Idiosyncratic Facial Movement in Face Perception and Recognition

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Vielen Dank meiner Familie dafür, dass ihr mir Rückhalt und gleichzeitig Flügel verliehen habt!

Table of Contents

Abstract

It has been proposed that different features of a face provide a source of information for separate perceptual and cognitive processes. Properties of a face that remain rather stable over time, so called invariant facial features, yield information about a face's identity, and changeable aspects of faces transmit information underlying social communication such as emotional expressions and speech movements. While processing of these different face properties was initially claimed to be independent, a growing body of evidence suggests that these sources of information can interact when people recognize faces with whom they are familiar. This is the case because the way a face moves can contain patterns that are characteristic for that specific person, so called idiosyncratic movements. As a face becomes familiar these idiosyncratic movements are learned and hence also provide information serving face identification. While an abundance of experiments has addressed the independence of invariant and variable facial features in face recognition, little is known about the exact nature of the impact idiosyncratic facial movements have on face recognition. Gaining knowledge about the way facial motion contributes to face recognition is, however, important for a deeper understanding of the way the brain processes and recognizes faces. In the following dissertation three experiments are reported that investigate the impact familiarity of changeable facial features has on processes of face recognition.

Temporal aspects of the processing of familiar idiosyncratic facial motion were addressed in the first experiment via EEG by investigating the influence familiar facial movement exerts on event-related potentials associated to face processing and face recognition. After being familiarized with a face and its idiosyncratic movement, participants viewed familiar or unfamiliar faces with familiar or unfamiliar facial movement while their brain potentials were recorded. Results showed that familiarity of facial motion influenced later event-related potentials linked to memory processes involved in face recognition. The second experiment used fMRI to investigate the brain areas involved in processing familiar facial movement. Participants' BOLD-signal was registered while they viewed familiar and unfamiliar faces with familiar or unfamiliar idiosyncratic movement. It was found that activity of brain regions, such as the fusiform gyrus, that underlie the processing of face identity, was modulated by familiar facial movement. Together these two experiments provide valuable information about the nature of the involvement of idiosyncratic facial movement in face recognition and have important implications for cognitive and neural models of face perception and recognition.

The third experiment addressed the question whether idiosyncratic facial movement could increase individuation in perceiving faces from a different ethnic group and hence reduce impaired recognition of these other-race faces compared to own-race faces, a phenomenon named the own-race bias. European participants viewed European and African faces that were each animated with an idiosyncratic smile while their attention was either directed to the form or the motion of the face. Subsequently recognition memory for these faces was tested. Results showed that the own-race bias was equally present in both attention conditions indicating that idiosyncratic facial movement was not able to reduce or diminish the own-race bias.

In combination the here presented experiments provide further insight into the involvement of idiosyncratic facial motion in face recognition. It is necessary to consider the dynamic component of faces when investigating face recognition because static facial images are not able to provide the full range of information that leads to recognition of a face. In order to reflect the full process of face recognition, cognitive and neural models of face perception and recognition need to integrate dynamic facial features as a source of information which contributes to the recognition of a face.

German abstract (Deutsche Zusammenfassung)

Klassische Gesichtsverarbeitungsmodelle postulieren die Unabhängigkeit der Wahrnehmung von unveränderlichen Gesichtsmerkmalen und zeitlich veränderlichen, dynamischen Aspekten eines Gesichts. Während zeitlich stabile Charakteristika die Basis für die Identifikation eines Gesichts bilden, wird Information über dynamische Gesichtsveränderungen im Rahmen sozialer Kommunikation herangezogen z.B. um emotionale Ausdrücke und Intentionen zu erkennen. Während diese Modelle allgemein starke empirische Fundierung aufweisen, mehren sich im Falle von bekannten Gesichtern die Hinweise, dass idiosynkratische Gesichtsbewegungen zur Identifikation einer Person beitragen können. Im Folgenden werden drei Experimente vorgestellt, die sich mit dem Einfluss bekannter Gesichtsbewegung auf die Gesichtsidentifikation befassen.

Im ersten Experiment wurde mittels EEG der Einfluss bekannter Bewegung auf evozierte Potentiale der Gesichtsverarbeitung und –erkennung untersucht. Es zeigt sich, dass die Bekanntheit der Gesichtsbewegung Potentiale der Gesichtserkennung beeinflusst. Im zweiten Experiment wurden durch fMRI die Gehirnareale untersucht, die an der Wahrnehmung bekannter Gesichtsbewegung beteiligt sind. Aktivität in Gehirnarealen, die der Verarbeitung von Gesichtsidentität zu Grunde liegen, wie z.B. der fusiforme Gyrus, wurde durch die Bekanntheit der Bewegung des Gesichts moduliert. Zusammen liefern diese beiden Experimente wertvolle Information über die Beteiligung idiosynkratischer Gesichtsdynamik bei der Gesichtsidentifikation.

Das dritte Experiment beschäftigte sich mit der Fragestellung, ob eine idiosynkratische Gesichtsbewegung die Individualisierung eines Gesichts im interkulturellen Kontext erhöhen kann und somit den *own-race bias*, d.h. eine schwächere Wiedererkennensleistung für

Gesichter einer anderen ethnischen Herkunft, verglichen mit Gesichtern der eigenen Ethnie, verringern kann. Die Ergebnisse dieses Experiments zeigen zwar eine geringere Wiedererkennensleistung europäischer Versuchspersonen gegenüber Afrikanischen Gesichtern, verglichen mit der Wiedererkennensleistung für Europäische Gesichter, die Salienz der idiosynkratischen Gesichtsbewegung zeigte jedoch keinen Einfluss auf die Wiedererkennensleistung. Die Ergebnisse werden im Kontext der Ergebnisse der EEG Studie diskutiert.

Zusammenfassend bieten die hier vorgestellten Daten weiteres Verständnis über das Zusammenspiel von stabilen und veränderlichen Gesichtscharakteristika bei der Gesichtsidentifikation. Es ist wichtig, die dynamische Komponente von Gesichtern zu berücksichtigen, wenn man ein ganzheitliches Bild über die Prozesse, die der Gesichtswahrnehmung und –erkennung zu Grunde liegen, gestalten will.

1 General Introduction

1.1 Models of face processing and recognition

Faces provide the observer with a whole range of information about the person. While on the one hand conveying a person's identity, faces also facilitate social communication by for example reflecting a person's emotional state and intentions. When expressing emotions and also while talking faces move dynamically and change their visual appearance. This, however, does not affect a person’s ability to recognize that it is still the same counterpart. Thus, a person's identity can be processed independent of the movement and changes in the expression of the face.

The classical model of face recognition for familiar faces by Bruce and Young (1986) states that faces are initially analysed at a perceptual structural encoding stage by processing individual facial features and their spatial configuration. In a subsequent step, these viewpoint and expression-independent structural representations are compared with already stored face representations, called face recognition units. In case of a strong enough match between structural representations and face recognition units a face will be perceived as familiar but information about who the face belongs to is not yet available. Processing familiar faces to this stage leaves the observer with the feeling of knowing the face without being able to actually say who the encountered person is. Explicit recognition of a face, i.e. accessing knowledge about the person the face belongs to, occurs when the activated face recognition units subsequently trigger identity-specific information stored in the associative memory in the form of person identity nodes. While the face recognition units are exclusively activated by information derived from the face, person identity nodes can also receive input from other parts of the associative memory such as the person’s voice, figure or clothing. The person identity nodes are imbedded in the cognitive system which e.g. stores episodic memory about the person and can also top-down modulate face processing through attentional processes. Looking for a specific person will allow us to selectively screen the faces around us for certain characteristic features of this person's face. Furthermore the cognitive system also combines information about facial speech, expression of the face and identity of the face which have so far been analysed independently in parallel processes since identification of a face is solely based on invariant structural features of faces. For a graphic summary of this model see Figure 1 below.

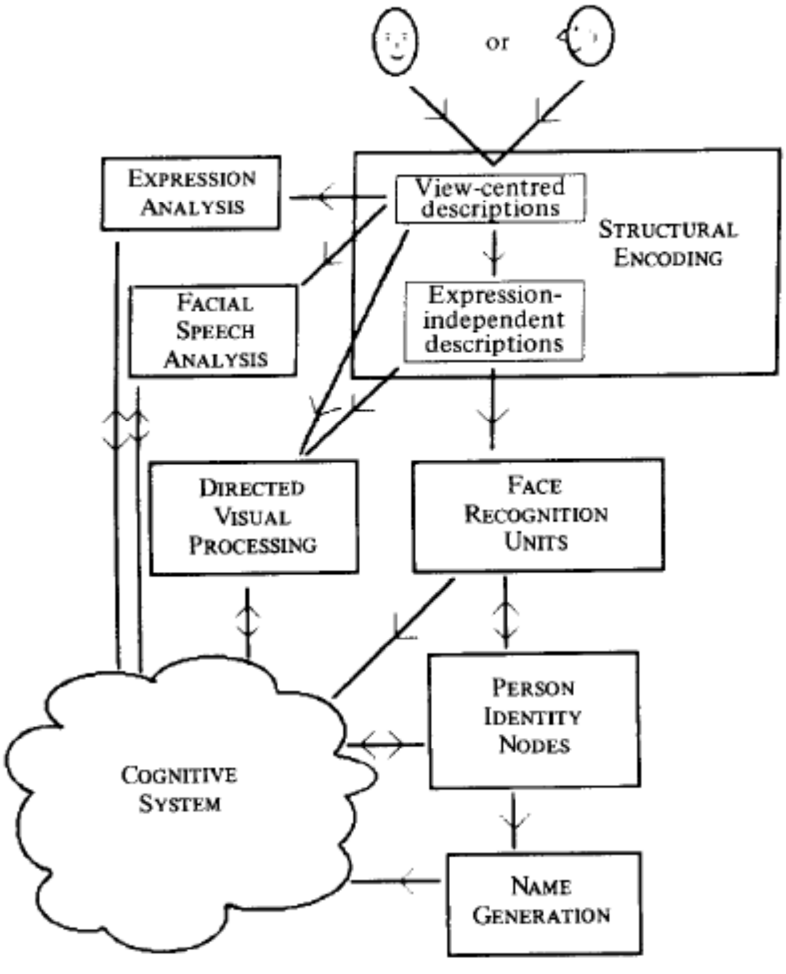


Figure 1. A functional model for face recognition by Bruce and Young (1986)

The Bruce and Young (1986) model of face recognition can be considered an important milestone in research on face processing and has initiated an abundant amount of studies in this direction. With increasing knowledge about the functioning of specific areas of the brain and the advancing of methods that allow studying brain activity non-invasively, questions have arisen regarding the brain areas involved in face processing and recognition.

Haxby, Hoffman and Gobbini (2000) integrated psychological face recognition models such as Bruce and Young's (1986) model with the accumulating knowledge of cortical regions involved in face processing and proposed a distributed human neural system for face perception (Figure 2). According to this model, face perception and recognition is divided into a core visual system and an extended system engaging further neural systems such as the memory, attention and emotion systems in the advanced processing and identification of the face. Within the core system of face perception, invariant aspects of faces which underlie recognition of unique identity are processed in the lateral fusiform gyrus while changeable and dynamic aspects of the face, such as eye gaze, expression and lip movements, are processed more dorsally in the superior temporal sulcus (STS). Therefore Haxby, Hoffman and Gobbini's (2000) neural model of face perception also states that face identification is based on information from invariant facial features, and that dynamic characteristics of the face are processed independently in a separate anatomical pathway. However the model allows for an interaction between the dorsal and ventral pathway, thus stating the possibility of an integration of invariant and variable face characteristics within the core system of face processing.

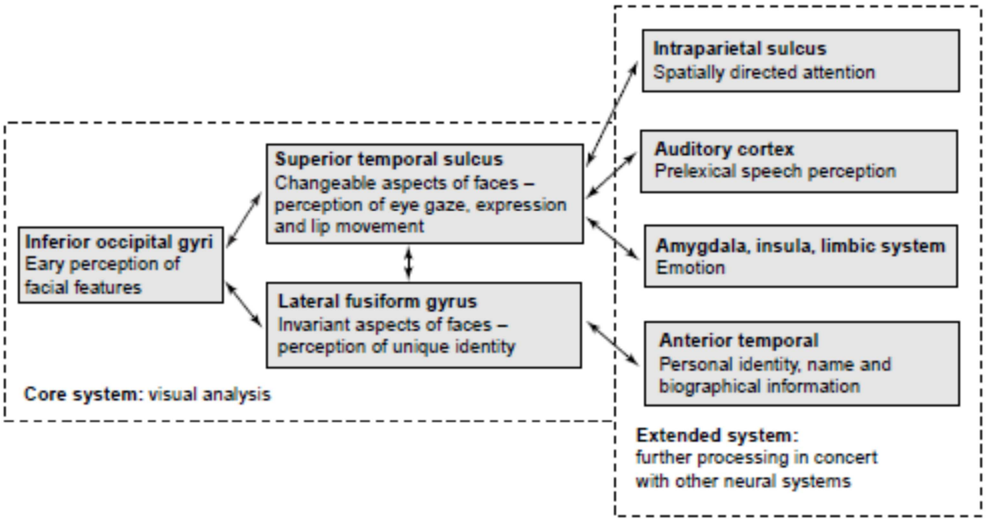


Figure 2. The model of the distributed human neural system for face perception by Haxby, Hoffman, and Gobbini (2000).

1.2 Independence of invariant and changeable face features

The independent processing of identity and changeable features of the face postulated by the presented models is supported by multiple evidence from different fields of psychology. Neuropsychological studies indicate a double dissociation between identity recognition and recognition of facial emotional expression. Patients with prosopagnosia perform poorly at recognizing facial identity while their ability to detect facial expressions seems to be mostly unaffected (Schweinberger, Klos, & Sommer, 1995). Conversely patients have been reported who are severely impaired at recognizing facial expressions but their ability to detect facial identity is preserved (Humphreys, Donnelly, & Riddoch, 1993). Furthermore, single-cell recordings in primates have identified cells in the superior temporal sulcus that respond selectively to facial expression and cells in the inferior temporal gyrus that are tuned to facial identity (Hasselmo, Rolls, & Baylis, 1989). Equivalently, brain imaging studies in healthy humans show differential activation in the superior temporal sulcus and the fusiform gyrus when participants attend either to changeable face features, such as eye gaze, or to facial identity (Hoffman & Haxby, 2000). Behavioral psychological experiments have shown that facial identity and facial expression can be selectively attended to and treated as independent sources of information (Etcoff, 1984) and that reaction times for judging an emotional expression are not influenced by the familiarity of the face (Bruce, 1986; Young, McWeeny, Hay, & Ellis, 1986). Taken together, these results provide strong evidence for the claim that invariant facial features and changeable aspects of the face are processed in different areas of the brain and can be analyzed independently from each other.

1.3 Benefit of facial movement on face recognition

However a string of observations have led to the suggestion that for familiar face recognition facial movement may be involved in face recognition. Walker, Bruce, and O'Malley (1995) were able to show that in the case of dynamically presented faces, the McGurk illusion (McGurk & MacDonald, 1976), i.e. the influence of visible facial speech on auditory perception, is reduced when the face and the voice belong to different people, but only when participants are familiar with the person the face belongs to. This provides evidence that facial speech movement and identity are not processed completely independently. Furthermore, Knight and Johnston (1997) found improved recognition of famous faces when these faces were shown dynamically in a video clip compared to static images but only when the faces were presented in negative. Furthermore, the benefiting influence of movement on recognition was absent for inverted faces. The authors concluded that movement aids face recognition when information derived from the facial form is non-optimal, as in the negative pictures of the faces. They suggested that the mechanisms through which facial movement improves face recognition is firstly an increased 3D perception of the moving stimulus and secondly that face recognition is supported by the characteristic configural changes of the individual face since the effect did not occur in inverted faces for which configural face processing is disturbed. Evidently the first argument should apply to unfamiliar as well as to familiar faces since it states that facial movement generally improves the structural representation of the face (hence also referred to as the *representation enhancement hypothesis*, O'Toole, Roak, & Abdi, 2002). The second argument, also known as the *supplemental information hypothesis* (O'Toole et al., 2002), on the other hand is only valid for familiar faces since it implies a knowledge of the characteristic movements of a face which is acquired as a face becomes familiar. Lander, Christie and Bruce (1999) replicated the advantage of recognizing famous people when the faces were presented dynamically compared to statically under non-optimal viewing conditions and extended these findings by showing that the effect is diminished when the dynamic pattern of the movement is interrupted or slowed down. This provides strong evidence that the individual characteristics of the facial movement are important. This effect is probably particularly prominent when viewing conditions are impaired as the high recognition rates under good viewing conditions normally produce ceiling effects with no space for improvement. Regarding the implications of their findings for models of face processing and recognition, Lander et al. (1999) suggest two possible ways by which the influence of facial movement on face recognition could be explained. The dynamic signature of a face could be stored separately from the structural face code, thus being extrinsic to initial face processing, and provide an additional source of information. Alternatively the static form-based face representations could be integrated within a dynamic face representation and the dynamic facial properties thus could be intrinsic to the stored identity information. In order to investigate these questions Lander and Bruce (2004) conducted a series of experiments with repetition priming in which they showed that static images of faces were primed more strongly by a dynamic prime than by a static prime and that this priming effect was strongest for natural movement patterns of the faces. Since repetition priming effects indicate that the two stimuli access a common visual representation, they concluded that dynamic characteristics are intrinsically incorporated into face representations. Pilz, Thornton, and Bülthoff (2005) were able to show that faces which were learned under dynamic conditions were later recognized faster under static conditions than faces which participants were familiarized with statically even if facial stimuli were not degraded. Finally, in an experiment by Knappmeyer, Thornton, and Bülthoff (2003), participants were initially familiarized with two different faces animated with two discrete motions, and for the subsequent test phase identity morphs of the two faces were created. Results revealed that participants' judgment of the identity of the morphs was biased by the respective motion the morphs were animated with.

1.4 Aim of the dissertation

There is increasing evidence, therefore, that in the case of familiar faces characteristic idiosyncratic movement influences face recognition. However, many questions remain unanswered. If characteristic facial movement influences face recognition then it should be possible to find an impact of familiar facial movement on event-related potentials reflecting face processing and recognition. Furthermore, it is not obvious how to integrate the influence of familiar facial motion on face recognition with neural models of face recognition which state an independent processing of invariant and variable face features. Functional imaging should be able to provide insight into which brain areas are involved in processing familiarity of facial motion.

To address these questions will be the aim of the first two experiments presented here which employ EEG as well as fMRI. Finally the third experiment will investigate whether using dynamic stimuli with characteristic facial movement can influence recognition in the context of cross-race face recognition. It is a common finding that people show impaired recognition of faces of an other race compared to faces of their own race, a phenomenon named own-race bias. Increasing the individuation of other-race faces has been effective at reducing the own-race bias. The question addressed in the third experiment is whether perception of idiosyncratic face movement will increase individuation of other-race faces and hence increase recognition memory for these faces.

2 Experiment I: The impact of familiar facial movement on event-related brain potentials

2.1 Pilot Studies

2.1.1 Aim of the pilot studies

The pilot studies were conducted in order to develop appropriate stimulus material and conditions under which the effect of familiar facial movement on face recognition could be observed. Regarding the development of the stimuli, the dynamic properties of the face were the largest challenge. Event-related potentials are measured starting with onset of the stimulus of interest, i.e. there is a distinct onset point for the stimulus. I aimed at creating dynamic stimuli where the pattern of movement would seem familiar or unfamiliar to the participants. However, with fully dynamic stimuli changes are inherently continuous thus rendering the definition of a specific onset point difficult, especially since the time at which the stimulus seems familiar will probably vary between subjects. I therefore decided to create stimuli analogous to Puce, Smith, & Allison (2000) in whose experiment movement was characterised by an abrupt change between two static images rather than a gradual change.

2.1.2 Development of facial stimuli

The stimuli were created with Poser software (Curious Labs, Santa Cruz, CA). Computer generated faces were chosen because they allow a higher control of the movement of the face as well as the textural and structural features of the faces compared to pictures of people. Mühlberger, Wieser, Herrmann, Weyers, Tröger, and Pauli (2009) compared event-related potentials towards natural photographic facial expressions from the KDEF database (Lundqvist, Flykt, & Öhman, 1998) and artificial faces created analogously to those used in the here presented experiment. Qualitatively computer generated faces elicited comparable event-related potentials as the natural photos; quantitatively computer generated faces evoked even increased amplitudes of event-related potentials indicating attentional processes and structural facial encoding. These results show that computer generated faces are suitable for investigating electrophysiological processes of face perception and might even have certain advantages over photographs of faces.

Because internal features are important for the recognition of facial expressions and the importance of external features declines with the familiarity of a face while the importance of internal features increases (Bonner, Burton, & Bruce, 2003), I wanted to avoid confounding face familiarity and salience of external or internal facial features. Thus, the facial stimuli were created with emphasis on the internal features by minimising the appearance of external features such as hair, clothing, and background.

Furthermore, as reported in 1.3, effects of familiar facial movement on face recognition are most prominent when recognition of the face via facial form is hampered by, for example, degrading the picture or presenting negatives. I therefore chose to complicate recognition via facial form by creating avatars that were all highly similar. Hence, eighteen different face forms were created from the same basic face, thus also ensuring that the textural and structural features of the different faces were identical and that the settings of the movement parameters created the same changes in facial expression for all different face forms. In order to create dynamic stimuli and at the same time to have a concrete temporal onset point of familiarity of the movement, each facial stimulus consisted of three frames of the same face with a smile of increasing intensity. Each frame was presented for 800 ms, thus creating the impression of a face with a pseudo-dynamic smile. A smile was chosen as facial movement since most experiments showing an influence of facial movement on face recognition have worked with emotional facial expressions (see 1.3). Two different types of smile were developed which differed only in the second frame of the stimulus (see 2.3.2.1 for an example). Therefore, upon presentation of the second frame participants knew whether the facial form and the facial movement were familiar or not. ERPs were assessed relative to the onset of the second frame of each facial stimulus. Each of the 18 different faces was combined with both kinds of smiles, thus resulting in 36 different stimuli. Each stimulus lasted 2400 ms. The reason only two different movements were created as opposed to 18 different face forms is that the movements were supposed to be relatively easy to distinguish and at the same time the two smiles were supposed to appear natural and of equal valence. While facial form provides a big range of variability it is much more difficult to create different natural smiles which furthermore convey the same emotional intensity.

