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Cerebral processing of faces: an EEG study on perceived facial attractiveness

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ABSTRACT

Humans seem to rely heavily on information gleaned from the face of a vis-à-vis in daily interaction with other people. Not only emotional expressions influence the way people interact with each other, but also seemingly superficial cues, like facial attractiveness, seem to provide important information. At second thought, facial attractiveness is not so superficial by signalling an individual's developmental and hormonal status and being hard to fake. Therefore it can be considered to be a stimulus of high biological relevance. Research has shown facial attractiveness to be an important factor in mate selection, which can be appraised in very short time. The aim of this study was to investigate neural processes associated with those rapid appraisal mechanisms. Cerebral processes involved in perception of facial attractiveness were studied using event-related-potential-technique (ERP).

200 frontal photos of female and male faces with neutral expression, but varying in their degree of attractiveness, served as stimuli for the 50 participants of this study. In order to detect effects of perceived facial attractiveness on ERPs, an analysis of mean amplitudes was performed for a timeframe of 500 ms post-stimulus to find topographical differences associated with differentially perceived attractiveness, as well as a peak analysis of the N170 component and an analysis of mean amplitude values of the P300 component.

Results revealed influences of perceived attractiveness from 150 ms after stimulus onset on. Peak amplitudes of the N170 showed that unattractive female faces evoked a stronger negativity of the N170 than attractive female faces, whereas the opposite was true for male faces, with attractive faces eliciting a higher N170 amplitude in all participants. P300 analysis revealed that attractive female faces elicit a higher P300 amplitude than unattractive female faces, whereas the opposite holds true for male faces in posterior electrodes, but not in frontal ones from 400 ms to 550 ms after stimulus onset.

The results confirm the predictions in so far as they revealed differential activation in relation to perceived attractiveness from a very early time window of visual processing on (~ 170 ms). This finding has implications for models of face processing, stressing an early influence of brain areas that are involved in processing socially and biologically relevant content on visual areas. My findings partly confirm the predictions that attractive faces elicit higher P300 amplitudes, as this effect could only be shown for female faces. Therefore modulations of ERPs in relation to attractiveness seem not only to reflect reward value of attractive faces, but have to be discussed in the context of mating strategies.

ZUSAMMENFASSUNG

In menschlichen Interaktionen spielt die Information, die vom Gesicht eines Gegenübers abgelesen werden kann, eine wichtige Rolle. Nicht nur der emotionale Ausdruck beeinflusst Handlungstendenzen, sondern auch scheinbar oberflächliche Merkmale, wie Attraktivität, liefern wichtige Informationen. Attraktivität scheint ein Merkmal zu sein, dass den Entwicklungs- und Hormonstatus eines Individuums widerspiegelt. Noch dazu handelt es sich um ein ehrliches Signal, das schwer zu fälschen ist. Daher kann es als biologisch hoch relevanter Reiz verstanden werden. Verhaltensbiologische Studien zeigen, dass Attraktivität einen wichtigen Faktor in der Partnerwahl darstellt, und darüber hinaus, dass die Attraktivität eines Gesichtes sehr schnell beurteilt werden kann. Das Ziel dieser Studie ist nun, herauszufinden, welche neurologischen Prozesse diesen Mechanismen zugrunde liegen. Dazu untersuchte ich mittels der „Event-Related-Potentials (ERP)"-Methode zerebrale Prozesses, die im Zusammenhang mit individuell wahrgenommener Attraktivität stehen.

200 Frontalaufnahmen von weiblichen und männlichen Gesichtern mit neutralem Gesichtsausdruck, aber von unterschiedlicher Attraktivität, dienten als Stimuli für die 50 Versuchspersonen dieser Studie. Die Auswertung umfasste die Analyse der mittleren Amplitudenwerte in einem Zeitbereich von 500 ms nach Beginn der Reizdarbietung, die Analyse des Peaks der N170 Komponente, sowie eine Analyse der mittleren Amplitudenwerte der P300 Komponente.

Die Ergebnisse zeigten eine von der Attraktivitätsbewertung abhängige Modulation der EEG-Aktivität ab 150 ms nach Reizdarbietung. Unattraktive weibliche Gesichter lösten eine größere N170 Amplitude aus als attraktive, wobei männliche Gesichter dem umgekehrten Muster folgten. Hier lösten attraktive Gesichter eine höhere Negativierung aus. Die Analyse der P300 zeigte in einem Zeitbereich von 400 bis 550 ms eine höhere Aktivierung (Positivierung) für attraktive weibliche Gesichter als für unattraktive, wohingegen männliche unattraktive Gesichter eine höhere P300 auslösten als attraktive, allerdings nur in posterioren Elektroden. Diese Ergebnisse bestätigen meine Vorhersagen insoweit, als sie eine frühe Modulation der visuellen Verarbeitung in Abhängigkeit von wahrgenommener Attraktivität zeigen (~ 170 ms). Das deutet auf frühe Einflüsse von Gehirnregionen, die sozial und biologisch relevante Information verarbeiten, auf visuelle Gebiete hin, und widerspricht damit klassischen Modellen der Gesichterverarbeitung. Entgegen der Vorhersagen dieser Studie lösten attraktive Gesichter nicht immer höhere Aktivierung aus. Unterschiedliche Aktivierung in Abhängigkeit von wahrgenommener Attraktivität scheint daher nicht nur den Belohnungswert eines attraktiven Gesichts zu reflektieren, sondern muss im Kontext von Partnerwahlstrategien diskutiert werden.

1 INTRODUCTION

The introduction is structured in three parts. The first one introduces the concept of facial attractiveness and its evolutionary basis. The second one focuses on the perception of a face, its evolutionary origin and social relevance. The third part gives an overview of the visual system as a basis for understanding models of visual face processing, which are subsequently described. It ends with an introduction into Electroencephalography (EEG) and a description of the EEG components to be analysed (N170 and P300).

Human face perception and recognition are well studied phenomena in a variety of disciplines, e.g. the Neurosciences, Behavioural Science and Social Psychology.
Faces undoubtedly are very important information sources in social life and communication. They reveal a great deal of information about people's personalities, emotional states and attention. Humans as well as other mammals use faces to recognise other individuals. Our actions and reactions heavily depend on our opponent and the emotional state of this person , what intentions we ascribe and what we know about his/her way of reacting in certain situations. Although there are several cues that human beings exploit for determining another individual's personality and state, the most prevalent cue is the face. Humans as well as other animals use their faces to show emotions, like anger, fear, happiness, etc.
But not only facial expressions govern the way humans interact with each other, also seemingly very superficial cues, like physical beauty, have an effect on social behaviour (Zebrowitz, 1997). Evolutionary Psychology has been investigating the effects of facial attractiveness especially on mating behaviour and challenged the idea that beauty is in the eye of the beholder. Darwinian aesthetics is the term under which research on the evolutionary backgrounds and universalities of beauty and attractiveness can be subsumed.

1.1 FACIAL ATTRACTIVENESS

Although notions of what is beautiful vary across different cultures and also across individuals, certain aspects have been found to be universal. Evolutionary theory provides accounts on why this could be the case. Like other species, humans are subject to the evolutionary processes of variation, selection and adaptation. Therefore a crucial point in the life of human beings is finding appropriate mates for successful reproduction to

promote ones own genetic survival. Due to asymmetric minimal parental investment, mate preferences are determined by several criteria, some (e.g. health) applying to both sexes, others, like economic resources or social status, being more relevant for one sex (in this case women). Attractiveness is an important quality for both sexes, because it seems to be a valid signal of an individual's health, i.e. its developmental and hormonal status, and therefore also of genetic mate value (Thornhill & Gangestad, 1999; Fink et al., 2006). Another important characteristic of physical beauty is that it cannot be faked easily.

Three major lines of research investigate the relation of facial attractiveness and an individual's health: studies on symmetry, averageness and secondary sex characteristics (hormone markers). (Thornhill & Gangestad, 1999; Scheib et al., 1999; Gangestad & Thornhill, 2003, Schaefer et al., 2006)

Symmetry of bilateral traits is positively correlated with heterozygosity and seems to display resistance against parasites, pathogens and toxins. Fluctuating asymmetry is asymmetry of traits that are symmetrical on population level. It is thought to reflect instabilities in development due to parasites, pathogens or toxins.

Averageness also denotes genetic heterozygosity. Average faces are usually perceived as being more attractive than individual faces. But it also depends on the sample of faces you build an average from. Averages of beautiful faces are more attractive than averages of not-so-beautiful faces, which should be equal in heterozygosity. The preference of average faces can be explained in a more general way as well, namely as a proclivity towards prototypical exemplars of a category.

Hormone markers are traits that develop on the basis of different levels of sex steroids. Male traits are influenced by testosterone, while female traits develop under the influence of estrogen. As high levels of these hormones have negative effects on the immune system, hormone markers should provide an honest signal of the quality of the individual according to Zahavi's handicap principle. (Zahavi & Zahavi, 1997)

Certainly hormones also influence behaviour and therefore hormone markers can to some degree be used to anticipate personality characteristics. This information seems to be especially used by females in their mating strategies, because their mate preferences vary depending on the context. In general, women look for long-term partners lacking those traits that develop under the influence of a high testosterone level. As testosterone also affects the level of aggressiveness, a low level would be better for a partner, who could also serve as potential father for the children. Nevertheless women also seem to look for men with a high level of testosterone when they are in the fertile days of their menstrual

cycle. They prefer them as short-term partners, e.g. having just a one-night-stand with them. This effect is sometimes called "gene shopping". (Perrett et al., 1998, Thornhill & Gangestad, 1999, Johnston et al., 2001)

There are two other factors that also have major influence on the way we perceive faces. Firstly there are age-related cues that provide information about a person and indicate whether he or she would be a potential partner, thereby enhancing or reducing individual attractiveness. Especially in women, youthfulness is a trait that enhances perceived attractiveness, because it serves as a powerful signal for a woman's reproductive status (Buss, 2007). In context with that also neothenic features, like e.g. blond hair, let people appear more attractive.

The shape of the face changes quite a lot during ontogeny with the youthful face being more brachycephalic than the adult one (Enlow, 1996). Anthropometric research currently investigates to what extent the growing of the face is just a linear process influenced by the level of testosterone, with men having extended growth under the influence of this hormone and the female face being more similar to an infantile face (Mitteroecker et al., 2004, Schaefer et al., 2004, Fink et al, 2005, Weston et al., 2007). The concept of baby-facedness is quite well known. Konrad Lorenz (1943) depicted the typical headform of young individuals and babies for several species, calling it *Kindchenschema*. Usually this round form of the head and face elicits care-taking behaviour and inhibits aggression in the beholder. It seems to have evolved as a kind of mechanism to protect babies and young children. Due to overgeneralisation effects people also tend to attribute more child-like traits to adults whose faces are more baby-faced than the average. These adults are then expected to be less dominant, less strong, warmer and more naïve. Research in this domain nicely depicts how much the outer appearance of a person immediately influences our attitude towards him or her. For example, attractive people, who break the law, usually get lower penalties than unattractive people convicted of a similar crime. Also studies on job applications with attached photographs of faces could show, that the same application was ranked higher, when an attractive face was attached to the resume. The effect that a perceived physical trait influences perception of the whole person is also known as "halo effect" (Zebrowitz, 1997). The idea that beauty is related to psychological traits and moral attitudes is quite old in Western thinking, as the following quote from Albertus Magnus (13th century) depicts: *„Das Gute ist dem Schönen inhärent, weil das Schöne dasselbe*

Substrat hat wie das Gute. (loosely translated: Well is inherent in the beautiful, as they share the same substrate" (Albertus Magnus, cited in Voland & Grammer, 2003)

Last but not least facial dynamics should not be forgotten. (Rubenstein, 2005; Morrison et al., 2007) Due to the far more complex experimental designs and apparatus needed for studying movement dynamics, research on attractiveness of facial movement patterns is far less advanced than research on static pictures. But one should not forget that in real life humans rarely encounter static pictures of conspecifics, but are influenced by the movement patterns of others at a sudden.
Nevertheless, humans seem to be capable of rating others' attractiveness after a very short time of looking at them (Olson & Marshuetz, 2005).

As behavioural research on facial attractiveness came to the conclusion that physical beauty is an important factor in social life, influencing the way we interact with other people and whom we mate with, this study now aims to investigate the neurological underpinnings of these behavioural processes. The question posed is in how far differences in perceived attractiveness of faces can even be seen at the level of early brain processes.

1.2 FACES

1.2.1 What makes a Face a Face?

Everybody would immediately be able to draw a face, which could easily be recognized as such by any other person. There is even a saying, which is used by parents when teaching the child how to draw a face that mentions every structure needed for a face: "Punkt, Punkt, Komma, Strich, fertig ist das Mondgesicht" (translation from LEO-online dictionary, 26.9.2008: "dot, dot, comma, dash, smiley face in a flash."). It is nicely depicting the simple features that are needed to create an abstract face that is immediately recognised as such. Kobatake and Tanaka (Kobatake and Tanaka, 1994, cited in Kandel, 2000) investigated in a single-cell study on macaque monkeys which features of an abstract face it takes to elicit a similar firing rate in a neuron that responds to the face of a toy monkey. Figure 1 depicts the firing rates of the neuron in the inferior temporal cortex and shows that two dots and a line in a circle seem to be enough to make this neuron fire.

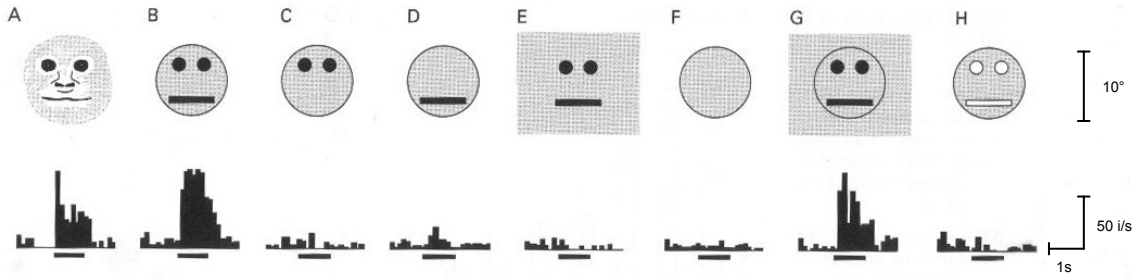

Figure 1. Face selective neuron responding to various abstractions of a face. (modified from Kandel, 2000)
Response of a neuron in the inferior cortex to complex stimuli. The cell responds strongly to the face of a toy monkey (A). The critical features producing the response are revealed in a configuration of two black spots and one horizontal black bar arranged on a gray disk (B). The bar, spots, and circular outline together were essential, as can be seen by the cell's response to images missing one or more of these features (C, D, E, F). The contrast between the inside and outside of the circular contour was not critical (G). However, the spots and bar had to be darker than the background within the outline (H). (I = spikes.) (Modified from Kobatake and Tanaka 1994.) (figure and figure caption after Kandel, 2000).

Whether these findings also apply to face processing in humans is hard to say, because of the ethical problems of doing single-cell studies in humans. But from personal experience one would expect recognition of a face with an even higher degree of abstraction. Probably because of the social relevance of this stimulus, we humans tend to see faces even in non-living matter, e.g. in clouds, in the moon (Guthrie, 1993).

The face seems to have evolved as an accumulation of sensory organs and the mouth on the front end of an organism. For organisms that no longer had a radial structure but developed a bilateral structure, predominantly moving in one direction, it made sense to have the mouth and the sensory organs on that end of the body that first gets in contact with new things in the environment. The face thereby became the most exposed part of the body. Later on the evolutionary timescale it also became an important means for social communication, with the facial musculature becoming more and more differentiated.
Because opinions on what constitutes a face are quite diverse, I want to give some definitions.

"*The term **face** refers to the central sense organ complex, for those animals that have one, normally on the ventral surface of the head and can depending on the definition in the human case, include the hair, forehead, eyebrow, eyes, nose, ears, cheeks, mouth, lips,*

philtrum, teeth, skin, and chin. The face has uses of expression, appearance, and identity amongst others." (Wikipedia, 30.8.2008)

"Die durch die Haaransatzlinie, Schläfen, Ohren und Hals begrenzte Fläche des Kopfes." (dtv Lexikon, 1999) (loosely translated: *"The surface of the head limited by hairline, temples, ears and neck."*)

As can be seen quite well from the two quotes, it is under discussion whether the hair and the ears are part of the face or more delimiting features that determine the boundaries of a face.
Although it is known that also hair and hairstyle influences judgements of attractiveness, I decided to use front views of faces including the hair as stimuli for my study, because pictures including hair are more natural providing a more realistic situation.

1.2.2 The Face: a Whole or Composition of Components?

So far, it could be clearly shown that a face is expected to have certain features in a certain configuration. Whether faces are perceived as a composition of features or analysed as a whole, has been subject to neuropsychological investigations for a long time. I will further elaborate on this issue in the section on face processing in the brain.
Also aesthetic surgery has to deal with that question when surgical changes in a face are undertaken. Results will be differently appreciated depending on whether surgical corrections in a face affect only a component, e.g. the nose, or these changes of a part also affect the whole face image.
The importance of an "intact" face, having all features in approximately the right configuration, for social life is depicted in reports about wounded veterans of WWI. Their distorted faces had to be made acceptable for their "owners" as well as "acceptable" to watch for other people. What was then done by building partial face masks, is now done by aesthetic surgery. Surgical corrections often result in much higher self-esteem and confidence. (Kemp, 2004)

1.2.3 The Social Importance of the Face

The importance of the face for social interaction and communication, and further for the development of personal individuality/identity becomes apparent when dealing with

people, who show some form of disability in exploiting facial expressions for social interaction. Jonathan Cole (1998) describes the impairments of blind people in communicating with people who can see, because their facial expressions often do not meet the expectations of people with normal sight. Furthermore, gaze has an influence on whether we perceive attractive and unattractive faces as rewarding or not (Kampe et al., 2001). This raises the question of how blind people are perceived by their conspecifics.

The role of facial expressions of emotions for feeling those emotions has been widely discussed, referred to as the facial feedback hypothesis recently, but dating back to Darwin (1872) and William James (1890). People with Möbius syndrome lack the ability to move their face muscles giving their faces a "mask-like appearance" (Cole, 1998). It seems that those people also have difficulties in feeling emotions. They report rather thinking to be happy than feeling happy, which seems to support the facial feedback hypothesis, giving hints on the connection between facial expression and the feeling of an emotional state. Merleau-Ponty's quote *"I live in the facial expressions of the other, as I feel him living in mine."* (Merlau-Ponty, 1964, cited in Cole, 1998, p. 179) stresses again the significance of facial expressions for interaction with and understanding other people.

Being able to read in the faces of our vis-à-vis seems to be very important for social interaction, partly because we try to understand others by mirroring their actions, especially facial movements. It would be interesting to investigate whether the impairment of face muscles influences perception of less variable aspects of faces, like attractiveness.

1.2.4 Face – Identity and Individuality

We usually use the face to identify others. Although the face changes a lot (as also the rest of the body does) over lifetime, we still focus on the face to recognise other people.

One can undeniably define universal features of faces, but nonetheless the appearance of the face is also determined by individual characteristics, and not only by the individual genetic code, but also phenotypic plasticity. The facial skin changes according to our lifestyle, wrinkles develop differently in different people in relation to the muscles predominantly used (Finn et al., 2003). So that George Orwell wrote in his notebooks: *"At 50, everyone has the face he deserves"* (quote from Kemp, 2005). This raises the question how much we can influence the appearance of our faces in order to make them more attractive. As smiling faces are rated as more attractive, one can assume that faces with laughing lines are rated as more attractive than those with frowning lines, even if they have a neutral expression. (Zebrowitz, 1997)

1.3 FACE PROCESSING IN THE BRAIN

Face perception and recognition in humans are well studied areas in cognitive neuroscience, because faces constitute a special class of visual stimuli. Few other visual stimuli are of the same biological relevance and importance, and show such a high degree of visual expertise. These facts can also pose a problem, because the adequacy of control stimuli can always be questioned. (Kanwisher & Moscovich, 2000)

The following chapter aims at describing the primate visual system as a basis for processing visual information on the face. It further gives an overview on other areas involved in the human perception of faces. After this general description of the brain areas and pathways for face processing, I will further elaborate on why I chose EEG to study processes of face perception and also introduce the most important EEG components related to my research question.

1.3.1 The Visual System

Clinical observations, neuroimaging studies as well as studies on macaque monkeys have shown a major differentiation of the visual system in two pathways.

Segregation into these two pathways begins with two types of ganglion cells in the retina, the so called parvocellular and magnocellular ganglion cells, resulting in the P- and M-pathway. Those cells transmit different aspects of visual information to different layers of the lateral geniculate nucleus of the thalamus and then further to different layers of the primary visual area (V1). The parvocellular axons project to layer 4Cβ, whereas the magnocellular axons project to layer 4Cα of the striate cortex.

The distinction of different pathways also remains beyond the striate cortex resulting in the dorsal (parietal) and ventral (temporal) pathway, of which the first receives input from the M-pathway, mainly processing spatial aspects and motion information, and the second one receives input from both the M- and P-pathway, mainly processing object form and colour. The two cortical visual pathways are also often described as the *Where*- (dorsal) and *What*- (ventral) pathway. Figure 2 depicts the two major pathways from the retina to the extrastriate visual areas, the ventral pathway involving V4 (secondary visual area) and projecting further to the inferior temporal cortex and the dorsal pathway involving the middle temporal cortex (MT = V5) before projecting further to posterior parietal areas.

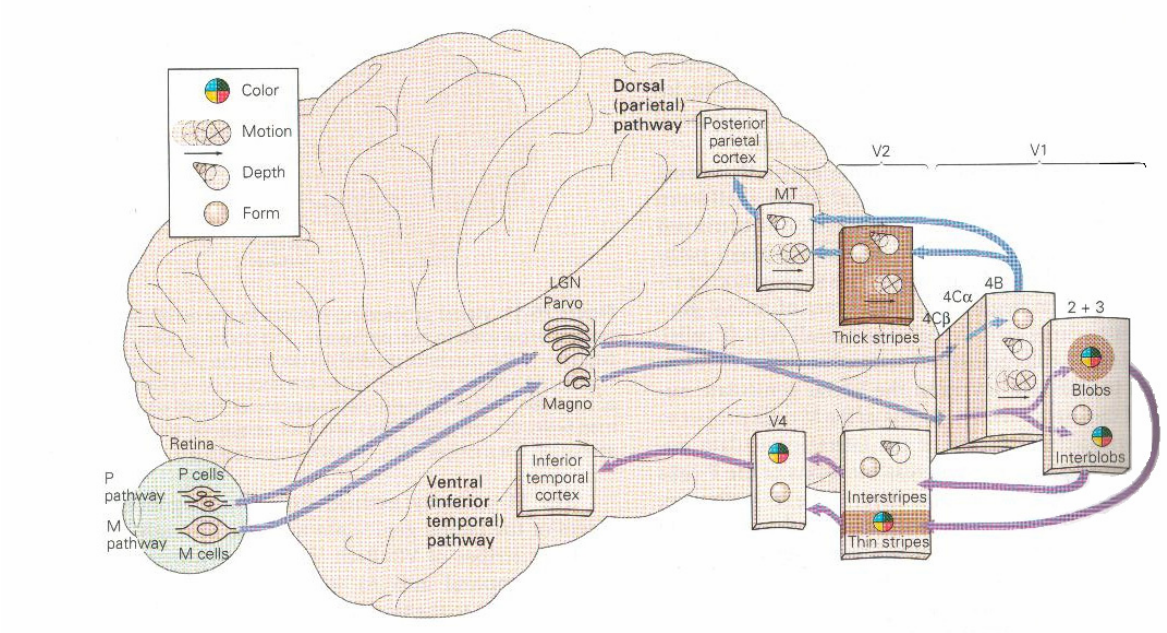

Figure 2. The two visual pathways. (after Kandel, 2000)
The graphic displays the two visual pathways and their functions. Icons represent features to which neurons in these areas are most responsive to. The dorsal pathway, extending to the parietal cortex, is processing information on motion and spatial cues. The ventral stream is more involved in processing aspects of form and colour. The parvo- and magnocellular pathways from the retina provide input for the two cortical streams. (MT = middle temporal cortex, LGN = lateral geniculate gyrus).

It is important to note that both pathways do not exclusively receive input from either the magnocellular or the parvocellular system, but that there exist several connections between them.

Nevertheless clinical findings from patients with lesions in MT or in the occipital and temporal regions of the ventral stream show that the two pathways process different kind of information. For example, a patient with lesions in MT cannot perceive motion anymore, but otherwise shows relatively normal vision. On the other hand, there is the clinical syndrome of *achromatopsia*, which results from lesions in the extrastriate regions of the ventral stream. Patients with damage in these regions do not perceive colours anymore and also have deficits in form perception.

With that general framework of the visual system in mind, we can now focus on areas especially involved in face processing. While studying properties of stimuli that activate cells in the inferior temporal cortex (IT), researchers (Perrett, 1982, cited in Haxby & Gobbini, 2000) found that some cells of the IT strongly respond to pictures of faces, while their response to other stimuli (e.g. objects) is weaker. These results gained from single-cell-studies in monkeys are in line with fMRI-studies in humans, which found enhanced

activity related to processing of faces in an area in the IT that is called fusiform face area (FFA). The FFA is located in the fusiform gyrus (also called Gyrus occipitotemporalis lateralis), which extends along the inferior temporal cortex and corresponds to Brodmann areas BA18 and BA19 (occipital lobe), BA20 and BA36 (temporal lobe) and BA37 (at the junction of the temporal and occipital lobe). The FFA lies in the centre of the fusiform gyrus. It is strongly debated, whether activity in the FFA is related to face processing or rather reflects processing of visual stimuli on subordinate category level, for which we have special visual expertise (Gauthier et al, 1999). Evidence from clinical work evoked further interest in the topic and gives support to a system especially derived for face processing. The syndrome of *prosopagnosia* can be described as the inability to recognise faces even though vision is otherwise normal. Patients with acquired prosopagnosia are able to recognise objects, although some of them have difficulties in making complex visual discriminations. They are able to recognise friends and relatives from their voice. They can also describe faces, e.g. as young or old, male or female, they can recognise emotions, but they cannot identify faces, even not those of familiar persons, although they show autonomic responses (e.g., skin conductance changes) to familiar faces. In contrast to that patients with *Capgras syndrome* can recognise the identity of faces, but lack an emotional reaction to those faces. They think that their vis-à-vis is a deceiver who just looks identical to the person they know. (Grüter et al., 2008; Kandel, 2000)

Those clinical findings suggest that there are several partly independent components with different functions involved in face processing. The following paragraph gives an overview on the most important models of face processing.

1.3.2 Models of Face Processing

The functional face recognition model of Bruce and Young (1986) describes face recognition as a sequential multistage process (Figure 3).

