger. This might be caused by the negative bias found in the depressed participants by Disner et al. (2011) or the dysfunctions of the happy face advantage.

According to survey data the therapy intervention improved the wellbeing of the participants. In spite these changes no statistically significant differences could be found between the N170 components of the first (before therapy) and second (after therapy) EEG-recordings. This finding could be due to the fact that almost no differences were found between the EEG-recordings of the control participants and the depressed participants in the first place. These findings contradict with the findings made by Chang et al. (2010). This might be due to the fact that they used schematic faces and not biological faces as stimuli in their study. In other words their study examined low-level features and basic vMMN. More evidence for this argument is gained from Qui's et al. (2011) experiment where visual shapes are used in an oddball paradigm giving similar results as Chang et al. (2010) experiment.

This study used a more complex stimulus design than many earlier vMMN studies. The complexity of our stimulus design gave us results that differed from the results of several earlier studies. For example Stefanics et al. (2011) presented four faces simultaneously while the participant's attention was drawn to a marker on the center of the screen. This experimental design was reported to evoke an eMMN. The facial affects used by Stefanics et al. (2011) as stimuli were Ekman's and Fiercen's (1976) fearful and happy faces. This is in conflicts with our assumption that fearful and happy facial affects don’t evoke different N170 components as found in our seven expressions experiment. Batty and Taylors (2003) found similar results in their experiment as we did in ours.

The two groups of depressed participants (initial treatment group, waitlist group) were considerably small. This can partly explain why significant differences could not be found in different experiments between groups. It can also be argued whether a five week period is long enough to cause changes in the neural levels of participants that can be detected using the EEG.

Recent studies have used a great variety of stimuli trying to identify the characteristics of the N170-component and the eMMN. It is yet to be found if traditional MMN effects can be elicited with complex emotional stimuli. To clarify the understanding of the N170 component and the MMN, experiments using socially important facial affects like fearful, angry, happy and disgust as frequent and infrequent stimuli should be conducted. Another point that needs further examination and clarification is the happy face advantage. This could be done by examining the differences in the ERP’s of depressed and non-depressed participants evoked by happy expressions in a totally different experimental design that doesn’t use an MMN paradigm.

It also remains unresolved how depression affects facial recognition and thus the N170 component. In our experimental design we tried to resolve this problem, but even so more research with more participants and longer time periods are required to define and find differences between the depressed and non-depressed participants.

In summary, emergence of visual MMN to emotion recognition seems to be more complex than hypothesized before. There is growing evidence that vMMN can be elicited to low-level features of faces. This study points out that when groups of changeable general-level features (eg. Gender, personality, emotions) are presented no mismatch negativity can be found. It seems that change detection of participants in the N170 component grasps and reacts to the emotional information of the stimulus from a variety of features.

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APPENDIX A: Sensory Net