2.1.3 Pilot Study I

2.1.3.1 Procedure

Fourteen psychology students who were awarded course credits for their participation contributed to the first pilot study. Initially they were shown one of the 18 faces with one of the two smiles 50 times and after each tenth subsequent presentation asked questions regarding their impression of the face. They rated the face according to three positive (*happiness*, *intelligence* and *trustworthiness*) as well as three negative (*selfishness*, *recklessness* and *opportunism*) character traits. Therefore participants were familiarised with the face and its movement without explicitly memorising it. After being familiarised with the face, the recognition task followed, in which participants were presented the faces with the familiar form and the familiar motion, faces with only familiar form, faces with only familiar motion and faces where neither form nor motion were familiar. Participants' task was to rate after each facial stimulus on a scale from *not at all* (1) to *very strongly* (9) how strongly the face reminded them of the face they had been shown in the previous part of the experiment. After the recognition task participants were presented all avatars again and rated them individually according to *likeability* from 1 (*not very likeable*) to 9 (*very likeable*), *valence* from 1 (*very negative*) to 9 (*very positive*) and *arousal* from 1 (*not arousing*) to 9 (*very arousing).*

2.1.3.2 Results

Familiarity ratings were entered into a 2 x 2 repeated-measures Analysis of Variance (ANOVA) with the within factors Form (familiar vs. unfamiliar) and Motion (familiar vs. unfamiliar) and a main effect of Form was revealed, $F(1, 13) = 64.47$, $p < .01$, $\eta_p^2 = .83$. There was no main effect of Motion, $F(1, 13) = .16$, $p = .70$, nor did the factors Form and Motion interact, $F(1, 13) = .03$, $p = .88$.

Faces with familiar form and familiar motion ($M = 6.57$, $SD = 1.51$) were rated as familiar as faces with only familiar form ($M = 6.54$, $SD = 1.41$) while faces with only familiar motion ($M = 3.47$, $SD = 1.39$) were rated as familiar as unfamiliar faces ($M = 3.40$, $SD = 1.38$). Hence while familiarity of form was reflected by the judgments, familiarity of motion did not affect them.

Likeability ($M = 4.51$, $SD = .66$), valence ($M = 4.77$, $SD = .67$) and arousal ($M = 3.73$, $SD = 1.13$) ratings of all facial stimuli ranged around the average of the scale and within three to six points. For only one face was likeability as well as valence rated below three.

2.1.3.3 Conclusions

Based on the absence of a measurable effect of familiarity of facial motion on the familiarity ratings of the face, I decided to increase the salience of the facial movement by directing participants’ attention directly towards it. Furthermore the number of learning trials was raised. Effects of these manipulations were assessed in the second pilot study. Furthermore the face which scored low on likeability and valence ratings was removed from the stimulus material and replaced by a different one.

2.1.3 Pilot Study II

2.1.3.1 Procedure

Thirteen psychology students attended the second pilot study and were again rewarded with course credits. Participation was restricted to students who had not joined the first pilot study. Again participants were familiarized with a face and its idiosyncratic movement in the learning phase. The face was presented 60 times and was rated on three positive (*happiness*, *intelligence* and *trustworthiness*) as well as three negative (*selfishness*, *recklessness* and *opportunism*) character traits.

The recognition task was organised in three blocks. In the first block participants' attention was directed randomly either to the form of the face or the motion of the face while the familiar and unfamiliar faces and facial movements were presented. In the second block attention was directed to the facial feature that was not attended to in the first block. Finally in the last block participants were instructed to concentrate on the facial form as well as the facial movement. In all three blocks participants' task was to judge the familiarity of the face on a scale from *not at all* (1) to *very strongly* (9). After the recognition task ratings of likeability, valence and arousal were conducted on 9-point Likert-scales.

2.1.3.2 Results

Familiarity ratings of the three different attention blocks are depicted below in Figure 3. Form (2: familiar vs. unfamiliar) x Motion (2: familiar vs. unfamiliar) x Block (3: attention-to-motion vs. attention-to-form vs. attention-to-both) repeated-measures Analysis of Variance

(ANOVA) for the familiarity ratings showed a highly significant Form x Block interaction, $F(2, 24) = 47.14$, $p < .01$, $\eta_p^2 = .80$, as well as a marginally significant Motion x Block interaction, $F(2, 24) = 3.21$, $p = .07$, $\eta_p^2 = .21$. Therefore separate 2 (form familiar vs. form unfamiliar) x 2 (motion familiar vs. unfamiliar) ANOVAs were conducted for the individual blocks.

A main effect of the factor Form was found in all three attention conditions, $F(1, 12) = 225.4$, $p < .01$, $\eta_p^2 = .95$ in the attention-to-form block, $F(1, 12) = 16.65$, $p < .01$, $\eta_p^2 = .58$ in the attention-to-motion block, and $F(1, 12) = 161.58$, $p < .01$, $\eta_p^2 = .93$ in the attention-to-both block. In the attention-to-motion block an additional main effect of Motion proved significant, $F(1, 12) = 8.24$, $p = .01$, $\eta_p^2 = .41$, while this effect was not present in the other two conditions, both ps > .10. The interaction Form x Motion ranged at marginal significance for the attention-to-form, $F(1, 12) = 4.52$, $p = .06$, $\eta_p^2 = .27$ and attention-to-both condition, $F(1, 12) = 4.50$, $p = .06$, $\eta_p^2 = .27$. In the attention-to-motion condition there was no interaction effect, $F(1, 12) = .09$, $p = .77$. Therefore, while when attention was directed to facial form or to form and motion of the face, the ratings strongly reflected the familiarity of the facial form, in the attention-to-motion condition, familiarity of facial motion also had an impact on familiarity ratings which was independent of familiarity of form.

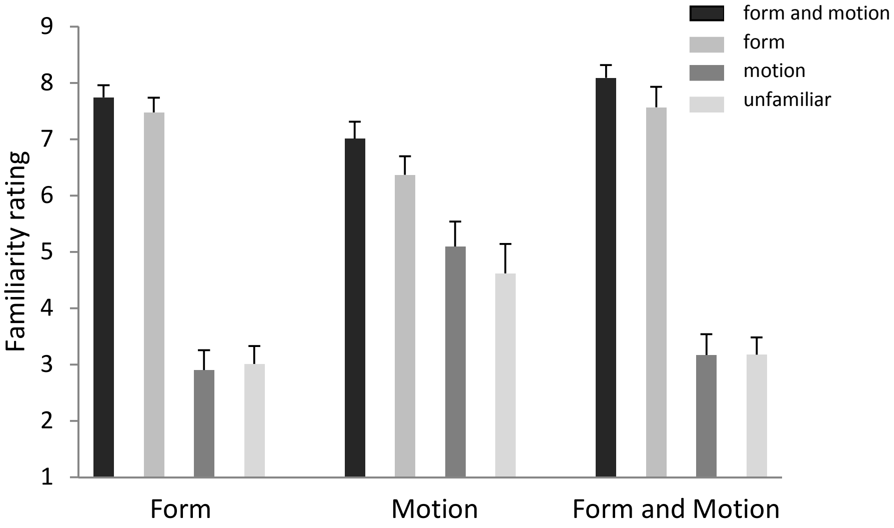


Figure 3. Familiarity ratings in the three different attention blocks for faces with familiar form and motion, familiar form, familiar motion, and unfamiliar faces.

The ratings for likeability, valence and arousal were combined with the ratings from the first pilot study. As can be seen in Table 1, the two different types of smiles did not differ in their likeability, *t*(26) = .37, *p* = .40, valence, *t*(26) = .79, *p* = .44, nor arousal, *t*(26) = .52, *p* = .52.

Table 1

Mean (M) and standard deviations (SD) for the trait ratings of facial stimuli, separately presented for the two types of facial motion. Data from pilot study I and II are merged.

	Smile 1		Smile 2	
Trait	*M*	*SD*	*M*	*SD*
Likeability	4.68	.68	4.60	.81
Valence	4.87	.73	4.81	.79
Arousal	3.81	1.22	3.87	1.21

2.1.3.3 Conclusions

The second pilot study showed that when participants' attention was directed towards the facial motion familiarity of facial motion was reflected by the ratings. The block in which participants were directed to attend to both facial form and motion did not differ from the attention-to-form condition. Furthermore participants reported having had problems directing their attention away from the motion and to the form once motion had been made salient through the instruction. Two implications were drawn from pilot study II. Firstly the main experiment would only contain two attention blocks, one where attention was drawn to the form of the face and one where it was drawn to the motion of the face. Secondly the attention-to-form block would precede the attention-to-motion block to avoid the problems participants reported from disengaging from the motion. The implications of this decision are that time effects might have a negative influence on the attention-to-motion block since there will be more time between this block and the learning phase. This might weaken the effects of familiarity in this block.

2.2 Introduction

2.2.1 Event-related potentials reflecting face processing and recognition

Electrophysiological studies have been able to identify several event-related potentials that are thought to reflect different stages of face processing and identification. The earliest electrophysiological correlate of face processing is the N170, an event-related negative potential which peaks around 170 ms over posterior temporal scalp electrodes and is found to be evoked by faces but not by other animate and inanimate non-face stimuli (Bentin, Allison, Puce, Perez, & McCarthy, 1996). The N170 is discussed to reflect the stimulus-based structural encoding of a face and therefore to indicate detection rather than identification of human faces (Bentin & Deouell, 2000; Eimer, 2000; Rossion, Campanella, Gomez, Delinte, Debatisse, Liard, et al., 1999) (but see Campanella, Hanoteau, Dépy, Rossion, Bruyer, Crommelinck, et al., 2000, for a controversial opinion).

Following the N170 a further negavity is found over infero-temporal areas which peaks at around 250 ms after stimulus onset. This N250 or N250r is the earliest potential at which memory-related face processes influence brain activity. Initially the N250r was shown to be sensitive towards immediate repetitions of previously primed faces and the priming effect on the N250 seemed to be very transient as it was eliminated when the interval between prime and repetition exceeded several faces or more than a few seconds (Schweinberger, Pickering, Burton, & Kaufmann, 2002). However, by increasing the strength of the prime through more initial presentations or using highly familiar faces such as the participant's own face, the effect of face familiarity on the N250 has been able to be shown in paradigms that do not involve immediate face repetition (Kaufmann, Schweinberger, & Burton, 2008; Tanaka, Curran, Porterfield, & Collins, 2006). It has been discussed that the N250 reflects the activation and accessing of stored perceptual face representations (Kaufmann, Schweinberger, & Burton, 2008; Schweinberger, Pickering, Burton, & Kaufmann, 2002).

Later potentials linked to face familiarity and face recognition have been found over parieto-central and fronto-central scalp electrodes and start around 300ms after stimulus onset. A negative-going deflection between 300 and 500ms has been named the Face-N400 (Bentin & Deouell, 2000) or N400f (Eimer, 2000) and distinguishes between familiar famous faces and novel faces. The N400f has also been found towards previously unfamiliar faces with which participants were familiarised during the experiment (Joyce & Kutas, 2005). As the N400f does not depend on overt face recognition it is likely to at least in part reflect an automatic activation of the face representation system which does not necessarily involve a conscious recollection of the face (Jemel, Schuller, & Goffaux, 2010). In line with this reasoning Curran & Hancock (2007) have discussed the frontal N400 as an indicator of familiarity based face recognition. However there is also evidence that it may also already reflect processes involved in person identification and activation of identity-specific semantic information (Paller, Gonsalves, Grabowecky, Bozic, & Yamada, 2000).

2.2.2 Impact of dynamic facial features on ERPs

Few studies have so far addressed the influence characteristics of changeable face properties have on event-related potentials reflecting face processing and recognition. One line of research has concentrated on the emotional content of a facial expression. For example investigating the emotion-induced memory enhancement for emotional compared to neutral faces Johansson, Mecklinger, and Treese (2004) found that the emotional expression of a face influenced the frontal old/new effect linked to familiarity processes in recognition memory for faces. Focusing more on the dynamic properties of changeable face attributes, Puce, Smith, and Allison (2000) were able to show that facial movement influences the N170. Furthermore, there is also evidence that the N170 is sensitive to changes in facial expression (Miyoshi, Katayama, & Morotomi, 2004). However, the role changeable face properties may play during later stages of face processing and person recognition and the role the familiarity of the movement holds have not yet been investigated electrophysiologically.

2.2.3 Aim of Experiment I

The goal of this experiment was to investigate the familiarity of idiosyncratic facial movement while expressing an emotion and its influence on face processing and recognition. I aimed at investigating the temporal characteristics of familiarity of facial movement on event-related potentials reflecting face processing and recognition. Of specific interest was whether familiarity of facial movement would modulate the N170 associated to structural face encoding, indicating an influence of familiar facial motion on the structural processing of the face, or if the familiarity of facial movement would modulate later potentials associated with face familiarity and person recognition such as the N250 and N400f.

An experiment was therefore conducted in which participants were initially familiarised with a face and its idiosyncratic smile. This face was an artificially created face, an avatar. Working with computer generated faces allowed me to independently manipulate facial form and facial motion in the subsequent test phase. In this test phase, participants were presented with faces in which either the familiarity of the facial form was varied or the familiarity of the facial movement. In two separate blocks participants' attention was either drawn to the facial form or the facial movement. Effects of the familiarity of facial form and of facial movement on the N170, N250, and N400f ERP components were investigated.

2.3 Methods

2.3.1 Participants

Twenty-five right handed participants with normal or corrected-to-normal vision were investigated. Participants were recruited online from the city population and received 10€ allowance. All participants signed informed consent prior to participation. Six participants were excluded from the analysis due to insufficient quality of the EEG recording. Therefore analyses were performed for 19 participants (13 women) ranging in age from 20 to 48 years (*M* = 24.90*, SD* = 6.37).

2.3.2 Stimuli and apparatus

2.3.2.1 Facial stimuli

Development of the facial stimuli is described in 2.1.2. Eighteen different faces were combined with two kinds of smiles, thus resulting in 36 different stimuli. Each stimulus consisted of three images which were each presented for 800 ms. The two distinct movements differed only in the second frame of the stimulus (see Figure 4). Therefore, upon presentation of the second frame participants knew whether the facial form and the facial movement were familiar or not and hence the onset of the second image constituted the onset point for the measurement of the event-related potentials.

Figure 4. Example for the two different smile categories for two different faces. The picture frames were presented subsequently for 800ms each. Only the second frame distinguishes the two smile categories.

2.3.2.2 EEG measurement and data analyses

The electroencephalogram (EEG) was recorded according to the 10-20 system from 29 active Ag-AgCl electrodes (Fp1, Fp2, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, CP5, CP1, CP2, CP6, TP10, P7, P3, Pz, P4, P8, O1, Oz, O2) at a sampling rate of 1000 Hz. Electrodes were attached to an elastic cap (*actiCAP*, Munich, Germany). The FCz electrode was used as reference during data acquisition.

Off-line the sampling rate was subsequently reduced to 200 Hz and data were mathematically re-referenced to an average reference of all 29 EEG electrodes and the implicit reference. Both vertical (above and below right eye) and horizontal (at outer canthi of both eyes) EOGs were recorded. Electrode impedance was kept below 5 kΩ. Using a Brain-amp-MR amplifier (*Brain Products*, Munich, Germany) and the software *Brain Vision Recorder* Version 1.03 (*Brain Products*, Munich Germany) electroencephalograms were amplified and recorded. Amplifier bandpass was set to 0.1 – 250 Hz. EEG data were analysed offline using the software *Brain Vision Analyzer* Version 2.00. Data were lowpass filtered with 12 Hz and corrected for horizontal and vertical ocular artefacts using the method introduced by Gratton, Coles, and Donchin (1983). The continuous data were segmented into trials lasting from 100ms before to 700ms after onset of the second frame of each stimulus and were baseline corrected with reference to the mean baseline interval (100ms before stimulus onset). Trials with a gradient criterion of more than 30 µV were rejected as artefacts. Furthermore, trials that exceeded an amplitude criterion of ± 100 µV were excluded from further analysis. Trials were averaged for each experimental condition and participant. The N170 was defined by the amplitude and latency of the peak negativity between 140 and 200 ms post-stimulus onset over P7 and P8 (Bentin & Deouell, 2000; Puce, Smith, & Allison, 2000). The N250 was identified over temporal electrodes (T7, T8) and mean amplitude was calculated between 230 and 270 ms (Kaufmann, Schweinberger, & Burton, 2008; Tanaka, Curran, Porterfield, & Collins, 2006). Finally, the N400 was quantified as the mean amplitude between 300 and 500 ms post-stimulus at frontal and fronto-central electrodes (F3, Fz, F4, FC1, FC2). The choice of electrodes was based on previous experiments (Bentin & Deouell, 2000, Eimer, 2000, Joyce & Kutas, 2005) as well as visual inspection of the data.

2.4 Procedure

After arriving at the laboratory, participants were informed about the experimental procedure and asked to give informed consent. They were told that they would be introduced to a computer generated face, representing a person called Markus, and that they would be shown Markus’ face several times and asked questions regarding Markus in order to gain an impression of him. In the second part of the experiment they would be shown further faces and would be asked to judge certain characteristics of these faces. EEG and EOG electrodes were then attached in a shielded cabin and the experimental procedure was started.

2.4.1 Training phase

In the training phase participants were shown one face with one of the two smiles 60 times and after each tenth subsequent presentation asked questions regarding their impression of the face that they were introduced to as Markus. They rated Markus’ personality on a 9-point Likert scale ranging from *not at all* (1) to *very* (9) with respect to 3 positive (*happiness*, *intelligence* and *trustworthiness*) as well as 3 negative (*selfishness*, *recklessness* and *opportunism*) character traits. The aim of the training phase was to familiarise participants with Markus’ face and his idiosyncratic movement without participants explicitly memorising Markus because explicit recognition tasks may bias observers to apply strategies that favour static, pictorial content (Pilz, Thornton, & Bülthoff, 2005).

2.4.2 Test phase

In the test phase which followed directly after the training phase participants were presented with different facial stimuli and were asked to rate after each stimulus on a scale from *not at all* (1) to *very strongly* (9) how strongly they were reminded of Markus. The facial stimuli were presented for 2400 ms and directly followed by the familiarity rating which was terminated upon reaction. Afterwards a fixation cross was presented for 1000 ms before the next stimulus was shown. Markus' face was presented 17 times with the idiosyncratic movement participants were familiar with from the training phase and 17 times with the unfamiliar movement. Furthermore, 17 unfamiliar faces were presented, animated with Markus' idiosyncratic movement as well as the unfamiliar movement. Thus, altogether 68 stimuli were presented in random order with the exception that no two stimuli of the same category were presented in direct succession.

The test phase was divided into two blocks. In the first block participants were instructed to concentrate on the faces' form, and in the second block their attention was drawn to the faces' movement. In the attention-to-form block it was anticipated that only the familiarity of the form would influence familiarity ratings while in the attention-to-motion block familiarity ratings were expected to reflect familiarity of form and of motion.

2.4.3 Manipulation check

To measure the degree of face familiarity, participants were asked to rate how strongly the presented face reminded them of Markus after each stimulus in the test phase. Familiarity was rated on a scale ranging from *not at all* (1) to *very strongly* (9). In the attention-to-form block faces with familiar form were generally expected to be rated as more familiar than faces with unfamiliar form. In the attention-to-motion block faces with familiar form as well as faces with familiar motion were expected to be rated as being more familiar than faces with unfamiliar form and motion.

2.4.4 Ratings

As a control variable, ratings of the individual faces were assessed at the end of the experiment. Participants were presented all avatars again and rated them individually according to *likeability* from 1 (*not very likeable*) to 9 (*very likeable*), *valence* from 1 (*very negative*) to 9 (*very positive*) and *arousal* from 1 (*not arousing*) to 9 (*very arousing).* The pilot studies had shown that the two smiles did not differ regarding their likeability, valence nor arousal and therefore differences were not expected.

2.4.5 Statistical analysis

Repeated-measures Analysis of Variance (ANOVA) with the within-factors Block (form vs. motion), Form (familiar vs. unfamiliar) and Motion (familiar vs. unfamiliar) were conducted for the familiarity ratings and the ERPs. For the N170, the N250 and the N400f an additional within-factor for the respective electrodes was added. Significance level was set to 0.05 and Bonferroni adjusted for multiple post-hoc tests. *F*-values were corrected according to Greenhouse-Geisser.

2.6 Results

2.6.1 Ratings

Ratings of likeability, valence and arousal for the two different types of movement can be seen in Table 2. Means of ratings are similar to those of the pilot studies and range around the mean of the scale. The two different smiles did not differ regarding their likeability, $t(18) = .32$, $p = .75$, valence, $t(18) = -.82$, $p = .42$, nor arousal, $t(18) = .87$, $p = .40$.

Table 2

Mean (M) and standard deviations (SD) for the trait ratings of facial stimuli, separately presented for the two types of facial motion.

	Smile 1		Smile 2	
Trait	*M*	*SD*	*M*	*SD*
Likeability	4.93	.70	4.89	.76
Valence	5.04	.63	5.11	.56
Arousal	4.89	1.03	4.81	1.08

2.6.2 Familiarity ratings

Familiarity ratings for both attention blocks can be seen in Figure 5. Repeated-measures ANOVA revealed a significant Block x Form, $F(1,18) = 24.29$, $p < .01$, $\eta_p^2 = .49$, and Block x Motion, $F(1,18) = 8.17$, $p = .01$, $\eta_p^2 = .31$, effect. Subsequent pairwise comparison showed that faces with familiar form were rated as more familiar in the attention-to-form block, $t(18) = 14.27$, $p < .01$, as well as in the attention to motion block, $t(18) = 5.63$, $p < .01$. Faces with familiar motion on the other hand were only rated as more familiar than faces with unfamiliar motion in the attention to motion block, $t(18) = 3.75$, $p < .01$, and not in the attention-to-form block, $t(18) = 1.51$, $p = .15$.