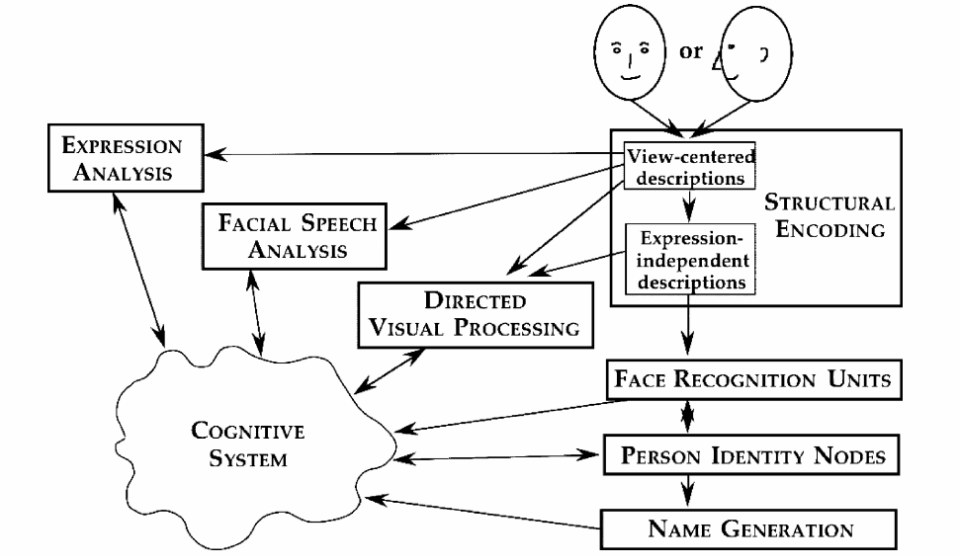

Figure 3. Model for face processing proposed by Bruce and Young (1986). (after Gobbini & Haxby, 2007)

The model proposes that in a first step a face is recognised as such. The structure of a face is detected and encoded. This phase is called structural encoding. It precedes processing of any emotional or individual information. In a second phase the face is compared to representations of known faces, mediated by so called *face recognition units (FRU)*. In a last step the visual information is integrated with person-specific episodic, semantic and emotional information. This person knowledge is mediated by the so called *person identity nodes (PIN)*.

Apart from its very abstract, representation-based approach the model also contradicts neuropsychological studies showing that an emotional response to a familiar face is independent from visual recognition. Furthermore recent studies (Blau et al., 2007) have found a very early influence of emotional information on processes of structural encoding. Moreover a connection of the proposed stages to brain structures is missing in this model.

Therefore another model (Fig. 4) has been proposed by Haxby and colleagues (2002), which suggests a more distributed approach and gives functional descriptions of the areas involved in face processing. It is supported by findings of a variety of single-cell studies on macaque monkeys as well as neuroimaging studies in humans. It emphasises the distinction of areas involved in processing invariant information and those processing changeable aspects of faces. Invariant aspects are those related to recognition of individuals, i.e. to identity of a face. Changeable aspects are emotional expressions, eye

gaze and lip movements, etc.. They are thought to be represented in different brain regions, in order to avoid changes in expression being interpreted as changes in identity. Such a distinction is also emphasised in Bruce and Young's (1986) model. Moreover it is supported by clinical findings of prosopagnosic patients.

Haxby and colleagues (2002) stress the involvement of multiple, bilateral regions and introduce a hierarchy in processing insofar as they discriminate between a core system and an extended system. The core system comprises the inferior occipital gyri, where early perception of facial features takes place, the lateral fusiform gyrus, involved in processing invariant aspects and the superior temporal sulcus, where changeable aspects are processed. The later two seem to receive their input from the inferior occipital gyri. Furthermore, other areas are recruited to process the information gleaned from a face. For example, emotional expressions further elicit activation of areas involved in processing of emotions, such as the amygdala, the insula and other regions of the limbic system. Those brain areas are described as part of the extended system for face processing, because they are involved in cognitive processing of what is visually perceived. Figur 4 describes the various areas of the core and extended system and their functions.

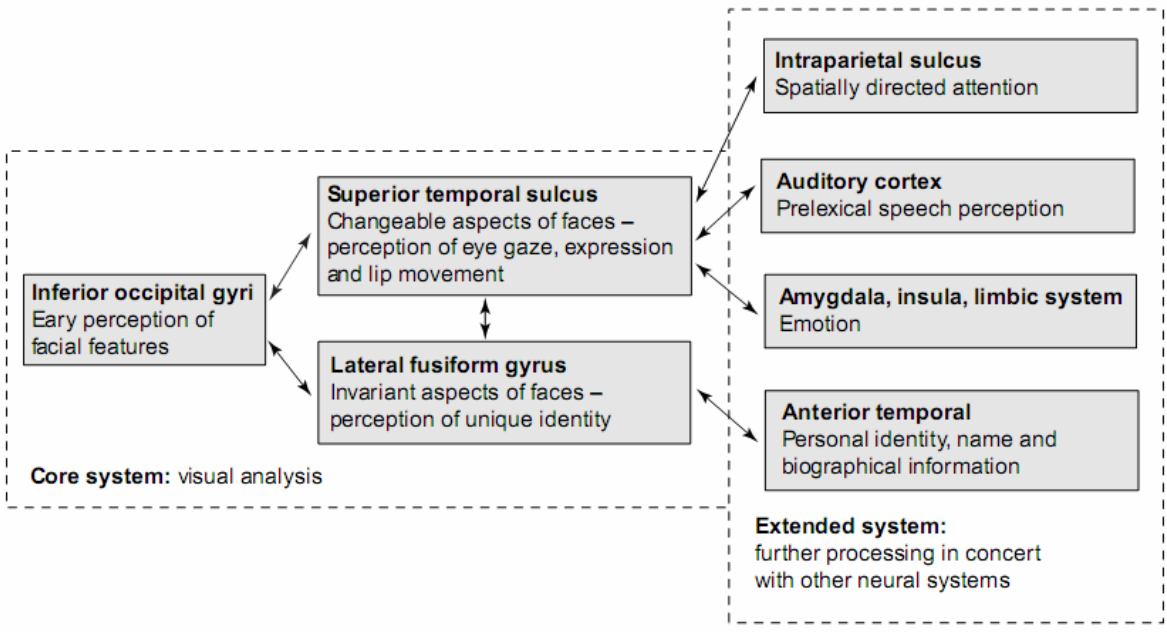

Figure 4. Model for face processing proposed by Haxby and colleagues (2002). (after Haxby et al., 2002)

In 2007, Gobbini and Haxby proposed a modified version of their model focusing more on processes involved in recognition of familiar faces. The new model is still based on a

core and extended system, but it is less hierarchical and also stressing the role of top-down modulatory feedback, thereby proposing a highly integrated network of neural areas involved in face processing (Fig. 5).

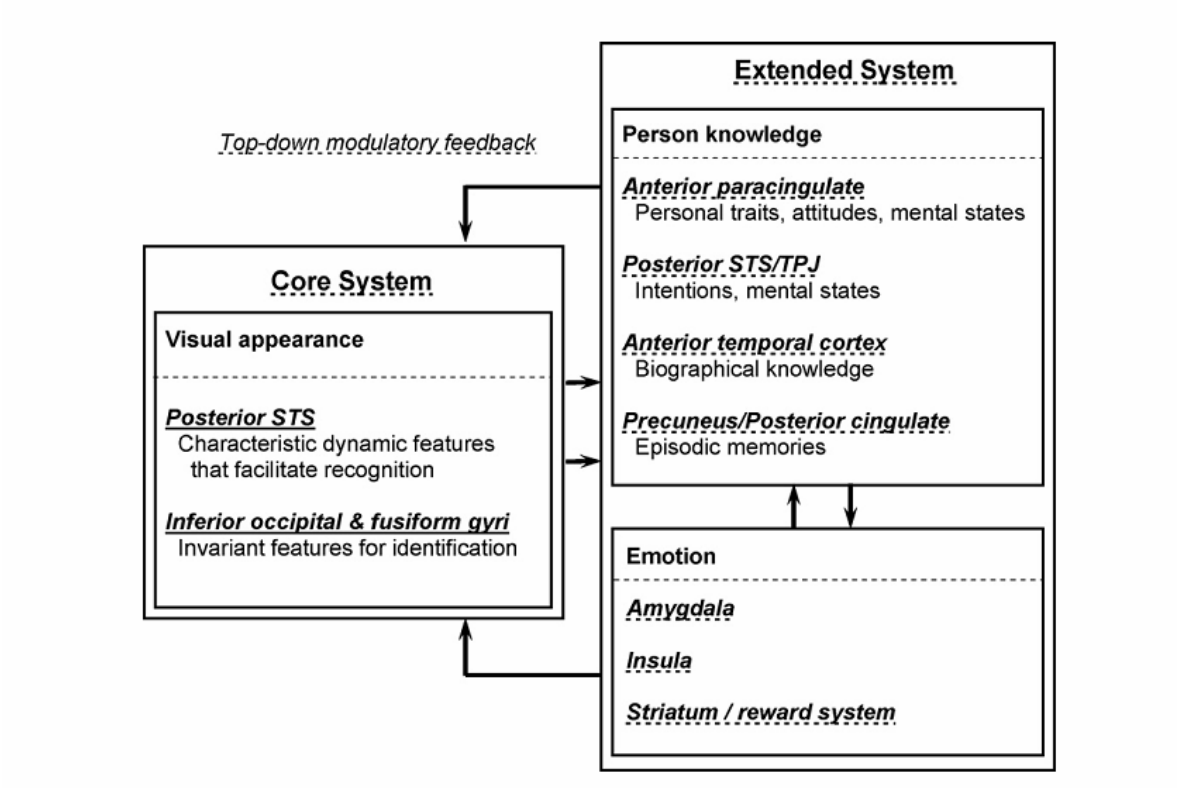

Figure 5. Modified model of Gobbini and Haxby for face processing. (after Gobbini & Haxby, 2007)

All models clearly depict the involvement of other than visual areas in face processing. These areas get information from the visual face processing areas, and most likely vice versa also influence visual face processing. Faces provide important social information. An early involvement of the amygdala and other emotion processing areas is necessary, because of the high relevance to instantaneously recognise the emotional status of another person to adapt one's own behaviour accordingly. For example, if a person shows a fearful expression it could be caused by a threat that could also affect me.

The role of the amygdala in modulating early visual processing has been highlighted in some recent studies (Adolphs & Spezio, 2006; Duncan & Feldman Barrett, 2007; Palermo & Rhodes, 2007). Neuroanatomical studies report projections from the amygdala to the ventral visual stream, from the rostral temporal areas to the caudal primary visual cortex. (Amaral et al, 2003, cited in Adolphs & Spezio, 2006). Furthermore single unit studies of

face selective neurons in the anterior temporal cortex and the STS of the macaque monkey showed that expression-dependent activity occurs in these cells as early as 150 ms after stimulus onset. (Sugase et al., 1999, cited in Adolphs & Spezio, 2006). Also recent EEG-studies report variation of early face-related components, like the N170 – which is commonly associated with structural encoding –, in relation to emotional expressions of faces (Blau et al., 2007), the intensity of emotional expressions (Sprengelmeyer & Jentzsch, 2006) as well as affective judgments (Pizzagalli et al., 2002). Those studies suggest that emotion sensitive processes run in parallel to visual processes and also have early effects on visual ERPs. The amygdala seems to modulate early visual processing, thereby increasing the probability of an affective stimulus to reach awareness. Pessoa and colleagues (2006, cited in Duncan & Feldman Barrett, 2007) found in their fMRI-study that amygdala activation is associated with the likelihood that an affective stimulus reaches awareness. "*A provocative implication of the Pessoa et al. findings is that core affective states not only influence how people interpret objects already seen but might determine what people visually detect in the first place."* (Duncan & Feldman Barrett, 2007, p.191)

As the amygdala is part of the core affective system, which also comprises the orbitofrontal cortex, the ventromedial prefrontal cortex and the ventral striatum, those other areas are considered to play a role in face processing as well.

Studies using depth electrodes in an epileptic patient as well as single-cell studies in macaques found multiple small face-selective regions in the prefrontal cortex. (Marinkovic et al. 2000, Ò Scalaidhe et al. 1997, both cited in Kanwisher & Moscovich, 2000) Also fMRI-studies as well as ERP-studies report early activation of the prefrontal cortex in association with emotional faces. (for an overview see Palermo & Rhodes, 2007.)

Figure 6 depicts Palermo and Rhodes' (2007) model of face processing. It is much more detailed in comparison to Gobbini and Haxby's (2007) model, by including the whole visual system, also the subcortical route, and by stressing the importance of emotion processing areas.

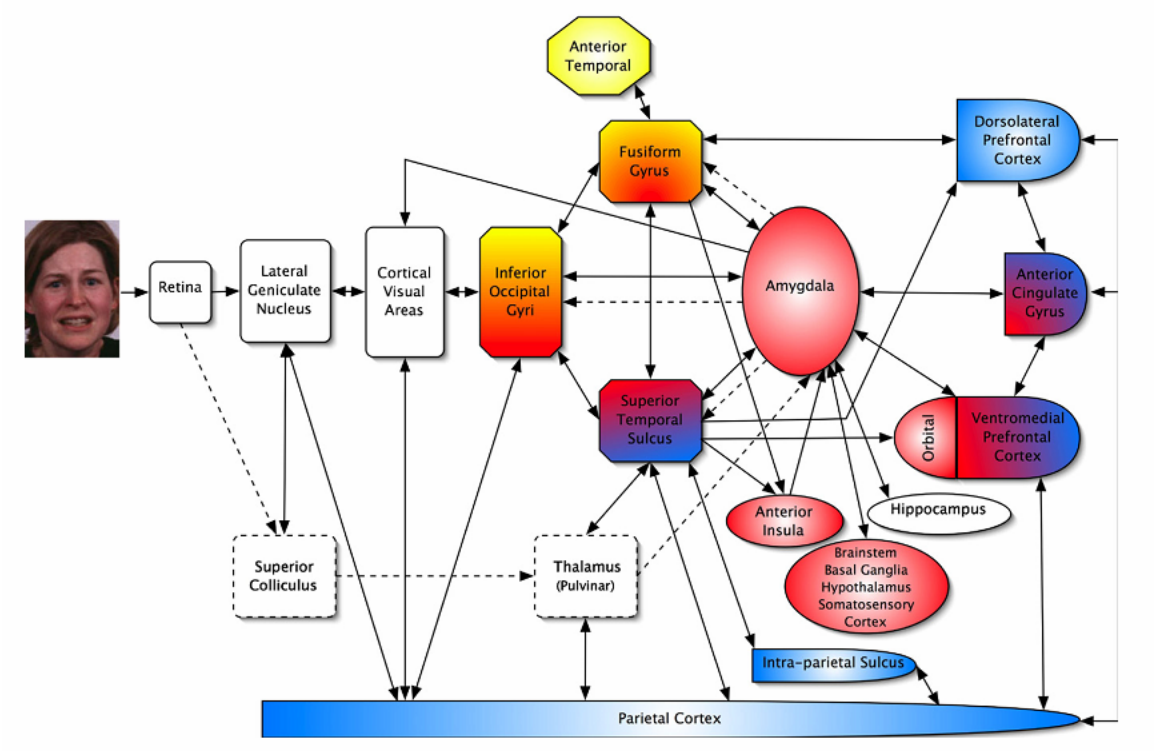

Figure 6. Face perception and attention system proposed by Palermo and Rhodes (2007). The three rectangles with beveled edges indicate the core system for face perception (Haxby et al., 2000). Areas shaded in yellow represent regions involved in processing identity and associated semantic information, areas in red represent regions involved in emotion analysis (Adolphs, 2002b), and those in blue reflect the fronto-parietal cortical network involved in spatial attention (Hopfinger, Buonocore, & Mangun, 2000). Solid lines indicate cortical pathways and dashed lines represent the subcortical route for rapid and/or coarse emotional expression processing. This model is highly simplified and excludes many neural areas and connections. In addition, processing is not strictly hierarchical (i.e., from left to right) but involves multiple feedback connections (Bullier, 2001). The face displayed is from the database collected by Gur et al. (2002). (figure and figure caption after Palermo & Rhodes, 2007)

After this overview on brain areas involved in face processing I want to focus on regions that have been associated with processing of facial attractiveness. As physical beauty is a quality that can elicit a strong affective response in an observer, some of the brain areas previously mentioned in the processing of emotional content, are also activated when subjects are confronted with faces varying in their degree of attractiveness. An attractive face can also be considered to be a rewarding stimulus, therefore activating parts of the reward circuit, which comprises the orbitofrontal cortex, the nucleus accumbens, the amygdala, the ventral tegmentum, and the hypothalamus. (Aharon et al., 2001; Ishai et al., 2005) The structures of the reward circuit partly overlap with those of the system for processing emotional information. This may be explained by the fact that those structures seem to process information that is of certain value to the observer. Carl Senior (2003) introduces a distinction in processing beautiful faces that are rewarding and those that are

merely aesthetic. Rewarding faces are those that have an adaptive value for the observer, because of mate value. Those are attractive faces of the opposite sex. In contrast to that, same-sex attractive faces are considered to be perceived merely as aesthetic, because the information on mate value of that person is not of importance, because he/she is not a potential partner for reproduction. Ishai (2007) questioned this view with her fMRI-experiment on perceived facial attractiveness in homosexual and heterosexual men and women. She found stronger activation of the orbitofrontal cortex (OFC) when subjects viewed attractive faces compared to neutral or unattractive faces. The results further showed stronger activation in heterosexual women and homosexual men to male faces, whereas heterosexual men and homosexual women had stronger activation in response to female faces. So, purely reproductive value does not seem to be enough to explain which stimuli are perceived as rewarding, but sexual relevance seems to be the aspect, which modulates activation in the OFC. Also other studies (O'Doherty et al., 2003; Winston et al., 2007) found a higher activation for attractive faces in the OFC, although Winston et al. (2007) also found higher activation for unattractive faces in the amygdala and some sectors of the OFC, which points to a non-linear response in those regions. They just show high activation for stimuli with high emotional value, irrespective of valence. Those studies also found significant effects of differential activation in parts of the cingulate cortex, the insula, and the STS. Moreover gaze direction of the stimulus face in connection with its attractiveness has an influence on activity in the ventral striatum. Eye contact with an attractive face increases activity in the ventral striatum, whereas averted gaze elicits enhanced activity in those structures when seeing unattractive faces. (Kampe et al., 2001) This study highlights the importance to control for such factors, as gaze direction, in the stimulus material.

Most of the previously mentioned studies on brain areas involved in processing of facial attractiveness are fMRI-studies, which are known to have good spatial resolution, but to be limited in temporal resolution. Therefore they cannot give much information about first occurence of differential activation in face processing areas. This is why complementary EEG studies are needed to investigate neural processing of faces. EEG-studies on processing of facial attractiveness will be discussed in the next chapter, when the most important ERP components associated with face processing are presented.

As mentioned above it is still under debate if and which of the previously described neural systems are exclusively involved in face processing, because most of those areas are also

active when other body parts, animals or objects are processed. Cells in the FFA seem to respond to stimuli on subordinate level to which individuals have been extensively trained in a similar way as to faces (Gauthier & Logothetis, 2000). But nevertheless, no cells have been found in monkeys that respond to both, those stimuli and faces.

A second heavily debated question in the research field of neural processing of faces is whether faces are differently recognised than other objects. A common view is that object recognition is analytic and based on the parts of an object, whereas face recognition is more holistic and configural. Studies have shown that face recognition is more impaired than object recognition when using inverted stimuli. This phenomenon is called "face inversion effect" (Yin, 1969 cited in Kanwisher & Moscovich, 2000). More recent studies support the hypothesis that face and object responsive regions use configural and orientation-specific information, but to a different degree. The "face inversion effect" shows that we rely more on configural information and spatial relationships in faces than in other objects. One reason for this special focus on spatial configuration of the elements of a face could be the importance to identify even small changes, e.g. subtle asymmetries that give a hint to developmental instabilities and health of a vis-à-vis, a potential partner.

To sum up, in the temporal and occipital cortex at least four regions are involved in face processing: superior temporal sulcus (STS), fusiform face area (FFA), lateral occipital area(OFA), as well as anterior temporal regions. The different areas in the temporal cortex have been suggested to have different roles in the processing of faces. Whereas the FFA is more involved in the processing of identity of faces, the STS is known to be active when changeable aspects of faces are processed. The lateral occipital area seems to provide input to both of these regions. (Haxby et al., 2000)

Moreover, the amygdala as well as the insula are also more strongly activated when observers view faces than non-face objects, especially when viewing emotional facial expressions. Additionally, it has been shown that assessment of facial attractiveness evokes activation in the prefrontal cortex and the reward circuitry. (Ishai et al., 2005; Aharon et al., 2001) These activations seem to depend also on the observer's sexual preferences, insofar that they are higher in response to pictures of the desired sex. (Kranz & Ishai, 2006)

The information on localisation that can be drawn from the fMRI studies was used to determine regions of interest for this study.
Moreover recent studies combining fMRI and ERP methodology for investigation of face processing could show that the hemodynamic response correlates with amplitude and latency of specific ERP components (Iidaka et al., 2006). These results stress the importance for integration of results from different experiments and show that brain activation found with different methodologies is to some degree comparable.

1.3.3 Electroencephalography

It was the aim of this study to find differences in brain activity related to differential perception of attractiveness of faces. As the focus of this study was on temporal aspects rather than on spatial ones (i.e., to find out how fast a person subconsciously distinguishes between an attractive and an unattractive face, even if this is not the task) EEG seemed to be the appropriate method because of its good temporal resolution (in the order of milliseconds).
As mentioned before, there is a broad spectrum of methods within the cognitive neurosciences, which have been used to study face processing. With regard to research history, EEG- (ERP-) studies have been among the first to deal with the processing of face-specific effects in the human brain. The following paragraph should provide a short introduction to EEG and ERP methods.
Electroencephalography directly measures electrical activity of the brain in contrast to imaging techniques like fMRI (which measures the haemodynamic response related to the activity of neurons) or PET (which mostly measures metabolic activity, depending on the radionucleotid in use). In 1929, Hans Berger was the first to measure activity of the human brain by placing electrodes on the scalp of a person.
Electrical potentials measured by such a surface EEG are generated by a population of neighbouring neurons, whose excitatory and inhibitory postsynaptic potentials sum up when the cells have a similar orientation. Each neuron can be understood as a dipole, when activated. Summation of the dipoles of thousands of neurons will result in an equivalent current dipole, which determines the positive or negative voltages recorded on the scalp. If neighbouring neurons differ more than 90 degrees in their orientation, their activity will cancel each other out. Therefore the measured EEG potentials reflect synchronous activity

of a population of neurons whose orientation is perpendicular to the scalp surface, because those of tangentially aligned neurons cannot be picked up.

With the event-related potential (ERP) technique one can investigate the response to a certain stimulus, be it visual, auditory or somatosensory. Presenting such a stimulus several times – presupposing that neural processing of it is always the same – enables one to build an average of all the time-locked responses to that stimulus, in which random neural activity (noise) is reduced to almost zero when signal-to-noise ratio is high. This is necessary because the amplitudes of ERPs are usually very small in relation to the background activity. As the signal-to-noise ratio increases as a function of the square root of the number of trials, one needs to limit noise and adjust the number of trials in order to be able to relate differences in amplitudes to stimulus related activity (It could be also a matter of noise, when the number of trials is too small).

As mentioned above, ERPs have a much better temporal resolution than fMRI or PET, ranging in the order of milliseconds. Therefore this technique is ideally suited to study brain processing activities. Not only time course but also topography of ERPs can be studied, providing information on changes at several points of the information processing stream related to a stimulus. In averaged ERP-data one can identify different components (peaks or troughs). Exogenous components reflect initial sensory processing (until 100ms after stimulus onset).They are followed by endogenous components, such as N1, P2, P3, N400, which reflect later more integrative cognitive processes, which have been shown to be less domain- or modality-specific. (Luck, 2005; Tommaso et al, 2008)

In the following ERP components, which are related to face processing, will be described in detail.

1.3.4 The N170 Component

In 1989, Jeffreys (1989) found a positive potential of 150-200 ms peak latency at central and parietal midline electrodes that could be associated with face stimuli. He noted that this effect inverted in polarity at more lateral sites. More recent studies, which used a broader range of electrodes, found the N170 wave at lateral occipital and temporal sites to be an EEG component that is specific for face stimuli (Bentin et al., 1996). The N170 is assumed to be generated in the gyrus fusiformis. It has been subject to various studies investigating different aspects of face processing, e.g. domain-specificity of face processing (whether faces are processed like other items of a basic category, which would

mean, that N170 is not especially associated with face processing, but with within-class discrimination) (Sagiv & Bentin, 2001, Thierry et al., 2007). This question is still being debated (Bentin et al., 2007). It is still under discussion not only whether the N170 is face-specific and but also whether this component is also influenced by other than structural aspects of faces. Some studies (e.g. Caharel et al, 2002) found differences in the N170 amplitudes related to the familiarity of faces, whereas Bentin & Deouell (2000) found no familiarity-related sensitivity of the N170. Other studies also describe modulation of the N170 in relation to emotional expression (Sprengelmeyer & Jentzsch, 2006; Blau et al., 2007) or to affective judgements (liking or disliking) of faces (Pizzagalli et al., 2002). A recent study by Werheid and colleagues (2007) did not find N170 differences in association with facial attractiveness, but only a later negativity at 250 ms after stimulus onset over posterior electrodes.

1.3.5 The P300 Component

The P300 is a widely studied endogenous component, which has lead to considerable controversies among neuroscientists. Some of the misunderstandings among different researchers may be due to the fact that a unitary phenomenon P300 does not exist, but it is more probably based on a variety of neural activations (subcomponents). Those result in different P300 occurrence in different experimental paradigms and settings. Some researchers therefore consider it to be more adequate to use the term "late positive complex or component" (LPC) to describe positive deflections in the range of 280 ms – 700 ms. (Altenmüller & Gerloff, 1998)

Most commonly the so called "oddball paradigm" is used to study effects on the P300. In the traditional two-stimulus oddball paradigm the subject sees frequent standard stimuli alternating with infrequent target stimuli. The target elicits a positive potential that increases from frontal to parietal electrodes and has its maximum 300 ms to 400 ms after stimulus onset over midline centroparietal electrodes. The component can be found for various stimulus modalities. It even occurs, when a stimulus in regular train of stimuli is omitted. It has been described to be inversely related to target probability and directly related to task difficulty, viz. target/nontarget discrimination.

The functional significance of P300 is still under discussion. Donchin and his colleagues (1981) proposed the idea of context updating. He considers the P300 to be a manifestation of *"processes invoked when events occur and create a need to revise the current representation in the working memory."* (Donchin, 1981, citation from Niedermeyer,

1999, p.642). P300 processes can be seen as an index of stimulus evaluation, which is separable from response selection and execution processes (McCarthy & Donchin, 1981).

Stimulus probability, as well as task relevance, are parameters that influence the P300. Task relevance is specified in the instructions in the classical paradigm, but it can also be learned by the participant, as in the studies of Begleiter et al. (1983) , Johnston (1979) or Johnston & Holcomb, (1980) (cited in Oliver-Rodriguez et al., 1999) , that used monetary rewards that labelled the stimuli relevant or not. This ecologically more plausible concept of task relevance, has also been applied in other domains, e.g. using stimuli that have intrinsic psychological relevance, like pictures of ill people, babies or naked males or females. Johnston and colleagues (1986) found that P300 amplitude varies with emotional value of stimuli in a U-shaped way. Pleasant and unpleasant pictures yielded a larger P300 amplitude than did neutral ones.

Another functional explanation of the P300, which is linked to attentional and memory-related processes, could be, that P300 is caused by brain mechanisms that inhibit extraneous acitivity. *"The implication of this hypothesis is that the P300 and its underlying subprocesses could reflect rapid neural inhibition of on-going activity to facilitate transmission of stimulus/task information from frontal (P3a) to temporal–parietal (P3b) locations."* (Polich, 2007, p.2137).

Several cortical and subcortical areas are considered to be involved in generating the P300 (e.g. hippocampus, parietal lobe, frontal lobe, thalamus), but have not been confirmed up to now.

As mentioned above P300 is not a unitary phenomenon. The most common distinction is those into two subcomponents, P3a and P3b. P3a has its maximum over frontocentral regions at 250 ms to 350 ms after stimulus onset. Perceptually novel stimuli elicit a P3a, therefore it is also called "novelty P300". Also an unfrequent nontarget stimulus (distractor) can elicit a P3a. P3b has a latency range from 500 ms to 1400 ms with its maximal positive deflection over parietal regions. It usually occurs in response to task-relevant stimuli. (Luck, 2005; Polich & Criado, 2006; Polich, 2007)

As stated above, the P300 is usually associated with task-relevant responses in an oddball paradigm but it has also been associated with emotional responses. Oliver-Rodriguez and colleagues (1999) and Johnston & Oliver-Rodriguez (1997) found correlations between the beauty ratings of female and male faces and the amplitude and latency of the P300 component. Their results provide a first account on the question of whether beautiful faces

are processed differently in the brain. Therefore I will also put a focus on the variation of this component (P300) in this ERP study.

1.4 PREDICTIONS

My predictions are based on theoretical backgrounds and results from research on facial attractiveness and face processing presented in the introduction. There are two prerequisites for testing my prediction are: First, behavioural ratings of attractiveness are expected to be equally distributed among the four attractiveness categories (attractive, somewhat attractive, somewhat unattractive and unattractive), because stimuli were selected to represent all categories. Second, I expect a high inter-rater-reliability for each stimulus face, because this result has been found in previous studies using the same stimulus material (Thornhill & Grammer, 1999), and is supported by cross-cultural studies on universal aspects of facial attractiveness.

1.4.1 Predictions for Brain Activity Patterns

Previously mentioned studies either do not deal with facial attractiveness or do not relate to subjective ratings of perceived attractiveness. Therefore my study aims at investigating the following predictions:

1.) Studies on effects of affective stimuli on the N170 component have already shown increased amplitudes in relation to intensity of emotion and individual affective judgements. As attractive and unattractive faces are as well of high social and biological relevance to an individual, I expect them to have a differential influence on early visual processes, which are traditionally related to structural processing of faces. Questioning a linear, hierarchical model of separate processing of structural and emotional aspects, I predict perceived facial attractiveness to modulate N170 in a way, that attractive faces elicit higher N170 amplitudes, being socially relevant and rewarding stimuli.

2.) I expect latency of the N170 to be the same for attractive and unattractive faces, because latency modulation of the N170 has so far been described only in context of inverted faces and configural aspects, which are assumed to be of the same quality for stimuli I used.

3.) As changes in the P300 component are related to attentional aspects as well as efficient processing of important information, I expect P300 amplitude to be

modulated by perceived facial attractiveness. Assuming that attractive faces are important stimuli having reward value, I expect P300 amplitudes to be higher for attractive faces.

4.) As reported earlier, attractive faces seem to have different reward value for same-sex and opposite-sex individuals. Therefore the sex of the participants will be considered in all analyses. I expect attractive faces of opposite-sex faces to elicit higher amplitudes than those of same-sex faces because of their higher reproductive relevance.

5.) fMRI-studies on facial attractiveness found a U-shaped pattern of activation, with attractive and unattractive faces eliciting higher activation than neutral faces. A further goal of this study is therefore to investigate differences in EEG amplitudes associated with ratings of attractive or unattractive faces with respect to somewhat attractive or somewhat unattractive ones.

1.4.2 Predictions for Rating Behaviour

1.) Predictions for reaction time differences are in the way that I expect the categories "attractive" and "unattractive" to be rated more quickly than the "somewhat (un)attractive" categories, due to the fact that both, very attractive and very unattractive faces, should be easily determinable, because of high biological. This effect should be especially pronounced in opposite-sex ratings.

2 METHODS & MATERIAL

2.1 SUBJECTS

25 male and 25 female right-handed subjects participated in the study. Participants were in the age range from 19 to 35 years, with the mean age being 25.98 (SD ± 3.198) years.
Handedness was assessed by using the Edinburgh Handedness Inventory and only those subjects, who could clearly be defined to be right-handed, were accepted as subjects for the study.
Subjects had different work and study background respectively, all having at least finished a secondary education (Matura, Abitur). The 50 participants reported to be heterosexual when asked for their sexual orientation.
All subjects furthermore reported to have no neurological or psychiatric illness and no current medication, and to have normal or corrected to normal vision. All participants were informed about the electrode application procedure and the design of the study and gave their written consent for participation.

From this sample of 50 participants, one subject had to be excluded from the behavioural analysis of the reaction times due to technical problems, as well as one male and two female subjects had to be excluded from EEG analysis due to artefacts.

Data acquisition took place at the Brain Research Lab of the Department of Psychology of the University of Vienna from November 2006 until April 2007.

2.2 STIMULUS MATERIAL

A set of 200 (100 female, 100 male) frontal photos of faces served as stimuli for the study. These persons had neutral facial expression, did not wear glasses, jewellery or piercings. The set was composed of three subsets of pictures, which were scaled to the same pixel size and transformed to greyscale pictures. All stimuli were 5 cm × 7 cm in size and displayed in the centre of a LCD monitor (resolution: 1024 × 768) during EEG deflection. Figure 7 shows two exemplars of face stimuli, a female and a male one.
The first subset consists of 106 standardised frontal photos of undergraduate students at the University of Vienna (50 males and 56 females). These faces have already been

subject to geometric morphometric analysis (Fink et al., 2005). These pictures have also already been rated with respect to their attractiveness and short-term/long-term-partnership by students in Göttingen.

The second subset consists of 50 standardised frontal photos of male students at the University of Göttingen. The photos have been taken during a university course in the summer semester 2006.

The third subset consists of 44 photos from the Akira Gomi sample, which have already been rated for their attractiveness (Thornhill & Grammer, 1999, Schaefer et al., 2006).

Figure 7. Exemplars of a female and male face used as stimuli. 200 frontal photos of faces with neutral expression, but varying in attractiveness, served as stimuli for the study. Stimuli were transformed to greyscale pictures and brought to the same size of 5 cm × 7 cm for presentation during EEG deflection.

2.3 Procedure & Stimulus Presentation

First, participants were informed about the electrode application procedure and had to give their written consent to participate in the experiment. While filling out the Edinburgh Handedness Inventory questionnaire, subjects were prepared for electrode application. The location of Cz was determined in order to locate the electrode cap (Easy-Cap) correctly. The cap was positioned accordingly and fixated with double-faced adhesive stickers on the forehead, which could easily be removed afterwards. Additional electrodes were set as described in chapter 2.4, with the same stickers. Below each electrode the skin was slightly scratched using a sterile needle in order to keep contact resistance between scalp surface and electrode low. Afterwards the electrode gel – an isotonic mixture of starch and sodium chloride – was applied to all electrodes, serving as the electrolyte.

Impedance values of all electrodes were measured before starting the experiment and controlled to be below 3 kOhm. During the application of the electrodes participants were informed about the experimental setting and the task they had to perform.

After participants were fitted with the electrodes, they were seated in a sound-attenuated, electrically-shielded semidark room, where EEG deflection took place. They were seated at a distance of one meter from the screen and instructed to sit quietly and look at the centre of the screen (fixation cross) to avoid muscle and eye movement artefacts. Stimuli were presented in the centre of the participant's visual field.

Before starting the test session of the experiment, participants performed standardised eye-movement-tasks, which served as a basis for subsequent artefact correction (see chapter 2.5). It took approximately one to one and a half hour(s) to apply the electrodes, connect them and perform the electrooculography (EOG)-tasks.

Thereafter stimuli were presented on the LCD monitor according to the experimental design presented in Figure 8. Each picture was shown for 500 ms followed by a noise picture (black and white pixels) for 1300 ms, then followed by a fixation cross for 1000 ms and again followed by a noise picture for 1200 ms. The 200 ms before each stimulus presentation served as baseline. This timeline of four seconds is later referred to as one trial.

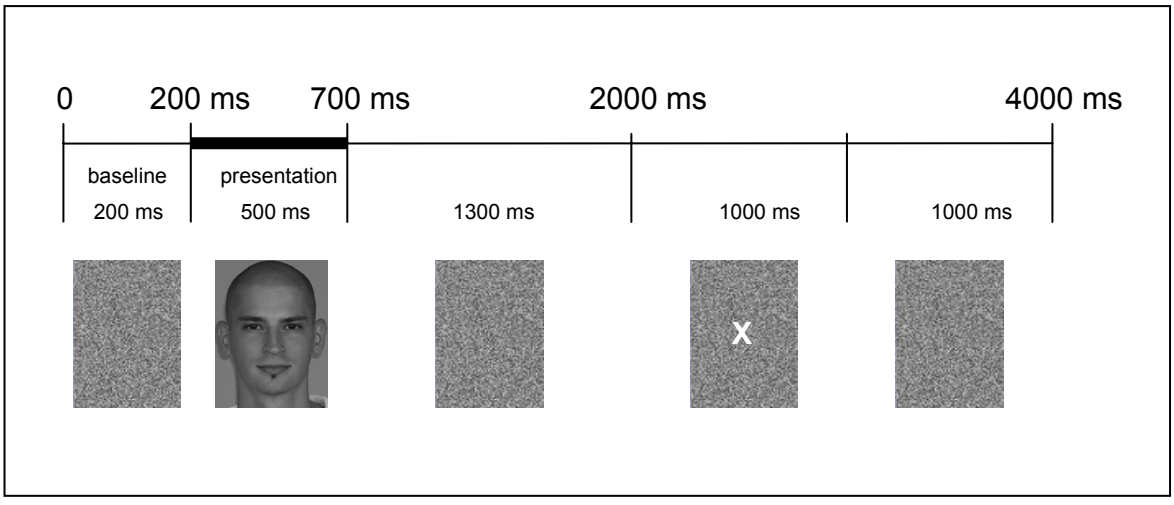

Figure 8. Timeline of stimulus presentation
Each picture was displayed for 500 ms, preceded by 200 ms baseline and followed by noise pictures. The timeline represents one trial that lasts four seconds.

The short time (500 ms) of stimulus presentation was chosen in order to avoid or minimize saccadic eye movements of the subjects. One disadvantage of this setting was that the N1

for stimulus offset overlapped with the later parts of the P300. Therefore I only analysed the earlier portion (300–500 ms) of the P300, although it was previously planned to analyse 1000 ms after stimulus onset.
I also tried to use scrambled faces as noise pictures, in order to allow for minimum change of basic visual properties of the stimuli, but decided against using them, because the scrambled faces already enabled recognition of the sex of the stimulus face, at least for some of the stimuli. This could have produced an effect that would not have been predictable.
The fixation cross should help subjects to keep their gaze on the middle of the screen to avoid eye movement artefacts. It also served as a signal for the participant to do an eye-blink at this point of the timeline in order to avoid blink artefacts during baseline and stimulus presentation (Figure 8).

After EEG deflection, participants were first asked to fill out a questionnaire on demographic data (Appendix 1) and then debriefed.

2.4 TASK

The experiment comprised three blocks, each of which consisted of the randomised presentation of the same 200 faces. Stimuli faces were randomised in order to avoid priming effects. Before the start of the first block, subjects were trained on the procedure during a test session. For that a different set of pictures of faces (in total 15 faces) was used.
In the first block subjects were asked to discern between female and male faces and press a key accordingly. Subjects were instructed to wait with their response until the offset of the stimulus and then press the key with one of their index fingers, which were placed on the key buttons. The EEG recordings of this block were later used for EEG analyses of differences in watching attractive and unattractive faces. The discrimination task should assure that participants pay attention to the pictures.
Participants were instructed in the following way: *"Du wirst jetzt in der Mitte des Bildschirms Gesichter sehen. Davor und danach kommt ein Rauschbild. Deine Aufgabe ist, das Geschlecht des Gesichts zu nennen. Für männliche Gesichter drücke bitte Taste 1, für weiblich Taste 2, jeweils mit dem Zeigefinger der rechten bzw. der linken Hand. Bitte warte mit dem Tastendruck bis das Gesicht weg ist und das Rauschbild zu sehen ist. Wenn*

das X, das Fadenkreuz kommt, blinzle bitte. Wenn Du an anderer Stelle im Experimentverlauf blinzelst, kann es sein, dass wir die Daten nicht verwenden können. Die Bilder kommen in fixen Abständen unabhängig von Deinem Tastendruck. Nun machen wir einen Übungsdurchgang; danach startet das Experiment."
Answer categories were assigned to the keys in a counterbalanced order between subjects.

During the second block participants rated the stimulus faces on a bipolar 1–4 Likert scale according to attractiveness. The four categories were: attractive (attraktiv), somewhat attractive (eher attraktiv), somewhat unattractive (eher unattraktiv) and unattractive (unattraktiv). Subjects used their left and right index fingers to press the corresponding key (i.e. attractive = right key, somewhat attractive = middle right key, somewhat unattractive = middle left key, unattractive = left key) and were instructed to do so as fast as possible. Fingers were placed between two key buttons, so that those two keys could be reached in equal time.
For the second and third block they were instructed in the following way: *"Im nächsten Block siehst Du nun wieder die gleichen Gesichter und sollst sie jetzt nach ihrer Attraktivität bewerten. Folgende Bewertungen sind möglich: attraktiv, eher attraktiv, eher unattraktiv, unattraktiv. Bitte verwende wieder Deine beiden Zeigefinger und positioniere sie zwischen den Tasten. Attraktiv ist die ganz rechte/linke Taste, dann kommt eher attraktiv, dann eher unattraktiv, dann ganz links/rechts unattraktiv. Bitte drück die Taste aber jetzt so schnell als möglich, ohne lange darüber nachzudenken, sondern triff die Entscheidung mehr aus dem Bauch heraus."*
Answer categories were assigned to the keys in a counterbalanced order (ascending or descending from attractive to unattractive from left to right or right to left) between subjects.

During the third block subjects rated the stimulus faces according to their preference as long-term- or short-term-partner as well on a 1–4 Likert scale. This part of the study is the diploma work of Hanna Steindl (in prep.) and therefore analysed and described in detail in her thesis.
Attractiveness ratings were performed in the second block by half of the participants and in the third block by the other half. (Those had to perform partner preference ratings in the second block.)

2.5 EEG RECORDING

For EEG deflection an EEG cap (Easy-Cap) with 61 equidistantly spaced Ag/AgCl-electrodes was applied. All electrodes were referenced against the average of the two reference electrodes, one attached at 7^{th} cervical vertebra (vertebra prominens) and one at the clavicula. Additionally 4 electrodes for electrooculography (EOG) were attached on the outer canthi of the right and left eye as well as above and below the left eye. A ground electrode was placed on the forehead (approximately at the glabella).
Electrode-positions correspond (are nearest) to the following Talairach-electrodes-positions: AFp6, F8h, FFT10h, AFz, AFF4h, FFC6h, FT8h, FTT10h, FFC2, FC4h, FCC6h, FCz, FCC2, C4, CCP6h, T8h,CCP2, CP4h, CPP6h, TP8h, TP10h, CPz, P2, PPO4, PP08h, P10h, PO2, POO6, POO10, Fpz, Afp5, F7h, FFT9h, AFF3h, FFC5h, FT7h, FTT9h, Fz, FFC1, FC3h, FCC5h, FCC1, C3, CCP5h, T7h, Cz, CCP1, CP3h, CPP5h, TP7h, TP9h, P1, PP03, PP07h, P9h, Pz, P01, P005, P009, Oz, Iz.

The localisation of the electrodes is depicted in Figure 9. Its correspondence to the 10/10 system is shown in Figure 10.

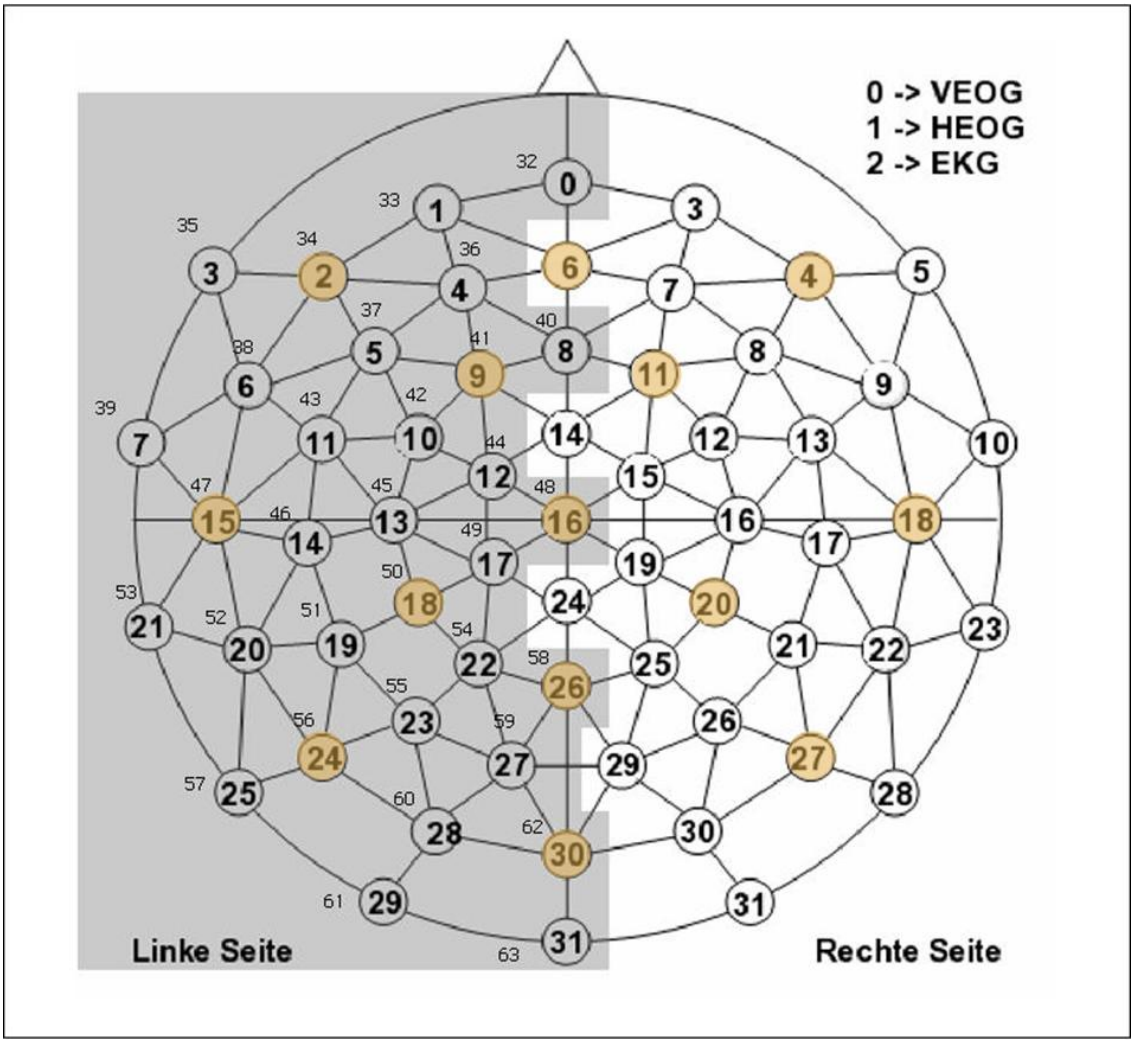

Figure 9. Electrode positions used in this experiment
The figure displays the electrode scheme used in the Brain Research Lab (BRL) of the Department for Psychology (University of Vienna). It matches positions on the EEG-cap (Easy-Cap) with channel numbers. Circled numbers reflect channel numbers for the right side, whereas for the left side small numbers next to the circled numbers reflect the channel numbers (electrodes) referred to in the text. Orange circles reflect the 14 electrodes used in the further analysis (see chapter 2.8.1).

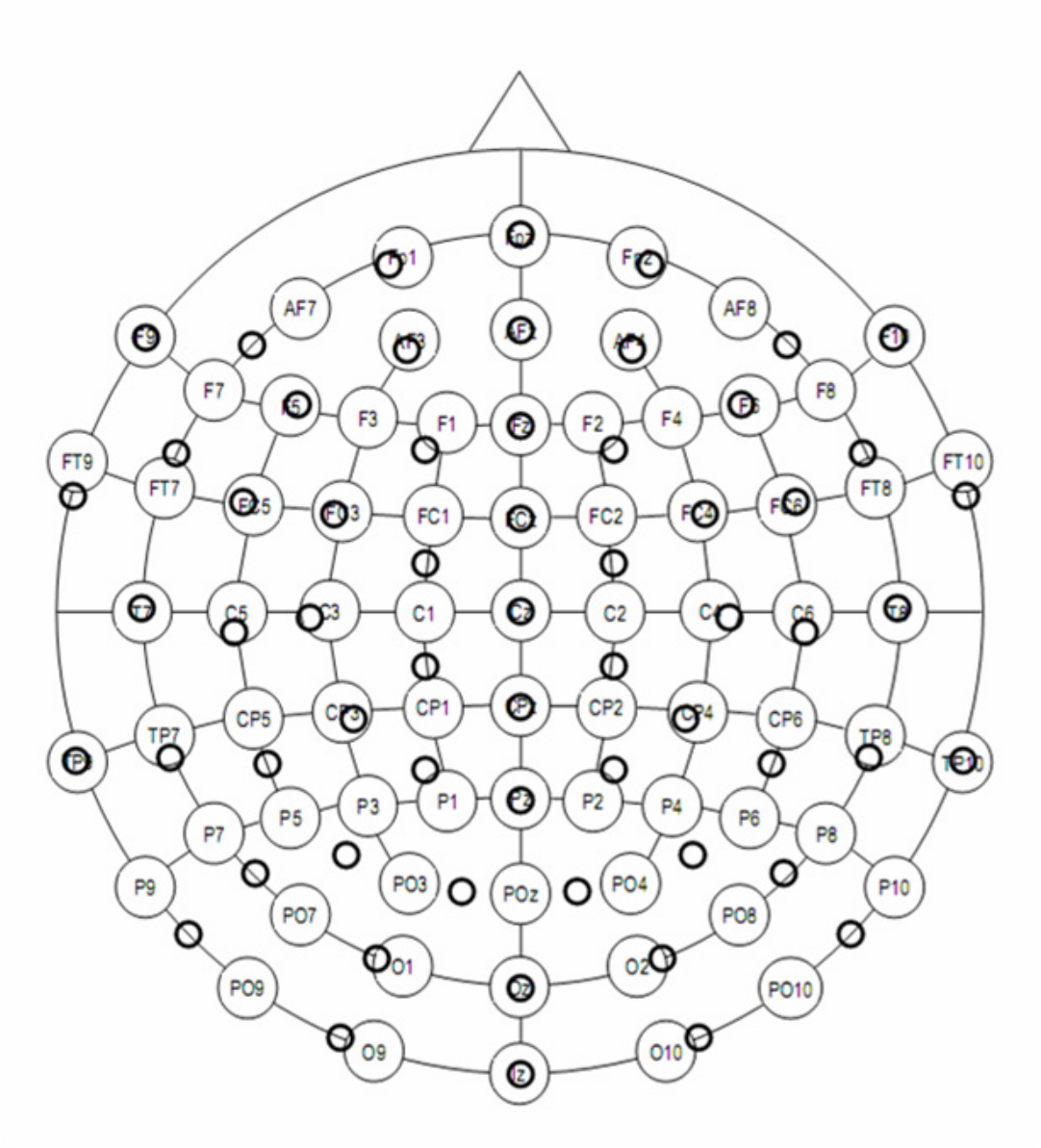

Figure 10. Correspondence of the Easy-Cap electrode positions to the 10/10 system.
Bold circles show relative positions of montage M10 of Easy Cap (displayed in Fig. 9) to 10/10 system. The figure also shows that the 14 electrodes used for further analysis approximately match positions of the 10/10 system.

Signals were registered with a 64 channel DC-amplifier and digitised using a sampling rate of 250 Hz, i.e. data points were recorded every 4 milliseconds.

During EEG recording an online-filter of DC 0–100 Hz as well as a 50 Hz-notchfilter (to filter out noise from electrical devices) was applied.

2.6 PREPROCESSING EEG DATA FOR ANALYSIS

Before EEG recording, EOG (electrooculography) was recorded while subjects were performing standardised eye movements, in order to determine the parameter for automatic EOG-correction. Also automatic blink correction was applied as a first step in preprocessing the data.

During preprocessing of the EEG data for further analysis a 30 Hz low-pass filter was applied. Moreover, trials (Fig. 8) were grouped according to the subjects' ratings. This means that all trials from the first block showing female faces that were rated "attractive" in the second/third block, were grouped together, all trials from the first block showing male faces that were rated "attractive" in the second/third block, were grouped together, and so on.

2.6.1 Artefact Correction

Following automatic correction, all trials also underwent subjective artefact correction. All trials showing muscle artefacts or drifts, i.e. slow tonic voltage changes, were excluded from further analysis. Trials that exceeded amplitudes of 50 μV in relation to the baseline were discarded. Furthermore trials in which subjects pressed the button too early (within 500 ms after stimulus onset) were also excluded.

2.6.2 Averaging

After preprocessing of the data the single trials were averaged per person and channel. During this procedure the average baseline value was subtracted from each data point of the according trial. This is done to consider the tonic level, which can change along with time and state of attention and motivation. As baseline the 200 ms of the signal before stimulus presentation were used. 1500 ms after stimulus onset were subject to averaging but in further analysis we considered only the first 500 ms due to the before mentioned reason, that later waveforms were contaminated with signals relating to stimulus offset and muscle activity.

2.6.3 Grouping for EEG Analysis

As described before, subjects had to rate faces for attractiveness on a 1–4 Likert scale with the following categories: attractive (attraktiv), somewhat attractive (eher attraktiv), somewhat unattractive (eher unattraktiv) and unattractive (unattraktiv). EEG trials were

grouped according to the attractiveness ratings as well as to the stimulus sex, yielding the groups displayed in Table 1 for further EEG analysis.