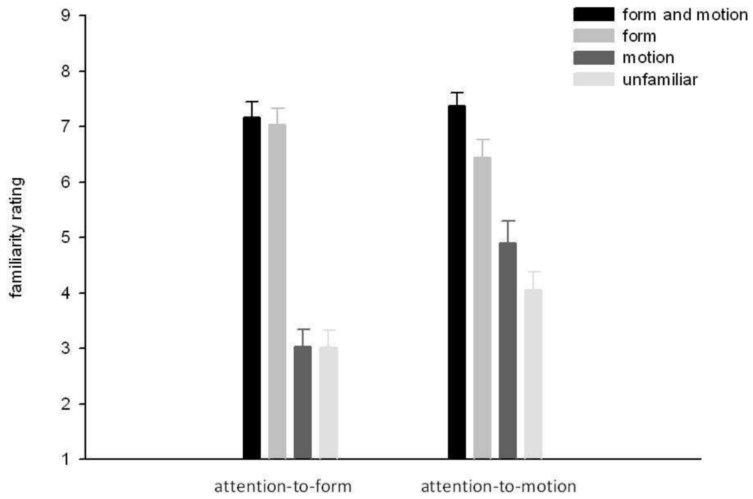


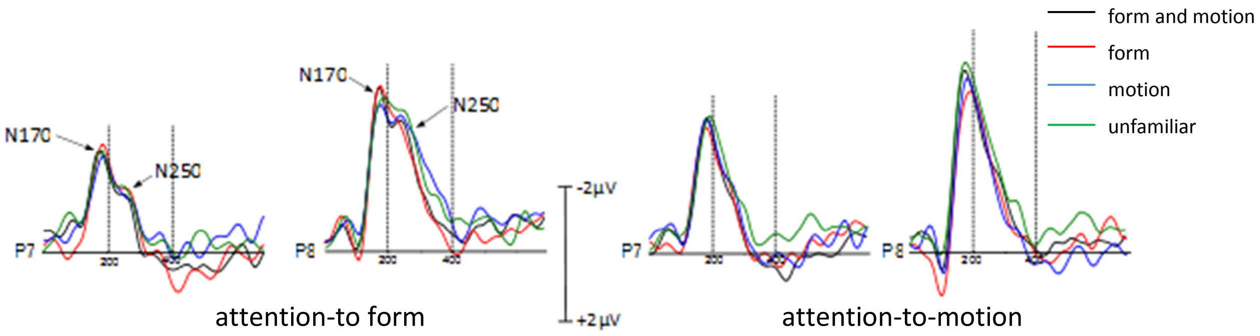
Figure 5. Familiarity ratings for the different categories of facial stimuli in the two separate attention blocks. Ratings range from 1 (*not familiar at all*) to 9 (*very familiar*). Faces with familiar form were rated more familiar in both blocks. Faces with familiar motion were rated as more familiar in the attention-to-motion block.

2.6.3 EEG measures

2.6.3.1 N170

The N170 towards the different categories of faces is depicted in Figure 6. Separate repeated-measures Block x Form x Motion x Hemisphere ANOVAs for amplitude and latency were conducted. For the amplitude a main effect of hemisphere, $F(1,18) = 8.72$, $p = .01$, $\eta_p^2 = .37$, and a main effect of block, $F(1,19) = 9.50$, $p = .01$, $\eta_p^2 = .35$, were detected. There was no significant main effect of the factors Form and Motion, nor were any significant interactions observed, all *p*s > .18. As Figure 6 shows, in average the amplitude of the N170 was larger over the right hemisphere (*M* = -5.62 µV; *SD* = 2.61) than over the left hemisphere (*M* = -3.94 µV; *SD* = 2.23). Furthermore, the N170 was more negative in the attention-to-motion block (*M* = -5.13 µV; *SD* = 2.41) than in the attention-to-form block (*M* = -4.52 µV; *SD* = 1.95).

Regarding the latency of the N170 a significant main effect of block was detected, $F(1, 18) = 25.65$, $p < .01$, $\eta_p^2 = .59$. Additionally, a marginally significant Block x Form interaction, $F(1, 18) = 3.85$, $p = .07$, $\eta_p^2 = .18$, was found and further investigated. Follow-up comparisons showed that the latency of the N170 did not differ for familiar or unfamiliar facial form in the two blocks, both *ps* > .18, but that the interaction was driven by a later N170 in the attention-to-motion compared to attention-to-form condition for familiar, $t(18) = -5.07$, $p < .01$, and unfamiliar facial form, $t(18) = -3.25$, $p < .01$. The significant main effect of block also indicated a delayed N170 in the attention-to-motion (*M* = 184.97 ms; *SD* = 7.35) compared to attention-to-form (*M* = 177.66 ms; *SD* = 8.55) block. Furthermore, a marginally significant Form x Hemisphere effect was observed, $F(1, 18) = 3.34$, $p = .08$, $\eta_p^2 = .16$. Follow-up comparisons however revealed no further significant results, all *ps* > .19.



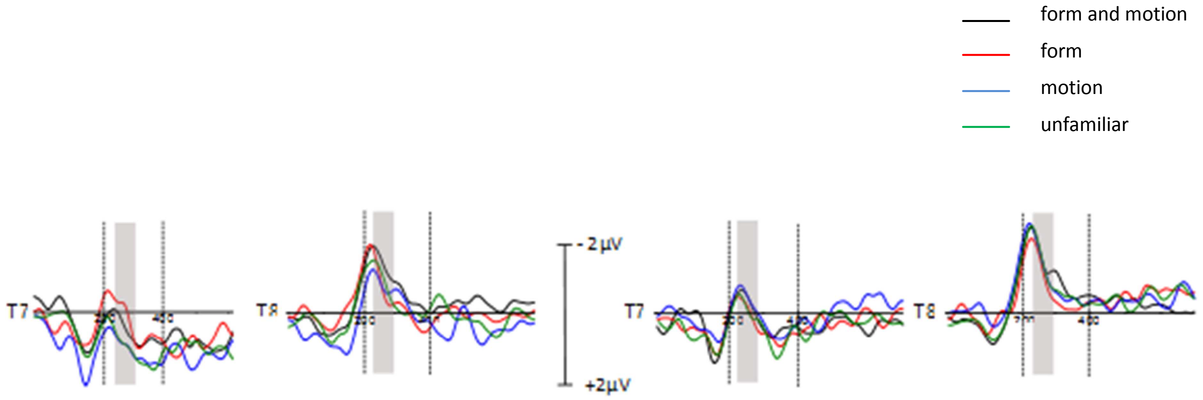
attention-to form

attention-to-motion

Figure 6. N170 at P7 and P8 towards faces with familiar form and motion (black), familiar form (red), familiar motion (blue) and unfamiliar faces (green) in the attention-to-form (left) and attention-to-motion (right) block. Familiarity of form and motion did not influence amplitude or latency. In the attention-to-form block the N250 was also visible at P7 and P8, as indicated. For better visualization, the first vertical line indicates 200 ms, the second 400 ms on the time scale.

2.6.3.2 N250

A Block x Form x Motion x Hemisphere repeated measures ANOVA was conducted and showed a significant main effect of Hemisphere, *F*(1, 18) = 26.41, p < .01, η_p^2 = .60. As can be seen in Figure 7, the N250 was stronger over the right hemisphere (*M* = - 1.55 µV; *SD* = .97) than over the left (*M* = .10 µV; *SD* = 1.07). Furthermore the Block x Form interaction almost reached significance, *F*(1, 18) = 3.65, p = .07, η_p^2 = .17. Follow-up t-tests showed that familiar facial form compared to unfamiliar facial form produced a significantly more negative N250 in the attention-to-form block, *t*(18) = -3.02, *p* = .01, while the comparison was non-significant in the attention-to-motion condition, *t*(18) = .32, *p* = .76.

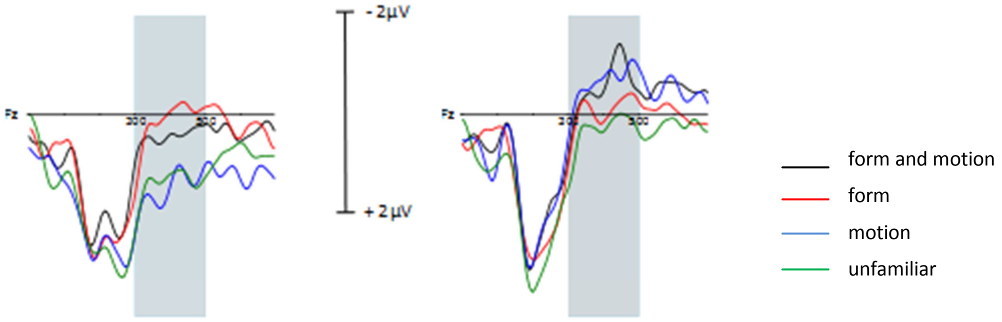


attention-to-form attention-to-motion

Figure 7. N250 depicted at temporal electrodes T7 and T8 for the two different attention blocks. The grey area shows the time frame (230-270 ms) over which amplitudes were averaged.

2.6.3.3 N400f

Block x Form x Motion x Electrode repeated measures ANOVA revealed a significant Form x Electrode, *F*(4, 72) = 7.57, p < .01, η_p^2 = .30, as well as a Block x Motion, *F*(1, 18) = 5.29, *p* = .03, η_p^2 = .23, interaction. Post-hoc pairwise comparison tests for the former interaction showed that over both blocks familiar form elicited a more negative potential than unfamiliar form at the electrodes F3, $t(18) = -4.17$, $p < .01$, Fz, $t(18) = -3.53$, $p < .01$, and F4, $t(18) = -3.91$, $p < .01$, while this was not the case at electrodes FC1 and FC2, both *p*s > .61. Following the latter interaction showed that familiarity of motion caused a stronger negativity compared to unfamiliar motion only in the attention-to-motion block, $t(18) = -2.15$, $p = .05$, while no difference was apparent in the attention-to-form block, $p = .18$ (Figure 8). Finally a significant Block x Electrode effect, $F(4, 72) = 7.85$, $p < .01$, $\eta_p^2 = .30$, was due to the fact that the potential was less negative at F3, $t(18) = 2.51$, $p = .02$, Fz, $t(18) = 2.55$, $p = .02$, and F4, $t(18) = 2.55$, $p = .02$, in the attention-to-form compared to attention-to-motion block.



attention-to-form attention-to-motion

Figure 8. N400f depicted at Fz. Mean activity is modulated by the familiarity of form in both attention blocks and by familiarity of motion in the attention-to-motion block. The time period for which the mean amplitude was accessed is highlighted (300-500 ms).

2.7 Discussion of Experiment I

The intention of this experiment was to investigate whether and at which stage of face processing and recognition a modulation of brain potentials by the familiarity of facial motion while expressing an emotion is detectable. Participants were familiarised with a face and its idiosyncratic smile and subsequently effects of the familiarity of the facial form as well as the facial movement on early structural face encoding as well as face recognition were studied.

2.7.1 Effect of familiarity of facial form and motion on event-related potentials

The results show that neither the familiarity of facial form nor of facial movement influenced the N170. This confirms and extends earlier research indicating that the N170 reflects visual structural encoding of a face and hence the identification of a face in general rather than at an individual level (Bentin & Deouell, 2000; Eimer, 2000; Schweinberger, Pickering, Burton, & Kaufmann, 2002). Although there is evidence that dynamic facial expressional change but not identity change modulates the N170 (Miyoshi, Katayama, & Morotomi, 2004), results show that the familiarity of the movement patterns of emotional expression change is not yet processed at this early stage.

Further results regarding the N170 revealed that its amplitude was larger over the right compared to the left hemisphere which has previously been reported by various researchers (e.g. Bentin, Allison, Puce, Perez, & McCarthy, 1996; Rossion, Joyce, Garrison, Cottrell, & Tarr, 2003). The N170 was also stronger and slightly delayed when participants directed their attention to the motion rather than to the form of the face. It has been shown that engaging in analytical processing of a face, such as, for example concentrating on the eyes rather than configurally processing the face, can lead to increased amplitudes and longer latencies of the N170 (Jemel, George, Chaby, Fiori, & Renault, 1999; Rossion, Gauthier, Tarr, Despland, Bruyer, Linotte, et al., 2000). Possibly participants focused more strongly on certain regions of the face such as the eyes and the mouth when directing their attention to the motion of the face.

With respect to the N250, a stronger negativity for faces with familiar form, compared to faces with unfamiliar form, was present but only if participants's attention was directed towards the form of the presented faces. If participants directed their attention away from the the facial form towards the facial motion, the impact of face familiarity on the N250 was eliminated. It has been shown that the N250 effect is modulated by the task relevancy of the stimulus (Tanaka, Curran, Porterfield, & Collins, 2006) thus indicating that it is susceptible to top-down attentional processes. An alternative explanation could be that this effect is caused by the experimental design in which the attention to motion block followed the attention to form block and therefore rendering the timespan between the learning and the test trial longer for this condition. There is, however, evidence rendering this explanation less likely, since both Tanaka et al. (2006) as well as Itier and Taylor (2004) have shown that the N250 effect for newly learned faces is enhanced with increasing number of recognition trials at test, leading to the conclusion that the increased N250 towards familiar faces indicates the forming of a face representation over the course of the expriment. Independent of participants' attentional focus, familiarity of facial motion showed no influence on the N250. If the N250 reflects the stage in face processing where a previously acquired identity-specific face representation is activated and the encoded perceptual face representation is compared with this stored facial code (Kaufmann, Schweinberger, & Burton, 2008; Schweinberger, Pickering, Burton, & Kaufmann, 2002; Tanaka et al., 2006), then the results presented here suggest that these stored face representations are structural in nature and do not contain information about the movement of the face.

Finally, results showed that the N400f is modulated by the familiarity of facial form independent of the focus of attention. In both attention conditions the N400f distinguished between familiar and unfamiliar facial form at the frontal electrodes. Furthermore, when attention was directed towards the movement of the face, familiarity of motion was also reflected by the N400f. Modulation of the N400f by the familiarity of facial form and movement is also mirrored by the familiarity ratings which, independent of the attentional focus, showed a higher familiarity for faces with familiar form, while only being biased by the familiarity of the motion in the attention-to-motion condition. Correspondence of familiarity ratings and the N400f can be used to argue in favour of the claim that this frontal negativity reflects familiarity based face recognition (Curran & Hancock, 2007). The familiarity of the face can be prompted by a matching of the processed face to stored facial representations and data presented here suggest that familiarity of a face can also be increased by familiar facial motion, when the motion is attended to. Thus, these results provide electrophysiological evidence that the movement of a face is a source of information for face identification and that information stored about faces which elicits face recognition is not only based on invariant facial features but also on changeable face characteristics.

2.7.2 Limitations

It is important to take into consideration some of the limitations of the current experiment. Firstly, participants were only familiarised with one face and one facial movement (although which face and which movement was randomised). Ideally participants should learn several faces with several idiosyncratic movements. However it must be taken into consideration that this will involve a much longer and more intense learning phase especially if the faces are to be learned incidentally. This experiment was restricted to one familiar and one unfamiliar movement to be able, as previously discussed, to create rather distinct, different smiles that at the same time were equally intense and natural. The here reported results should not be generalised over all facial movement as they strictly spoken only apply to facial movement while expressing a positive emotion. In future experiments it would be important to include further kinds of movements such as different emotional and non-emotional movements. This will at the same time increase the possibility of familiarising participants with a higher number of faces and motions.

Secondly, the results regarding the N250 in particular would benefit from replication. The N170 has so far received a lot more attention in research on face processing than the N250 and here presented findings on the N170 are in line with that research. Since as previously discussed the effects on the N250 vary depending on the experimental setup and have been found to be rather transient in some experimental designs (Schweinberger, Pickering, Burton, & Kaufmann, 2002), an experiment optimising conditions especially for the N250 would be fruitful in this regard. Such an experiment could, e.g. involve immediate repetition priming and an electrode setup with a dense array of electrodes especially in the inferior temporal regions.

2.7.3 Conclusion

Taken together the current experiment provides valuable information about the temporal nature of the influence of familiar facial movement on face processing and recognition. While early ERPs linked to structural facial encoding and activation of stored face representations were not sensitive to the influence of familiar facial motion, later brain processes representing memory processes involved in associating the familiar face to a specific person were modulated by the familiarity of familiar facial motion when this was attended to. These results provide electrophysiological evidence for the claim that as a face becomes familiar information about its movement patterns are also encoded and later facilitate face and person recognition. The following functional imaging experiment will give further insight about the brain areas involved in the recognition of familiar facial motion.

3 Experiment II: Functional imaging of brain areas involved in processing familiar facial motion

3.1 Introduction

3.1.1 Separate anatomical pathways for processing dynamic and invariant facial features

Support from brain imaging data in favor of the distributed neural system for face perception (Haxby, Hoffman, & Gobbini, 2000) stems from a double dissociation the authors found in an fMRI experiment when they directed participants' attention either to a face's identity or to its eye gaze. Attention to identity elicited a greater activation in the lateral fusiform gyrus while attention to eye gaze was associated to a stronger response in the posterior superior temporal sulcus (Hoffman & Haxby, 2000). The posterior superior temporal sulcus has also been shown to be sensitive towards emotional expression (Narumoto, Okada, Sadato, Fukui, & Yonekura, 2001) as well as mouth and lip movements (Calvert et al., 1997; Puce, Allison, Bentin, Gore, & McCarthy, 1998). Using functional MRI-adaptation technique, Winston, Henson, Fine-Goulden, and Dolan (2004) were able to show that the right mid-STS showed adaptation for emotional expression while the posterior lateral right fusiform cortex showed adaptation for identity. Adaptation of a region using this technique indicates that the region contains neurons that are excited by the respective aspect of a stimulus and therefore habituate if this stimulus aspect is repeated. However, it is important to note that the authors also report adaptation of neurons towards identity in the posterior right STS. A further fMRI-adaptation experiment by Andrews and Ewbank (2004) also revealed adaptation of a face-selective region of the fusiform gyrus towards repetition of the same face while the face-selective region in the STS did not adapt to face identity. It did, however, prove to be sensitive to changes of facial expression as well as viewpoint.

There is therefore evidence supporting the involvement of the STS region in the perception of changeable facial features. Consistent with the assumption that changeable facial features facilitate social communication, the posterior STS and the temporal-parietal junction have also been associated to social perception of others' mental states (for a review see Allison, Puce, and McCarthy, 2000). While it is true that both eye and mouth movements contain a dynamic character, they also imply signaling of intention. Especially eye gaze shifts are strong indicators of another's mental state and social attention. Therefore it is possible that rather than simply analyzing the dynamic properties of faces, the STS region responds to the social information these facial movements convey. This argument is strengthened by experiments showing that the STS region is also sensitive towards static 'theory of mind' scenes in which mental states are attributed to the protagonists (Gallagher et al., 2000). The STS therefore seems to be a functionally somewhat heterogeneous region in which dynamic features as well as social intentions of faces are analyzed.

3.1.2 The fusiform gyrus and face identification

Evidence for the involvement of the fusiform gyrus in the processing of individual face identity is strong yet not fully conclusive. Gauthier et al. (2000) argue that the fusiform face area (the area within the fusiform gyrus that selectively responds to faces) can analyze faces on the individual level and not merely detect the general presence of a face. Furthermore populations of neurons within the fusiform face area seem to be tuned to face geometry (Loffler, Yourganov, Wilkinson, & Wilson, 2005). In line with these arguments, unfamiliar faces have been found to produce a stronger activation in the fusiform gyrus than newly learned faces (Leveroni et al., 2000; Rossion, Schiltz, Crommelinck, 2003; Rossion, Schiltz, Robaye, Pirenne, & Crommelinck, 2001). Furthermore, a range of experiments have been able to detect adaptation towards identity repetition within the fusiform gyrus (Andrews and

Ewbank, 2004; Pourtois, Schwartz, Seghier, Lazeyras, and Vuilleumier, 2005; Winston, Henson, Fine-Goulden, and Dolan, 2004). Rotshtein, Henson, Treves, Driver, and Dolan (2004) were able to show that the fusiform gyrus adapts to repetition of face identity even if the physical properties of the face change, thus showing that it is sensitive to individual face identity. Abnormal activation of the right fusiform gyrus has also been found in a patient with acquired prosopagnosia who could still detect but no longer discriminate faces (Schiltz et al., 2005).

However, famous faces have also been shown to *increase* activation in the fusiform gyrus compared to unfamiliar faces (Elfgren et al., 2006). Using PET, Dubois et al. (1999), on the other hand, were not able to find a modulation of the activation in the fusiform gyrus by the familiarity of newly learned faces compared to unknown faces. Most likely these inconsistent data regarding the involvement of the ventral extrastriate visual system in the processing of individual face identity are due to different sets of stimuli that were chosen as familiar (famous faces, newly learned faces, personally familiar faces) and due to the different kinds of memory and attention tasks. Gauthier et al. (2000) argue that when participants' attention is not directed to the identity of faces, habituation towards a face that is repeatedly presented will take place in the fusiform face area which processes that face at an individual level. Therefore familiar faces will elicit a weaker activation in this area. However, if attention is specifically directed to the identity of the face, habituation will not occur. Hence, drawing attention towards different aspects of the face such as identity and emotion will modulate activation patterns in the occipital and temporal extrastriate visual system.

3.1.3 Extended neural system for the recognition of familiar faces

As the presented research shows, different aspects of faces are processed within different areas of the occipital and temporal lobe. Dynamic features seem to follow a dorsal route along the STS region while invariant features are mostly processed in a more ventral pathway especially within the fusiform gyrus and it is within the fusiform gyrus that the effects of face familiarity are most consistently found in the core system of face processing (Haxby, Hoffman, & Gobbini, 2000). Familiarity of a face, however, also exerts effects within other regions of the brain beyond the visual system. For newly learned faces compared to novel faces, Gobbini and Haxby (2006) detected increased activity in the precuneus for familiar faces and decreased activation in the fusiform gyrus as well as in areas associated with emotional responses such as the amygdala. Consequently, Gobbini and Haxby (2007) extended their model of distributed neural systems for the recognition of familiar faces with emphasis not only on areas of the visual system but also on areas that primarily have cognitive and social functions like the paracingulate cortex, the precuneus, the amygdala and the insula. Identification of familiar individuals not only depends on visual familiarity but also on knowledge about the person as well as emotional responses. In this extended model the authors discuss the theory that the role of the STS region may also be to facilitate recognition of a person by processing dynamic features that are characteristic for a person, like a facial expression. Furthermore Gobbini and Haxby also integrate the role of the posterior STS region in detecting mental states into the extended model.

The involvement of the STS region in processing characteristic facial movement which supports face recognition had previously been discussed by O’Toole, Roark, and Abdi (2002) who state in their review that the inferotemporal area including the fusiform face area is crucial in the recognition of unfamiliar as well as familiar faces. For the recognition of familiar faces, additional information can be derived from dynamic facial characteristics which are processed via the middle temporal and superior temporal sulcus. Dynamic information of a face processed in the middle temporal sulcus can also contribute to the structural information processing in the inferotemporal cortex. Experimental evidence for the involvement of the middle temporal and superior temporal region in the detection of characteristic dynamic facial features has not yet been provided, however.

3.1.4 Aim of Experiment II

The aim of the current work was to experimentally investigate the processing of familiar facial movement. Based on the theoretical framework highlighted above, familiarity of facial motion was expected to modulate activation on the dorsal pathway including the middle temporal and posterior STS region, while familiar facial form should modulate areas on the ventral inferotemporal pathway such as the fusiform gyrus. Furthermore modulation of areas beyond the visual system by the familiarity of facial form and/or motion was of interest.