Considering a minimum of at least 10 EEG trials per category as a necessary requirement for averaging ERPs (in order to have an acceptable signal-to-noise-ratio), only three male participants and seven female participants fulfilled this criterion even before artefact correction. Most of the participants had less than 10 trials in one of the categories "attractive" (female attractive, male attractive) or "unattractive" (female unattractive, male unattractive). After artefact correction only two male and four female subjects had more than 10 trials in each of the categories. Therefore I decided to build pooled categories consisting of faces rated (un)attractive and those rated somewhat (un)attractive, in order to be able to compare groups also including "attractive" and "unattractive" ratings. This is shown in Table 1.

Table 1. Depiction of the composition of the pooled categories.
Because of trial numbers too low for adequate statistical analysis in the categories "attractive" and "unattractive", categories had to be systematically merged as summarised below.

Pooled category	***Original category***
pooled attractive female faces	female attractive faces
	female somewhat attractive faces
pooled unattractive female faces	female somewhat unattractive faces
	female unattractive faces
pooled attractive male faces	male attractive faces
	male somewhat attractive faces
pooled unattractive male faces	male somewhat unattractive faces
	male unattractive faces

In the following, averages were computed for each category for each subject. Afterwards grand means were computed for each condition by building an average across all subjects' averages. Table 2 shows the numbers of trials of grand averages (average across all female participants and across all male participants by perceived attractiveness) after artefact correction. As can be seen, trial numbers of the pooled categories vary more than those of the intermediate categories (somewhat attractive, somewhat unattractive). Therefore only the intermediate categories were subjected to analysis of the N170 and P300, in order to avoid effects of unequal trial numbers.

Table 2. Numbers of trials that remained after artefact correction
After artefact correction data of 47 subjects were left to be subjected to analysis of ERPs. This table shows numbers of trials in the grand averages (across female and across male participants). It further illustrates the differences in trial numbers of the categories "attractive" and "unattractive" in comparison to the "somewhat (un)attractive"-categories.

Female subjects

Category	Number of trials	Category	Number of trials
female attractive faces	356	female unattractive faces	361
female somewhat attractive faces	673	female somewhat unattractive faces	666
pooled attractive female faces	1029	pooled unattractive female faces	1027
male attractive faces	159	male unattractive faces	626
male somewhat attractive faces	498	male somewhat unattractive faces	751
pooled attractive male faces	657	pooled unattractive male faces	1377

Male subjects

Category	Number of trials	Category	Number of trials
female attractive faces	415	female unattractive faces	244
female somewhat attractive faces	782	female somewhat unattractive faces	742
pooled attractive female faces	1197	pooled unattractive female faces	986
male attractive faces	124	male unattractive faces	358
male somewhat attractive faces	791	male somewhat unattractive faces	897
pooled attractive male faces	915	pooled unattractive male faces	1255

2.7 Analysis of Behavioural Data

Being a prerequisite for subsequent analysis, ratings of attractiveness were analysed according to their frequency. Percentages of ratings for each of the four defined categories were calculated for all subjects together and split between male and female. Furthermore, inter-rater-agreement/reliability for each stimulus face was controlled using χ^2-tests for equal distributions (i.e. random ratings). Moreover frequencies for each stimulus face were plotted and visually inspected to assure, that non-randomly distributed ratings were not based on very conflictive ratings (e.g. half attractive, half unattractive).

Reaction times of the ratings (button presses) from the second or third block respectively (i.e. the attractiveness ratings) were subjected to a univariate multi-factor Analysis of

Variance (ANOVA), with attractiveness rating, stimulus sex and subject sex being between subject factors. Before performing the ANOVA based on a General linear model (GLM), we tested whether the reaction time data followed a normal distribution. Although not all classes of ratings were confirmed to follow a normal distribution even after logarithmic transformation of the data (see Appendix 2 for results of the Kolmogorov-Smirnov-test), it can be assumed that ANOVA is robust enough against minor violations of normality (F. Bookstein, personal communication, 2008).

2.8 Analysis of Electrophysiological Data

Analysis of the EEG data comprises on the one hand statistical analysis of the mean amplitudes as well as peak amplitude and peak latency, and on the other hand, descriptive analysis and source localisation with sLORETA.

2.8.1 Analyses of Variance

Repeated measures ANOVAs of the EEG data were done using SPSS software (15.0). Analyses are subdivided into three parts. First, a global analysis of mean amplitudes was performed to find topographical differences associated with differentially perceived attractiveness. In order to reduce the degrees of freedom and the probability of type I error, 14 electrodes were selected from the 61. The waveforms of all electrodes were visually inspected for their typicality for a region. This served as a basis for selecting the 14 electrodes as well as the constraint to have them almost equally spaced upon the scalp. Furthermore I tried to choose those matching best to the 10/10-system for reasons of comparability. The following electrodes were selected: F8h (4), AFz (6), FFC2 (11), T8h (18), CP4h (20), PPO8h (27), F7h (34), FFC1 (41), T7h (47), Cz (48), CP3h (50), PPO7h (56), Pz (58), Oz (62). (see also Fig.9)

The time window of interest (500 ms stimulus presentation) was divided into 10 timeframes (Tab. 3) using 50 ms overlap.

Table 3. Timeframes for analysis of mean amplitudes
Ten timeframes were defined for analysis of mean amplitudes. They were chosen to have an overlap of 50 ms in order to decrease the probability of missing amplitude differences on the edges of each timeframe.

Timeframe	*Time window*
TF1	0–100 ms
TF2	50–150 ms
TF3	100–200 ms
TF4	150–250 ms
TF5	200–300 ms
TF6	250–350 ms
TF7	300–400 ms
TF8	350–450 ms
TF9	400–500 ms
TF10	450–550 ms

The analysis of mean amplitudes has the advantage that it is less sensitive to high-frequency noise than peak amplitude measures, because it is based on 25 time points (in this study) and not just on one. Furthermore, mean amplitude measures are not biased by different noise levels. Therefore it is possible to compare mean amplitudes based on different numbers of trials. A disadvantage is that it reduces temporal resolution.

A repeated-measures-ANOVA was performed on the mean amplitude data using electrodes (14), stimulus sex (2) and perceived attractiveness (2) as within-subject factors and subject sex (2) as between subject factor.

This statistical analysis serves the purpose to detect significant interactions of perceived attractiveness and stimulus sex with electrode site, i.e. to determine differences in brain activity in relation to those factors. A significant main effect for the factor “electrode” is expected, because usually different amplitude values occur upon different electrodes in healthy human subjects. To find this main effect increases the plausibility of the data. A main effect in either “perceived attractiveness” or “stimulus sex” expresses general differences between the two values of a factor. An interaction effect with electrode would yield information on differential activation of brain areas related to the levels of a factor. But it cannot be concluded that differences in mean amplitudes relate to activation of different neural generators. According to Luck (2005) one cannot draw conclusions on

neural generators from such an analysis, because when multiple neural generators are involved an interaction effect could be absent. Also normalisation procedures are not corrective, because they fail to adjust for multiplicative interactions within an ANOVA with electrode as a factor (Luck, 2005). Therefore no normalisation of the data was done within this study.
Because EEG data usually do not meet ANOVA assumptions of homogeneity of variances and correlation of factor levels, Greenhouse-Geisser-Correction was used to account for that violation. The problem arises from the fact that neighbouring electrodes show a higher correlation than ones that are more distant.

Second, an analysis of the N170 component was performed in order to investigate whether this early component is already influenced by processing faces differing in their degree of perceived attractiveness. A peak analysis was performed for electrodes 27 and 56, in which N170 showed the strongest occurrence (by visual inspection). Its location at occipitotemporal sites is also in line with the existing literature (Bentin et al., 1996, Luck, 2005). A repeated-measures-ANOVA (GLM) was used for testing differences in amplitude and latency according to the factors hemisphere, stimulus sex, perceived attractiveness and subject sex.
The measured local amplitude minimum (peak) for the N170 was determined by finding the minimum in the time window of 150 ms to 230 ms after stimulus onset. The minimum had to have the same values on four consecutive data points, thereby limiting the risk of assuming a minimum due to muscular artefacts.
The peak analysis was based on the intermediate category ratings (“somewhat attractive”, “somewhat unattractive”) only, because those do not vary as much in trial numbers as do the pooled categories. Differences in trial numbers can heavily affect peak amplitude data, because peak amplitudes tend to be larger for noisier data (comprising less trials) (Luck, 2005).

Third, a mean amplitudes analysis was performed on the electrodes 6, 48 and 58 in order to investigate differences in the P300. Electrodes 6, 48 and 58 were selected for this analysis, because P300 is commonly described to show highest amplitudes at midline electrodes (Altenmüller & Gerloff, 1998, Luck, 2005, Polich, 2007). In order to investigate differences of frontal aspects and parietal aspects of this component, those

electrodes were subjected to analysis. Furthermore, previous studies on facial attractiveness (Oliver-Rodriguez et al., 1999) selected similar electrode positions.
I decided to investigate P300 amplitude differences by analysing mean amplitudes rather than peak amplitude, because the P300 component is a very broad component and often does not show a pronounced peak. Therefore for peak analysis one would need to define a broad time window to search for the peak, which increases the possibility of detecting a random peak elicited by noise.

2.8.2 Descriptive Analysis of the Waveforms with GRACE

The programme "Grace" was used to plot the EEG amplitudes of the grand means for visual inspection and to determine the 14 electrodes, which were characteristic for the specific regions. It further served to display peak amplitude differences for the N170.

2.8.3 Source Localisation with sLORETA (Standardized Low Resolution Electromagnetic Tomography)

In order to determine the neuronal generators underlying the voltage differences on the head surface measured with the EEG, I performed a source localisation analysis with sLORETA. (Pascual-Marqui, 2002)
Source localisation techniques have to somehow tackle the so called inverse problem. Assuming a single dipole in a conductive sphere, you can quite easily predict the observable voltage distribution on the surface of the sphere. This is the *forward problem* and it is easy to solve even for multiple dipoles. The difficulties arise when trying to find the solution to the *inverse problem*, that means, finding the positions and localisations of dipoles on the basis of the observed voltage distribution on the head surface. The problem lies within the fact that there simply is no unique solution to the problem, because for any given voltage distribution there is an infinite number of possible underlying dipole sources.
Approaches trying to solve the problem fall in two main categories, *equivalent current dipole models* and *distributed source models*. Whereas the first rely on pre-set assumptions about the number, position and orientation of dipole sources, which magnitudes are then modelled to fit the surface voltage distribution, the later are based on

the idea, that the brain can be divided into a number of voxels for which a pattern of activation can be found which best fits the surface voltage pattern. Each voxel would then contain three dipoles, which can vary in strength. The problem of this approach is that each model has a large number of free parameters, which ask for an even higher number of independent data points. This criterion is hard to fullfill, therefore many different sets of strengths can account for the observed ERP distribution. Consequently, all approaches are using strategies to reduce the number of dipoles.

sLORETA is based on the assumption that the voltage changes gradually and therefore selects the distribution of source magnitudes that is maximally smooth. This constraint is biologically plausible in many cases, but sharp borders between adjacent neuroanatomical areas also exist, which would sometimes be expected to lead to sudden changes in cortical current flow. Therefore sLORETA should not be the model of choice in an experiment design, where activation in one area, but not the neighbouring area is expected. As this is not the case for my study, sLORETA can be used for source localisation. It is also important to stress the point that sLORETA is only appropriate for finding the centre of an activation but not for assessing the extent of activation.

sLORETA was used in order to determine the centre of activation for the N170.

3 RESULTS

As a prerequisite for subsequent analysis, descriptive statistics of the attractiveness ratings and results on inter-rater-agreement are presented. Further analysis of the behavioural data includes the analysis of the reaction times. In a second a step, I will report on the analysis of the electrophysiological data. This comprises a global analysis of mean amplitudes, performed to find topographical differences associated with differentially perceived attractiveness, an analysis of the peak amplitude and peak latency of the N170 component, as well as an analysis of mean amplitude values of the P300 component.

3.1 BEHAVIOURAL DATA

All 50 participants were considered in the analysis of attractiveness ratings and in the reliability analysis, but one female subject had to be excluded from analysis of reaction times due to a technical problem, leaving a sample size of 49.

Analysis of the behavioural data included all trials, in which a person rated a face within one of the four attractiveness categories. Ideally this should be 50 (participants) × 200 (stimuli faces), leaving a total of 10.000, for the attractiveness ratings, but due to the fact that participants in some cases forgot to press the button, the number was 9986.

3.1.1 Attractiveness Ratings

Each participant had to rate each stimulus face as either “attractive”, “somewhat attractive”, “somewhat unattractive” or “unattractive”.

Table 4 shows how stimulus faces were assessed by the participants of this study.

Table 4. Attractiveness ratings.
Attractiveness ratings of all 50 subjects for female and male stimulus faces. Ratings are shown for all subjects, as well as separately for men and women. Trial numbers can be understood in the following way: e.g. 924/4994 = female faces rated attractive by all subjects / total number of ratings for female faces. The table shows male faces were especially rarely rated as attractive by male participants, but also by female participants.

All subjects rating female stimulus faces		
Category	**Percentage**	**Trial numbers out of total**
attractive	18%	924/4994
somewhat attractive	34%	1716/4994
somewhat unattractive	34%	1674/4994
unattractive	14%	680/4994
All subjects rating male stimulus faces		
Category	**Percentage**	**Trial numbers out of total**
attractive	7%	351/4992
somewhat attractive	31%	1556/4992
somewhat unattractive	38%	1907/4992
unattractive	24%	1178/4992

Male subjects rating female stimulus faces		
Category	**Percentage**	**Trial numbers out of total**
attractive	19%	475/2496
somewhat attractive	36%	891/2496
somewhat unattractive	35%	868/2496
unattractive	10%	262/2496
Male subjects rating male stimulus faces		
Category	**Percentage**	**Trial numbers out of total**
attractive	6%	153/2496
somewhat attractive	38%	954/2496
somewhat unattractive	40%	1004/2496
unattractive	16%	385/2496

Female subjects rating female stimulus faces		
Category	**Percentage**	**Trial numbers out of total**
attractive	18%	449/2498
somewhat attractive	33%	825/2498
somewhat unattractive	32%	806/2498
unattractive	17%	418/2498
Female subjects rating male stimulus faces		
Category	**Percentage**	**Trial numbers out of total**
attractive	8%	198/2496
somewhat attractive	24%	602/2496
somewhat unattractive	36%	903/2496
unattractive	32%	793/2496

The data clearly show that subjects tended to rate the somewhat-categories considerably more often, leaving a sample size of 351 ratings for the smallest category, attractive male faces, i.e. too few trials per participant for subsequent ERP analysis.

3.1.2 Reliability Analysis

As described in chapter 2.7 ratings for each picture were tested for equal distribution (random rating) using χ^2-tests. These tests were performed three times, 1.) including ratings of all participants ($N = 9986$), 2.) including only ratings of female participants ($N = 4994$), 3.) including only ratings of male participants ($N = 4992$).

1.) All 200 tests (100 female stimulus faces, 100 male stimulus faces) on the ratings of all participants, showed that the stimulus was not randomly judged as attractive or unattractive ($P < 0.05$ each).

2.) Out of 200 tests on ratings of the female participants, 75% of the female stimuli as well as 83% of the male stimuli were not rated randomly ($P < 0.05$ each).

3.) Out of 200 tests on ratings of male participants, 95% of the female stimuli as well as 95% of the male stimuli were not rated randomly ($P < 0.05$ each).

Visual inspection of the frequency plots of the ratings for each stimulus face showed that non-randomly distributed ratings were not due to very conflictive ratings (e.g. half attractive, half unattractive). Usually one category or two neighbouring categories yielded the highest frequencies. So it could be shown that participants agreed in rating the stimulus faces of this study, which was a prerequisite for subsequent analysis.

3.1.3 Reaction Times

Before performing a univariate multi-factor ANOVA (GLM), I tested whether the reaction time data followed a normal distribution by using Kolmogorov-Smirnov Tests (Appendix 2). Although not all classes of ratings were confirmed to follow normal distributions even after logarithmic (ln) transformation of the data, it can be assumed that the univariate multi-factor ANOVA is robust enough with regard to the deviations from normalitiy in these data. (F. Bookstein, personal communication, 2008).

The following table (Tab. 5) shows the results of the univariate ANOVA on logarithmised reaction times, using attractiveness rating (4), stimulus sex (2) and subject's sex (2) as factors.

Table 5. Results of ANOVA of logarithmised (ln) reaction time data for all subjects.
49 subjects were included in the ANOVA of reaction times. All factors show significant interaction effects and significant main effects, but an R^2= 0.043 shows that there is much variance in the data. *P*-values are rounded to the third decimal. (subject sex = sex of the participant, stimulus sex = sex of rated face, attractiveness contains the four categories: attractive, somewhat attractive, somewhat unattractive, unattractive).

Source	***df***	***F***	***P***
subject sex	1	11.145	0.001
stimulus sex	1	25.928	0.000
attractiveness	3	32.361	0.000
subject sex * stimulus sex	1	4.339	0.037
subject sex * attractiveness	3	10.760	0.000
stimulus sex * attractiveness	3	58.151	0.000
subject sex * stimulus sex * attractiveness	3	4.110	0.006

R Squared = 0.043 (Adjusted R Squared = 0.042)

Table 5 shows that the model does not explain the variance in the data very well (R^2 = 0.043). All factors show a significant main effect as well as significant interactions with each other.

Therefore, and in accordance with my hypotheses, I divided the sample into male and female participants as well as into the two stimulus sex conditions. This resulted in four One-Way-ANOVAs on the attractiveness ratings with Post Hoc Tests (Scheffé). (See Appendix 3)

Figure 11 shows that women pressed the button significantly (ca. 50–100 ms) faster when judging female faces as attractive or unattractive as compared to the intermediate categories (somewhat attractive, somewhat unattractive) ($P < 0.001$ each). Male unattractive faces were rated quicker by women than male attractive faces, male somewhat attractive as well as male somewhat unattractive faces (ca. 100–130 ms). ($P < 0.001$ each). All other differences were not significant. (Fig. 11)

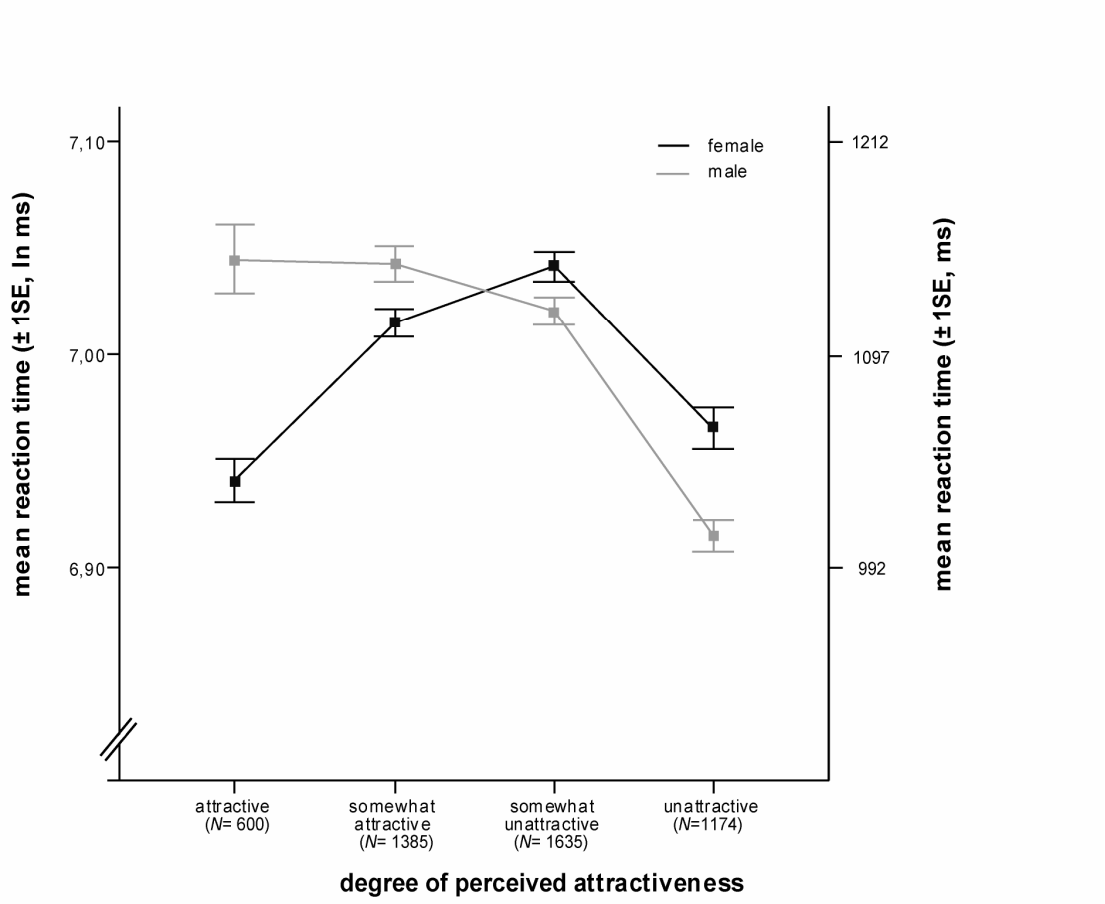

Figure 11. Logarithmised reaction times of female raters.
Female attractive and unattractive faces were rated quicker than somewhat attractive as well as somewhat unattractive faces ($P < 0.001$ each). Male unattractive faces were rated quicker than attractive, somewhat attractive as well as somewhat unattractive male faces ($P < 0.001$ each). (black line = female faces, grey line = male faces).

Figure 12 shows that men rated attractive female faces significantly faster in comparison to every other category (ca. 70–100 ms) ($P < 0.001$ each). All other differences were not significant. Post Hoc Tests further showed that when rating male faces the differences between all the categories reached statistical significance, with judging attractive faces fastest, followed by somewhat attractive, somewhat unattractive and unattractive ones ($P < 0.05$ each). (Fig. 12)

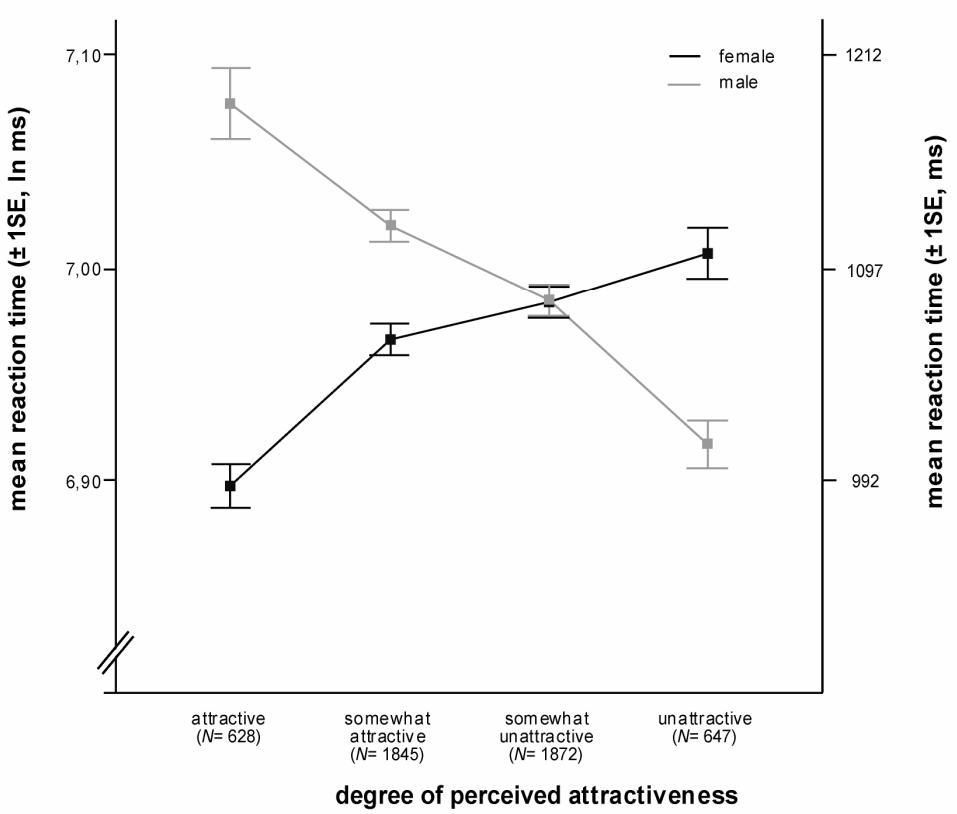

Figure 12. Logarithmised reaction times of male raters.
Rating female faces logarithmised reaction times were significantly shorter for "attractive" ratings in comparison to "unattractive", "somewhat attractive" as well as "somewhat unattractive" ratings ($P < 0.001$ each). Rating male faces logarithmised reaction times were significantly shorter for "unattractive" ratings in comparison to "attractive", "somewhat attractive" as well as "somewhat unattractive" ratings ($P < 0.001$ each). Furthermore reaction times for "attractive" ratings were significantly longer than for "somewhat attractive" ($P = 0.042$), as well as for "somewhat unattractive" ratings $P < 0.001$). Also reaction times for "somewhat attractive" ratings were significantly longer than for "somewhat unattractive" ratings ($P = 0.012$).

A comparison of Figure 11 and Figure 12 shows that women tended to have longer reaction times in general, especially when using the intermediate categories in the ratings, as is confirmed by a significant main effect as well as significant interaction effects of participant's sex (Tab. 5).

Reaction time patterns were similar in men and women in so far as both showed fast responses to attractive female faces and unattractive male faces. They differed in rating unattractive female faces, where men's responses were slower, and also in rating attractive male faces, where also men took longer to respond.

Comparing men's and women's reaction time pattern to opposite-sex faces, one can detect a reversed pattern, with women rating male faces fastest as "unattractive" and men rating female faces fastest as "attractive".

3.2 ELECTROPHYSIOLOGICAL DATA

Out of the 50 participants three (two women and one man) had to be excluded from EEG analyses due to extensive artefacts. The numbers of trials that were use in the following analyses are displayed in Table 2 in chapter 2.6.3.

3.2.1 Global Analysis of Mean Amplitudes

In order to investigate topographical differences associated with different degrees of perceived facial attractiveness, a repeated measures ANOVA (GLM) was performed on the mean amplitude data using electrodes (14), stimulus sex (2) and perceived attractiveness (2) as within-subject factors and subject sex (2) as between-subject factor. Mean amplitudes were computed for 10 timeframes, each as an average of data points over 100 ms (see Tab. 3). The 14 electrodes selected for this analysis are depicted in Figure 9 and described in chapter 2.8.1.

This repeated measures ANOVA was performed twice, 1.) with the factor "perceived attractiveness" including the pooled categories (see Tab. 1) and 2.) for the intermediate categories only, in order to show differences related to including the extreme ratings: "attractive" and "unattractive". Table 6 and Table 7 display the significant main effects and interactions for those two repeated measures ANOVAs.