The experiment was conducted with functional MRI. In a passive viewing condition, participants were presented dynamic faces with whose form and motion they had previously been familiarized with or were unfamiliar with. Sensitivity to familiarity of form and motion was confirmed in a separate behavioral task. Brain regions that responded to familiarity of facial form and familiarity of facial motion were examined.

3.2 Methods

3.2.1 Participants

Thirty volunteers participated in the experiment. Participants were recruited online and received 12 Euros for taking part in the experiment. Due to technical problems with the scanner, data of three participants could not be analyzed. Furthermore two participants were excluded from the analysis because of insufficient results in the target recognition task, implying that participants did not pay appropriate attention to the stimuli. Therefore data of

25 participants (14 females; age *M* = 24.24, *SD* = 3.60) were included in the analysis. All participants were right handed and did not report any psychiatric or neurological history. Furthermore they reported normal or corrected-to-normal vision.

3.2.2 Stimuli and apparatus

3.2.2.1 Facial stimuli

Analogous to the EEG-experiment, the stimuli consisted of computer generated faces created with *Poser* software (*Curious Labs*, Santa Cruz, CA). The 18 different face forms from the EEG experiment were used and 3 additional face forms were added. Since the temporal resolution of fMRI is much lower than the temporal resolution of EEG, it was possible to use fully dynamic stimuli for this experiment. Each facial form was animated with two distinct smiles. Each animation consisted of 120 frames at a presentation speed of 30 frames per second. The first 60 frames consisted of an increasing smile while the last 60 frames showed a decreasing smile. On- and offset of each animation was a neutral expression (Figure 9).

Figure 9. Example of two different facial stimuli with the two different types of smile. Frames 1 (left), 30, 60, 90 and 120 (right) are depicted. On- and offset frames were emotionally neutral. Maximum intensity of the smile at frame 90 was equal for the two different smiles. Images were presented fully dynamically with 30 frames/sec.

3.2.2.2 Image acquisition

Functional and structural MRI was performed with a Siemens 1.5 T MRI whole body scanner (SIEMENS Avanto) with a standard 12-channel head coil and an integrated head holder to reduce head movements. For each subject structural high-resolution T1-weighted magnetization-prepared rapid gradient-echo imaging (MP-RAGE) 3D MRI sequence was obtained (MPRAGE, 1-mm slice thickness, TR: 1870 ms, TE: 3.74 ms, flip angle: 15°, FOV: 250 mm; matrix size: 256 x 256). For functional imaging, T2*-weighted single-shot gradient echoplanar imaging (EPI) sequence was registered (TR: 2500ms, TE: 40ms, 90° flip angle, FOV: 240 mm, matrix size: 64 x 64). Each EPI volume contained 25 axial slices (5mm thickness, 1 mm gap), acquired in interleaved order and covering the whole brain. The orientation of the axial slices was parallel to the AC-PC line. Each EPI-scanning session contained 550 functional images of which the first 7 volumes were discarded to allow for T1 equilibrium.

Since EPI images often exhibit spatial distortions in regions where the magnetic field is inhomogenous (Hutton, Bork, Josephs, Deichmann, Ashburner, & Turner, 2002) field maps (GREfieldmap, TR: 1000ms, TE: 10 ms, slices: 25, slice thickness: 5mm, FOV: 240 mm, matrix size: 64 x 64) were collected which measure the field inhomogeneity, to undistort the images.

3.2.2.3 Image processing and analyses

Data were analyzed with the Statistical Parametric Mapping software (SPM 8; Wellcome Department of Imaging Neuroscience, London, UK) implemented in Matlab 7.0 (Mathworks Inc., Sherborn, MA, USA).

Before preprocessing, a voxel displacement map was created with the unwrapped field maps to later unwarp the distorted EPI during the preprocessing. In the initial preprocessing step, echo-planar imaging volumes were slice-time corrected, spatially realigned to correct for movement artefacts and unwarped based on the previously-generated voxel displacement map. Subsequently the mean functional image was normalized to the Montreal Neurological Institute (MNI) single subject template (Evans, Marrett, Neelin, Collins, Worsley, Dai, et al., 1992). Normalization parameters were then applied to the functional echo-planar images and coregistered to the T1-image. Images were resampled at 2 x 2 x 2 mm^3 voxel size and smoothed using an 8-mm Gaussian kernel.

3.3 Procedure

After arriving at the laboratory, participants were informed about the experimental procedure and asked to give informed consent. Furthermore they were informed about the procedure for the functional imaging and confirmed that they had no metal in their body nor any known health risks. After removing all metal from their clothing and pockets participants were bedded in the scanner and viewed instructions over the MR presentation goggles. They were told that they would be introduced to a computer generated face, representing a person called Markus, and that they would be shown Markus' face several times and asked questions regarding Markus in order to gain an impression of him. In the second part of the experiment the influence of social stimuli, such as faces, on the perception of non-social stimuli, such as squares, would be investigated. This cover-story was intended to prevent participants from using memorising strategies during the learning phase.

3.3.1 Training phase

The training phase was implemented in the scanner to ensure that viewing conditions of the faces were stable over learning and test phase. Participants were instructed to equally direct their attention to the form and motion of the presented face, while they were shown one face with one of the two smiles 70 times and after each tenth subsequent presentation asked questions regarding their impression of the face which they were introduced to as Markus. They rated Markus' personality with respect to 3 positive (*happiness*, *intelligence* and *trustworthiness*) as well as 3 negative (*selfishness*, *recklessness* and *opportunism*) character traits. Therefore the training phase was analogous to the training phase in the EEG experiment. After the training phase a localizer sequence for the functional imaging as well as the GREfieldmapping were run. This procedure lasted about 6 minutes for each subject.

3.3.2 Test phase

In the test phase, which directly followed the fieldmapping, participants were presented with different facial stimuli and were asked to press the button under their right index finger as fast as possible whenever they saw an orange square presented in the centre of the screen. An implicit recognition task was chosen since previously reported experiments have shown that directing attention to certain aspects of the face modulates activation in the visual cortex and that directing attention to facial identity can diminish familiarity effects in the fusiform gyrus (Gauthier et al., 2000). Each presentation trial consisted of 7 scanner pulses (17500 ms) with the facial stimulus lasting 4000 ms. Each stimulus was preceded by a jittertrial that was randomised between 100 and 2400 ms. The jittertrial was implemented to avoid a systematic correlation of stimulus onset with scan onset and thus confounding the area of the brain that is scanned at a certain time with the time of stimulus processing. The rest of the trial consisted of the fixation cross which lasted between 11100 ms and 13400 ms depending on the duration of the jittertrial. Markus' face was presented 19 times with the idiosyncratic movement that participants were familiar with from the training phase and 19 times with the unfamiliar movement. Furthermore, 19 unfamiliar faces were presented, animated with Markus' idiosyncratic movement as well as the unfamiliar movement. Additionally 19 trials were added where the face stimulus was replaced by a fixation cross.

These trials constituted the baseline. Furthermore 10 target trials were implemented. These trials consisted of a face stimulus which was immediately followed by an orange square in the middle of the screen presented for 100 ms. The square followed each stimulus category twice and the target trials were excluded from the analysis. Participants' task during the presentation was to react upon the presentation of the squares. This task was chosen since it did not direct participants' attention to either of the facial attributes nor did the task involve processing the facial identity. Furthermore it is a very easy task which all participants were expected to be able to perform effortlessly at 100%. A similar indirect task has previously been used in face recognition experiments (George et al., 1999). Altogether 105 trails were presented in randomized order. In 76 trials faces were presented (face trials), in 19 trials fixation crosses (fixation trials) and in 10 faces followed by the square target (target trials).

3.3.3 Manipulation check

After the test phase the MPRAGE was recorded. This measurement lasted about 10 minutes and afterwards participants completed a recognition task. In this task they were presented 12 faces of each category and were asked to indicate with a yes/no answer whether the form of the face or the movement of the face resembled Markus'. The 12 faces were chosen randomly from the 19 available faces. Not all faces were shown to reduce the time participants had to spend in the scanner.

After the recognition task participants left the scanner. Subsequently they were asked to describe how well they recognized Markus' form and movement and completed a short questionnaire with demographic data. Finally they were thanked for their participation, paid and dismissed.

3.3.4 Statistical analyses

To investigate the effects of familiar motion and familiar facial form independently, contrasts were created between categories of stimuli where one of the two conditions varied while the other was kept constant. Therefore for each subject *t*-contrasts were computed comparing *familiar motion* vs*. familiar form and motion* and *familiar form* vs. *familiar form and motion.* Furthermore a contrast *face vs. fix* was conducted, accessing activation caused by the facial stimuli compared to baseline. These individual contrast images (first-level) then entered the second-level analysis over all subjects. Data were analyzed at each voxel (whole brain analysis) with $p < .01$, uncorrected for multiple comparisons, and meaningful clusters exceeding five significant voxels, to minimize false-positive activation due to data smoothing. Activation peaks were located by their MNI coordinates in the WFU Pick Atlas (Maldjian, Laurienti, Kraft, & Burdette, 2003), implemented in SPM 8.

3.4 Results

3.4.1 Manipulation check

The manipulation check only contains data of 23 subjects because due to technical problems recognition task data of two participants were not recorded. The subjects correctly identified familiar facial form as familiar in 85 % of the cases and familiar facial motion as familiar in 68%. For the familiar facial form all participants performed well above chance (> 60%) while for the familiar motion two participants performed below chance at 30 and 31 % and two participants at chance with 50 % and 51 %.

3.4.2 Faces vs. baseline

Activation towards all facial stimuli was compared to activation towards the baseline which was constituted by the fixation cross trials. As would be expected for dynamic faces, all faces compared to baseline produced a significant activation in the dorsal and ventral visual stream of the right hemisphere. This is shown in Figure 10 below.

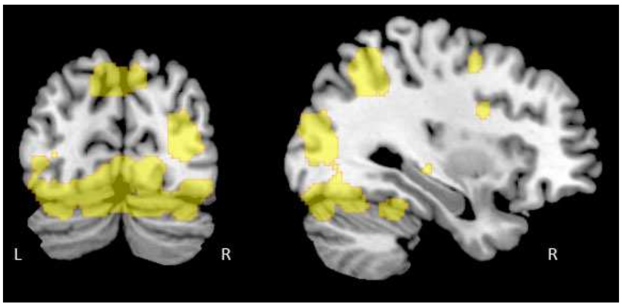
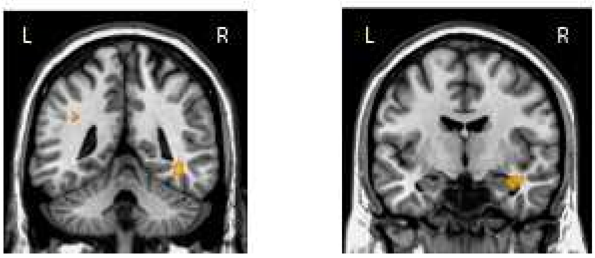


Figure 10. Activation for all faces versus the fixation baseline. Coronal (y = -78 mm) and sagittal (x = 32 mm) sections are shown. In the right hemisphere activation of ventral and dorsal visual extrastriate cortex is observed, *p* = .001 (uncorrected).

3.4.3 Familiar motion vs. familiar form and motion

As depicted in Figure 11, faces with only familiar motion (M) caused increased activation compared to faces with familiar form and motion (FM) in the right fusiform gyrus as well as in the right parahippocampal region and hippocampus. Furthermore increased activation was registered in the left and right insula, the left and right supramarginal gyri as well as in frontal areas. The regions of activation maxima are summarized in Table 3.



Y = - 45 Y = -8

Figure 11. Increased activation within the fusiform gyrus (left) and the parahippocampal gyrus (right) towards faces with unfamiliar facial form but familiar motion compared to faces with familiar form and familiar motion, *p* = .01 (uncorrected).

When investigating where faces with familiar form as well as familiar motion elicited stronger activation than faces with only familiar motion, significant results were found in the left parahippocampal gyrus, the left precuneus, the left angular gyrus and in several areas of the frontal lobe such as the left supplementary motor cortex, and the left superior and right middle frontal gyri (see Table 3).

Table 3

Faces with familiar motion (M) versus faces with familiar form and motion (FM)

Comparison	*x*	*y*	*z*	*Z*	*k*	Lobe	Brain region
M > FM							
	0	48	50	2,45	75	Frontal	Rolandic Operculum L
	-44	-20	20	2,63	8		Frontal Superior Medial Gyrus L
	66	-20	36	2,81	25	Parietal	Supramarginal Gyrus R
	-34	-48	30	2,44	6		Supramarginal Gyrus L
	36	-6	-20	3,64	93	Temporal	Parahippocampal Gyrus R
	40	-46	-8	3,88	35		Fusiform Gyrus R
	48	12	-22	2,51	7		Temporal Superior Gyrus Pole R
	68	-30	-8	2,61	5		Temporal Middle Gyrus R
	-36	-18	24	3,09	75		Insula L
	48	2	-4	2,67	16		Insula R

FM > M							
	-38	50	2	2,80	57	Frontal	Frontal Middle Gyrus L
	-42	44	8	2,54	57		Frontal Inferior Triangular Gyrus L
	20	16	54	2,71	22		Frontal Superior Gyrus R
	-14	58	10	2,87	19		Frontal Superior Medial Gyrus L
	14	34	24	2,67	11		Anterior Cingulum R
	-6	4	58	2,52	8		Supplementary Motor Area L
	-2	-60	14	3,15	51	Parietal	Precuneus L
	-40	-68	30	2,46	6		Angular Gyrus L
	-44	-34	-10	2,99	10		parahippocampal Gyrus L

Note: Alpha = .01 (uncorrected) with minimum cluster size of k = 5. L = left, R = right. The cluster with the largest number of significant voxels within each region is reported.

3.4.4 Familiar form vs. familiar form and motion

Comparing activation to stimuli that differed in the familiarity of the facial motion, faces with unfamiliar motion but familiar form prompted stronger activity in frontal, temporal and occipital regions compared to faces with familiar motion and familiar form (see Table 4). Most notably, as highlighted by Figure 12, clusters of stronger activation were found in the right anterior temporal superior gyrus, as well as in the right temporal middle gyrus and inferior sulcus and the right fusiform gyrus. The activation in the temporal inferior sulcus was also apparent in the left hemisphere. In the occipital lobe a prominent cluster was located in the right middle and superior gyrus. Furthermore the right hippocampus and several gyri in the frontal lobe showed higher activation for this comparison such as the left superior medial frontal gyrus, the right medial frontal gyrus and the right inferior triangular gyrus as well as the left middle frontal gyrus. As in the comparison M > FM here also significant activation in the right insula was detected.

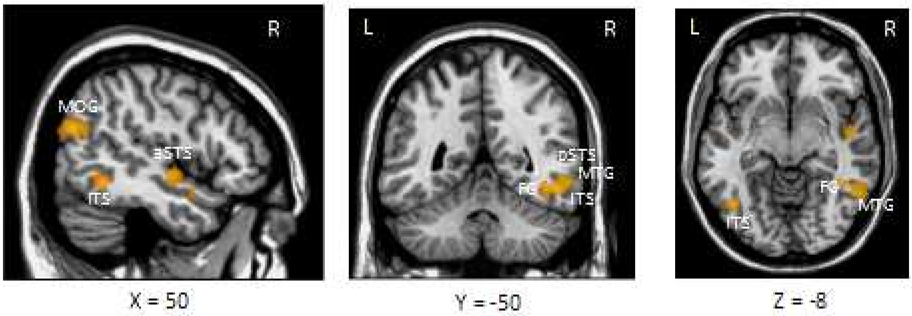


Figure 12. Areas of significantly increased activation in the left and right occipital and temporal lobe towards faces with familiar form and unfamiliar motion compared to faces with familiar form and familiar motion. *p* = .01 (uncorrected), k = 5.

Anatomical locations of the right middle occipital gyrus (MOG), the right fusiform gyrus (FG), the right middle temporal gyrus (MTG), the left and right Inferior temporal sulcus (ITS) and right anterior superior temporal sulcus (aSTS) and posterior STS (pSTS) are indicated.

Comparing the region of the fusiform gyrus that was activated in the current comparison as well as the areas that responded to familiarity of facial form showed that the centers of activation partly overlapped. The same part of the fusiform gyrus responded to familiarity of facial form as well as to familiarity of facial motion. This is depicted below in Figure 13.

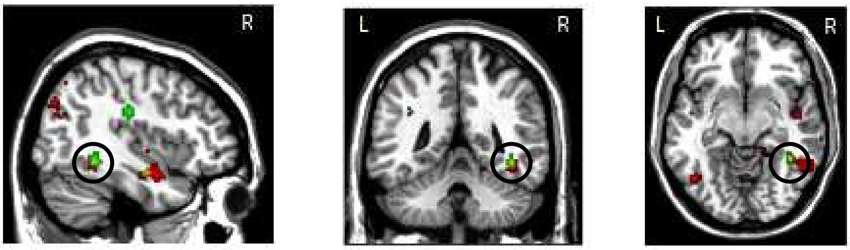


Figure 13. Overlap (yellow) of activation in the fusiform gyrus for the comparisons F > FM (red) and M > FM (green) at x = 40, y = -47, z = -9.

Faces with familiar form and motion caused a stronger activation than faces with only familiar form in several areas that were also observed when these faces were compared to faces with only familiar motion. These are the left precuneus as well as the left middle and right superior frontal gyri. Furthermore faces with familiar form and motion were associated to a stronger activation in the right supplementary motor area, the right cingulate gyrus, the left paracentral lobule, the left temporal middle gyrus and the right cerebellum.

Table 4

Faces with familiar form (F) versus faces with familiar form and motion (FM)

Comparison	*X*	*y*	*z*	*Z*	*k*	Lobe	Brain region
F > FM							
	-8	38	56	3,64	47	Frontal	Frontal Superior Medial Gyrus L
	14	36	-4	2,70	13		Frontal Medial Gyrus R
	44	46	-6	2,79	13		Frontal Inferior Triangular Gyrus R
	-40	44	28	2,58	8		Frontal Middle Gyrus L
	-54	32	12	2,71	5		Frontal Inferior Orbital Gyrus L
	66	-12	32	2,56	7	Parietal	Postcentral Gyrus R
	48	-8	-6	3,17	310	Temporal	Temporal Superior Gyrus R
	36	-12	-22	2,97	310		Hippocampus R
	56	-50	-8	3,17	209		Temporal Middle Gyrus R
	42	-48	-14	2,85	209		Fusiform Gyrus R
	-44	-64	-10	3,09	55		Temporal Inferior Gyrus L
	-48	-6	-8	2,48	9		Temporal Superior Gyrus L
	48	-68	24	3,46	415	Occipital	Occipital Middle Gyrus R
	30	-72	46	3,15	415		Occipital Superior Gyrus R
	-24	-80	36	2,68	33		Occipital Superior Gyrus L
	38	0	-20	3,53	310		Insula R
	16	-40	-16	3,35	81		Cerebellum R
	-26	-62	-30	3,09	43		Cerebellum L
	-14	-2	36	2,89	18		Cingulate Gyrus L
	-8	-8	8	2,58	11		Thalamus L
FM > F							
	10	-16	58	3,38	41	Frontal	Supplementary Motor Area R
	26	-10	68	2,50	10		Frontal Superior Gyrus R
	-28	46	14	2,51	7		Frontal Middle Gyrus L
	-6	-28	74	3,29	91	Parietal	Paracentral Lobule L
	-4	-76	52	2,85	38		Precuneus L
	6	-78	48	2,63	38		Precuneus R
	-66	-44	0	2,56	8	Temporal	Temporal Middle Gyrus L
	8	2	26	3,6	100		Cingulate Gyrus R
	34	-76	-22	2,61	15		Cerebellum R

Note: Alpha = .01 (uncorrected) with minimum cluster size of k = 5. L = left, R = right. The cluster with the largest number of significant voxels within each region is reported.

3.5 Discussion

The results of the recognition task show that participants were able to recognize familiar facial form as well as familiar facial movement. However, recognizing familiar facial movement seems to be a more difficult task than recognizing familiarity of facial form (see Calder & Young, 2005). This result does not come unexpectedly and is one of the reasons why the different facial forms were all created in a way that made them look more similar to each other than faces normally would. People develop a high level of expertise in discriminating and recognizing different faces, leaving those who fail to master it with severe problems, as in the case of prosopagnosia (De Renzi, 1986; Tranel, Damasio, & Damasio, 1997). Recognizing a familiar facial movement on the other hand is a task people are less practiced in and which is in its nature slightly more artificial because in a natural setting the facial movement will not be isolated from the very salient facial form that will most likely dominate the recognition process.

The aim of the current research was to identify areas involved in the processing of familiarity of facial movement and to investigate their involvement with areas associated to face recognition. Hence, conditions were compared in which the familiarity of either facial motion or facial form was manipulated while the familiarity of the other was kept constant. Therefore, faces with familiar form but unfamiliar motion as well as faces with unfamiliar form but familiar motion were compared with faces with familiar form and familiar motion. In the former case the effects of modulating familiarity of motion, in the latter the effects of modulating familiarity of form are observable.

3.5.1 The extended system of face recognition

Supporting previous findings, familiarity of facial form increased activation in certain areas such as the precuneus and the superior and middle frontal gyrus (Gobbini & Haxby, 2006) while leading to a lower activation, compared to unfamiliar faces, in visual temporal extrastriate areas (Leveroni, Seidenberg, Mayer, Mead, Binder, & Rao ,2000; Rossion, Schiltz, Crommelinck, 2003; Rossion, Schiltz, Robaye, Pirenne, & Crommelinck, 2001). A similar pattern was found for the familiarity of facial movement. Here also a higher level of activation in the precuneus was detected, while a lower activation level was registered in occipital and temporal visual areas when motion was familiar. Therefore the precuneus seems to respond to the familiarity of the stimulus independently of the modality of the stimulus. This is in line with the current research that shows activation of the precuneus by familiar stimuli compared to novel stimuli for a wide variety of stimulus categories such as voices (Nakamura et al., 2001), faces (Gobbini, Leibenluft, Santiago, & Haxby, 2004) and spatial context (Burgess, Maguire, Spiers, & O'Keefe, 2001). Gobbini and Haxby (2006) were able to show that the response of the precuneus is modulated by the degree of familiarity of a face. The results presented here wherein the precuneus responds more strongly when both facial attributes are familiar as compared to only familiar form or familiar motion support this claim.