1.) Mean amplitudes when viewing attractive versus unattractive faces

Table 6 shows the *P*-values for all significant effects and interactions ($P \leq 0.05$) for all the ten timeframes. They are verbally described in the following paragraphs. Detailed results of this ANOVA are displayed in Appendix 4.

Effects of attractiveness:

In TF10, a main effect of perceived attractiveness occurred ($P = 0.023$) with attractive faces eliciting a higher amplitude than unattractive ones. A significant interaction between electrode and perceived attractiveness occurred from TF6 to TF10 ($P < 0.03$ each), showing higher amplitudes for attractive faces, especially in the frontal and midline electrodes. Furthermore a significant three-way interaction between stimulus sex, perceived attractiveness and subject sex can be observed for TF3 ($P = 0.031$), TF4 ($P = 0.046$), TF6 ($P = 0.015$) and by trend in TF5 ($P = 0.082$). As this interaction effect occurs in the timeframe in which the N170 is expected, a detailed description of the interactions

is provided in the analysis of the N170. A second three-way interaction between electrode*stimulus sex*perceived attractiveness was significant in TF10 ($P = 0.036$).

Effects of stimulus sex:

Results show that female faces elicited higher mean amplitudes than male faces from TF5 to TF10 ($P < 0.03$ each). (Fig. 13) Furthermore, female faces elicited a higher amplitude at frontal electrodes in comparison to posterior electrodes in TF1 ($P = 0.04$).

Effects of the rater's sex:

A significant interaction between electrode and subject sex was observed from TF5 to TF7 ($P \leq 0.05$ each), with women showing higher amplitudes than men at lateral electrodes and lower amplitudes at midline and frontal electrodes.

The factor electrode had a significant main effect in almost all timeframes. This finding is expected in healthy human subjects (for *P*-values below 0.05 see Table 6)

Further effects occurring in one timeframe only are not discussed any further, because they could also be due to type I error.

2.) Mean amplitudes when viewing somewhat attractive versus somewhat unattractive faces

Table 7 shows *P*-values for all significant effects ($P \leq 0.05$) in all ten timeframes. They are verbally described in the following paragraphs. Detailed results of this ANOVA are displayed in Appendix 5.

Effects of attractiveness:

A significant three-way interaction between stimulus sex and perceived attractiveness and subject sex was present only in TF3 ($P = 0.039$). As described above, directions of this effect will be discussed when reporting the analysis of the N170. No significant interaction between electrode and perceived attractiveness could be reported for the intermediate category data, only a trend in TF7 ($P = 0.070$), showing the same pattern as in the pooled data. A three-way electrode*stimulus sex*perceived attractiveness interaction was significant in TF9 and TF10 ($P < 0.03$ each), with attractive female faces eliciting a higher amplitude in parietal midline electrodes than unattractive female and male faces.

Effects of stimulus sex:

Results show that female faces elicited higher mean amplitudes than male faces from 200 ms to 550 ms ($P < 0.05$ each, except TF6: $P = 0.064$). Also in TF1 female faces elicited a

higher amplitude at frontal electrodes in comparison to posterior electrodes ($P = 0.042$). In TF10 women showed higher amplitudes in response to female faces than to male faces and also higher amplitudes than men, which also showed higher amplitudes to female faces but to a lesser degree ($P = 0.019$).

Effects of the rater's sex:

A significant interaction between electrode and subject sex was observed for TF5 and TF6 ($P \leq 0.04$ each) and a trend in TF7 ($P = 0.057$), with women showing higher amplitudes than men at lateral electrodes and lower amplitudes at midline and frontal electrodes.

The factor electrode had a significant main effect in almost all timeframes. As reported above, this finding is expected in healthy human subjects. (for *P*-values below 0.05 see Table 7)

To conclude, perceived attractiveness differentially influences brain activity from as early as 150 ms after stimulus onset on. This effect was further investigated in the N170 peak analysis.

Furthermore, attractive faces elicited higher amplitudes, especially in the frontal and midline electrodes, from 250 ms on, when analysing the pooled categories (i.e. including the "extreme" ratings "attractive" and "unattractive" in the data). This effect failed to reach significance in the analysis of the intermediate categories alone, but a trend could be observed for TF7. Therefore this timeframe was selected for presentation of the differences in the 14 electrodes in relation to perceived attractiveness. Figure 14 shows that attractive faces elicit higher amplitudes at the frontal electrodes (4, 6, 11, 34, 41) and also at more central and parietal sites (48, 58). Due to location and timing, those differences point to differences in the P300. Therefore a separate analysis on the P300 was performed (see chapter 3.2.3).

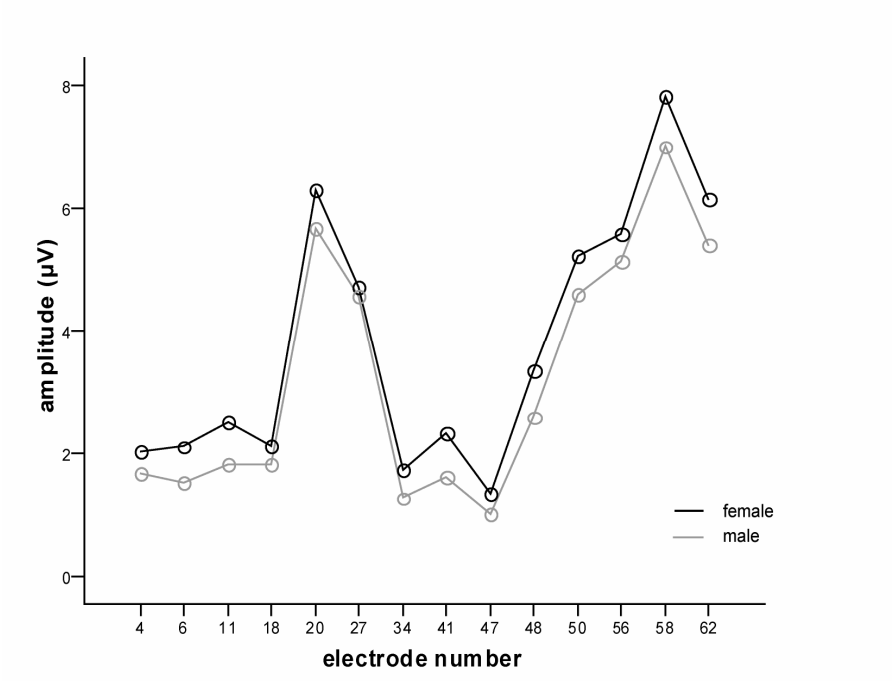

Figure 13. Viewing female and male faces in TF7 (300-400 ms).
TF7 has been selected to depict effects of "stimulus sex" on all participants (*N*=47). The factor stimulus sex has a significant main effect from TF5 to TF10 in the pooled category data as well as in the intermediate category data. This graph is based on the pooled data. Mean amplitude values are higher for viewing female faces in all electrodes. (black line = female faces, grey line = male faces).

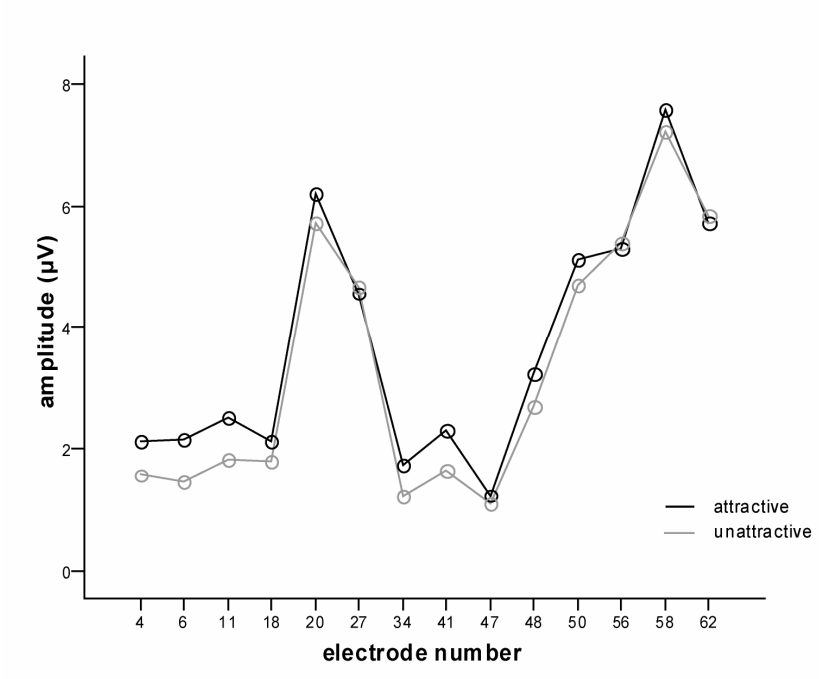

Figure 14. Viewing attractive versus unattractive faces in TF7 (300-400 ms).
A significant electrode*perceived attractiveness interaction could be observed from TF6 to TF10 for the pooled categories but not for the intermediate categories. Even in the latter a trend occurred in TF7, therefore this timeframe has been selected to display interaction effects for the pooled categories. (black line = attractive faces, grey line = unattractive faces).

Table 6. Main effects and interactions of the mean amplitude analysis for the pooled categories for all timeframes.
Significant results of a repeated measures ANOVA with electrode (14) × stimulus sex (2) × perceived attractiveness (2; pooled attractive faces, pooled unattractive faces) × subject sex (2). Only *P*-values ≤ 0.05 are displayed. All *P*-values are rounded to the third decimal and corrected after Greenhouse-Geisser.
(elec = electrode, stimsex = stimulus sex, cond = perceived attractiveness, vpsex = subject sex).

Timeframe		*stimsex*	*cond*	*elec*stimsex*	*elec*cond*	*elec*vpsex*	*stimsex*vpsex*	*stimsex*cond*vpsex*	*elec*stimsex*cond*	*elec*
TF1	**0 – 100 ms**			0.040						0.046
TF2	**50 – 150 ms**									0.000
TF3	**100 – 200 ms**							0.031		0.000
TF4	**150 – 250 ms**							0.046		0.000
TF5	**200 – 300 ms**	0.031				0.036				
TF6	**250 – 350 ms**	0.002			0.026	0.030		0.015		0.000
TF7	**300 – 400 ms**	0.001			0.001	0.050				0.000
TF8	**350 – 450 ms**	0.013			0.008					0.000
TF9	**400 – 500 ms**	0.034			0.008					0.000
TF10	**450 – 550 ms**	0.009	0.023		0.006				0.036	0.000

Table 7. Main effects and interactions of the mean amplitude analysis for the intermediate categories for all timeframes.
Significant results of a repeated measures ANOVA with electrode (14) × stimulus sex (2) × perceived attractiveness (2; somewhat attractive, somewhat unattractive) × subject sex (2). Only *P*-values ≤ 0.05 are displayed. All *P*-values are rounded to the third decimal and corrected after Greenhouse-Geisser.
(elec = electrode, stimsex = stimulus sex, cond = perceived attractiveness, vpsex = subject sex).

Timeframe		*stimsex*	*cond*	*elec*stimsex*	*elec*cond*	*elec*vpsex*	*stimsex*vpsex*	*stimsex*cond*vpsex*	*elec*stimsex*cond*	*elec*
TF1	**0 – 100 ms**			0.042						0.166
TF2	**50 – 150 ms**									0.000
TF3	**100 – 200 ms**							0.039		0.000
TF4	**150 – 250 ms**									0.000
TF5	**200 – 300 ms**	0.033				0.037				
TF6	**250 – 350 ms**					0.033				0.000
TF7	**300 – 400 ms**	0.047								0.000
TF8	**350 – 450 ms**	0.013								0.000
TF9	**400 – 500 ms**	0.025							0.030	0.000
TF10	**450 – 550 ms**	0.009					0.019		0.029	0.000

3.2.2 N170 Peak Analysis

In order to investigate the relationship between perceived attractiveness and early visual processes, an analysis of the peak amplitude and peak latency of the N170 component was performed.

3.2.2.1 N170 Peak Amplitude Analysis

Peak amplitude analysis for the N170 was only performed for the intermediate categories ("somewhat attractive", "somewhat unattractive"), because peak analyses are very sensitive to differences in trial numbers (Luck, 2005). As explained in chapter 2.8.1, electrodes 27 and 56 were selected to investigate differences in hemisphere. A repeated measures ANOVA was performed on the peak amplitude data using electrode (2), stimulus sex (2) and perceived attractiveness (2) as within-subject factors and sex of the participant (2) as between-subject factor to investigate whether differentially perceived attractiveness results in differences in the N170 amplitude.

Results showed that the N170 peak amplitude was on average twice as high in the right hemisphere than in the left hemisphere ($P \leq 0.001$). Table 9 displays the mean peak values for the left (electrode 56) and right hemisphere (electrode 27). Furthermore, results show that unattractively rated female faces evoked a stronger negativity of the N170 than attractive female faces, whereas the opposite was true for male faces ($P = 0.045$). (Tab. 8 & Fig. 15, 16, 17)

Differences between female and male participants were not significant, but are displayed in Figures 16 and 17 due to the fact that a four-way interaction between hemisphere, stimulus sex, perceived attractiveness and subject sex showed a statistical trend ($P = 0.065$).

Table 8. Variation of the N170 amplitude.
Main effects and interaction effects for the N170 peak amplitude are displayed in this table. A main effect of hemisphere as well as a significant interaction between stimulus sex and perceived attractiveness (could be observed. . All *P*-values are rounded to the third decimal and significant *P*-values printed in bold. df=1.
(hem= hemisphere (left = electrode 56, right =electrode 27, stimsex = stimulus sex, cond = perceived attractiveness , vpsex = subject sex).

Source	*F*	*P*
hem	16.030	**0.000**
hem * vpsex	0.300	0.586
stimsex	0.043	0.837
stimsex * vpsex	0.010	0.922
cond	0.827	0.368
cond * vpsex	1.113	0.297
hem * stimsex	0.033	0.857
hem * stimsex * vpsex	0.111	0.741
hem * cond	0.005	0.941
hem * cond * vpsex	0.053	0.819
stimsex * cond	4.238	**0.045**
stimsex * cond * vpsex	0.033	0.856
hem * stimsex * cond	0.646	0.426
hem * stimsex * cond * vpsex	3.570	0.065

Table 9 shows that the mean of the N170 amplitude is on average twice as high in the right hemisphere (electrode 27) than in the left (electrode 56).

Table 9. Differences in peak amplitude values of the N170 for electrodes 27 and 56

Electrode	*Category*	*Mean (µV)*	*SD (µV)*
27	female somewhat attractive faces	-5.0513	4.38021
27	female somewhat unattractive faces	-5.9679	5.15724
27	male somewhat attractive faces	-5.7379	3.81956
27	male somewhat unattractive faces	-5.3670	4.60818
56	female somewhat attractive faces	-2.4511	4.43596
56	female somewhat unattractive faces	-3.1585	4.41230
56	male somewhat attractive faces	-2.9889	4.72291
56	male somewhat unattractive faces	-2.7945	4.43002

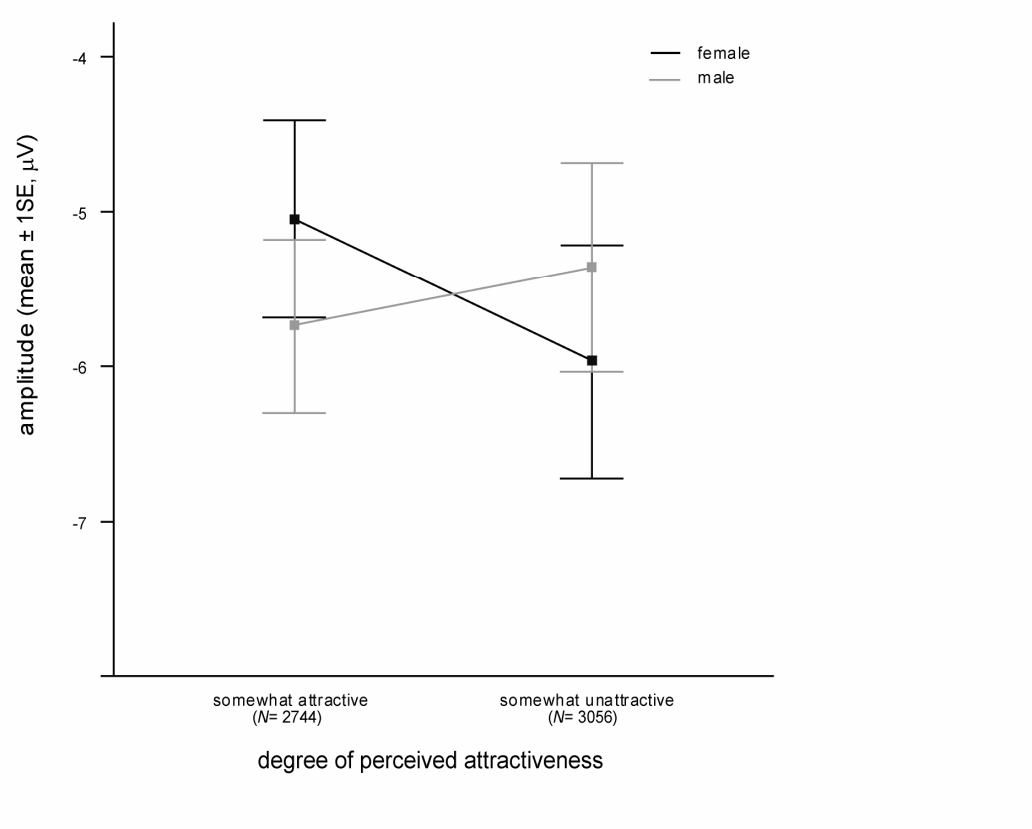

Figure 15. Peak amplitudes of the N170 for all participants. Interaction of perceived attractiveness and stimulus sex. Unattractive female faces elicit a stronger negativation than attractive female faces, whereas attractive male faces elicit a lower negativation than unattractive male faces. ($N = 47$) (black line = female faces, grey line = male faces)

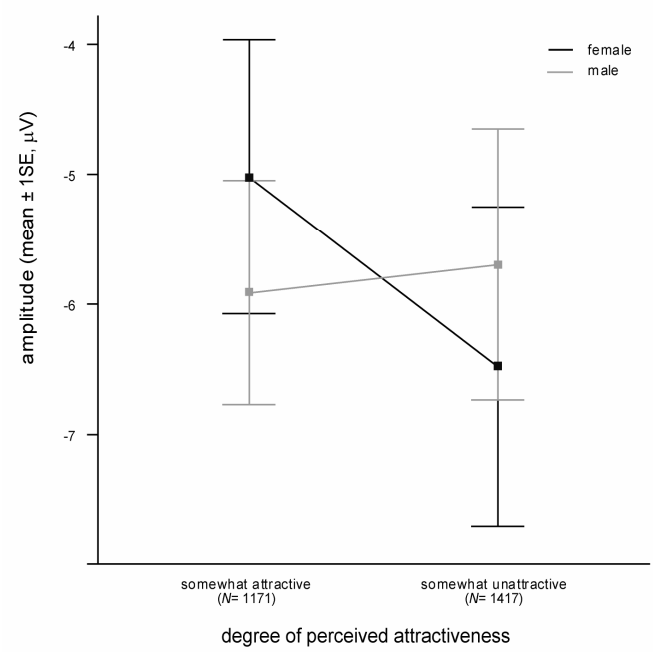

Figure 16. Peak amplitudes of the N170 for female participants.
Interaction of perceived attractiveness and stimulus sex. Unattractive female faces elicit a stronger negativation than attractive female faces, whereas the opposite was true male faces. ($N = 23$) (black line = female faces, grey line = male faces).

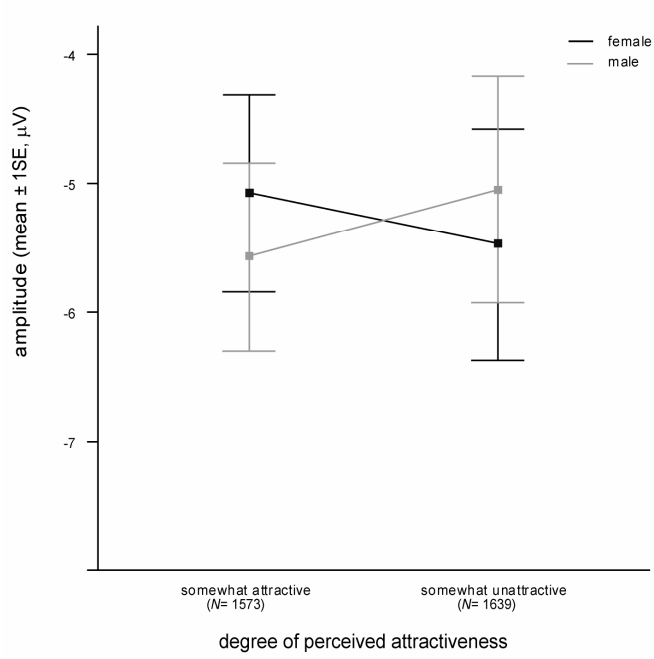

Figure 17. Peak amplitudes of the N170 for male participants.
Interaction of perceived attractiveness and stimulus sex. Unattractive female faces elicit a stronger negativation than attractive female faces, whereas the opposite was true male faces. ($N = 24$) (black line = female faces, grey line = male faces).

In the following, grand average plots of the ERP waveforms are displayed to illustrate amplitude differences in the N170 for women and men perceiving female and male faces varying in their degree of perceived attractiveness.

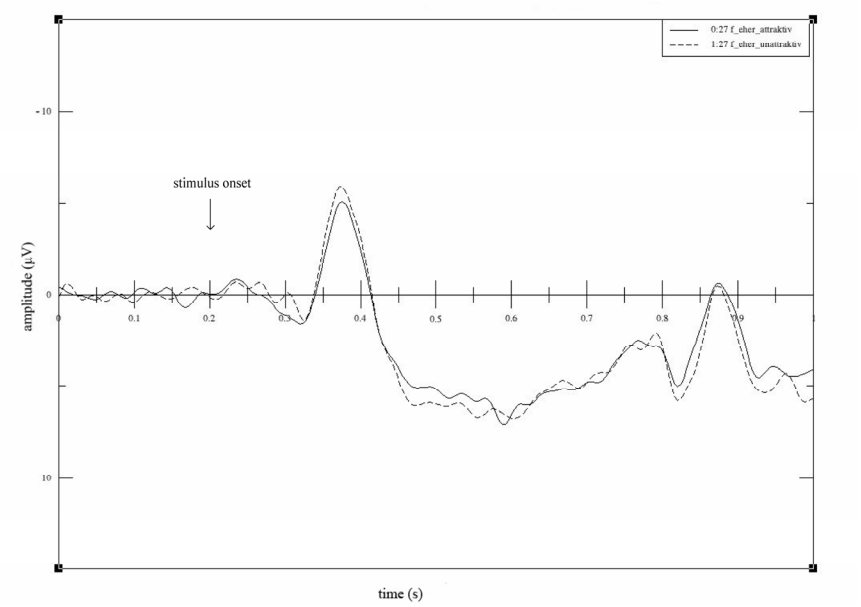

Figure 18. N170 amplitudes in women in response to somewhat attractive and unattractive female faces.
Plot of the grand average over all female participants ($N = 23$) judging female faces as "somewhat attractive" (N= 673) (solid line) and "somewhat unattractive" (N= 666) (dashed line) at electrode 27. The first 200 ms are used as a baseline.

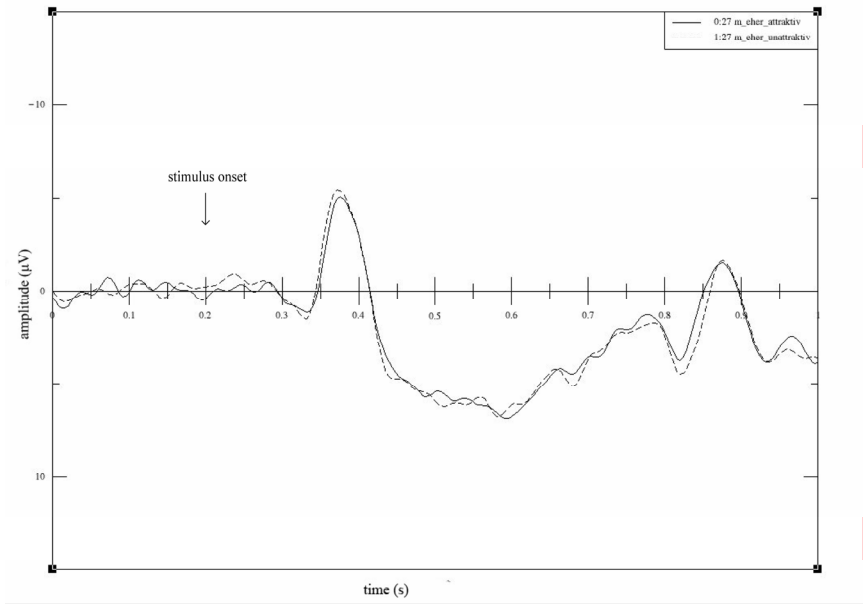

Figure 19. N170 amplitudes in women in response to somewhat attractive and unattractive male faces.
Plot of the grand average over all female participants ($N = 23$) judging male faces as "somewhat attractive" (N= 498) (solid line) and "somewhat unattractive" (N= 751) (dashed line) at electrode 27. The first 200 ms are used as a baseline.

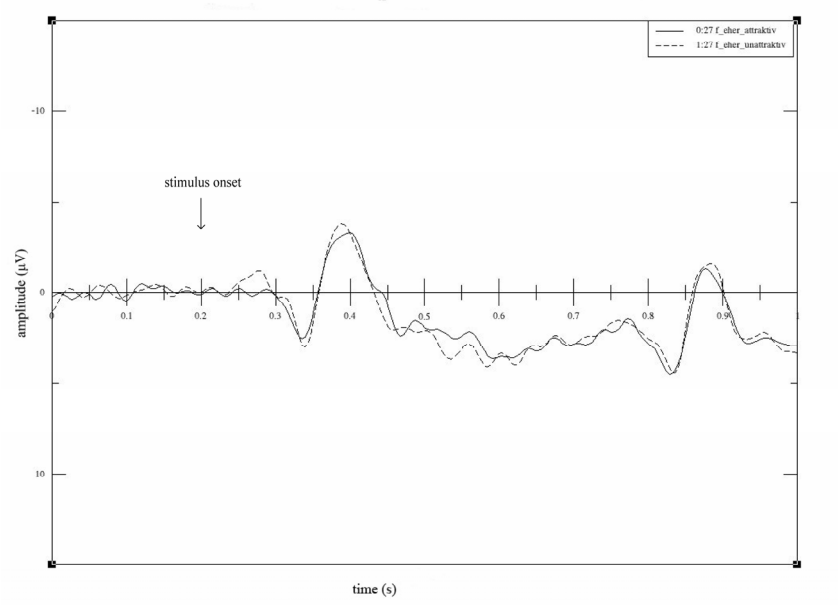

Figure 20. N170 amplitudes in men in response to somewhat attractive and unattractive female faces.
Plot of the grand average over all male participants (*N* = 24) judging female faces as "somewhat attractive" (*N*= 782) (solid line) and "somewhat unattractive" (*N*= 742) (dashed line) at electrode 27. The first 200 ms are used as a baseline.