Increased activation of the right and left insula when facial form was not familiar and of the right insula towards unfamiliar facial motion was detected. Increased insula activation towards unfamiliar compared to familiar faces has been previously reported (Phillips et al., 1998) and Gobbini and Haxby (2007) emphasize the fact that emotions play a strong role in the recognition of familiar faces. The insula, among other areas, constitutes the emotional component of face recognition. Being familiar with a face will result in emotional reactions when seeing that face again and these emotional reactions are based on processing the face in the core system of face recognition but will also feed back into it, thus modulating face recognition of familiar faces in a top-down process. Regarding the right insula specifically, it has been discussed in the context of judging the trustworthiness of a face (Winston, Strange, O’Doherty & Dolan, 2002). People are less likely to trust people they do not know and therefore a less familiar face may be linked to an increased activation of the insula.

Furthermore, for faces with unfamiliar motion compared to familiar motion as well as for faces with unfamiliar form compared to familiar form, the insula activation did not occur in isolation but in concert with neighbouring areas of the medial temporal lobe memory system such as the hippocampus and parahippocampal gyrus. Increased activation of the hippocampus towards new, compared to old items, in general has been linked to an increased engagement of the hippocampus in encoding of novel stimuli (Yonelinas, Hopfinger, Buonocore, Kroll, & Baynes, 2001). Rotshtein, Henson, Treves, Driver, and Dolan (2004) also report that the degree of familiarity participants report with a famous face correlates to the effect that change of identity elicits within the hippocampus and the anterior temporal pole.

3.5.2 The occipito-temporal cortex

Decreased activation of the fusiform gyrus was found towards faces with familiar form compared to unfamiliar form, thus supporting the claim that identity based on invariant facial features is processed in the ventral visual stream. However decreased activation in the fusiform gyrus was also found towards faces with familiar motion compared to unfamiliar motion although the facial form was familiar in both cases. The center of activation in the fusiform gyrus was very similar in both conditions and also partly overlapped. Furthermore it was located in close proximity to the fusiform face area (Kanwisher, McDermott, & Chun, 1997; Mur, Ruff, Bodurka, Bandettini, & Kriegeskorte, 2010). The finding that activation in the ventral visual pathway was modulated by the familiarity of dynamic facial features while familiarity of invariant facial characteristics did not vary argues against a strictly separate processing of facial form and motion. The familiarity of facial movement results in modulation of activation of brain areas that are associated with the processing of invariant facial features and facial identity. This is in line with results reported by Sato, Kochiyama, Yoshikawa, Naito, and Matsumura (2004) who found an increased activation of the fusiform gyrus for dynamic compared to static facial expressions. The authors suggested that the increased activation of the fusiform gyrus for dynamic faces indicates processing of dynamic characteristics that relate to familiarity and identity of the face. Furthermore several recent experiments have been able to show that the fusiform gyrus is sensitive to facial expression (Fox, Moon, Iaria, & Barton, 2009; Suzuki et al., 2010; Xu & Biederman, 2010).

In addition, familiarity of facial motion modulated activation in the right middle temporal gyrus reaching into the inferior temporal sulcus as well as in the superior occipital gyrus. A similar pattern was prominent in the left hemisphere although the effect here was less pronounced. The superior occipital gyrus, the occipital temporal junction and the middle temporal gyrus have been discussed as constituting a cortical network for the processing of visual properties of biological movement (Grèzes, Costes, & Decety, 1998). This claim has been supported by the finding that the human equivalent of V5, which is associated with the perception of visual motion, is located in the ascending limb of the inferior temporal sulcus, at the confluence of the occipital and temporal lobe (Watson et al., 1993). Furthermore, applying transcranial magnetic stimulation to this area disturbs perception of motion (Hotson, Braun, Herzberg, & Boman, 1994). While the network has been shown to be more strongly activated in the left hemisphere by the perception of hand movement the data presented here show a stronger involvement of the network in the right hemisphere which is in line with the right lateralization of face perception. Further evidence also argues in favor of the claim that the middle and inferior temporal sulcus are sensitive to biological motion and action. Puce, Allison, Bentin, Gore, and McCarthy (1998) showed that the inferior temporal sulcus, as well as the superior temporal sulcus, is sensitive to eye and mouth movement but not to non-biological movement. Pelphrey, Morris, Michelich, Allison, and McCarthy (2005) found the middle temporal gyrus to be especially activated by mouth movement as compared to hand and eye movement, and Rizzolatti et al. (1996) showed that the middle temporal as well as middle occipital gyrus are activated by the observation of a grasping movement. Interestingly, the center of activation that the authors report in the left middle occipital gyrus is very close to the center of activation the current experiment finds in the left inferior temporal gyrus. As already mentioned, this confluence of the occipital and temporal lobe is where the associative visual area V5 is located in humans (Watson et al., 1993). Familiarity of facial motion therefore seems to be associated with a decrease of activation in areas of the associative visual cortex that are involved in the processing of motion perception. This decrease in activation was accompanied by an increased activation in a further area linked to motion perception as well as execution, the supplementary motor area. The supplementary motor area is involved in planning motor actions (Goldberg, 1985; Tanji & Shima, 1994) and is also activated when a movement is imagined (Lotze et al., 1999). Possibly, once participants realized that the movement they were observing was familiar, they mentally imagined and predicted the following movement pattern.

In their review in which they try to integrate the influence of facial motion on face recognition, O'Toole, Roark, and Abdi (2002) hypothesize that the middle temporal gyrus is a candidate region to communicate to the fusiform gyrus information about the dynamic properties of faces that support face identification. In their model, familiarity of facial movement is primarily processed along the dorsal pathway in the STS. While the current experiment did not show any influence of the familiarity of facial movement on the posterior STS directly, as previously mentioned, areas associated with the STS such as the inferior temporal sulcus which is located directly ventral to the STS and the middle temporal gyrus which belongs to the extended 'STS region' (Allison, Puce & McCarthy, 2000) were modulated by familiarity of facial movement. Furthermore, an area in the anterior STS was sensitive to familiarity of facial motion. Although the majority of studies investigating face perception have reported an involvement of the posterior STS in the perception of dynamic facial features, further anterior regions of the STS have also been found to be sensitive to face identity (Rotshtein, Henson, Treves, Driver, and Dolan, 2004) as well as to emotional expression (Winston, Henson, Fine-Goulden, and Dolan, 2004). Given the known role of the posterior STS with regard to perceiving the intentions of people's actions, the fact that the here presented data only show a modulation of the associated regions of the posterior STS such as the middle and inferior temporal gyrus but not of the posterior STS itself through the familiarity of facial motion may be due to the choice of a non-object directed action. Possibly distribution of activity in the STS differs for the analysis of object directed behavior that indicates intention (Pelphrey et al., 2005).

3.5.3 Limitations

In the context of the sensitivity of the STS to social perception it is also important to note the use of avatars as stimulus material. While computer generated faces have the advantage of providing precise control over the form and movement of the stimulus, and virtual characters have successfully been used in brain imaging experiments investigating biological motion (Pelphrey et al., 2005) and emotional facial expressions (Moser et al., 2007), there is also some evidence indicating that at least for hand movements, the use of virtual hands does not engage the full network observed to be activated by real hand movements (Perani et al., 2001) and Moser et al. (2007) also report a stronger activation of the fusiform gyrus by real compared to computer generated faces. Therefore although the facial stimuli compared to baseline did activate the STS region the impact of familiarity of facial movement within the STS may have been less pronounced than in other face and motion sensitive areas and thus not reached statistical significance.

Finally, it is important to consider some further limitations of the current experiment. The data presented here strictly speaking only apply to movements during positive emotional facial expressions. In a recently published article, Suzuki et al. (2010) report evidence that happy faces are processed differently from neutral and angry faces within the inferior occipital and fusiform gyri. They found that for happy faces neural processing within these regions does not decline over repeated presentation which indicates that visual encoding of face identity is sustained over multiple presentations leading to a richer representation of happy faces. These results also argue against an independent processing of face identity and facial expression. The emotional expression probably leads to a stronger salience of the face which results in top-down modulation of face processing in the occipital and temporal lobe. The two different smiles used in the here presented experiment did not differ in their emotional valence and should therefore be equally emotionally salient. Nonetheless it is important to keep in mind that familiarity of a smile is possibly processed differently from familiarity of a neutral facial movement. However, here one has to consider that it is very difficult to create natural facial movements that involve the upper and lower part of the face and at the same time to keep the facial expression neutral, even if the movement does not depict a prototypical emotion (Wallbott & Ricci-Bitti, 1993). One possibility of a neutral facial movement would be to investigate speech movements although these are restricted to movements of the lower part of the face such as mouth and chin. Furthermore speech movements are likely to involve the auditory cortex (Allison, Puce, & McCarthy, 2000). It is therefore reasonable to assume that speech movements are at least to a certain degree processed differently from emotional facial movement.

3.5.4 Conclusions

The here presented research on the one hand supports the prevailing models of familiar face processing by showing that familiarity of facial form modulates the fusiform gyrus in the ventral visual stream of the core system as well as regions in the extended face processing system such as the precuneus and the insula (Gobbini & Haxby, 2007). However, as familiarity of facial motion modulated activation within the fusiform gyrus, the data also argue against an independence of invariant and variable face attributes in the processing of facial identity within the fusiform gyrus, as previous fMRI experiments have already suggested (Fox, Moon, Iaria, & Barton, 2009; Winston, Henson, Fine-Goulden, & Dolan, 2004; Xu & Biederman, 2010). Familiarity of facial form and facial motion in this experiment modulated a very similar area of the fusiform gyrus. Familiarity of facial motion furthermore modulated activation in areas associated with the perception of biological movement such as the middle and superior occipital gyrus and the middle temporal gyrus and inferior temporal sulcus. Furthermore the anterior superior temporal sulcus was found to be sensitive towards familiar facial movement. There are at least two possible explanations for these results. As suggested by O'Toole, Roark, and Abdi (2002) the motion sensitive areas such as the MTG and STS could be in direct interplay with the fusiform gyrus. Alternatively the information about dynamic and invariant facial features could be integrated in brain regions beyond the associative visual cortex such as memory and attention centers within the frontal lobes and the hippocampal cortex, and top-down processes could then modulate activation within the occipital and inferior temporal cortex. The low temporal resolution of fMRI makes it difficult to conclude when characteristic dynamic facial features influence processes within the fusiform gyrus and this is a question future research should address. Both possible explanations however are not in concordance with the assumption that a person’s identity is only derived from his or her invariant facial features. The idiosyncratic dynamic properties of a face provide information that supports face recognition and lead to a modulation of activation within the associative visual cortex that is sensitive to processing of facial identity.

4 Experiment III: Influence of idiosyncratic facial motion on the own-race bias effect

4.1 Introduction

When investigating face recognition in the context of different ethnic groups, scientists have very robustly encountered the phenomenon that people of one ethnic group show a deficit in recognizing faces of another ethnic group compared to faces of their own ethnic group (Meissner & Brigham, 2001). This phenomenon has been termed the cross-race recognition deficit, the cross-race effect or own-race bias (Sporer, 2001). The own-race effect has most consistently been found towards White and Black faces mostly in the White and Black population in the US but there are also studies showing that the bias is shown by White Germans in Germany (Sporer, 2001).

There are multiple theoretical assumptions regarding the origin of the own-race bias and the purpose of this introduction is not to discuss them all individually (the reviews by Sporer, 2001, and Meissner and Brigham, 2001, provide a good overview). One model that attempts to integrate the various social-cognitive theories regarding the development of the own-race bias with the theoretical framework of face processing is the In-group/out-group model (IOM) of face processing (Sporer, 2001). According to this model own-race and other-race faces follow two different processing pathways. People form a schema for faces based on the faces they encounter every day and hence develop an expertise for recognizing faces that match this schema. A face that matches the schema is processed automatically and holistically and recognition rates are high. However if a face does not match the schema it will be categorized as out-group. These faces will not be processed automatically and holistically but the individual features will be analyzed. Furthermore they may gain less attention (cognitive disregard) and be processed more shallowly. As a result recognition rates decline.

Recognition rates are also reduced because categorization leads to increased perception of the differences between categories while making the members of one category seem more similar. Hence faces that are labeled as out-group will be perceived according to their category-specific features and as being more homogenous than the in-group faces which are processed with a stronger individuation (Levin, 2000).

Targeting the different mechanisms that characterize the processing of in-group/own-race and out-group/other-race faces, researchers have been able to modulate the appearance of the own-race bias. Johnson and Fredrickson (2005) were able to show that positive mood reduces or even eliminates the own-race bias by increasing recognition of other race faces. The mechanism behind this finding may be that positive mood increases holistic processing of faces or reduces categorization of faces by race. Furthermore there is evidence that increasing the degree of individuation with which participants process other race faces increases recognition of other-race faces. For example, informing people about the own-race bias and motivating them to attend to the individuating features of the other-race faces eliminates the own race bias (Hugenberg, Miller, & Claypool, 2007). Increasing the personal relevance of an other-race face and thus motivating people to adopt a more individuated style of processing also increases recognition scores of other-race faces (Shriver & Hugenberg, 2010).

Since increasing the individuation of a face reduces the own-race bias, an experiment was conducted to test whether increasing the individuality of a face by presenting it with an idiosyncratic movement would increase recognition rates for other-race faces. Idiosyncratic movement patterns must be individually learned for each person and as previously discussed, there is growing evidence that facial movement can serve as a cue for recognition of familiar faces (see 1.3). To test this hypothesis, a typical own-race bias experiment was created, in which White German participants were presented White and Black faces that each smiled in an idiosyncratic way. In a recognition task these faces (targets) were then presented amongst other unknown faces (distractors) and participants had to decide whether they had previously seen the face or not. The experiment was conducted with two independent groups. In one group participants’ attention was drawn to facial form while in the other facial movement was made more salient. Should individual movement of a face lead to stronger individuation and hence to a reduced own-race bias, a difference in recognition rates for Black faces in the two groups would be expected, with recognition being higher in the attention-to-motion group.

4.2 Methods

4.2.1 Participants

50 female white Caucasian participants were recruited for the experiment. Partly they were psychology students in their first semester who received course credits for their participation; partly participants were recruited online and received six Euros for taking part in the experiment. Data of three participants were not recorded due to technical problems. Additionally two participants were excluded from the analysis because of noncompliance with the instructions. Therefore data of 45 participants between 18 and 29 years of age (*M* = 22.29, *SD* = 2.85) entered the analysis. For one participant the rating of the facial stimuli was not recorded. All participants had spent the majority of their life living in Germany or another European country and apart from one participant who reported having 5 African or Afro-American friends, participants counted no or only one African or Afro-American among their friends.

4.2.2 Stimuli

30 White European faces and 30 Black African faces were created with the *Poser* software (*Curious Labs*, Santa Cruz, CA). As in the previous experiments only male faces were used. The *Poser* software allows the user to choose the degree of typicality for a specific race. All European faces and all African faces were set at the same degree of typicality for their respective race. Furthermore the same texture for skin and eyes was applied to all European faces and to all African faces respectively. Analogous to the two previous experiments, the facial stimuli were created with emphasis on the internal features and therefore the appearance of external features such as hair, clothing and background was minimised. All 60 faces were individually animated with a unique smile, with no two smiles resembling each other. The video clips were constituted of 90 frames with a presentation rate of 30 frames per second. Over the course of three seconds the faces were animated with a rising and subsequently declining smile. The first and last frame showed a neutral expression. For a better visualisation, examples of European and African faces are depicted in Figure 12.

Figure 12. Examples for the two categories of faces, Black Africans (left) and White Europeans (right). One individual frame is selected for each face.

4.2.3 Mood and ratings

As previously discussed, there is evidence that mood can influence the degree of the own-race bias (Johnson & Fredrickson, 2005). Mood was therefore assessed as a control variable via a Self-Assessment Manikin (SAM) scale (Bradley & Lang, 1994) ranging from 1 (*very bad mood*) to 9 (*very good mood*) as well as arousal by a SAM scale ranging from 1 (*very calm*) to 9 (*very nervous*).

Participants rated the facial stimuli according to their typicality (*How difficult would it be to pick this person out of a crowd?*) from 1 (*not very difficult*) to 7 (*difficult*), their likeability (*Is this person likeable?*) from 1 (*not very likeable*) to 7 (*likeable*), their attractiveness (*Is this person attractive?*) from 1 (*not very attractive*) to 7 (*attractive*), their memorability (*Would it be easy to remember this person?*) from 1 (*not very easy*) to 7 (*easy*), and finally their familiarity (*Is this face confusable with someone you know?*) from 1 (*not very confusable*) to 7 (*confusable*). Observer ratings of these attributes of faces have been shown to influence the performance variable d’ in face recognition tasks. Distinct faces, which score high on memorability and low on typicality, are remembered better than indistinct faces (O’Toole, Deffenbacher, Valentin, & Abdi, 1994; Vokey & Read, 1992).

4.3 Procedure

Upon arrival in the laboratory, participants gave written consent to participate in the experiment and rated their initial mood and arousal (SAM 1). Afterwards they were placed in front of a PC and informed that their task was to evaluate European and African faces according to certain criteria. Depending on the condition the participant was randomly assigned to, these criteria were either the age and manliness of the face or the flow of the movement and friendliness of the smile. This manipulation was intended to draw participants’ attention either to the form of the face or to the movement of the face and at the same time participants would closely observe the faces without explicitly memorizing them.

4.3.1 Learning phase

After participants had been instructed, 15 European and 15 African faces were presented which were randomly drawn for each run of the experiment. Participants passed their judgment about the age and manliness of the face/flow of the movement and friendliness of the smile on nine-point Likert scales ranging from 1 (*very young*) to 9 (*very old*) and 1 (*very manly*) to 9 (*very feminine*)/1 (*very stagnant*) to 9 (*very fluent*) and 1 (*very unfriendly*) to 9 (*very friendly*) after the presentation of each face. Once participants had reacted the next video was shown. After seeing all 30 faces once, participants rated their mood and arousal (SAM 2) and subsequently engaged in a computer game named *Space Hockey* for five minutes, which served as the distractor task during the retention interval.

4.3.2 Recognition phase

Subsequently, both groups completed the same recognition task in which all 60 faces were presented in random order and participants were by force choice required to categorize a face as previously seen (*old*) or not previously seen (*new*). They were instructed to react as spontaneously as possible, following their first impression. After the recognition task all 60 faces were shown again and participants rated them according to their typicality, their likeability, their attractiveness, their memorability, and their familiarity. At the end of the experiment, participants filled in a questionnaire with demographic data, completed a final mood and arousal questionnaire (SAM 3), were paid, thanked and dismissed.

4.3.3 Statistical analyses

For the mood and arousal ratings, repeated-measures Analysis of Variance (ANOVA) with the within-factor Time (SAM1 vs. SAM2 vs. SAM3), and the between-factor Attention focus (form vs. motion) were conducted. For the ratings of the face attributes one-sample *t*-test were applied to compare ratings of African and European faces over all participants.

The own-race bias was operationalized by counting and z-transforming the hits and false alarms for African and European faces. Following Signal Detection Theory, the discriminability index d' was calculated for Africans and Europeans as the difference between the standardised hits and false alarms. Furthermore also the response criterion C was calculated according to signal detection theory. The own race bias was defined as the difference between d' for African and European faces. The presence of the own race bias was tested with a one-sample *t*-test and group differences were investigated with independent sample *t*-tests.

For all tests the significance level was set to 0.05. *T*-tests were conducted two-sided. *F*-values were corrected according to Greenhouse-Geisser.

4.4 Results

4.4.1 Mood and arousal

For both mood and arousal, repeated measures ANOVAs showed significant effects of the factor Time on the ratings, $F(2,86) = 11.83$, $p < .001$, $\eta_p^2 = .216$, for mood, and $F(2,86) = 10.27$, $p < .001$, $\eta_p^2 = .193$, for arousal. Participants' mood initially increased during the experiment and then declined again, while their arousal steadily decreased throughout the experiment. No main effect of the between group factor Attention focus was detected for mood, $p = .319$, nor arousal, $p = .475$, nor did the attention focus significantly interact with the factor Time for either, both *p*s > .681.

4.4.2 Ratings

Participant's explicit ratings showed that they regarded the African faces as less typical and less familiar than the European faces, *t*(43) = -2.95 , *p* = .005, and *t*(43) = -3.39 , *p* = .001, respectively. African faces were seen as more likeable *t*(43) = 10.20, *p* < .001, and attractive, *t*(43) = 8.61, *p* < .001, than the European faces and were furthermore judged as being more memorable, *t*(43) = 3.83 , *p* < .001 (Figure 13).

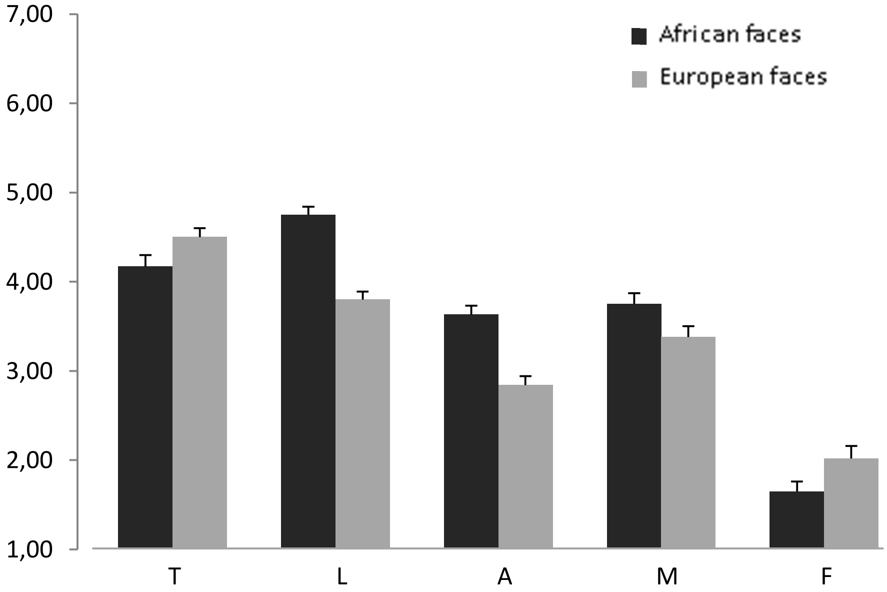


Figure 13. *M* and *SEM* for the ratings of typicality (T), likeability (L), attractiveness (A), memorability (M) and familiarity (F) of African and European faces.