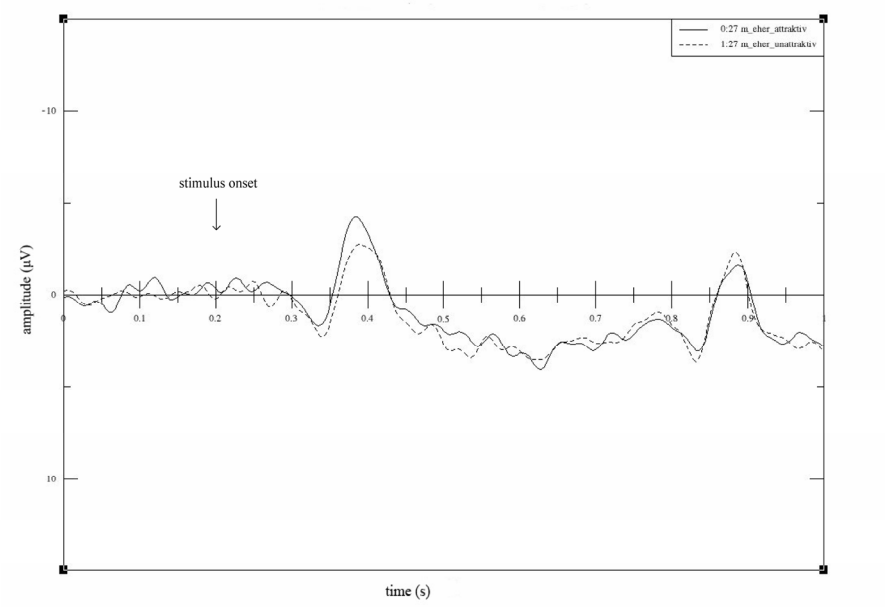

Figure 21. N170 amplitude differences in men in response to somewhat attractive and unattractive male faces.
Plot of the grand average over all male participants (*N* = 24) judging male faces as "somewhat attractive" (*N*= 791) (solid line) and "somewhat unattractive" (*N*= 897) (dashed line) at electrode 27. The first 200 ms are used as a baseline.

To examine where the centre of activation for the N170 is located, a sLORETA analysis was performed.

sLORETA localisations show the centre of activation in the right hemisphere in Brodmann area 19. The activation exhibits a stronger lateralisation in male than in female subjects. (Fig. 22 to 24) The condition of judging a female face as somewhat attractive was chosen representative for other categories. No significant differences could be shown by using sLORETA statistics for non-parametric mapping.

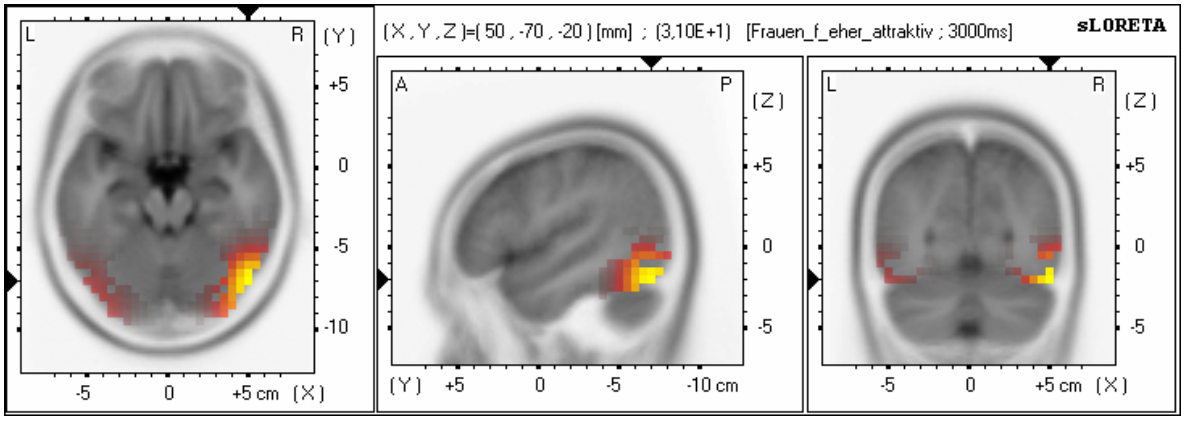

Figure 22. Localisation of the N170 in women when rating female faces "somewhat attractive".
sLORETA source localisation finds the centre of activation in Brodman area 19 (fusiform gyrus, temporal lobe). A transversal, a sagittal and a coronal view depict the area of highest current density (yellow).

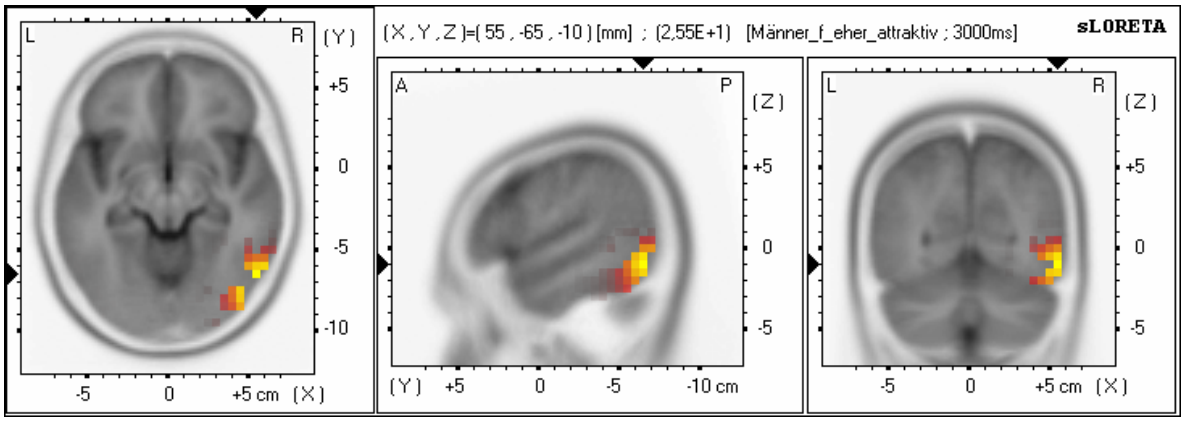

Figure 23. Localisation of the N170 in men when rating female faces "somewhat attractive".
sLORETA source localisation finds the centre of activation in Brodman area 19 (middle occipital gyrus, occipital lobe). A transversal, a sagittal and a coronal view depict the area of highest current density (yellow).

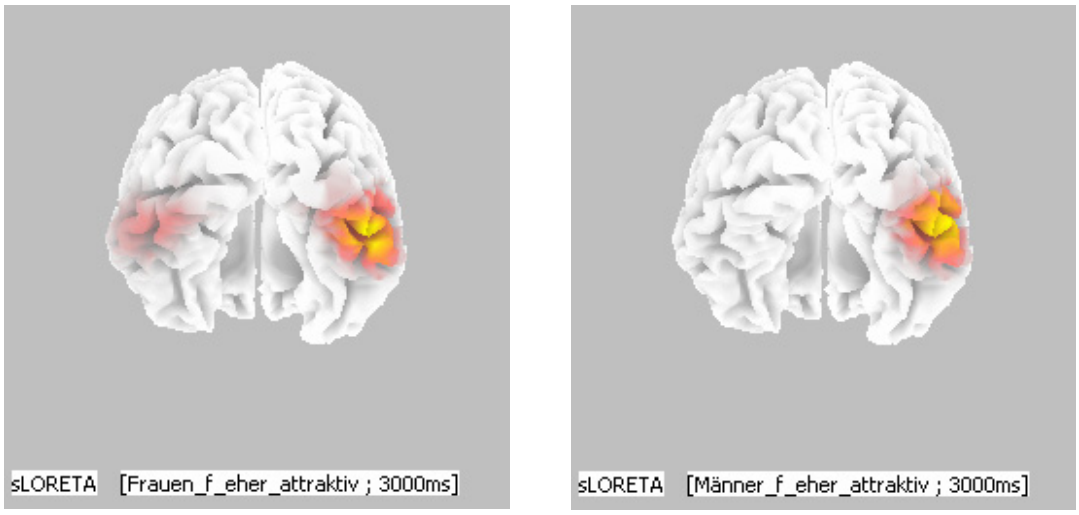

Figure 24. Localisation of N170 in women (on the left) and men (on the right).
Posterior-ventral view on a model brain. sLORETA localisation shows more lateralised activity in men than in women. Both male and female participants show the centre of activation in the right BA 19, when rating female faces as "somewhat attractive".

3.2.2.2 N170 Peak Latency Analysis

In order to investigate temporal differences in the N170, a repeated measures ANOVA on the peak latency of the N170 was performed at electrode 27 with stimulus sex (2) and perceived attractiveness (2) as within-subject factors and sex of the participant (2) as between subject factor.

Table 10: Variation in the N170 latency.
Main and interaction effects for the N170 peak latency are displayed. A significant main effect of subject sex can be observed, as well as a significant interaction between stimulus sex and perceived attractiveness. All *P*-values are rounded to the third decimal. Significant *P*-values printed in bold. df=1. (stimsex = stimulus sex, cond = perceived attractiveness, vpsex = subject sex)

Source	***F***	***P***
stimsex	0.079	0.779
stimsex * vpsex	0.010	0.921
cond	1.892	0.176
cond * vpsex	1.423	0.239
stimsex * cond	9.891	**0.003**
stimsex * cond * vpsex	0.134	0.716
vpsex	12.586	**0.001**

Results show a significant interaction between stimulus sex and degree of perceived attractiveness (Table 10), as well as a significant between-subject difference. In female participants the peak of the N170 occurs earlier in time (mean = 176.261 ms ± SE 2.482 after stimulus onset) than in male subjects (mean = 188.583 ms ± SE 2.430 after stimulus onset). Furthermore, N170 peak latency is longer for somewhat attractive female faces than for somewhat unattractive female faces, whereas the contrary effect is found for male faces. Figure 25 and 26 display the pattern of interaction.

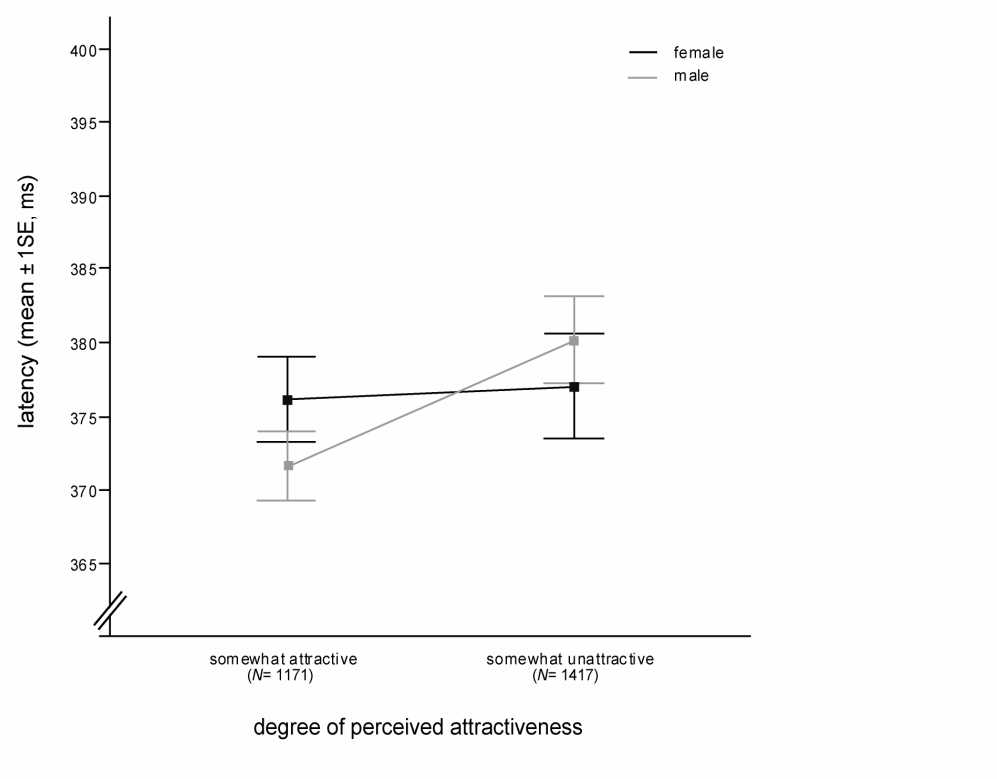

Figure 25. Peak latency of the N170 in female participants.
The chart displays the interaction between stimulus sex and perceived attractiveness. Latency measures include 200 ms baseline. (N = 23)
(black line = female faces, grey line = male faces)

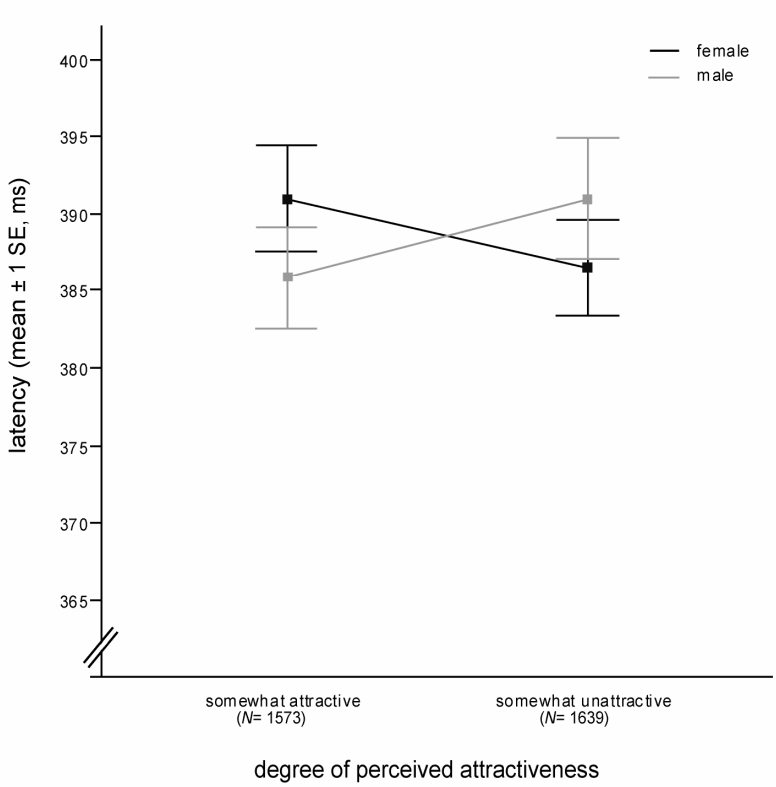

Figure 26. Peak latency of the N170 in male participants.
The chart displays the interaction between stimulus sex and perceived attractiveness. Latency measures include 200 ms baseline. ($N = 24$) (black line = female faces, grey line = male faces)

3.2.3 P300 Mean Amplitudes Analysis

In order to investigate effects of attractive and unattractive faces – being stimuli of high social and biological relevance – on attentional aspects of brain activation, a focus of this study was on the P300 component.

Three electrodes (6, 48 and 58) were selected for this analysis, because they represent regions, where P300 is generally observed. Mean amplitudes were computed only for six timeframes (TF5 to TF10 = 200 ms to 550 ms), because the early part of the component (P3a) is supposed to have its maximum at 250 ms – 300 ms and the later part (P3b) has a latency range from 500 ms to 1400 ms (Polich, 2007). A repeated measures ANOVA was performed on the mean amplitude data using electrodes (3), stimulus sex (2) and perceived attractiveness (2) as within-subject factors and sex of the participant (2) as between-subject factor. Table 11 shows the *P*-values for significant main effects and interactions ($P \leq 0.05$)

for the six timeframes. The detailed list of all within-subject and between-subject effects can be found in the appendix (Appendix 6).

Table 11: Main effects and interactions in the mean amplitude analysis of the P300.
Significant results of a repeated measures ANOVA with electrode (3) × stimulus sex (2) × perceived attractiveness (2; somewhat attractive, somewhat unattractive) × subject sex (2). All *P*-values are rounded to the third decimal and corrected after Greenhouse-Geisser. Only *P*-values ≤ 0.05 are displayed.
(elec = electrode, stimsex = stimulus sex, cond = perceived attractiveness , vpsex = subject sex).

Timeframe		*stimsex*	*stimsex*vpsex*	*elec*stimsex*cond*	*elec*stimsex*vpsex*	*elec*
TF5	**200 – 300 ms**	0.040				0.038
TF6	**250 – 350 ms**					0.000
TF7	**300 – 400 ms**	0.035				0.000
TF8	**350 – 450 ms**	0.014				0.000
TF9	**400 – 500 ms**	0.047		0.007		0.000
TF10	**450 – 550 ms**	0.030	0.026	0.006	0.010	0.000

A significant main effect of electrode position was found. Electrode 58 showed higher amplitudes than the more anterior electrodes 48 and 6 in all six timeframes ($P \leq 0.04$ each), which is in accordance with the results from other studies that found highest P300 amplitudes over central parietal electrodes.

The main effect of stimulus sex showed that female faces elicit a higher P300 amplitude than male faces. ($P \leq 0.05$ each), only in TF6 this effect did not reach significance ($P = 0.067$). In TF10 female faces elicited a higher amplitude than male faces in women, but not in men. ($P = 0.026$). A significant three-way interaction of electrode, stimulus sex and sex of the participant in this timeframe shows higher amplitudes in women in response to female faces compared to male faces at all three electrodes, but only at electrode 6 in men (Fig. 26 and 27).

Furthermore, there was a significant interaction between electrode, stimulus sex and perceived attractiveness in TF9 and TF10 (400–550 ms), which failed to reach significance in TF8 ($P = 0{,}058$). As shown in the Figures 29 and 30 attractive female faces elicit a higher P300 amplitude than unattractive female faces, whereas attractive male faces elicit a lower P300 amplitude than unattractive male faces at electrode 48 and 58, but not in 6.

This pattern of attractive female faces eliciting a higher P300 amplitude than unattractive female faces und vice versa for male faces can also be observed in the other timeframes, but failed to reach statistical significance.

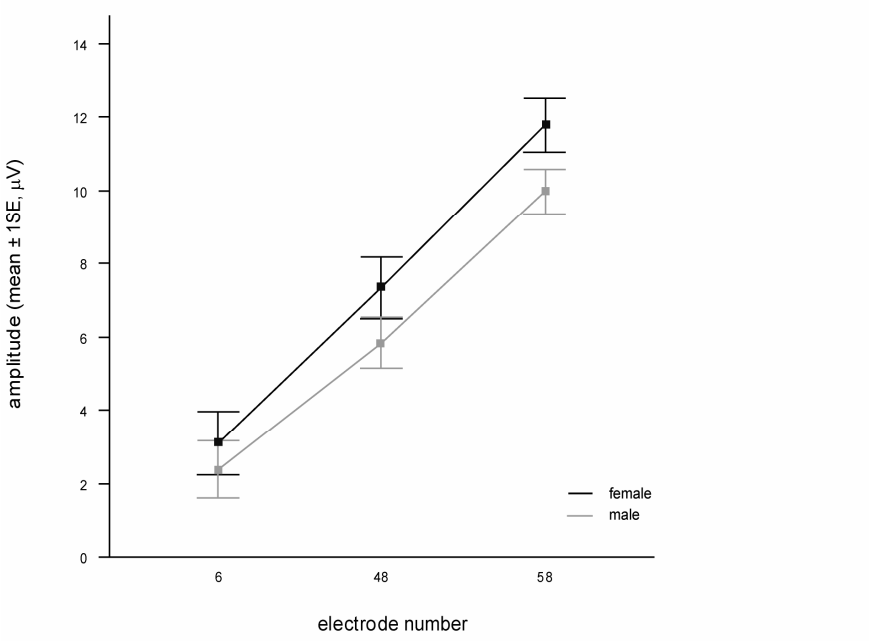

Figure 27. P300 in women in response to viewing female and male faces.
A significant three-way interaction of electrode, stimulus sex and subject sex in TF10 shows higher amplitudes in women (*N*= 23) in response to female faces (*N*= 1339) than to male faces (*N*= 1249) at all three electrodes. Men (Fig.28) show a higher amplitude when viewing female faces only at electrode 6. In women the difference between the amplitudes increases at posterior electrodes. (black line = female faces, grey line = male faces)

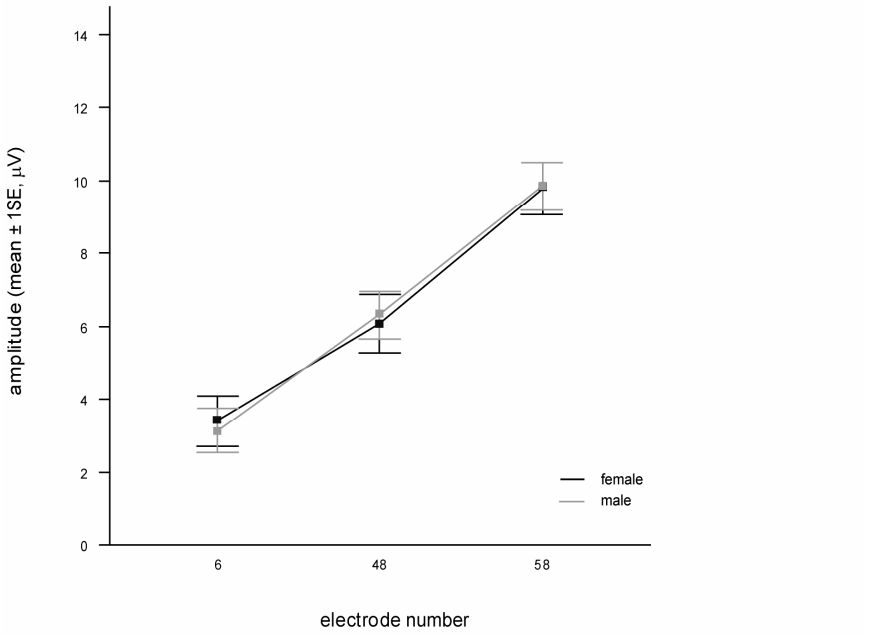

Figure 28. P300 in men in response to viewing female and male faces.
A significant three-way interaction of electrode, stimulus sex and subject sex in TF10 shows a higher amplitude in men (*N*= 24) when viewing female faces (*N*= 1524) in comparison to male faces (*N*= 1688) only at electrode 6, whereas women show higher amplitudes in response to female faces than to male faces at all three electrodes (Fig. 27). Men show less difference in amplitudes in response to female or male faces than do women. (black line = female faces, grey line = male faces).

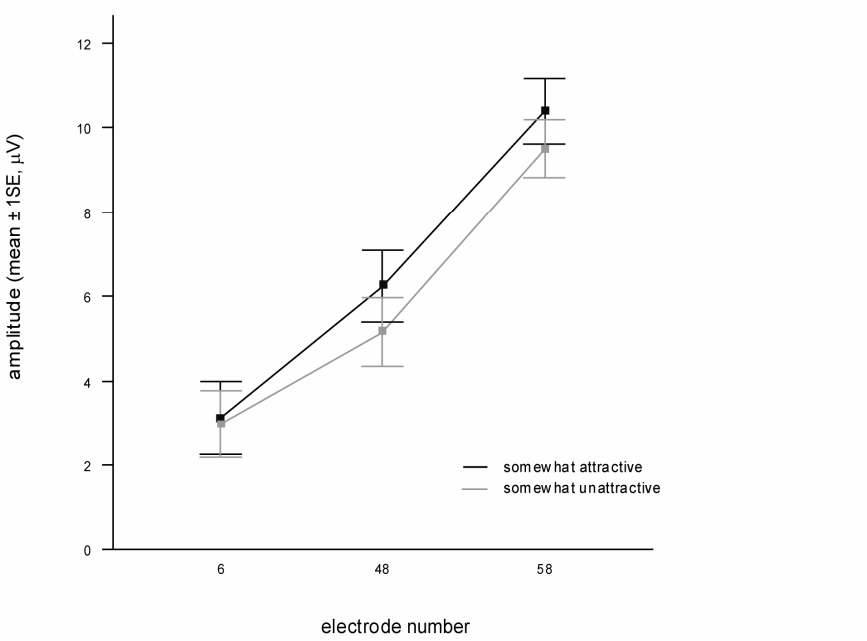

Figure 29. P300 amplitudes for all participants viewing attractive and unattractive female faces. Participants (*N*= 47) show higher amplitudes in response to attractive female faces (*N*= 1455) compared to unattractive female faces (*N*= 1408) at all three electrodes in TF9, whereas this pattern is different for male faces (Fig. 30). (black line = attractive faces, grey line = unattractive faces).

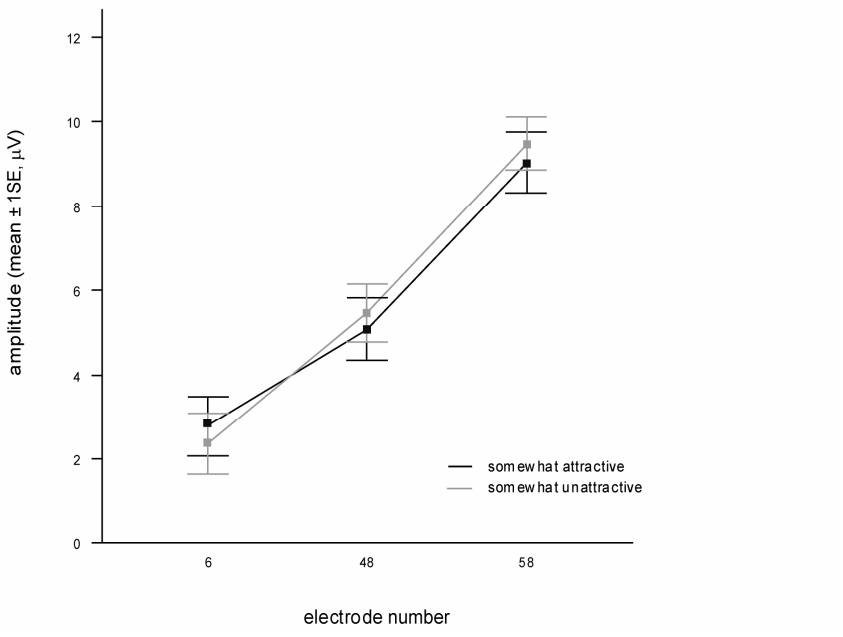

Figure 30. P300 amplitudes for all participants viewing attractive and unattractive male faces. All participants (*N*= 47) show higher amplitudes in response to unattractive male faces (*N*= 1648) compared to attractive male faces (*N*= 1289) at the more posterior electrodes, but not at the frontal electrode. In contrast to that, female attractive faces yield higher amplitudes at all electrodes (Fig. 29) (black line = attractive faces, grey line = unattractive faces).

4 DISCUSSION

Before starting the discussion of my findings, I will give a short summary on my results.
The analysis of the frequencies of the attractiveness ratings showed a strong tendency of participants to rate the intermediate categories more often. Reliability analysis confirmed that participants agreed on the degree of attractiveness of the stimulus faces. The reaction time patterns were similar in men and women, in so far as both responded faster to female faces perceived as attractive and also faster to unattractive male ones. However, men's responses were slower, when rating female faces as unattractive. They also took longer to rate a male face as attractive, than women did. Women tended to have longer reaction times in general, especially when rating the intermediate categories.
The analysis of mean amplitudes revealed differential effects of perceived attractiveness from 150 ms after stimulus onset on, which were further explored in the peak analysis of the N170 and a mean amplitude analysis of the P300 component. The peak amplitude of the N170 was higher in the right hemisphere than in the left hemisphere. Furthermore, it could be shown that unattractive female faces evoked a stronger negativity of the N170 than attractive ones, whereas the opposite was true for male faces. The N170 peak was later when judging a female face more attractive, whereas the contrary effect was found for male faces. Moreover, women showed in general an earlier N170 peak than men. The N170 could be localised in BA 19, in both men and women. From 400 ms to 550 ms after stimulus onset, P300 analysis revealed that attractive female faces elicited a higher P300 amplitude than unattractive ones, whereas attractive male faces elicited a lower P300 amplitude than unattractive ones in electrode 48 and 58, but not in 6 in the timeframe from 400 ms to 550 ms after stimulus onset.

4.1 DISCUSSION OF THE RATING BEHAVIOUR

4.1.1 Attractiveness Ratings

It was obvious that subjects tended to select the intermediate categories more often. This caused difficulties for ensuing ERP-analysis that should be based on similar trial numbers for each category. One solution to this problem could be, to show each stimulus face several times and perform the attractiveness rating after the EEG recording. But such an approach risks recognition effects, which might confound the results. Another solution would be to include a higher number of faces rated as extremely attractive. But increasing

the number of stimulus faces, also increases the length of the experiment, which reduces attention and motivation of the participants.

Werheid and colleagues (2007) avoided this problem by using already categorised stimulus faces. Those faces had been subject to attractiveness ratings prior to the ERP study and only those faces that yielded very high or low ratings were used for the EEG experiment. This way the shown faces were classified according to "objective" attractiveness ratings and not according to subjective ratings of each participant as it was the case in my study. Although the stimuli I used had also been previously subject to attractiveness rating studies – which provided basis for selecting the stimulus set –, I decided against grouping the EEG recordings according to "objective" ratings, because I was essentially interested in subjectively experienced attractiveness. This decision was based on studies showing differences in attractiveness ratings related to individual mating strategies (Thornhill & Gangestad, 1999) and also takes individual differences in the perception of attractiveness into account.

4.1.2 Reliability Analysis of Attractiveness Ratings

The greater percentage of randomly distributed ratings by female participants could be explained by the fact that for women other mate values, such as status, commitment, etc., play an important role and influence the perception of a man as attractive. Furthermore, temporal aspects, i.e. if someone is looking for a long-term partnership rather than for a short-term one, changes the qualities of a man that are perceived as attractive. However, men rely much more on physical attractiveness as a cue for mate value and also stronger agree in rating the attractiveness of a woman (Buss, 2007).

Moreover, women that participated in this study were at different phases of their menstrual cycle. This might also have resulted in the pursuit of different mating strategies and in different assessment of faces as attractive. (Thornhill & Gangestad, 1999)

In order to test this assumption and improve reliability between ratings of different subjects, one should consider testing more women, grouped according to their menstrual cycle.

4.1.3 Reaction Time Differences in Women and Men

Reaction time patterns were similar in men and women in so far as both showed fast responses when confronted with a female face they found attractive or a male faces they found unattractive. They differed when rating unattractive female faces, where men's responses were slower, and also when rating attractive male faces, where also men took longer to respond.

Werheid and colleagues (2007) as well as Ishai (2007) reported faster response to non-attractive faces in their study, irrespective of the sex of the rater and the stimulus. This effect is also found in my study, but only for male faces. The different reaction time pattern for female faces could be due to the fact that I used a 4-point scale to rate attractiveness, whereas Werheid and colleagues (2007) just used two categories, "attractive" versus "non-attractive". The greater choice of options could result in longer reaction times in general. The delayed response to unattractive female faces in male subjects might be explained by the fact that men could consider all young and fertile women as rather attractive and potential mating partners. Men can increase their fitness with the number of copulations, while this strategy does not work for women. Women have the higher obligatory parental investment, which increases the costs for a wrong decision (Trivers, 1972; Buss, 2007). Therefore men are also expected to be less choosy than women. This is reflected in the reaction time pattern. Women's reaction times to opposite-sex stimuli were about the same length for attractive, somewhat attractive and somewhat unattractive faces, but faster to unattractive ones. This could reflect the higher risk of making a wrong choice. A men that is neither attractive as a potential long-term partner nor as a potential short-term partner should be identified as unattractive fast, which is confirmed by the results of my study.

Men's slow response to attractive male faces could be related to high intrasexual competition that could result in a tendency to downplay attractiveness of same-sex individuals. Therefore it could take more time to decide whether another man is attractive.

Other studies (e.g. Aharon et al., 2001) show slower responses to attractive/beautiful stimuli, irrespective of their sex. They stress the reward value of the stimulus, which evokes the desire to watch an attractive face for a longer period of time than unattractive ones. The fact that this effect did not occur in my reaction time results can be explained by the specific study design. In my study, viewing time of the stimulus was constant and independent of the button press.

4.2 DISCUSSION OF THE ELECTROPHYSIOLOGICAL PATTERNS

Due to the small numbers of trials in the categories "attractive" and "unattractive", I had to merge them with the specific intermediate category for the analysis of mean amplitudes. Therefore I was not able to investigate differences between these more extreme ratings and the intermediate ratings, which could have been very informative. As a study of Winston and colleagues (2007) showed, some brain regions do not respond in a linear way to facial attractiveness. They found non-linear effects in the right amygdala, the right middle temporal gyrus (adjacent to STS) as well as in the medial orbitofrontal cortex showing greater activation in response to highly attractive or unattractive faces in comparison to neutral ones. Also Johnston and colleagues (1986) found that P300 amplitude varies with emotional value of stimuli in a U-shaped way. Pleasant and unpleasant pictures yielded a larger P300 amplitude than did neutral ones. Although participants of this study did not have the possibility to rate a face as neutral, but had to decide between attractive or unattractive, one can assume that subjects tended to rate faces, they considered as neutral, within the "somewhat" categories. This could provide an explanation for the higher amplitudes for attractive faces, especially at the frontal and midline electrodes from 250 ms on in the pooled data, whereas this effect cannot be found in the intermediate categories, suggesting an influence of the "extreme" ratings ("attractive" and "unattractive") on the ERPs related to perceived attractiveness.

4.2.1 Early Effects of Perceived Attractiveness on Visual Processing – N170

The most important finding of this study is that unattractive female faces evoked a stronger negativity of the N170 than attractive female faces, whereas the opposite was true for male faces in both, men and women.

The N170 as an early visual component is generally associated with structural encoding of faces (Sagiv & Bentin, 2001) and has only recently been discussed to be modulated by emotional expression of a face (Sprengelmeyer & Jentzsch, 2006; Blau et al., 2007) as well as familiarity (Caharel et al, 2002) or race (Ito & Urland, 2005). Pizzagalli and colleagues (2002) found affect-modulated brain activity between 100 ms and 170 ms in response to the "Szondi portraits" (portraits of psychiatric patients), when the task was to rate faces as likable or non-likable. Activity in the fusiform gyrus around 160 ms was higher for liked than for disliked faces. Although those faces were also rated for

attractiveness in an independent study, that also correlated likable and attractive, attractiveness was not explicitly investigated in this experiment. Event related potential studies on facial attractiveness (Werheid et al., 2007) reported the earliest activation differences relating to facial attractiveness at 250 ms after stimulus onset. Werheid and colleagues therefore were first to report modulation of ERPs in relation to attractiveness prior to the late positive complex (LPC), which has been described by Oliver-Rodriguez and colleagues (1999) and Johnston & Oliver-Rodriguez (1997). Results of my current study provide further evidence that ERPs are modulated by facial attractiveness prior to the P300 and even earlier than 250 ms after stimulus onset. Thus, the results of this study once more question the approach of bottom-up processing of visual information, which assumes that configural aspects of faces are processed prior to emotional and motivational aspects. My findings provide evidence for a very early influence of evaluative processes on visual processing of faces, as also discussed in the models of face processing of Gobbini & Haxby (2007) and Palermo & Rhodes (2007).

Both, statistical analysis as well as source localisation showed that the N170 amplitude is higher in the right hemisphere, an effect that has also been reported in previous studies (Sagiv & Bentin, 2001, Pizzagalli et al., 2002). A stronger lateralisation is observed in male participants, which is congruent with findings of a greater brain asymmetry in men (for a review on brain asymmetry see Toga & Thompson, 2003).

Although I could only include ERP data from the “somewhat attractive” and “somewhat unattractive” ratings in the N170 peak analysis, a significant interaction of stimulus sex with perceived attractiveness was found. It showed a stronger negativity of the N170 for somewhat unattractive female faces than for somewhat attractive ones, whereas the opposite was true for male faces. Both sexes showed this effect. In women the difference in amplitude between somewhat unattractive and somewhat attractive perceived female faces was bigger, but did not produce a significant sex difference.
As discussed in the study of Adolph and Spezio (2006) as well as by Duncan and Feldman Barrett (2007), variation in early periods of visual processing can be due to influences of the amygdala, that signal social or emotional significance of a stimulus. The amygdala seems to modulate early visual processes, thereby also increasing the probability of an affective stimulus to reach awareness. (Pessoa et al., 2006; cited in Duncan & Feldman Barrett, 2007) A higher N170 amplitude in response to certain faces can therefore be

interpreted in the way that those faces were more salient because of their higher biological and social relevance. Higher N170 amplitude in response to attractive male faces in women could reflect a mechanism that immediately draws attention to a biologically relevant stimulus. Women do not only rely on physical attractiveness as a mate value, but also on other qualities, such as the ability to provide resources, the strength to protect the offspring, etc. Because women have higher minimal parental investment, and the costs that an undesired gestation would impose on them are great, a tendency to be very selective and examine potential partners carefully, developed in women. For them, engaging in a copulation can impose greater costs than missing an opportunity to reproduce. A rapid mechanism drawing attention to attractive men could motivate to examine further mate qualities. Nevertheless one has to be careful, when interpreting this amplitude difference, because it is very small and also not shown in the grand mean plots. The differences between the statistical results of the analysis of variance (i.e. interaction effects of attractiveness and stimulus sex for the peak amplitude of the N170) and the grand mean plots can be due to the problem that peak amplitude and latency measures are non-linear in contrast to grand mean plots (Luck, 2005). This could explain the discrepancy of the ANOVA results stating that attractive male faces elicit a higher N170 amplitude than unattractive ones while the grand average plot (Fig. 19) shows the opposite.

The stronger negativity of the N170 in men in response to attractive male faces can be interpreted as the need to quickly detect potential rivals, in order to know whom he has to watch when it comes to courting a potential partner in competition with other men.

As already mentioned, effects of female faces are different from those evoked by male faces, with unattractive faces eliciting a higher N170 amplitude in both male and female participants. This effect in men could relate to their reproductive strategies. Men can increase their reproductive success with the number of copulations. The costs of missing an opportunity are higher than mating with a partner of lower mate value. Nevertheless, there are still costs, like other mating opportunities that are missed. Therefore rapid appraisal mechanism should identify mates that would impose more costs than benefits.

The much stronger negativity in women in response to unattractive female faces might as well be explained by mechanisms of intrasexual competition. Female intrasexual competition is expected to occur when attractive men (those having high genetic quality) are considered as a resource. Women then tend to derogate competitors in such situations by devaluing their rival's attractiveness. (Fisher, 2004) Unattractive same-sex individuals

are maybe perceived as a kind of rewarding stimuli, because the pose no immediate threat to one's own mating success.

With regard to the latency of the N170 peak, attractive female faces yielded a later N170 peak than unattractive ones, whereas the contrary effect was found for male faces. Moreover, women in general showed an earlier N170 peak than men. It is known that N170 peak can be delayed when viewing inverted faces (Sagiv & Bentin, 2001), but studies on facial expression did not find an effect an N170 peak latency (Blau et al., 2007). Therefore differences in N170 latency have so far been interpreted as related to (holistic versus component-based) processing strategies. Due to technical reasons latency jitter up to 40 ms affects the data of this study. Therefore results on N170 latency have to be interpreted very cautiously.

4.2.2 P300 as a Signal of Biological and Social Relevance of a Face?

My aim was to investigate differences in the P300 related to facial attractiveness, a quality that is considered to be of high biological, emotional and social value. Research on the P300 is usually based on the "oddball paradigm", to study effects of task relevance of a stimulus, task difficulty and stimulus probability. Results show that P300 is higher for target stimuli, is inversely related to target probability and directly related to task difficulty. (Luck, 2005, Polich, 2007) Oliver-Rodriguez and colleagues (1999) questioned the classical view on task relevance (i.e. a target is specified in the instructions) and put an emphasis on the subjective significance of a stimulus.

"According to this more general model, a stimulus will be considered relevant if it is emotionally significant to the subject, whether that significance is established by task instructions or by his or her internal states or past experiences. ... From an adaptive viewpoint, emotionally significant stimuli have utility for the accomplishment of survival and reproductive functions." (Oliver-Rodriguez et al., 1999, p.177)

This highlights that subjective relevance can be context dependent, as also a study by Farwell & Donchin (1991; cited in Oliver-Rodriguez et al.,1999) showed. Stimuli that were not defined to be targets, but were seen the day before, elicited the same P300 amplitude as defined targets. It seems that participants subjectively assigned significance to those stimuli. Other stimuli may have intrinsic emotional relevance, which developed in the course of evolution. I expected faces to have such an intrinsic emotional relevance, because of their importance in social life.

Investigation of the P300 included three electrodes: 6 (AFz), 48 (Cz) and 58 (Pz), for which a significant difference could be shown for all timeframes under investigation (200–550 ms after stimulus onset). The measured P300 amplitude, which was highest on electrode 58, seems to reflect rather the P3b component, which has its maximum over central parietal sites (Polich, 2007). Furthermore a significant main effect of stimulus sex could be observed across almost all timeframes, which showed that female faces elicit a higher P300 amplitude than male faces. Oliver-Rodriguez and colleagues (1999) also found scores of the score of the second principal component of their principal component analysis (which they describe to resemble P300) to be larger for female faces.

Only from TF9 on (400–550 ms after stimulus onset) a significant interaction between electrode, stimulus sex and perceived attractiveness could be observed. This finding is congruent with results from other studies on facial attractiveness with respect to timing. Werheid and colleagues (2007) reported lower LPC amplitudes in response to non-attractive faces in the time window of 400 ms to 600 ms after stimulus onset. Oliver-Rodriguez and colleagues (1999) and Johnston & Oliver-Rodriguez (1997) found correlations between the beauty ratings of female and male faces and the amplitude of the P300 component (with its maximum at 550 ms).

In my study attractive female faces elicit a higher P300 amplitude than unattractive ones, whereas the opposite was true for male faces in electrode 48 and 58, but not in 6. This pattern is also present in other timeframes, but failed to reach statistical significance. My findings are not in line with those of Werheid and colleagues (2007), insofar as I did not find higher P300 amplitude in relation to attractive faces in general, but only for female faces. Whether attractive faces elicited a higher P300 depended on the sex of the shown face, a factor that Werheid and colleagues (2007) did not consider in their study.

Results of this study suggest a difference between rating attractiveness of same-sex individuals and those of opposite-sex individuals, thereby being in line with Carl Senior's (2003) hypothesis that beautiful faces have to be divided in those that are rewarding and those that are merely aesthetic. Rewarding faces are attractive faces of the opposite sex, because they have an adaptive value for the observer, insofar as they signal mate value. In contrast to that, same-sex attractive faces are considered to be perceived merely as aesthetic. Ishai (2007) questioned this view, because she found sexual orientation to play an important role in perceiving face stimuli as rewarding. She found stronger activation in the orbitotfrontal cortex (OFC) in heterosexual women and homosexual men to male faces,

whereas heterosexual men and homosexual women had stronger activation in response to female faces. As I included only heterosexual subjects in my study, I could equate reproductive value with sexual relevance for this study.

Oliver-Rodriguez and colleagues (1999) reported a correlation between score of the second principal component of their analysis (reflecting P300 amplitude) and beauty ratings of female faces in men and a trend in the same direction for male stimulus faces. They also observed a trend in the same direction in female subjects. Results of my study are similar in so far, as I also found an increased amplitude when participants perceived attractive female faces. But I did not find male faces following the same trend. The inconsistence of these results with those of my study could be caused by the different methods of analysis in use or by the fact, that Oliver-Rodriguez and colleagues (1999) used another classification scheme. Subjects in their study rated faces of the same sex as "handsome", but those of the opposite sex as "beautiful" on a 1-5 Likert scale. The use of different wordings for rating attractiveness could have an effect on the processing of the stimuli. The concept of "attractive" might also be understood differently when rating same-sex faces compared to opposite-sex faces, because the word per se invokes some kind of (sexual) interest in the other (lat. attraho = to pull in, pull closer). When rating opposite-sex faces, one can refer to his own desire, but when rating same-sex faces, one has to think how a person of the opposite sex would perceive the face. This involves some kind of perspective taking that is not needed for rating opposite-sex faces. These speculations of course only apply to heterosexual subjects. Controlled experiments on the influence of wording used are needed here.

As I had to exclude the "extreme" categories (attractive and unattractive) from my analysis, I could not investigate, whether P300 amplitudes vary with attractiveness in a U-shaped way, as Johnston and colleagues (1986) reported it for emotional stimuli, such as babies, ill people etc. But also Oliver-Rodriguez and colleagues (1999) did not find U-shaped effects, but rather linear effects of attractiveness. They explained this finding with the assumption that unattractive faces may elicit lower arousal than more aversive stimuli, like skin diseases. (Oliver-Rodriguez et al.,1999).

When investigating differences in the P300 amplitude one has to consider other processes influencing the P300, like the ones mentioned above: stimulus probability, task relevance

or task difficulty (target/non-target discrimination). Those can also result in an elevation of this component.

In the classical "oddball paradigm" task relevance is defined by the experimental instructions. It is important to note, that I did not specify one stimulus category to be more important in this experiment, because I expected them to have different emotional significance. Moreover, the task was to discriminate female and male stimuli. One can argue that subjects consider attractive faces as more relevant, because they have intrinsic rewarding value (Senior, 2003). The data contradict this idea, insofar as I could not report higher P300 amplitudes for attractive male faces, but only attractive female faces, in both sexes.

Task difficulty and stimulus probability were intended to be the same for all categories, but attractiveness ratings showed that the four categories were not used in the same frequencies, i.e. that attractive, somewhat attractive, somewhat unattractive and unattractive faces were not equiprobable. This could have affected participants' perception of the stimuli, rendering attractive faces less probable. But considering only the intermediate categories, as I did in this ERP analysis, accounts for this potential confounding effect, because they show approximately same numbers of ratings. Furthermore ERP trials analysed in this study were taken from the first session of the experiment, where the instruction was to discriminate male and female stimuli, thereby assuring that subjects pay attention to the stimuli. Female and male faces were equiprobable. Attractiveness was considered to be passively perceived and processed, which could be confirmed by findings of the significant interactions with the factor perceived attractiveness. Nevertheless one could argue that task instructions had a major influence on processing and therefore the predominant stimulus sex effect may also be caused by the instruction to distinguish between male and female faces.

Interpreting the function of the P300 as reflecting a process of inhibition of ongoing neural activity in order to enable transmission of an incoming stimulus (Polich, 2007), one would assume that biologically and socially relevant stimuli elicit higher P300 amplitudes. They are expected to minimize extraneous brain activity. Applying this hypothesis to the results of this study suggests that attractive female faces have a higher relevance than unattractive ones to both, women and men. But attractive male faces are of lower significance than unattractive ones. The pattern found in the P300 is reversed in comparison to the one of the N170. Assuming immediate influence of the amygdala on early visual processing – the

N170 – (via the subcortical route) in order to direct attention to biologically important stimuli, one could explain the pattern of the N170 amplitude as caused by direct attribution of reproductive significance to a stimulus. The reversal of the pattern in the P300, could reflect top-down influences of attention on processing and memorising the faces. As discussed before relevance of stimulus depends on the subjective experience and can vary from one context to another. Therefore I think it is important to also consider individual mate preferences when investigating effects of perceived facial attractiveness on the P300, which was not part of this study.

Dolcos & Cabeza (2002) found an effect of emotional stimuli on subsequent memory insofar as ERPs for items that were remembered after the experiment tended to be more positive. This effect was greater for emotional stimuli. It would be interesting to study this effect in relation to facial attractiveness, i.e. to see whether this corresponds with P300 amplitudes found in this study. This could then mean that emotionally and socially relevant stimuli are more efficiently processed, which also leads to better subsequent memory. As my study did not use a follow-up questionnaire on remembered faces, this effect could not be investigated.

The sex of the participant rarely produced significant effects in my study. This could be due to the fact that inter-subject variability is relatively high in my sample. In order to reduce inter-subject variability, future studies should consider menstrual cycle phase the context of an individual's mate preference of female participants, when investigating processing of facial attractiveness.

4.2.3 Questions and Implications for Future Research

My study revealed a very early effect of facial attractiveness on brain processes, and also confirmed P300 differences relating to this factor. Nevertheless, still quite some methodological as well as theoretical issues should be considered in future research on this topic.

1.) What does the word "attractive" mean to the participant?

As already mentioned, different studies on facial attractiveness used different words to rate attractiveness, like "beautiful", "handsome", "attractive", etc.. Some studies use the terms synonymously. Grammer (1996) equates attractiveness with beauty and sexual attraction, drawing on a study by Henss (1988, cited in Grammer, 1996), which found the same standards for judging those qualities. But systematic investigations on differential influence of wording on ERPs are needed in order to assure comparability of studies. Moreover, different scales of attractiveness are applied (2-point: attractive versus non-attractive, 3-point: attractive, neutral, unattractive, 4-point, 5-point, 7-point Likert scales.). This could also result in a difference in ERPs. Assuming that more attractive faces elicit higher amplitudes in N170 and P300, ERPs based on 2-point classification will differ from ERPs based on 3-point classification, where subjects have the possibility to rate neutral. Experiments on the same data set using different scales could provide insight to this problem.

2.) How to select stimulus material?

The stimulus set of this study included faces varying in their degree of perceived attractiveness from highly attractive to highly unattractive. But also faces with average attractiveness were included. This resulted in a high number of "somewhat attractive" and "somewhat unattractive" faces, which diminished the number of trials for the extreme categories "attractive" and "unattractive" faces. In a future experiment one should consider the tendency of participants to avoid "extreme" ratings and adapt the scale accordingly. Moreover, one should include more highly attractive and highly unattractive faces in the sample. One problem is that people are biased in their expectancy of beautiful faces, because they are exposed to a great amount of highly attractive models in the media, usually displayed in a way that makes them even more attractive. (Buss, 2007)

Standardised front-view pictures of students are then often not able to meet those standards.

3.) What is the influence of task instructions on cognitive processes?

Especially when investigating P300, one has to be very cautious about task instructions because they might produce a confounding effect. Furthermore, one can influence the level of processing, i.e. from focusing on superficial aspects of a face to emotionally and socially significant aspects. I decided to withhold information on the task (attractiveness rating) until the second session and use a simple classification task (male, female) for the first session, in order to keep participants alert. I assumed that facial attractiveness is relevant enough to elicit effects even when not consciously attended to. But it would be interesting to investigate differences between consciously attended and subconsciously perceived facial attractiveness.

4.) What men and women consider as attractive?

Although data failed to show significant sex differences for the N170 and in most timeframes of the P300, one should consider to investigate effects in men and women separately, due to two reasons: a) women and men are known to differ in their degree of lateralisation, also in respect to face processing (Proverbio et al., 2006) and b) attractive female faces have different relevance for men than they have for women, and so do male faces. Moreover, men tend to rely more on facial attractiveness as a cue for mate value, whereas for women other qualities, such as social status or commitment, are equally or even more important in mate selection.

Furthermore when investigating women's perception of male faces, one should consider menstrual phase. Apart from a lot of research on the behavioural level, Johnston & Wang (1991; cited in Oliver-Rodriguez et al., 1999) have shown that P300 amplitudes vary with the menstrual cycle. Therefore future research should consider this factor.

4.3 CONCLUSION

The findings of this study suggest that facial attractiveness is appraised at a glance and influences visual processing within 150 ms, which was previously believed to be merely devoted to structural encoding of a face. Facial attractiveness seems to be a biologically and socially highly relevant quality, which alters our perception of a person immediately. The fact that facial attractiveness provides important information on mate value seems to have enabled the development of such early appraisal mechanisms, which can immediately influence our action tendencies. Since these processes are adaptations to our ancestors' environment, having developed over a long period of time and enabled survival and reproductive success, we are often not aware of them and the prejudices they entail. The more we understand the brain and the neural processes involved in perception, cognition and action, the more possibility and responsibility we have to reflect on our own perception of the world.

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GLOSSARY OF ABBREVIATIONS

BA	Brodmann Area
EEG	electroencephalography
ERP	event related potential
FFA	fusiform face area
fMRI	functional magnetic resonance imaging
IT	inferior temporal cortex
LPC	late positive component (= P300)
MT	middle temporal cortex (= V5)
OFC	orbitofrontal cortex
STS	superior temporal sulcus
V1	primary visual area

APPENDIX

Appendix 1. Questionnaire on demographic data

PROBANDENNUMMER:

Angaben zur Person

Alter: _____

Geschlecht: □ männlich □ weiblich **Nationalität:** _____

Wo sind Sie aufgewachsen? □ Stadt □ Land

Höchste abgeschlossene Ausbildung: _____

Beruf: _____

Studienrichtung (wenn Student): _____

Monatsnettoeinkommen: □ 0-499 □ 500-999 □ 1000-1999 □ 2000-2999 □ 3000-mehr Euro

Fehlsichtigkeit: □ ja □ ja, aber korrigiert □ nein

Sexuelle Ausrichtung: □ heterosexuell □ homosexuell □ bisexuell

Beziehungsstand: □ single □ in fester Beziehung seit:_____

Sind Sie auf Partnersuche? □ ja □ nein

Könnten Sie sich vorstellen, einen One-night-stand zu haben? □ ja □ nein

Nehmen Sie die Pille? □ ja seit:_____
□ nein nicht mehr seit:_____

Haben Sie innerhalb der letzten 3 Monate Medikamente, Hormonpräparate oder Psychopharmaka eingenommen?

□ ja □ nein

Wenn ja, welche? _____

Durchschnittliche Zykluslänge: _____

Erster Tag der letzten Menstruation: _____

Appendix 2: Testing for normal distribution of reaction time data.
Results of the One-Sample-Kolmogorov-Smirnov Test for testing normal distribution of reaction times and logarithmised reaction time.