4.4.3 Own-race bias

Over both conditions participants showed a significant bias towards having a higher discriminability for European faces compared to African faces, *t*(44) = 2.06, *p* = .05 (two-sided). While the probability for hits did not differ for the two facial stimulus categories (*p*(hit_Afro) = .58; *p*(hit_Euro) = .57), *t*(44) = .29, *p* = .78, false alarm rates were higher for

African faces (*p* = .44) compared to European faces (*p* = .38), *t*(44) = -1.98, *p* = .05. As highlighted by figure 14, the bias was however equally present in both attention conditions and d' neither differed between groups for European faces, *t*(43) = .52, *p* = .61, nor for African faces, *t*(43) = .78, *p* = .44.

Over both groups, the criterion for participants' response did not differ for the two stimulus categories, *t*(44) = 1.04, *p* = .30. Furthermore, the response criterion did not differ between the two groups, neither for European faces, *t*(43) = -.86, *p* = .40, nor for African faces, *t*(43) = -1.35, *p* = .19.

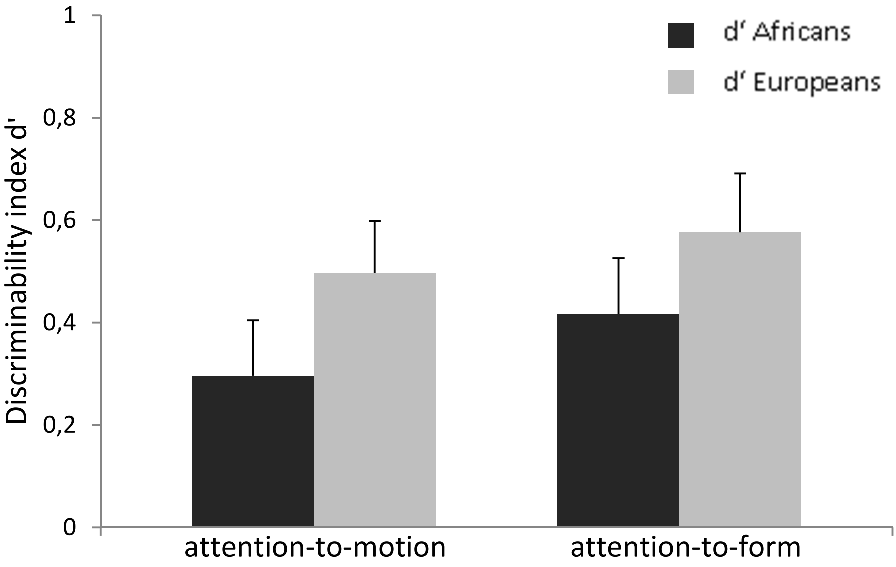


Figure 14. The discriminability index d' for European faces and African faces in the attention to motion and the attention to form conditions. Discriminability for African faces was generally lower than for European faces. No differences were found between groups.

4.5 Discussion

4.5.1 The own-race bias and facial movement

The experiment presented here was able to replicate the own-race bias using computer generated facial stimuli as opposed to pictures or video clips of real faces. Overall participants showed higher discriminability for the White own-race faces compared to the Black other race faces. Own-race and other-race faces were correctly recognized as previously seen to the same degree but participants were more likely to say that they had previously seen a face although they had not seen it when this face was an other-race face. Therefore the own-race bias was apparent on the measures d' as well as on the rates of false alarms. Slone, Brigham, and Meissner (2000) have shown that the own-race bias in White participants most consistently stems from a tendency to falsely identify unknown Black other-race faces as "seen before" and the here reported data are in line with this finding.

The bias towards a better discriminability for own-race compared to other-race faces on the recognition task was present despite participants subjectively judging the other-race faces as being more memorable and less typical. While participants thought that it would be easier to remember the African faces, their actual behavioral performance showed that they remembered them less well than the European faces. The discrepancy between people's judgment of their memory and their actual performance can be especially crucial e.g. in cases of eyewitness testimony where a low correlation is found between witnesses' confidence in and the actual accuracy of their judgment (Sporer, Penrod, Read, & Cutler, 1995). However it is also important to consider that explicit judgments are susceptible to social desirability. Since it is socially desirable to not judge people from another ethnic race differently from one's own, participants may have tried to bias their judgments accordingly. This explanation may also account for the reason why the African faces were rated as more likeable and attractive although there are also other reason why this might have been the case such as the texture of the skin or the fact that the faces were presented without hair and this might be a more common sight in the context of African faces.

The fact that the computer generated faces proved to be suitable stimulus material for producing the own-race bias will be useful for future own-race bias experiments since they provide a powerful tool to individually manipulate specific face attributes such as the typicality of the face for its race or the skin texture. In this context it might be relevant that participants were not directed towards the virtualness of the faces by the instruction. Work by Longo and Bertenthal (2009) shows that the effectiveness of a virtual hand in representing a human hand was modulated by the degree of attention that was directed towards the virtualness of the computer generated hand. When participants were explicitly told that a presented hand was computer generated, automatic imitation was significantly reduced. In the here presented experiment participants were told that they would see faces and the virtualness of the faces was never explicitly addressed.

While showing that the own-race bias exists towards computer generated faces, the here presented data also provide evidence that the own-race bias is present towards dynamic facial stimuli with a positive facial expression. Investigating the effect of emotional facial expressions on face recognition, Corneille, Hugenberg, and Potter (2007) found that Black other-race faces were remembered better by White participants when they displayed a happy expression compared to an angry expression while the opposite effect was found for white own-race faces. Since the authors however were not able to detect a general recognition advantage for own-race faces they concluded that the own-race bias may only be present for neutral faces. This conclusion was furthermore supported by the fact that the own-race bias is eliminated towards angry facial stimuli (Ackerman et al., 2006). The here presented data contradict this assumption and show that the own-race bias also exists towards positive emotional faces. Possibly the fact that Corneille, Hugenberg, and Potter varied between different emotions and emphasized shallow encoding of the face made the presence of an emotional expression more salient and hence the race less salient. A further important difference is the use of dynamic compared to static stimuli. In this context it is important to mention that the on- and off-set of the stimuli used in the here presented experiment depicted a neutral expression. It is however very unlikely that the recognition of the faces was merely based on the few neutral frames at the beginning and end of the stimuli while the majority of the frames depicted an emotional expression.

Idiosyncratic facial movement did not prove to have an impact on recognition rates of other nor of own-race faces. Whether participants' attention was directed towards the facial form or the facial movement did not influence their performance on the recognition task. This result indicates that the idiosyncratic facial movement was not able to increase the individuality of the face or of preventing it to be categorized as an other-race face. In order to explain this observation, results from the EEG experiment are useful, since they give insight into the temporal aspects of the influence of familiar facial movement on face recognition. While the previously presented data indicate that familiarity of facial movement does not influence the N170 which reflects structural facial encoding, the race of a face has been found to influence event-related potentials as early as 120ms (Ito & Urland, 2005), thus even preceding the N170 and implying that social categorization does not necessarily depend on the complete structural analysis of a face. Furthermore the race of a face also modulates the N170 (Ito & Urland, 2003), hence influencing the face's structural encoding. In line with this argumentation, Golby, Gabrieli, Chiao, and Eberhardt (2001), have shown that increased recognition rates for own-race faces correlates with activation of the left fusiform cortex. Therefore idiosyncratic facial movement may be processed at a stage when the face has already been classified according to its race and is therefore not able to influence the different processing of the other-race face which results in its weaker recognition. This assumption is supported by a recent study by Vizioli, Rousselet, and Caldara (2010) who showed that the N170 adapted to the identity of an own-race face but not to the identity of an other-race face. Furthermore the N170 was not influenced by the expression of the face for either face category and the own-race bias was also not modulated by different facial expressions. The authors conclude that the neural populations that provide early discriminating information about individual faces are not activated by other-race faces. This is in line with the assumption that early categorization of a face by its race goes at cost of individuating information about the face which leads to the own-race bias.

4.5.2 Limitations

Following a different line of argument, the lack of effect of familiarity of facial movement on the own-race bias may be due to the experimental setup. Since every face was animated with an individual movement, the differences between the movements were very subtle. Unlike in the previous two experiments the time pattern of the smile was also changed, i.e. some smiles increased and decreased faster or slower than others, thus providing a larger variety of possible movement patterns. Debriefing of the participants also showed that they noticed a difference in the way the faces moved although they were not able to explicitly point these differences out. Nonetheless, given the fact that the movement differences were subtle, possibly a modification of the classical own-race bias design would have been more efficient to show an effect. The classical paradigm of the standard own-race bias experiment implies single and short initial presentations and operationalizes the own-race bias through the rate of hits or false alarms or an index aggregating both variables such as the discriminability index d’ for own- and other-race faces. Possibly choosing a different dependent variable such as an interval scale for familiarity ratings rather than quantitative yes/no replies, or measuring reactions times for the time the familiarity decision takes would have been able to reflect subtle effects of the idiosyncratic facial motion. Also an adaptation of the recognition task such as a delayed match-to-sample task could be considered (Lindsay, Jack, & Christian, 1991). At least in the classical setup of the own-race bias experiment idiosyncratic facial movement does not prove to have an impact on participants’ discriminability of other-race faces.

Finally it is also important to consider the fact that the facial movement was operationalized by a smile. As already mentioned, in the case of negative facial expressions, it has been shown that the own-race bias can be diminished by the emotional expression of the target faces (Ackerman et al., 2006; Krumhuber & Manstead, 2010). Ackerman et al. (2006) argued that it may be more functional to attend to an out-group face displaying anger which leads to a higher recognition of other-race faces when they show an angry facial expression. Although neither of these experiments investigated the impact of a smiling target face on the own-race bias, it could e.g. be the case that a smiling face is more relevant when seen in an in-group face. If this were the case then this would work against a possible impact the idiosyncratic facial movement might have on individuating the other-race faces. Future research should more closely investigate the impact an emotional expression can have on the own-race bias especially considering the use of dynamic facial stimuli. Furthermore it could be fruitful to investigate whether familiarity of idiosyncratic non-emotional facial movement may succeed in reducing the own-race bias.

4.5.3 Conclusions

In summary this experiment was able to support the validity of computer generated facial stimuli in psychological experiments. It replicated the own-race bias towards computer generated faces, showing that White virtual faces are perceived as own-race faces by White participants and the same recognition bias occurs towards the artificial White and Black computer generated faces as towards the natural faces. Furthermore, the experiment was able to show that the own-race bias exists towards target faces displaying a dynamic positive facial expression. The hypothesis that idiosyncratic facial movement may increase individuation of other-race faces and thus increase their recognition rate could not be supported. It is most likely that since facial movement does not yet influence initial structural face encoding, the mechanisms that lead to the own-race bias, which modulate very early processing of the face, dominate over the influence which facial movement may have in the recognition process.

5 General Discussion

The aim of this dissertation was to more closely investigate the effect of idiosyncratic facial movement on face recognition and to investigate the neural processes underlying the role of familiar facial movement in face recognition. Three experiments were conducted, each applying a different method and highlighting a specific characteristic of the involvement of facial movement idiosyncrasies in the recognition of faces. The temporal aspects of brain processes leading to face recognition were addressed in the first experiment employing EEG while the second experiment more strongly emphasized the brain structures underlying face recognition and hence fMRI was the choice of method. Finally the third experiment investigated a possible application of the knowledge about the involvement of facial movement in face recognition on intercultural face perception. The following general discussion will focus on integrating the knowledge gained from these three separate experiments. Points of discussion concerning the specific experiments have been addressed in the individual discussions of each experiment.

5.1 Integrating electrophysiological and functional imaging data

In summary, the electrophysiological as well as neuroimaging data presented here support the growing body of evidence that idiosyncratic facial movement aids recognition of familiar faces. Both the EEG as well as the fMRI experiment hold evidence for the familiarity of facial motion engaging memory processes associated to face recognition. Faces with familiar facial motion were more familiar than faces with unfamiliar facial motion in the EEG experiment, as reflected by ratings as well as a modulation of the N400f. In concordance the fMRI experiment showed an engagement of areas involved in recognizing familiarity of a stimulus such as the precuneus and the medial temporal lobe memory system. A N400-like potential elicited by famous compared to non-famous faces has been discussed to originate in the medial temporal lobe in an invasive ERP study (Trautner et al., 2004).

Besides engaging areas involved in general memory processes, familiarity of facial motion also modulated areas in the occipital and temporal cortex involved in visual processing of the stimulus. Familiar facial movement led to a reduced activation in areas associated to the perception of motion like the superior occipital and middle temporal gyrus as well as areas involved in processing facial identity such as the fusiform gyrus. This may suggest an early discrimination of familiar and unfamiliar facial movement already in the right visual cortex. However the fact that early event-related potentials of face processing such as the N170 were not yet influenced by familiarity of facial movement (nor of facial form) rather suggests that the observed reduced activation in the right visual cortex is due to re-entrant feedback modulation from further anterior regions. Possibly once a facial movement has been recognized as familiar, it requires less further visual analysis than unfamiliar movement and hence the level of activation is reduced through top-down mechanisms (Rossion, Schiltz, Robaye, Pirenne, & Crommelinck, 2001).

A similar explanation could account for the modulation of activation in the fusiform gyrus by familiar facial movement. However the EEG experiment showed an impact of familiar facial form on the N250 and source analysis of the N250 has indicated that its origin may be located in the fusiform gyrus (Schweinberger, Pickering, Burton, & Kaufmann, 2002). This argues in favor of the fusiform gyrus discriminating between familiar facial form and unfamiliar facial form in the initial processing of the face. The absence of an effect of the familiarity of facial movement on the N250 may indicate that its familiarity is initially detected on a separate route, e.g. via the middle temporal gyrus and the anterior temporal lobe memory system and that this processed information feeds back into the fusiform gyrus to modulate processing of the structure of the face. Hence the reduced activation in the fusiform gyrus may be due to the fact that fewer resources are allocated to the identification of the facial form since information about the face's movement has already provided a cue to its identity. Alternatively, it is important to consider the fact that the stimuli in the fMRI experiment were fully dynamic while in the EEG experiment, familiarity of facial motion was only indicated by the change between two static images. Therefore it can be assumed that the degree of information about the movement contained by the dynamic stimuli in the fMRI experiment was richer than in the EEG experiment as there was a series of frames that differed between the two motions. Consequently, the exact temporal nature of the activation of the fusiform gyrus through familiar facial movement is one of the core issues future experiments should investigate. Combining EEG and fMRI within the same experiment would be very suitable to address this topic. Furthermore two recent experiments have employed interesting new techniques to investigate spatio-temporal patterns of face processing in the brain which I would briefly like to elaborate. Goffaux et al. (2011) investigated spatio-temporal dynamics of high-level vision in the context of face processing by varying the level of spatial frequency as well as the exposure time of the facial stimuli. Different steps in the process of face recognition rely on different levels of spatial frequency. The holistic perception of a face is based on low spatial frequency while for the processing of the face's identity especially intermediate spatial frequency is crucial. Finally for local face details the stimulus needs to contain high spatial frequency. When combining faces of these three categories of spatial frequency with very short, intermediate and long stimulus presentation times the authors were able to show which spatial frequency and hence which information was processed fastest. For the fusiform face area they found a coarse-to-fine temporal pattern, meaning that low spatial frequency was processed first and the higher frequencies with increasing stimulus exposure time. One could imagine applying this technique to the investigation of dynamic face properties on face processing. Identifying idiosyncratic characteristics of facial movement patterns will probably rely on higher spatial frequencies than simply perceiving the movement of the face. This would be an interesting technique to more closely investigate the spatiotemporal pattern within the fusiform gyrus towards familiar facial motion. The second experiment worth mentioning in this context was recently reported by Rossion and Boremanse (2011) who were able to show that the steady state visual-evoked potential (SSVEP) is sensitive to face identity over the right lateral occipital cortex. The SSVEP is an oscillating electrical response of the brain to a repetitive stimulation at a constant frequency. This oscillating response will be at the same frequency as the stimulation and can be recorded from the scalp via EEG. The amplitude of the SSVEP has been shown to correspond to the synaptic activity of the stimulated neurons. Following the same rationale as the fMRI-adaptation technique, the SSVEP will be smaller if the stimulated neurons are sensitive to the property of the stimulus that is repeatedly presented since adaptation will take place. Rossion and Boremanse found a larger SSVEP over the right lateral occipital cortex towards repetition of different facial identity compared to same facial identity and argue that the high signal-to-noise ratio of the SSVEP makes it a very potent technique to study sensitivity of the brain to visual features of individual faces. Analogously one could investigate the SSVEP towards repeated presentation of different familiar facial motions compared to unfamiliar facial motions. Dynamic facial stimuli have successfully been used to evoke the SSVEP (Mayes, Pipingas, Siberstein, & Johnston, 2009).

5.2 General limitations

General limitations of all three experiments can be found in the choice of stimulus material. As already discussed for the fMRI and own-race bias experiment it must be considered that the facial stimuli were constituted of computer generated faces. While this provided a lot of benefits in the process of creating stimuli that only differed in one facial feature such as form or motion while all other facial parameters such as skin texture and eye color were kept constant, it remains obvious to the observer that the faces are not fully natural. However all of the here presented experiments replicated findings that were previously discovered towards natural facial stimuli hence supporting the validity of the data. It is therefore also reasonable to assume that the additionally gained findings should be able to be replicated with natural facial stimuli.

Furthermore in all experiments, the investigated facial movement was operationalized by different variations of a smile. Strictly speaking, results are therefore only applicable to facial movements in the context of expressing positive emotions. Although the emotional content of the emotional expression was balanced out, it is reasonable to assume that movements related to emotional expressions are qualitatively different from e.g. speech movements. For instance emotional facial expressions usually involve the upper and lower part of the face while speech movements will primarily involve the mouth. Since there is also behavioral evidence that identity and speech movements are not processed entirely independently (Walker, Bruce, & O’Malley, 1995), familiarity of facial movement during speech should also be investigated more closely in the context of its impact on face recognition.

Finally, the facial stimuli were restricted to male faces with the aim of reducing interstimulus variance, and results thus need to be replicated for female faces. It has been shown that women are emotionally more expressive than men (Kring & Gordon, 1998) and one could imagine that possibly idiosyncratic facial movements while expressing an emotion play a stronger role in recognizing women because it is a source of information that is present more often and more strongly.

5.3 Conclusions

In summary, the data presented here favor the hypothesis that idiosyncratic facial movement contributes to recognition of familiar faces. Brain potentials that were sensitive to the familiarity of a face were also modulated by the familiarity of its movement and furthermore brain areas involved in face recognition responded to the familiarity of facial movement. Regarding the mechanisms how idiosyncratic dynamic face properties influence face recognition is has been discussed that the dynamic characteristics may constitute a further source of information that increases face familiarity or alternatively that the stored identity information is intrinsically dynamic (Lander et al., 1999; Lander & Bruce, 2004). Since the fMRI experiment was able to identify brain areas that strongly responded to the familiarity of facial motion while being insensitive to the familiarity of facial form, such as the middle temporal gyrus/inferior temporal sulcus, the here presented data more argue for the case of familiar facial motion serving as an additional source of information which interacts with the process of face recognition based on structural face properties, although future research should address this topic in closer detail.

The findings presented here were able to foster a deeper understanding of the way the brain processes and recognizes faces and have important implications for cognitive and neural models of face perception and recognition. A conclusive and comprehensive model of face perception needs to account for the fact that processing of facial motion and facial identity are more interrelated than reflected by the current models of face processing and recognition (Bruce & Young, 1986; Haxby & Hoffman, 2000). However, it is important to note that while this research provided evidence for the impact dynamic face characteristics have on face recognition, all three experiments also consistently showed that this impact seems to be rather weak and that primarily face recognition relies on invariable facial features. In the EEG experiment familiarity effects of facial motion were only found when attention was directed towards the dynamics of the face. In the fMRI experiment recognition rates for facial motion were lower than for facial form and the third experiment was not able to find an influence of characteristic face movements on the own-race bias. The primary route of face identification is founded on the form and structure of the face. The dynamic features, albeit assisting face recognition, primarily serve a different purpose, the interaction with other people, be it by talking or expressing emotions. Nevertheless, it is evident that experiments investigating face recognition with merely static stimuli are not able to reflect the full processes of recognizing a familiar face and that the role of dynamic facial features in the process of face recognition needs to be considered in models of face processing.

References

Ackerman, J. M., Shapiro, J. R., Neuberg, S. L., Kenrick, D. T., Becker, D. v., Griskevicius, V., Maner, J. K., & Schaller, M. (2006). They all look the same to me (unless they're angry). Form out-group homogeneity to out-group heterogeneity. Psychological Science, 17, 836-840.

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: role of the STS region. *Trends in Cognitive Sciences, 4*, 267-278.

Andrews, T. J. and Ewbank, M. P. (2004). Distinct representations for facial identity and changeable aspects of faces in the human temporal lobe. *NeuroImage, 23*, 905-913.

Bonner, L., Burton, A.M., & Bruce, V. (2003). Getting to know you: How we learn new faces. *Visual Cognition, 10,* 527-536.

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience, 8,* 551-565.

Bentin, S., & Deouell, L. Y. (2000). Structural encoding and identification in face processing: ERP evidence for separate mechanisms. *Cognitive Neuropsychology, 17,* 35-54.

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25*, 49-59.

Bruce, V. (1986). Influences of familairity on the processing of faces. *Perception, 15*, 387-397.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology, 77,* 305-327.

Burgess, N., Maguire, E. A., Spiers, H. J., O'Keefe, J. (2001). A temporoparietal and prefrontal network for retrieving the spatial context of lifelike events. *NeuroImage, 14*, 439-453.

Calder, A. J., & Young, A. W. (2005). Understanding the recognition of facial identity and facial expression. *Nature Reviews Neuroscience, 6*, 641-651.

Calvert, G. A., Bullmore, E. T., Brammer, M. J., Campbell, R., Williams, S. C. R., McGuire, P. K., Woodruff, P. W. R., Iversen, S. D., & David, A. S. (1997). Activation of auditory cortex during silent lipreading. *Science, 276*, 593-596.

Campanella, S., Hanoteau, C., Dépy, D., Rossion, B., Bruyer, R., Crommelinck, M., & Guérit, J. M. (2000). Right N170 modulation in a face discrimination task: An account for categorical perception of familiar faces. *Psychophysiology, 37*, 796-806.

Campbell, R., MacSweeney, M., Surguladze, S., Calvert, G., McGuire, P., Suckling, J., Brammer, M. J., & David, A. S. (2001). Cortical substrates for the perception of face actions: an fMRT study of the specificity of activation for seen speech and for meaningless lower-face acts (gurning). *Cognitive Brain Research, 12*, 233-243.

Corneille, O., Hugenberg, K., Potter, T. (2007). Applying the attractor field model to social cognition: Perceptual discrimination is facilitated, but memory is impaired for faces displaying evaluatively congruent expressions. *Journal of Personality and Social Psychology, 93*, 335–352.

Curran, T., & Hancock, J. (2007). The FN400 indexes familiarity-based recognition of faces. *NeuroImage, 36,* 464-471.

De Renzi, E. (1986). Prosopagnosia in two patients with CT scan evidence of damage confined to the right hemisphere. *Neuropsychologia, 24*, 385–389.

Dubois, S., Rossion, B., Schiltz, C., Bodart, J. M., Michel, C., Bruyer, R., & Crommelinck, M. (1999). Effect of familiarity on the processing of human faces. *NeuroImage, 9*, 278–289.

Eimer, M. (2000). Event-related brain potentials distinguish processing stages involved in face perception and recognition. *Clinical Neurophysiology, 111,* 694-705.

Elfgren, C., van Westen, D., Passant, U., Larsson, E., Mannfolk, P., & Fransson, P. (2006). fMRI activity in the medial temporal lobe during famous face processing. *NeuroImage, 30,* 609– 616.

Etcoff, N. L. (1984). Selective attention to facial identity and facial emotion. *Neuropsychologia, 22*, 281-295.

Evans, A. C., Marrett, S., Neelin, P., Collins, L., Worsley, K., Dai, W., Milot, S., Meyer, E., & Bub, D. (1992). Anatomical mapping of functional activation in stereotactic coordinate space. *NeuroImage, 1*, 43-53.

Fox, C. J., Moon, S. Y., Iaria, G., & Barton, J. J. S. (2009). The correlates of subjective perception of identity and expression in the face network: An fMRI adaptation study. *NeuroImage, 44*, 569-580.

Gallagher, H.L., Happé, F., Brunswick, N., Fletcher, P. C., Frith, U., & Frith, C. D. (2000). Reading the mind in cartoons and stories: an fMRI study of ‘theory of mind’ in verbal and nonverbal tasks. *Neuropsychologia, 38*, 11–21.

Gauthier, I., Tarr, M. J., Moylan, J., Skudlarski, P., Gore, J. C., & Anderson, A. W. (2000). The fusiform “face area” is part of a network that processes faces at the individual level. *Journal of Cognitive Neuroscience, 12*, 495-504.

George, N., Dolan, R. J., Fink, G. R., Baylis, G. C., Russel, C., & Driver, J. (1999). Contrast polarity and face recognition in the human fusiform gyrus. *Nature Neuroscience, 2*, 574-580.

Gobbini, M. I., & Haxby, J. V. (2006). Neural response to the visual familiarity of faces. *Brain Research Bulletin, 71*, 76-82.

Gobbini, M. I., & Haxby, J. V. (2007). Neural systems for recognition of familiar faces. *Neuropsychologia, 45*, 32-41.

Gobbini, M. I., Leibenluft, E., Santiago, N., & Haxby, J. V. (2004). Social and emotional attachment in the neural representation of faces. *NeuroImage, 22*, 1628-1635.

Goffaux, V., Peters, J., Haubrechts, J., Schiltz, C., Jansma, B., & Goebel, R. (2011). From coarse to fine? Spatial and temporal dynamics of cortical face processing. *Cerebral Cortex, 21*, 467-476.

Golby, A. J., Gabrieli, J. D. E., Chiao, J. Y., & Eberhardt, J. L. (2001). Differential responses in the fusiform region to same-race and other-race faces. *Nature Neuroscience, 4*, 845-850.

Goldberg, G. (1985). Supplementary motor area structure and function: Review and hypotheses. *Behavioral and Brain Sciences, 8*, 567-588.

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

Grèzes, J., Costes, N. & Decety, J. (1998) Top-down effect of the strategy on the perception of biological motion: a PET investigation. *Cognitive Neuropsychology, 15*, 553–582.

Hasselmo, M. E., Rolls, E. T., & Baylis, G. C. (1989). The role of expression and identity in the face-selective responses of neurons in the temporal visual cortex of the monkey. *Behavioural Brain Research, 32,* 203-218.

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences, 4,* 223-233.

Hill, H., & Johnston, A. (2001). Categorizing sex and identity from biological motion of faces. *Current Biology, 11,* 880-885.

Hoffman, E. A., & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience, 3,* 80-84.

Hotson, J., Braun, D., Herzberg, W., & Boman, D. (1994). Transcranial magnetic stimulation of extrastriate cortex degrades human motion direction discrimination. *Vision Research, 43*, 2115-2123.

Hugenberg, K., Miller, J., & Claypool, H. M. (2007). Categorization and individuation in the cross-race recognition deficit: Toward a solution of an insidious problem. *Journal of Experimental Social Psychology, 43*, 334-340.

Humphreys, G. W., Donnelly, N., & Riddoch, M. J. (1993). Expression is computed separately from facial identity, and it is computed separately for moving and static faces: Neuropsychological evidence. *Neuropsychologia, 31,* 173-181.

Hutton, C., Bork, A., Josephs, O., Deichmann, R., Ashburner, J., & Turner, R. (2002). Image distortion correction in fMRI: A quantitative evaluation. *NeuroImage, 16*, 217-240.

Itier, R. J., & Taylor, M. J. (2004). Effects of repetition learning on upright, inverted and contrast-reversed face processing using ERPs. *NeuroImage, 21*, 1518–1532.

Ito, T. A., & Urland, G. R. (2003). Race and gender on the brain: Electrocortical measures of attention to the race and gender of multiply categorizable individuals*. Journal of Personality and Social Psychology, 85*, 616-626.

Ito, T. A., & Urland, G. R. (2005). The influence of processing objectives in the perception of faces: An ERP study of race and gender perception. *Cognitive, Affective, & Behavioral Neuroscience, 5*, 21-36.

Jemel, B., George, N., Chaby, L., Fiori, N., & Renault, B. (1999). Differential processing of part-to-whole and part-to-part face priming: an ERP study. *NeuroReport, 10*, 1069-1075.

Jemel, B., Schuller, A.-M., & Goffaux, V. (2010). Characterizing the spatio-temporal dynamics of the neural events occurring prior to and up to overt recognition of famous faces. *Journal of Cognitive Neuroscience, 22*, 2289-2305.

Johnson, K. J., & Fredrickson, B. L. (2005). “We all look the same to me”. Positive emotions eliminate the own-race bias in face recognition. *Psychological Science, 16*, 875-881.

Johansson, M., Mecklinger, A., & Treese, A-C. (2004). Recognition memory for emotional and neutral faces: An event-related potential study*. Journal of Cognitive Neuroscience, 16*, 1840-1853.

Joyce, C. A., & Kutas, M. (2005). Event-related potential correlates of long-term memory for briefly presented faces. *Journal of Cognitive Neuroscience, 17*, 757-767.

Kanwisher, N., McDermott, J., Chun, M. M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *The Journal of Neuroscience, 17*, 4302-4311.

Kaufmann, J. M., Schweinberger, S. R., & Burton, A. M. (2008). N250 ERP correlates of the acquisition of face representations across different images. *Journal of Cognitive Neuroscience, 21*, 625-641.

Knappmeyer, B., Thornton, I. M., & Bülthoff, H. H. (2003). The use of facial motion and facial form during the processing of identity. *Vision Research, 43,* 1921-1936.

Knight, B., & Johnston, A. (1997). The role of movement in face recognition*. Visual Cognition, 4*, 265-273.

Kring, A. M., & Gordon, A. H. (1998). Sex differences in emotion: Expression, experience, and physiology. *Journal of Personality and Social Psychology, 74*, 686-703.

Krumhuber, E. G., & Manstead, A. S. R. (2010). When memory is better for out-group faces: On negative emotions and gender rols. *Journal of Nonverbal Behavior*, DOI 10.1007/s10919-010-0096-8.

Lander, K., & Bruce, V. (2004). Repetition priming from moving faces. *Memory & Cognition, 32,* 640-647.

Lander, K., Christie, F., & Bruce, V. (1999). The role of movement in the recognition of famous faces. *Memory & Cognition, 27,* 974-985.

Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics: (de) constructing the N400*. Nature Reviews Neuroscience, 9*, 920-933.

Leveroni, C. L., Seidenberg, M., Mayer, A. R., Mead, L. A., Binder, J. R., & Rao, S. M. (2000). Neural systems underlying the recognition of familiar and newly learned faces. *The Journal of Neuroscience, 20*, 878–886.

Levin, D. T. (2000). Race as a visual feature: Using visual search and perceptual discrimination tasks to understand face categories and the cross-race recognition deficit. *Journal of Eyperimental Psychology: General, 129*, 559-574.

Lindsay, D. S., Jack, P. C. Jr., Christian, M. A. (1991). Other-race face perception. *Journal of Applied Psychology, 76*, 587-589.

Loffler, G., Yourganov, G., Wilkinson, F., & Wilson, H. R. (2005). fMRI evidence for the neural representation of faces. *Nature Neuroscience, 8,* 1386-1390.

Longo, M. R., & Bertenthal, B. I. (2009). Attention modulates the specificity of automatic imitation to human actors. *Experimental Brain Research, 192*, 739–744.

Lotze, M., Montoya, P., Erb, M., Hülsmann, E., Flor, H., Klose, U., Birbaumer, N. & Grodd, W. (1999). Activation of cortical and cerebellar motor areas during executed and imagined hand movements: An fMRI study. *Journal of Cognitive Neuroscience, 11*, 491–501.

Lundqvist, D., Flykt, A., & Öhman, A. (1998). Karolinska Directed Emotional Faces (KDEF). Stockholm: Karolinska Institutet.

Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces. *Psychology, Public Policy, and Law, 7*, 3-35.

Maldjian, J. A., Laurienti, P. J., Kraft, R. A., & Burdette, J. H. (2003). An automated method for neuroanatomic and cytoarchitectonic atlas-based interrogation of fMRI data sets. *NeuroImage, 19,* 1233-1239.

Mayes, A. K., Pipingas, A., Silberstein R. B., & Johnston P (2009). Steady state visually evoked potential correlates of static and dynamic emotional face processing. *Brain Topography, 22*, 145–157.

McGurk, H., & MacDonald, J. (1976). Hearing lips and seeing voices. *Nature, 264*, 746-748.

Miyoshi, M., Katayama, J., & Morotomi, T. (2004). Face-specific N170 component is modulated by facial expressional change. *Cognitive Neuroscience and Neuropsychology, 15*, 911-914.

Moser, E., Derntl, B., Robinson, S., Fink, B., Gur, R. C., Grammer, K. (2007). Amygdala activation at 3T in response to human and avatar facial expressions of emotions. *Journal of Neuroscience Methods, 161*, 126–133.

Mühlberger, A., Wieser, M. J., Herrmann, M. J., Weyers, P., Tröger, C., & Pauli, P. (2009). Early cortical processing of natural and artificial emotional faces differs between lower and higher socially anxious persons. *Journal of Neural Transmission, 116,* 1435-1463.

Mur, M., Ruff, D. A., Bodurka, J., Bandettini, P. A., & Kriegeskorte, N. (2010). Face-identity change activation outside the face system: “Release from adaptation” may not always indicate neuronal selectivity. *Cerebral Cortex, 20*, 2027-2042.

Nakamura, K., Kawashima, R., Sugiura, M., Kato, T., Nakamura, A., Hatano, K., Nagumo, S., Kubota, K., Fukuda, H., Ito, K., Kojima, S. (2001). Neural substrates for recognition of familiar voices: a PET study. *Neuropsychologia, 39*, 1047-1054.

Narumoto, J., Okada, T., Sadato, N., Fukui, K., & Yonekura, Y. (2001). Attention to emotion modulates fMRI activity in human right superior temporal sulcus. *Cognitive Brain Research, 12*, 225–231.

O'Toole, A. J., Deffenbacher, K. A., Valentin, D., & Abdi, H. (1994). Structural aspects of face recognition and the other-race effect. *Memory & Cognition, 22*, 208-224.

O'Toole, A. J., Roark, D. A., & Abdi, H. (2002). Recognizing moving faces: a psychological and neural synthesis. *Trends in Cognitive Sciences, 6,* 261-266.

Paller, K. A., Gonsalves, B., Grabowecky, M., Bozic, V. S., & Yamada, S. (2000). Electrophysiological correlates of recollecting faces of known and unknown individuals. *NeuroImage, 11*, 98-110.

Pelphrey, K. A., Morris, J. P., Michelich, C. R., Allison, T., & McCarthy, G. (2005). Functional anatomy of biological motion perception in posterior temporal cortex: An fMRI study of eye, mouth and hand movements. *Cerebral Cortex, 15*, 1866-1876.

Perani, D., Fazio, F., Borghese, N. A., Tettamanti, M., Ferrari, S., Decety, J., & Gilardi, M. C. (2001). Different brain correlates for watching real and virtual hand actions. *NeuroImage, 14*, 749-758.

Pilz, K. S., Thornton, I. M., & Bülthoff, H. H. (2005). A search advantage for faces learned in motion. *Experimental Brain Research, 171,* 436-447.

Phillips, M. L., Bullmore, E. T., Howard, R., Woodruff, P. W. R., Wright, I. C., Williams, S. C. R., Simmons, A., Andrew, C., Brammer, M., & David, A. S. (1998). Investigation of facial recognition memory and happy and sad facial expression perception: an fMRI study. *Psychiatry Research: Neuroimaging Section, 83*, 127-138.

Pourtois, G., Schwartz, S., Seghier, M. L., Lazeyras, F., & Vuilleumier, P. (2005).Portraits or people? Distinct representations of face identity in the human visual cortex. *Journal of Cognitive Neuroscience, 17*, 1043–1057.

Puce, A., Allison, T., Bentin, S., Gore, J. C., & McCarthy, G. (1998). Temporal cortex activation in humans viewing eye and mouth movements. *The Journal of Neuroscience, 18*, 2188-2199.

Puce, A., Smith, A., & Allison, T. (2000). ERPs evoked by viewing facial movements. *Cognitive Neuropsychology, 17*, 221-239.

Rizzolatti, G., Fadiga, L., Matelli, M., Bettinardi, V., Paulesu, E., Perani, D., & Fazio, F. (1996). Localization of grasp representations in humans by PET : 1. Observation versus execution. *Experimental Brain Research, 111*, 246-252.

Rossion, B., & Boremanse, A. (2011). Robust sensitivity to facial identity in the right human occipito-temporal cortex as revealed by steady-state visual-evoked potentials. *Journal of Vision, 11*, 1–21.

Rossion, B., Campanella, S., Gomez, C. M., Delinte, A., Debatisse, D., Liard, L., Dubois, S., Bruyer, R., Crommelinck, M., & Guerit, J.-M. (1999). Task modulation of brain activity related to familiar and unfamiliar face processing: an ERP study. *Clinical Neurophysiology, 110,* 449-462.

Rossion, B., Gauthier, I., Tarr, M.J., Despland, P., Bruyer, R., Linotte, S., & Crommelinck, M. (2000). The N170 occipito-temporal component is delayed and enhanced to inverted faces but not to inverted objects: an electrophysiological account of face- specific processes in the human brain. *NeuroReport, 11,* 69-74.

Rossion, B., Joyce, C. A., Cottrell, G. W., & Tarr, M. J. (2003). Early lateralization and orientation tuning for face, word, and object processing in the visual cortex. *NeuroImage, 20,* 1609-1624.

Rossion, B., Schiltz, C., & Crommelinck, M. (2003). The functionally defined right occipital and fusiform “face areas” discriminate novel from visually familiar faces. *NeuroImage, 19*, 877–883.

Rossion, B., Schiltz, C., Robaye, L., Pirenne, D., & Crommelinck, M. (2001). How does the brain discriminate familiar and unfamiliar faces?: A PET study of face categorical perception. *Journal of Cognitive Neuroscience, 13*, 1019-1034.

Rotshtein, P., Henson, R. N. A., Treves, A., Driver, J., & Dolan, R. J. (2004). Morphing Marilyn into Maggie dissociates physical and identity face representations in the brain. *Nature Neuroscience, 8*, 107-113.

Sato, W., Kochiyama, T., Yoshikawa, S., Naito, E., Matsumura, M. (2004). Enhanced neural activity in response to dynamic facial expressions of emotion: an fMRI study. *Cognitive Brain Research, 20*, 81-91.

Schiltz, C., Sorger, B., Caldara, R., Ahmed, F., Mayer, E., Goebel, R., & Rossion, B. (2005). Impaired face discrimination in acquired prosopagnosia is associated with abnormal response to individual faces in the right middle fusiform gyrus. *Cerebral Cortex, 16*, 574-586.

Schweinberger, S. R., Klos, T., & Sommer, W. (1995). Covert face recognition in prosopagnosia: a dissociable function? *Cortex, 31*, 517-529.

Schweinberger, S. R., Pickering, E. C., Burton, A. M., & Kaufmann, J. M. (2002). Human brain potential correlates of repetition priming in face and name recognition, *Neuropsychologia, 40*, 2057-2073.

Shriver, E. R., & Hugenberg, K. (2010). Power, individuation, and the cross-race recognition deficit. *Journal of Experimental Social Psychology, 46*, 767-774.

Slone, A. E., Brigham, J. C., & Meissner, C. A. (2000). Social and cognitive factors affecting the own-race bias in Whites. *Basic and Applied Social Psychology, 22*, 71–84.

Sporer, S. L. (2001). Recognizing faces of other ethnic groups. *Psychology, Public Policy, and Law, 7*, 36-97.

Sporer, S. L., Penrod, S., Read, D., & Cutler, B. (1995). Choosing, confidence, and accuracy: A Meta-Analysis of the confindence-accuracy relation in eyewitness identification studies. *Psychological Bulletin, 118*, 315-327.

Suzuki, A., Goh, J. O. S., Hebrank, A., Sutton, B. P., Jenkins, L., Flicker, B. A., & Park, D. C. (2010). Sustained happiness? Lack of repetition suppression in right-ventral visual cortex for happy faces. *Social Cognitive and Affective Neuroscience*, doi: 10.1093/scan/nsq058.

Tanaka, J. W., Curran, T., Porterfield, A. L., & Collins, D. (2006). Activation of preexisting and acquired face representations: The N250 event-related potential as an index of face familiarity. *Journal of Cognitive Neuroscience, 18*, 1488-1497.

Tanji, J., & Shima, K. (1994). Role for supplementary motor area cells in planning several movements ahead. *Nature, 371*, 413-416.

Tranel, D., Damasio, H. & Damasio, A.R. (1997). A neural basis for the retrieval of conceptual knowledge. *Neuropsychologia, 35*, 1319–1327.

Trautner, P., Dietl, T., Staedtgen, M., Mecklinger, A., Grunwald, T., Elger, C. E., & Kurthen, M. (2004). Recognition of famous faces in the medial temporal lobe: An invasive ERP study. *Neurology, 63,* 1203-1208.

Vizioli, L., Rousselet, G. and Caldara, R. (2010). Neural repetition suppression to identity is abolished by other-race faces*. Proceedings of the National Academy of Sciences of the United States of America, 107,* 20081-20086.

Vokey, J. R., & Read, J. D. (1992). Familiarity, memorability, and the effect of typicality on the recognition of faces. *Memory & Cognition, 20*, 291-302.

Walker, S., Bruce, V., & O'Malley, C. (1995). Facial identity and facial speech processing: Familiar faces and voices in the McGurk effect. *Perception & Psychophysics, 57*, 1124-1133.

Wallbott, H. G., & Ricci-Bitti, P. (1993). Decoders' processing of emotional facial expression - a top-down or bottom-up mechanism? *European Journal of Social Psychology, 23*, 427-443.

Watson, J. D. G., Myers, R., Frackowiak, R. S. J., Hajnal, J. V., Woods, R. P., Mizziota, J. C., Shipp, S., Zeki, S. (1993). Area V5 of the human brain: Evidence from a combined study using positron emision tomography and magnetic resonance imaging. *Cerebral Cortex, 3*, 79-94.

Winston, J. S., Henson, R. N. A., Fine-Goulden, M. R., & Dolan, R. J. (2004). fMRI-Adaptation reveals dissociable neural representations of identity and expression in face perception. *Journal of Neurophysiology, 92*, 1830–1839.

Winston, J. S., Strange, B. A., O'Doherty, J., & Dolan, R. J. (2002). Automatic and intentional brain responses during evaluation of trustworthiness of faces. *Nature Neuroscience, 5*, 277-283.

Xu, X., & Biederman, I. (2010). Loci of the release from fMRI adaptation for changes in facial expression, identity, and viewpoint. *Journal of Vision, 10*, 1–13.

Yonelinas, A. P., Hopfinger, J. B., Buonocore, M. H., Kroll, N. E. A., & Baynes, K. (2001). Hippocampal, parahippocampal and occipital-temporal contributions to associative and item recognition memory: an fMRI study. *NeuroReport, 12,* 359-363.

Young, A. W., McWeeny, K. H., Hay, D. C., & Ellis, A. W. (1986). Matching familiar and unfamiliar faces on identity and expression. *Psychological Research, 48*, 63-68.

Appendix A: Instructions

Appendix A1: Instructions for the EEG experiment.