Attractiveness Ratings		*ln reaction time*	*reaction time*
attractive male	N	339	339
	Kolmogorov-Smirnov Z	.866	1.663
	Asymp. Sig. (2-tailed)	.441	.008
somewhat attractive male	N	1543	1543
	Kolmogorov-Smirnov Z	1.364	3.192
	Asymp. Sig. (2-tailed)	.048	.000
somewhat unattractive male	N	1862	1862
	Kolmogorov-Smirnov Z	1.258	2.998
	Asymp. Sig. (2-tailed)	.084	.000
unattractive male	N	1148	1148
	Kolmogorov-Smirnov Z	1.856	3.354
	Asymp. Sig. (2-tailed)	.002	.000
attractive female	N	889	889
	Kolmogorov-Smirnov Z	.787	1.955
	Asymp. Sig. (2-tailed)	.566	.001
somewhat attractive female	N	1687	1687
	Kolmogorov-Smirnov Z	1.414	3.188
	Asymp. Sig. (2-tailed)	.037	.000
somewhat unattractive female	N	1645	1645
	Kolmogorov-Smirnov Z	1.377	3.091
	Asymp. Sig. (2-tailed)	.045	.000
unattractive female	N	673	673
	Kolmogorov-Smirnov Z	.854	1.906
	Asymp. Sig. (2-tailed)	.459	.001

Appendix 3.a. Results of One-Way-ANOVA on logarithmised reaction times data and following Post Hoc Test (Scheffé)
All *P*-values are rounded to the third decimal.

female subjects

stimsex		*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
female	Between Groups	3.448	3	1.149	30.747	.000
	Within Groups	89.500	2394	.037		
	Total	92.948	2397			
male	Between Groups	7.206	3	2.402	58.336	.000
	Within Groups	98.487	2392	.041		
	Total	105.693	2395			

Multiple Comparisons

Dependent Variable: ln_rt_attr
Scheffe

stimsex	*(I) attractiveness ratings*	*(J) attractiveness ratings*	*Mean Difference (I-J)*	*Std. Error*	*Sig.*
female	attractive	somewhat attractive	-,07391(*)	,01172	,000
		somewhat unattractive	-,10064(*)	,01177	,000
		unattractive	-,02428	,01346	,355
	somewhat attractive	attractive	,07391(*)	,01172	,000
		somewhat unattractive	-,02673	,00975	,057
		unattractive	,04963(*)	,01174	,000
	somewhat unattractive	attractive	,10064(*)	,01177	,000
		somewhat attractive	,02673	,00975	,057
		unattractive	,07636(*)	,01179	,000
	unattractive	attractive	,02428	,01346	,355
		somewhat attractive	-,04963(*)	,01174	,000
		somewhat unattractive	-,07636(*)	,01179	,000
male	attractive	somewhat attractive	,00247	,01707	,999
		somewhat unattractive	,02443	,01641	,529
		unattractive	,12973(*)	,01659	,000
	somewhat attractive	attractive	-,00247	,01707	,999
		somewhat unattractive	,02196	,01086	,252
		unattractive	,12726(*)	,01113	,000
	somewhat unattractive	attractive	-,02443	,01641	,529
		somewhat attractive	-,02196	,01086	,252
		unattractive	,10530(*)	,01010	,000
	unattractive	attractive	-,12973(*)	,01659	,000
		somewhat attractive	-,12726(*)	,01113	,000
		somewhat unattractive	-,10530(*)	,01010	,000

* The mean difference is significant at the .05 level.

Appendix 3.b. Results of One-Way-ANOVA on logarithmised reaction times data and following Post Hoc Test (Scheffé)
All *P*-values are rounded to the third decimal.

male subjects

stimsex		*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
female	Between Groups	2.924	3	.975	20.770	.000
	Within Groups	116.955	2492	.047		
	Total	119.879	2495			
male	Between Groups	4.058	3	1.353	25.372	.000
	Within Groups	132.849	2492	.053		
	Total	136.907	2495			

Multiple Comparisons

Dependent Variable: ln_rt_attr

Scheffe

stimsex	*(I) attractiveness ratings*	*(J) attractiveness ratings*	*Mean Difference (I-J)*	*Std. Error*	*Sig.*
female	attractive	somewhat attractive	-,06828(*)	,01231	,000
		somewhat unattractive	-,08624(*)	,01236	,000
		unattractive	-,10947(*)	,01667	,000
	somewhat attractive	attractive	,06828(*)	,01231	,000
		somewhat unattractive	-,01795	,01033	,389
		unattractive	-,04119	,01523	,063
	somewhat unattractive	attractive	,08624(*)	,01236	,000
		somewhat attractive	,01795	,01033	,389
		unattractive	-,02324	,01527	,510
	unattractive	attractive	,10947(*)	,01667	,000
		somewhat attractive	,04119	,01523	,063
		somewhat unattractive	,02324	,01527	,510
male	attractive	somewhat attractive	,05772(*)	,02011	,042
		somewhat unattractive	,09234(*)	,02004	,000
		unattractive	,16044(*)	,02207	,000
	somewhat attractive	attractive	-,05772(*)	,02011	,042
		somewhat unattractive	,03463(*)	,01044	,012
		unattractive	,10272(*)	,01394	,000
	somewhat unattractive	attractive	-,09234(*)	,02004	,000
		somewhat attractive	-,03463(*)	,01044	,012
		unattractive	,06809(*)	,01384	,000
	unattractive	attractive	-,16044(*)	,02207	,000
		somewhat attractive	-,10272(*)	,01394	,000
		somewhat unattractive	-,06809(*)	,01384	,000

* The mean difference is significant at the .05 level.

Appendix 4: Global mean amplitudes analysis for the pooled categories.
Repeated-measures ANOVA with electrode (14) × stimulus sex (2) × perceived attractiveness (2; pooled attractive faces, pooled unattractive faces) × subject sex (2) as factors. All *P*-values are rounded to the third decimal and corrected after Greenhouse-Geisser. Significant *P*-values in bold.

Timeframe	*Source*	*df*	*F*	*Sig.*
1	elect	2.706	2.847	**.046**
	elect * VpSex	2.706	.360	.761
	stimsex	1.000	1.667	.203
	stimsex * VpSex	1.000	2.562	.116
	cond	1.000	1.873	.178
	cond * VpSex	1.000	.000	.989
	elect * stimsex	3.081	2.825	**.040**
	elect * stimsex * VpSex	3.081	2.274	.081
	elect * cond	2.361	1.587	.205
	elect * cond * VpSex	2.361	.291	.784
	stimsex * cond	1.000	.172	.680
	stimsex * cond * VpSex	1.000	2.024	.162
	elect * stimsex * cond	2.881	.261	.846
	elect * stimsex * cond * VpSex	2.881	.251	.853
2	elect	3.029	8.505	**.000**
	elect * VpSex	3.029	1.097	.353
	stimsex	1.000	1.676	.202
	stimsex * VpSex	1.000	2.059	.158
	cond	1.000	.944	.336
	cond * VpSex	1.000	.001	.980
	elect * stimsex	3.502	2.178	.083
	elect * stimsex * VpSex	3.502	1.114	.349
	elect * cond	2.280	.910	.417
	elect * cond * VpSex	2.280	.383	.710
	stimsex * cond	1.000	.512	.478
	stimsex * cond * VpSex	1.000	1.342	.253
	elect * stimsex * cond	2.927	.660	.574
	elect * stimsex * cond * VpSex	2.927	.440	.720
3	elect	1.974	13.217	**.000**
	elect * VpSex	1.974	2.257	.111
	stimsex	1.000	1.483	.230
	stimsex * VpSex	1.000	2.353	.132
	cond	1.000	.898	.348
	cond * VpSex	1.000	1.146	.290
	elect * stimsex	4.138	1.116	.351
	elect * stimsex * VpSex	4.138	.584	.681
	elect * cond	2.753	.574	.619
	elect * cond * VpSex	2.753	.603	.600
	stimsex * cond	1.000	1.603	.212
	stimsex * cond * VpSex	1.000	4.958	**.031**
	elect * stimsex * cond	3.332	.650	.600
	elect * stimsex * cond * VpSex	3.332	1.034	.384

4	elect	1.853	31.767	**.000**
	elect * VpSex	1.853	.233	.776
	stimsex	1.000	.906	.346
	stimsex * VpSex	1.000	2.570	.116
	cond	1.000	.589	.447
	cond * VpSex	1.000	1.038	.314
	elect * stimsex	3.829	1.285	.278
	elect * stimsex * VpSex	3.829	.857	.487
	elect * cond	2.976	1.078	.360
	elect * cond * VpSex	2.976	.565	.638
	stimsex * cond	1.000	2.889	.096
	stimsex * cond * VpSex	1.000	4.224	**.046**
	elect * stimsex * cond	3.215	.419	.753
	elect * stimsex * cond * VpSex	3.215	.748	.534
5	elect	1.817	2.342	.107
	elect * VpSex	1.817	3.584	**.036**
	stimsex	1.000	4.970	**.031**
	stimsex * VpSex	1.000	3.927	.054
	cond	1.000	.518	.476
	cond * VpSex	1.000	.014	.907
	elect * stimsex	3.168	1.927	.125
	elect * stimsex * VpSex	3.168	2.103	.099
	elect * cond	3.095	.866	.463
	elect * cond * VpSex	3.095	.475	.706
	stimsex * cond	1.000	1.632	.208
	stimsex * cond * VpSex	1.000	3.161	.082
	elect * stimsex * cond	2.418	1.701	.181
	elect * stimsex * cond * VpSex	2.418	.283	.795
6	elect	2.041	12.074	**.000**
	elect * VpSex	2.041	3.611	**.030**
	stimsex	1.000	10.883	**.002**
	stimsex * VpSex	1.000	2.106	.154
	cond	1.000	1.823	.184
	cond * VpSex	1.000	.009	.925
	elect * stimsex	3.470	2.452	.057
	elect * stimsex * VpSex	3.470	1.192	.316
	elect * cond	3.117	3.135	**.026**
	elect * cond * VpSex	3.117	.319	.819
	stimsex * cond	1.000	2.872	.097
	stimsex * cond * VpSex	1.000	6.376	**.015**
	elect * stimsex * cond	3.051	2.273	.082
	elect * stimsex * cond * VpSex	3.051	.185	.909
7	elect	2.195	21.665	**.000**
	elect * VpSex	2.195	2.999	**.050**
	stimsex	1.000	11.803	**.001**
	stimsex * VpSex	1.000	2.147	.150
	cond	1.000	3.511	.067
	cond * VpSex	1.000	.150	.701
	elect * stimsex	3.556	2.061	.096
	elect * stimsex * VpSex	3.556	.742	.550

	elect * cond	3.129	5.393	**.001**
	elect * cond * VpSex	3.129	.552	.655
	stimsex * cond	1.000	.965	.331
	stimsex * cond * VpSex	1.000	2.687	.108
	elect * stimsex * cond	3.352	1.776	.148
	elect * stimsex * cond * VpSex	3.352	.105	.967
8	elect	2.303	27.793	**.000**
	elect * VpSex	2.303	2.670	.066
	stimsex	1.000	6.663	**.013**
	stimsex * VpSex	1.000	2.409	.128
	cond	1.000	2.950	.093
	cond * VpSex	1.000	.008	.928
	elect * stimsex	3.478	.707	.569
	elect * stimsex * VpSex	3.478	.873	.469
	elect * cond	2.928	4.108	**.008**
	elect * cond * VpSex	2.928	.907	.438
	stimsex * cond	1.000	.276	.602
	stimsex * cond * VpSex	1.000	2.897	.096
	elect * stimsex * cond	2.783	1.517	.216
	elect * stimsex * cond * VpSex	2.783	.127	.934
9	elect	2.386	33.364	**.000**
	elect * VpSex	2.386	1.821	.159
	stimsex	1.000	4.803	**.034**
	stimsex * VpSex	1.000	.328	.570
	cond	1.000	2.100	.154
	cond * VpSex	1.000	.039	.844
	elect * stimsex	4.002	.500	.736
	elect * stimsex * VpSex	4.002	.781	.539
	elect * cond	3.179	4.005	**.008**
	elect * cond * VpSex	3.179	.864	.467
	stimsex * cond	1.000	1.708	.198
	stimsex * cond * VpSex	1.000	1.987	.166
	elect * stimsex * cond	2.826	2.584	.060
	elect * stimsex * cond * VpSex	2.826	.717	.536
10	elect	2.540	40.115	**.000**
	elect * VpSex	2.540	1.136	.333
	stimsex	1.000	7.426	**.009**
	stimsex * VpSex	1.000	1.395	.244
	cond	1.000	5.573	**.023**
	cond * VpSex	1.000	.432	.514
	elect * stimsex	4.170	.704	.596
	elect * stimsex * VpSex	4.170	1.139	.340
	elect * cond	3.436	3.983	**.006**
	elect * cond * VpSex	3.436	1.069	.369
	stimsex * cond	1.000	2.100	.154
	stimsex * cond * VpSex	1.000	.660	.421
	elect * stimsex * cond	3.320	2.810	**.036**
	elect * stimsex * cond * VpSex	3.320	.373	.792

Tests of between-subjects effects of the sex of the participant

Timeframe	*df*	*F*	*Sig.*
1	1	,088	,768
2	1	,020	,889
3	1	,000	,994
4	1	,818	,370
5	1	3,600	,064
6	1	1,686	,201
7	1	,078	,781
8	1	,024	,878
9	1	,001	,970
10	1	,074	,787

Appendix 5: Global mean amplitudes analysis for the intermediate categories.
Repeated-measures ANOVA with electrode (14) × stimulus sex (2) × perceived attractiveness (2; somewhat attractive, somewhat unattractive) × subject sex (2) as factors. All *P*-values are rounded to the third decimal and corrected after Greenhouse-Geisser.

Timeframe	*Source*	*df*	*F*	*Sig.*
1	elect	2.773	1.742	.166
	elect * VpSex	2.773	.351	.773
	stimsex	1.000	1.705	.198
	stimsex * VpSex	1.000	.317	.576
	cond	1.000	1.751	.192
	cond * VpSex	1.000	.240	.627
	elect * stimsex	3.705	2.601	**.042**
	elect * stimsex * VpSex	3.705	1.480	.214
	elect * cond	2.555	.831	.463
	elect * cond * VpSex	2.555	.497	.655
	stimsex * cond	1.000	.145	.705
	stimsex * cond * VpSex	1.000	.689	.411
	elect * stimsex * cond	3.006	.547	.652
	elect * stimsex * cond * VpSex	3.006	.161	.923
2	elect	3.033	8.341	**.000**
	elect * VpSex	3.033	1.057	.370
	stimsex	1.000	1.905	.174
	stimsex * VpSex	1.000	.006	.941
	cond	1.000	1.120	.296
	cond * VpSex	1.000	.533	.469
	elect * stimsex	3.714	1.500	.208
	elect * stimsex * VpSex	3.714	.959	.427
	elect * cond	2.754	.777	.499
	elect * cond * VpSex	2.754	.712	.535
	stimsex * cond	1.000	1.011	.320
	stimsex * cond * VpSex	1.000	1.358	.250
	elect * stimsex * cond	2.821	.876	.450
	elect * stimsex * cond * VpSex	2.821	.492	.677
3	elect	2.052	12.254	**.000**
	elect * VpSex	2.052	1.953	.147
	stimsex	1.000	2.286	.138
	stimsex * VpSex	1.000	.006	.941
	cond	1.000	.497	.484
	cond * VpSex	1.000	.114	.737
	elect * stimsex	3.986	.865	.486
	elect * stimsex * VpSex	3.986	.632	.640
	elect * cond	3.068	.271	.850
	elect * cond * VpSex	3.068	.629	.601
	stimsex * cond	1.000	1.564	.217
	stimsex * cond * VpSex	1.000	4.540	**.039**
	elect * stimsex * cond	3.290	.570	.651
	elect * stimsex * cond * VpSex	3.290	1.128	.342

4	elect	1.890	30.602	**.000**
	elect * VpSex	1.890	.246	.770
	stimsex	1.000	1.734	.195
	stimsex * VpSex	1.000	.025	.876
	cond	1.000	.245	.623
	cond * VpSex	1.000	.480	.492
	elect * stimsex	3.922	1.214	.307
	elect * stimsex * VpSex	3.922	1.285	.278
	elect * cond	3.375	.240	.889
	elect * cond * VpSex	3.375	.319	.834
	stimsex * cond	1.000	1.373	.247
	stimsex * cond * VpSex	1.000	1.880	.177
	elect * stimsex * cond	3.253	.282	.854
	elect * stimsex * cond * VpSex	3.253	.443	.738
5	elect	1.838	2.322	.109
	elect * VpSex	1.838	3.538	**.037**
	stimsex	1.000	4.813	**.033**
	stimsex * VpSex	1.000	.701	.407
	cond	1.000	.247	.622
	cond * VpSex	1.000	.006	.939
	elect * stimsex	3.084	1.478	.222
	elect * stimsex * VpSex	3.084	1.524	.210
	elect * cond	3.101	.540	.662
	elect * cond * VpSex	3.101	.352	.794
	stimsex * cond	1.000	.109	.743
	stimsex * cond * VpSex	1.000	1.022	.317
	elect * stimsex * cond	2.419	.738	.504
	elect * stimsex * cond * VpSex	2.419	.165	.884
6	elect	2.055	12.948	**.000**
	elect * VpSex	2.055	3.496	**.033**
	stimsex	1.000	3.617	.064
	stimsex * VpSex	1.000	.851	.361
	cond	1.000	.432	.515
	cond * VpSex	1.000	.032	.859
	elect * stimsex	3.496	.991	.407
	elect * stimsex * VpSex	3.496	.898	.456
	elect * cond	3.119	1.602	.190
	elect * cond * VpSex	3.119	.203	.900
	stimsex * cond	1.000	.612	.438
	stimsex * cond * VpSex	1.000	1.879	.177
	elect * stimsex * cond	2.943	1.156	.329
	elect * stimsex * cond * VpSex	2.943	.239	.865
7	elect	2.204	22.603	**.000**
	elect * VpSex	2.204	2.859	.057
	stimsex	1.000	4.181	**.047**
	stimsex * VpSex	1.000	.312	.579
	cond	1.000	.306	.583
	cond * VpSex	1.000	.001	.976
	elect * stimsex	3.246	1.424	.236
	elect * stimsex * VpSex	3.246	.803	.502

	elect * cond	3.210	2.356	.070
	elect * cond * VpSex	3.210	.319	.825
	stimsex * cond	1.000	.610	.439
	stimsex * cond * VpSex	1.000	.003	.954
	elect * stimsex * cond	3.126	1.079	.361
	elect * stimsex * cond * VpSex	3.126	.297	.835
8	elect	2.327	28.870	**.000**
	elect * VpSex	2.327	2.594	.071
	stimsex	1.000	6.619	**.013**
	stimsex * VpSex	1.000	.001	.980
	cond	1.000	.208	.651
	cond * VpSex	1.000	.005	.945
	elect * stimsex	3.075	1.168	.325
	elect * stimsex * VpSex	3.075	.747	.529
	elect * cond	2.945	1.161	.327
	elect * cond * VpSex	2.945	.494	.684
	stimsex * cond	1.000	.329	.569
	stimsex * cond * VpSex	1.000	.062	.805
	elect * stimsex * cond	2.846	1.544	.208
	elect * stimsex * cond * VpSex	2.846	.162	.914
9	elect	2.402	34.570	**.000**
	elect * VpSex	2.402	1.801	.163
	stimsex	1.000	5.393	**.025**
	stimsex * VpSex	1.000	1.207	.278
	cond	1.000	.196	.660
	cond * VpSex	1.000	.234	.631
	elect * stimsex	3.884	.769	.543
	elect * stimsex * VpSex	3.884	.839	.499
	elect * cond	2.862	.857	.461
	elect * cond * VpSex	2.862	.342	.785
	stimsex * cond	1.000	1.481	.230
	stimsex * cond * VpSex	1.000	.165	.687
	elect * stimsex * cond	2.998	3.061	**.030**
	elect * stimsex * cond * VpSex	2.998	.176	.912
10	elect	2.563	40.289	**.000**
	elect * VpSex	2.563	1.033	.373
	stimsex	1.000	7.346	**.009**
	stimsex * VpSex	1.000	5.901	**.019**
	cond	1.000	.732	.397
	cond * VpSex	1.000	.580	.450
	elect * stimsex	4.390	1.286	.275
	elect * stimsex * VpSex	4.390	1.848	.115
	elect * cond	2.917	.910	.436
	elect * cond * VpSex	2.917	.386	.758
	stimsex * cond	1.000	1.334	.254
	stimsex * cond * VpSex	1.000	.007	.934
	elect * stimsex * cond	3.387	2.960	**.029**
	elect * stimsex * cond * VpSex	3.387	.254	.880

Tests of between-subjects effects of the sex of the participant

Timeframe	*df*	*F*	*Sig.*
1	1	,018	,893
2	1	,082	,776
3	1	,016	,901
4	1	,705	,406
5	1	2,981	,091
6	1	1,165	,286
7	1	,028	,868
8	1	,014	,907
9	1	,028	,868
10	1	,101	,752

Appendix 6: P300 Mean Amplitudes Analysis.
ANOVA results for the within-subject differences and between-subject differnces. (position = electrode position (6, 48, 58), VpSex = subject sex, stimsex = stimulus sex, cond = perceived attractiveness). All *P*-values are rounded to the third decimal and corrected after Greenhouse-Geisser.

Timeframe	*Source*	*df*	*F*	*Sig.*
5	position	1.711	3.612	**.038**
	position * VpSex	1.711	.664	.495
	stimsex	1.000	4.478	**.040**
	stimsex * VpSex	1.000	.349	.558
	cond	1.000	.262	.611
	cond * VpSex	1.000	.078	.781
	position * stimsex	1.441	.657	.474
	position * stimsex * VpSex	1.441	2.760	.087
	position * cond	1.470	.200	.750
	position * cond * VpSex	1.470	.576	.514
	stimsex * cond	1.000	.431	.515
	stimsex * cond * VpSex	1.000	.847	.362
	position * stimsex * cond	1.295	.254	.678
	position * stimsex * cond * VpSex	1.295	.033	.909
6	position	1.616	31.880	**.000**
	position * VpSex	1.616	1.991	.152
	stimsex	1.000	3.516	.067
	stimsex * VpSex	1.000	.474	.495
	cond	1.000	.624	.434
	cond * VpSex	1.000	.109	.743
	position * stimsex	1.498	.000	.998
	position * stimsex * VpSex	1.498	1.531	.225
	position * cond	1.507	.404	.611
	position * cond * VpSex	1.507	.128	.822
	stimsex * cond	1.000	1.618	.210
	stimsex * cond * VpSex	1.000	1.280	.264
	position * stimsex * cond	1.337	1.039	.334
	position * stimsex * cond * VpSex	1.337	.216	.714
7	position	1.522	53.347	**.000**
	position * VpSex	1.522	1.753	.188
	stimsex	1.000	4.738	**.035**
	stimsex * VpSex	1.000	.022	.883
	cond	1.000	.505	.481
	cond * VpSex	1.000	.015	.903
	position * stimsex	1.415	.833	.403
	position * stimsex * VpSex	1.415	1.154	.306
	position * cond	1.355	1.086	.322
	position * cond * VpSex	1.355	.679	.456
	stimsex * cond	1.000	1.521	.224
	stimsex * cond * VpSex	1.000	.012	.912
	position * stimsex * cond	1.305	1.398	.250

	position * stimsex * cond * VpSex	1.305	.347	.616
8	position	1.438	58.422	**.000**
	position * VpSex	1.438	1.558	.221
	stimsex	1.000	6.503	**.014**
	stimsex * VpSex	1.000	.114	.738
	cond	1.000	.503	.482
	cond * VpSex	1.000	.000	.991
	position * stimsex	1.417	1.067	.330
	position * stimsex * VpSex	1.417	.989	.352
	position * cond	1.274	.819	.397
	position * cond * VpSex	1.274	1.102	.314
	stimsex * cond	1.000	1.218	.276
	stimsex * cond * VpSex	1.000	.056	.814
	position * stimsex * cond	1.262	3.464	.058
	position * stimsex * cond * VpSex	1.262	.192	.720
9	position	1.409	67.485	**.000**
	position * VpSex	1.409	1.558	.221
	stimsex	1.000	4.153	**.047**
	stimsex * VpSex	1.000	1.284	.263
	cond	1.000	.911	.345
	cond * VpSex	1.000	.075	.785
	position * stimsex	1.493	.656	.479
	position * stimsex * VpSex	1.493	1.686	.198
	position * cond	1.273	.142	.768
	position * cond * VpSex	1.273	.843	.389
	stimsex * cond	1.000	2.424	.126
	stimsex * cond * VpSex	1.000	.303	.585
	position * stimsex * cond	1.214	7.066	**.007**
	position * stimsex * cond * VpSex	1.214	.021	.922
10	position	1.428	79.689	**.000**
	position * VpSex	1.428	.946	.366
	stimsex	1.000	5.052	**.030**
	stimsex * VpSex	1.000	5.270	**.026**
	cond	1.000	1.918	.173
	cond * VpSex	1.000	.276	.602
	position * stimsex	1.587	1.334	.266
	position * stimsex * VpSex	1.587	5.458	**.010**
	position * cond	1.290	.338	.619
	position * cond * VpSex	1.290	1.248	.280
	stimsex * cond	1.000	1.690	.200
	stimsex * cond * VpSex	1.000	.003	.957
	position * stimsex * cond	1.228	7.355	**.006**
	position * stimsex * cond * VpSex	1.228	.076	.833

Tests of between-subjects effects of the sex of the participant

Timeframe	***Source***	***F***	***Sig.***
5	VpSex	3.534	.067
6	VpSex	1.901	.175
7	VpSex	.327	.570
8	VpSex	.186	.669
9	VpSex	.000	.992
10	VpSex	.065	.800

CURRICULUM VITAE

PERSONAL

1978	Born in Korneuburg, Austria.

EDUCATION

1996 – 2008	Studies in Anthropology at the University of Vienna: Focus on behavioural biology, neuroscience and cognition.
1996	Matura mit ausgezeichnetem Erfolg.
1988 – 1996	Bundesgymnasium in Schwechat.
1984 – 1988	Volkschule in Schwechat.

WORK

2005 – current	Studienassistentin at the Dept. f. Philosophy of Science/ Dept. f. Philosophy, University of Vienna: Coordination of the "MEi:CogSci – Middle European interdisciplinary master program in Cognitive Science" Collaboration in the SOCRATES Project for development of a joint degree programme in cognitive science
WS 2003/04	Tutorial for the seminar: „Kognition - Wissen - Wissensmanagement" (Inst. f. Wissenschaftstheorie und -forschung, Universität Wien; ao.Prof. DI Dr. Markus F. Peschl)
August 2001	Assistance at the archeological excavation in Stillfried/March