Between instructions 3 and 4 participants viewed Markus' face 60 times and rated it on a 9-point Likert scale ranging from *not at all* (1) to *very* (9) with respect to *happiness, intelligence, trustworthiness*, *selfishness*, *recklessness* and *opportunism*. Between instruction 6 and 7 as well as 9 and 10 stimuli were presented and EEG recorded. After instruction 11 all stimuli were presented again and participants rated them according to *likeability* from 1 (*not very likeable*) to 9 (*very likeable*), *valence* from 1 (*very negative*) to 9 (*very positive*) and *arousal* from 1 (*not arousing*) to 9 (*very arousing).*

1. Herzlich Willkommen! Vielen Dank, dass Sie an dieser Studie zur Gesichterwahrnehmung teilnehmen. Die folgende Studie besteht aus zwei unterschiedlichen Teilen. Im ersten Teil dieser Studie wird Ihnen ein computergeneriertes Gesicht (Avatar) vorgestellt. Dieser Avatar repräsentiert eine Person von der Sie sich anhand des Gesichts und der Gesichtsbewegung einen Eindruck bilden sollen. Dazu werden Ihnen verschiedene Fragen zu der Person gestellt und Sie sollen diese, basierend auf Ihrem Eindruck, den Sie durch den Avatar gewinnen, beantworten. Dabei gibt es keine falschen oder richtigen Antworten. Uns interessiert Ihr persönlicher Eindruck.
2. Während des Experiments werden über die Elektroden an Ihrem Kopf Ihre Gehirnströme aufgezeichnet. Nehmen Sie dazu nun bitte eine bequeme Sitzposition ein und versuchen Sie sich während des Experiments so wenig wie möglich zu bewegen

3. Ihnen wird nun Markus vorgestellt. Dazu wird Ihnen Markus einige Male hintereinander gezeigt und anschließend werden Ihnen einige Fragen zu Markus gestellt werden. Bitte machen Sie sich einen Eindruck von Markus.
4. Vielen Dank. Nachdem Ihnen nun also Markus vorgestellt wurde, werden Ihnen im zweiten Teil der Studie verschiedene Personen gezeigt werden. Ihre Aufgabe ist es anzugeben, ob diese Personen Sie an Markus erinnern.
5. Ihnen werden nun hintereinander verschiedene Avatare gezeigt. Bitte konzentrieren Sie sich auf die FORM des Gesichts und der Gesichtspartien. Nach jedem präsentierten Gesicht, werden Sie gebeten werden anzugeben, wie stark die GESICHTSFORM Sie an Markus erinnert hat.
6. Achten Sie nun also bitte besonders auf die GESICHTSFORM der Avatare. Um mit der Aufgabe zu beginnen, drücken Sie bitte die Leertaste.
7. Vielen Dank. Diese Aufgabe ist nun beendet. Bitte drücken Sie die Leertaste um mit der nächsten Aufgabe fortzufahren.
8. Nun beginnt die nächste Aufgabe. Ihnen werden erneut hintereinander verschiedene Avatare gezeigt. Bitte konzentrieren Sie sich auf die BEWEGUNGEN des Gesichts. Nach jedem präsentierten Gesicht, werden Sie gebeten werden anzugeben, wie stark die GESICHTSBEWEGUNGEN Sie an Markus erinnert haben.
9. Achten Sie nun also bitte besonders auf die GESICHTSBEWEGUNG der Avatare. Um mit der Aufgabe zu beginnen, drücken Sie bitte die Leertaste.
10. Vielen Dank. Dieser Aufgabenabschnitt ist nun beendet und die Aufzeichnung Ihrer Gehirnströme wird nun beendet.
11. Abschließend möchten wir Sie nun noch bitten, einige Gesichter zu bewerten. Um mit der Bewertung zu beginnen, drücken Sie bitte die Leertaste.

Appendix A2: Instructions for the fMRI experiment.

Between instructions 2 and 3 participants were presented Markus’ face 70 times and rated it on a 9-point Likert scale ranging from *not at all* (1) to *very* (9) with respect to *happiness*, *intelligence, trustworthiness*, *selfishness*, *recklessness* and *opportunism*. Between instructions 5 and 6 participants saw the target to which they were to respond during the test phase. EPI measures were conducted between instructions 6 and 7 while participants viewed faces with familiar or unfamiliar form and/or motion. At the end of the experiment the recognition task was conducted in the scanner.

1. Im ersten Teil dieser Studie wird Ihnen ein computergeneriertes Gesicht (Avatar) vorgestellt. Dieser Avatar repräsentiert eine Person namens Markus, von der Sie sich an Hand des Gesichts einen Eindruck bilden sollen.
2. Ihnen wird nun Markus vorgestellt. Dazu wird Ihnen Markus Gesicht und seine Art zu lächeln mehrere Male hintereinander gezeigt. Um festzustellen was für einen Eindruck Markus auf sie macht, werden Ihnen einige Fragen zu Markus gestellt werden.

   Bitte bilden Sie sich einen Eindruck von Markus. Achten Sie dabei sowohl genau auf die FORM DES GESICHTS als auch auf die BEWEGUNG DES GESICHTS UND MARKUS ART ZU LÄCHELN.
3. Vielen Dank. Hiermit ist nun dieser Teil der Studie beendet.

   Im nächsten Teil der Studie geht es darum festzustellen, wie die Verarbeitung von sozialen Reizen (Gesichter) die Verarbeitung von nicht-sozialen Reizen beeinflusst.
4. Dazu werden Ihnen im Folgenden verschiedene Gesichter gezeigt. Während der Präsentation der Gesichter wird manchmal für kurze Zeit ein Viereck eingeblendet. Ihre Aufgabe ist es durch Tastendruck (Zeigefinger) anzuzeigen, dass Sie dieses Viereck wahrgenommen haben.

5. Wir zeigen Ihnen nun das Viereck, auf das Sie durch Tastendruck reagieren sollen. Bitte drücken Sie so schnell wie möglich die TASTE UNTER IHREM ZEIGEFINGER, sobald Sie das Viereck sehen.
6. Nachdem Sie das Viereck gesehen haben, beginnen wir nun mit der Präsentation der Avatare. Während dieser Präsentation wird Ihre Gehirnaktivität aufgezeichnet. Versuchen Sie daher bitte sich so wenig wie möglich zu bewegen.

   Konzentrieren Sie sich bitte auf die Gesichter. Manchmal werden Sie für kurze Zeit das Viereck sehen. Reagieren Sie mit Tastendruck sobald Sie das Viereck sehen. Die Präsentation und Messung wird gleich gestartet.
7. Vielen Dank. Hiermit ist nun dieser Teil der Studie beendet. Wir führen nun noch kurz ein paar abschließende Messungen durch. Bitte bleiben Sie ruhig liegen.
8. Im letzten Teil dieser Studie werden Ihnen nun erneut verschiedene Avatare gezeigt. Ihre Aufgabe ist anzugeben, welche Eigenschaften dieser Avatare sie an Markus, von dem Sie sich im ersten Teil einen Eindruck gebildet haben, erinnern.
9. Insgesamt werden Ihnen mit gleicher Häufigkeit Gesichter gezeigt, die 1. die GLEICHE GESICHTSFORM wie Markus haben und auf die GLEICHE ART LÄCHELN wie er,

   2. die GLEICHE GESICHTSFORM wie Markus haben, aber auf eine ANDERE ART LÄCHELN als er,

   3. eine ANDERE GESICHTSFORM als Markus haben, aber auf die GLEICHE ART LÄCHELN wie er,

   4. eine ANDERE GESICHTSFORM als Markus haben und auch auf eine ANDERE ART LÄCHELN.
10. Konzentrieren Sie sich bitte sowohl auf die GESICHTSFORM als auch auf die ART DES LÄCHELNS. Nach jedem Avatar werden Sie gebeten anzugeben ob Ihnen die

GESICHTSFORM von Markus bekannt war und ob Ihnen DIE ART DES LÄCHELNS von Markus bekannt war.

Versuchen Sie sich bitte so gut wie möglich an Markus zu erinnern. Die Präsentation wird gleich gestartet.

Appendix A3: Instructions for the own-race bias experiment.

The learning phase took place between instructions 3 and 6 or 5 and 6, depending on the condition the participant was assigned to. Participants passed their judgment about the age and manliness of the face/flow of the movement and friendliness of the smile on nine-point Likert scales ranging from 1 (*very young*) to 9 (*very old*) and 1 (*very manly*) to 9 (*very feminine*)/1 (*very stagnant*) to 9 (*very fluent*) and 1 (*very unfriendly*) to 9 (*very friendly*).

The test phase took place between instructions 6 and 7 in which participants rated target and distractor faces as *old* or *new*. At the end of the experiment ratings of typicality (*How difficult would it be to pick this person out of a crowd?*) from 1 (*not very difficult*) to 7 (*difficult*), their likeability (*Is this person likeable?*) from 1 (*not very likeable*) to 7 (*likeable*), their attractiveness (*Is this person attractive?*) from 1 (*not very attractive*) to 7 (*attractive*), their memorability (*Would it be easy to remember this person?*) from 1 (*not very easy*) to 7 (*easy*), and finally their familiarity (*Is this face confusable with someone you know?*) from 1 (*not very confusable*) to 7 (*confusable*) were implemented.

1. Hallo! In der folgenden Studie geht es darum Gesichter europäischer und afrikanischer Herkunft nach bestimmten Eigenschaften zu bewerten.

Attention-to-form condition:

2. Ihnen werden europäische und afrikanische Gesichter in zufälliger Reihenfolge für kurze Zeit gezeigt. Nach jedem Gesicht werden Sie gebeten, dieses nach Alter und Erscheinungsbild zu bewerten. Damit Sie sich nur auf das Gesicht konzentrieren werden alle Gesichter ohne Haare präsentiert.
3. Wir beginnen nun mit der Präsentation der Gesichter. Ihnen wird jedes Gesicht für 3 Sekunden gezeigt und anschließend werden Sie gebeten, Ihr Urteil abzugeben wie ALT Sie das Gesicht fanden. Anschließend werden Sie das gleiche Gesicht erneut für 3

Sekunden sehen und sie werden gebeten, es nach seiner MÄNNLICHKEIT zu bewerten. Schauen Sie sich die Gesichter bitte ganz genau an, um ein möglichst genaues Urteil abgeben zu können. Falls Sie noch Fragen haben wenden Sie sich bitte jetzt an die Versuchsleitung. Falls nicht, starten Sie bitte die Präsentation mit der Leertaste.

Attention-to-motion condition:

4. Ihnen werden europäische und afrikanische Gesichter in zufälliger Reihenfolge für kurze Zeit gezeigt. Nach jedem Gesicht werden Sie gebeten, dieses nach der Dynamik der Bewegung und dem Erscheinungsbild zu bewerten. Damit Sie sich nur auf das Gesicht konzentrieren werden alle Gesichter ohne Haare präsentiert.
5. Wir beginnen nun mit der Präsentation der Gesichter. Ihnen wird jedes Gesicht für 3 Sekunden gezeigt und anschließend werden Sie gebeten, Ihr Urteil abzugeben wie FLIESSEND DIE BEWEGUNG war. Anschließend werden Sie das gleiche Gesicht erneut für 3 Sekunden sehen und sie werden gebeten, es nach seiner FREUNDLICHKEIT zu bewerten.

   Schauen Sie sich die Gesichter bitte ganz genau an, um ein möglichst genaues Urteil abgeben zu können. Falls Sie noch Fragen haben wenden Sie sich bitte jetzt an die Versuchsleitung. Falls nicht, starten Sie bitte die Präsentation mit der Leertaste.
6. Nun werden Ihnen erneut Gesichter europäischer und afrikanischer Herkunft gezeigt. Zum Teil haben Sie die Gesichter bereits im ersten Durchgang gesehen. Zum Teil sind sie neu. Ihre Aufgabe ist anzugeben, ob Sie das Gesicht bereits aus dem ersten Durchgang kennen. Versuchen Sie möglichst spontan zu antworten und nicht allzu lange zu überlegen, da der erste Eindruck meist richtig ist. Falls Sie keine Fragen haben, starten Sie bitte nun mit der Leertaste die Präsentation.

7. Vielen Dank. Abschließend möchten wir Sie nun noch bitte, die Gesichter die Sie gesehen haben zu bewerten. Bitte antworten Sie möglichst spontan.

Appendix B: Stimuli ratings

Appendix B1: Ratings of *likeability* from 1 (*not very likeable*) to 9 (*very likeable*), *valence* from 1 (*very negative*) to 9 (*very positive*) and *arousal* from 1 (*not arousing*) to 9 (*very arousing)* of the two different movement patterns in the pilot studies I and II.

trait	Face stimulus	Smile 1		Smile 2	
		M	*SD*	*M*	*SD*
Likeability	1_1	5,44	1,99	4,93	1,96
	2_1	3,44	1,31	3,56	1,40
	3_1	3,93	1,52	4,07	2,07
	5_1	3,81	1,57	3,59	1,60
	6_1	3,85	1,81	3,96	2,16
	7_1	3,81	1,69	4,11	1,69
	8_1	5,30	1,73	4,63	1,82
	9_1	4,59	1,42	4,48	1,91
	10_1	5,52	1,58	5,10	2,00
	11_1	5,00	1,59	4,96	1,58
	12_1	5,22	1,60	5,11	1,74
	13_1	4,19	1,80	4,30	1,56
	14_1	4,11	1,40	4,85	1,61
	15_1	5,85	1,43	5,37	1,67
	16_1	5,81	1,52	5,85	1,59
	17_1	5,04	1,37	4,74	1,97
	18_1	4,63	1,71	4,70	1,54
Valence	1_1	5,56	1,63	5,37	1,74
	2_1	3,48	1,16	3,96	1,43
	3_1	4,22	1,45	4,63	1,88
	5_1	4,44	1,76	3,70	1,56
	6_1	4,11	1,72	4,44	1,93
	7_1	4,44	1,76	4,11	1,63
	8_1	5,19	1,69	4,67	1,73
	9_1	4,81	1,49	4,59	1,67
	10_1	5,63	1,45	4,95	1,64
	11_1	5,00	1,27	4,93	1,54
	12_1	5,37	1,50	5,44	1,58
	13_1	4,44	1,67	4,67	1,49
	14_1	4,41	1,37	5,00	1,44
	15_1	6,00	1,11	5,41	1,42
	16_1	5,85	1,43	6,04	1,48
	17_1	5,15	1,23	5,19	1,59
	18_1	4,74	1,63	4,74	1,29
Arousal	1_1	4,70	2,11	4,52	2,05
	2_1	3,07	1,44	3,30	1,64

3_1	3,44	1,60	3,78	1,60
5_1	3,22	1,53	3,44	1,37
6_1	3,89	2,26	3,74	2,03
7_1	3,48	1,58	3,56	1,74
8_1	4,11	1,89	3,56	1,60
9_1	3,70	1,81	3,93	1,84
10_1	3,96	1,85	4,35	1,73
11_1	3,78	1,72	3,74	1,91
12_1	4,11	1,80	4,26	2,10
13_1	3,52	1,85	3,63	1,57
14_1	3,56	1,69	4,11	1,93
15_1	4,41	2,24	4,11	2,06
16_1	4,70	2,03	4,74	2,31
17_1	3,85	1,63	3,78	1,69
18_1	3,30	1,54	3,41	1,72

Appendix B2: Ratings of *likeability* from 1 (*not very likeable*) to 9 (*very likeable*), *valence* from 1 (*very negative*) to 9 (*very positive*) and *arousal* from 1 (*not arousing*) to 9 (*very arousing)* of the two different movement patterns in the EEG experiment.

trait	Face stimulus	Smile 1		Smile 2	
		M	*SD*	*M*	*SD*
Likeability	1_1	5,53	1,54	5,16	1,83
	2_1	4,26	1,82	4,05	1,65
	3_1	4,26	1,82	4,37	1,61
	5_1	3,37	1,21	3,47	,96
	6_1	3,95	1,65	4,42	1,77
	7_1	4,63	1,92	4,11	1,94
	8_1	4,63	1,77	5,16	1,54
	9_1	5,11	1,56	4,68	1,53
	10_1	5,42	1,80	5,16	1,83
	11_1	4,79	1,84	5,42	1,92
	12_1	5,53	1,87	5,74	1,45
	13_1	4,95	1,68	4,58	1,71
	14_1	5,00	1,56	5,26	1,94
	15_1	5,89	1,73	6,05	1,43
	16_1	5,89	2,21	5,47	1,78
	17_1	5,11	1,76	5,26	1,82
	18_1	5,50	1,15	4,79	1,27
Valence	1_1	5,58	1,35	5,53	1,54
	2_1	4,58	1,17	4,74	1,37
	3_1	4,79	1,47	4,63	1,30
	5_1	4,21	1,65	3,68	1,42
	6_1	4,11	1,28	4,53	1,26
	7_1	4,58	1,77	4,63	1,54
	8_1	5,16	1,57	5,26	1,19
	9_1	4,89	1,59	5,00	1,29
	10_1	5,42	1,50	5,53	1,39
	11_1	4,63	1,74	5,63	1,54
	12_1	5,37	1,42	5,58	1,02
	13_1	5,05	1,39	4,74	1,76
	14_1	4,95	1,08	5,26	1,24
	15_1	5,95	1,35	6,05	1,47
	16_1	5,74	1,41	5,32	1,45
	17_1	4,95	1,84	5,58	1,46
	18_1	5,67	1,08	5,16	1,17
Arousal	1_1	5,68	1,63	5,63	1,64
	2_1	4,37	1,30	4,74	1,82

3_1	4,68	1,49	4,47	1,39
5_1	4,16	1,83	4,21	1,87
6_1	4,47	1,68	4,58	1,54
7_1	5,05	1,75	4,74	2,02
8_1	4,53	1,68	4,79	1,40
9_1	5,16	1,26	4,84	1,46
10_1	5,05	1,84	4,79	1,44
11_1	5,16	1,61	5,21	2,07
12_1	4,63	1,61	5,11	1,37
13_1	4,74	1,91	4,47	1,87
14_1	4,58	1,80	4,89	1,52
15_1	5,47	1,54	5,58	1,57
16_1	5,47	1,61	4,63	2,09
17_1	4,89	1,82	4,68	1,77
18_1	4,94	1,66	4,32	1,63

Appendix B3: Ratings of facial stimuli in the own-race bias experiment. European and African faces were rated according to their typicality (*How difficult would it be to pick this person out of a crowd?*) from 1 (*not very difficult*) to 7 (*difficult*), their likeability (*Is this person likeable?*) from 1 (*not very likeable*) to 7 (*likeable*), their attractiveness (*Is this person attractive?*) from 1 (*not very attractive*) to 7 (*attractive*), their memorability (*Would it be easy to remember this person?*) from 1 (*not very easy*) to 7 (*easy*), and their familiarity (*Is this face confusable with someone you know?*) from 1 (*not very confusable*) to 7 (*confusable*).

Face stimulus		Typicality		Likeability		Attractiveness		Memorability		Familiarity	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
European	01	4,50	1,45	3,86	1,32	3,23	1,36	3,55	1,53	2,39	1,67
	02	4,89	1,50	3,86	1,23	3,09	1,20	3,39	1,35	2,27	1,45
	03	4,32	1,44	3,57	1,23	2,80	1,15	3,61	1,57	2,05	1,55
	04	4,48	1,42	4,11	1,28	3,23	1,54	3,43	1,35	2,23	1,44
	05	4,32	1,70	3,32	1,46	2,50	1,09	3,59	1,78	1,73	1,13
	06	4,93	1,09	3,27	1,25	2,34	1,01	2,91	1,18	1,86	1,15
	07	4,82	1,30	4,43	1,25	3,20	1,23	3,05	1,18	2,05	1,61
	08	4,50	1,70	4,07	1,32	3,20	1,37	3,39	1,56	2,23	1,57
	09	4,43	1,66	3,48	1,42	2,82	1,28	3,39	1,70	2,14	1,53
	10	4,64	1,42	3,82	1,32	2,77	1,10	3,20	1,49	1,70	1,11
	11	4,75	1,50	4,41	1,24	3,45	1,35	3,27	1,50	2,41	1,63
	12	4,11	1,38	3,34	1,38	2,55	1,28	3,32	1,64	1,77	1,34
	13	4,25	1,60	3,48	1,44	2,55	1,13	3,48	1,49	1,84	1,29
	14	4,95	1,40	4,41	1,23	3,43	1,37	3,59	1,23	2,14	1,52
	15	4,16	1,46	3,61	1,22	2,84	1,27	3,75	1,63	1,98	1,34
	16	3,82	1,35	3,45	1,39	2,00	0,96	3,84	1,67	1,75	1,43
	17	3,82	1,66	2,95	1,20	2,45	1,04	3,75	1,57	1,75	1,20
	18	4,91	1,57	3,55	1,32	2,61	1,08	3,05	1,40	1,77	1,12
	19	4,91	1,36	3,91	1,24	2,80	1,07	3,05	1,20	2,00	1,45
	20	4,30	1,64	4,41	1,54	2,82	1,33	3,82	1,65	2,09	1,52
	21	4,57	1,61	3,98	1,27	2,89	1,17	3,14	1,53	1,84	1,36
	22	4,89	1,47	3,64	1,37	2,66	1,12	3,11	1,38	2,23	1,57
	23	3,77	1,65	3,11	1,45	2,14	1,25	3,84	1,66	1,80	1,34
	24	4,39	1,47	4,00	1,26	3,00	1,18	3,18	1,30	2,27	1,77
	25	4,86	1,49	3,93	1,48	2,75	0,94	3,34	1,55	1,73	1,32
	26	4,86	1,37	4,07	1,26	3,20	1,50	3,25	1,51	2,20	1,62
	27	4,77	1,36	4,20	1,23	3,20	1,25	3,23	1,49	2,48	1,59
	28	5,00	1,40	3,75	1,40	2,59	1,17	3,18	1,42	1,89	1,17
	29	3,75	1,50	3,91	1,27	2,80	1,34	3,66	1,49	2,02	1,52
	30	4,45	1,44	4,07	1,26	3,30	1,39	3,00	1,03	2,11	1,53
African	01	4,80	1,42	4,57	1,35	3,55	1,28	3,41	1,56	1,57	1,17
	02	4,00	1,52	4,61	1,32	3,73	1,53	3,93	1,48	1,57	0,95
	03	4,02	1,64	5,68	0,96	4,41	1,17	4,45	1,39	2,09	1,61
	04	4,52	1,45	5,07	1,30	4,41	1,39	3,80	1,50	1,89	1,57
	05	4,07	1,47	5,00	1,20	3,89	1,24	3,70	1,27	1,66	1,16
	06	4,34	1,41	4,66	1,41	3,66	1,33	3,66	1,48	1,57	1,07
	07	3,43	1,89	4,75	1,35	2,98	1,23	4,52	1,72	1,68	1,12
	08	4,23	1,61	4,68	1,31	3,70	1,19	3,73	1,53	1,95	1,58
	09	4,36	1,66	5,07	1,07	4,41	1,50	3,59	1,39	1,68	0,91
	10	3,95	1,61	4,14	1,36	3,23	1,57	4,00	1,70	1,98	1,61

11	4,20	1,65	4,18	1,17	3,11	1,02	3,43	1,48	1,64	1,14
12	4,11	1,50	4,57	1,21	3,52	1,44	3,57	1,48	1,52	0,98
13	3,36	1,46	4,18	1,24	3,05	1,12	3,82	1,37	1,52	1,15
14	4,27	1,53	4,68	1,25	3,43	1,45	3,43	1,44	1,43	0,97
15	4,25	1,48	4,20	1,19	3,18	1,30	3,41	1,37	1,41	0,82
16	3,61	1,62	4,66	1,27	3,18	1,24	3,84	1,36	1,61	1,02
17	4,52	1,50	5,11	0,97	4,11	1,20	3,66	1,52	1,61	1,10
18	4,39	1,47	4,30	1,41	3,32	1,41	3,48	1,49	1,52	1,05
19	4,55	1,44	4,48	1,15	3,30	1,13	3,80	1,52	1,64	1,10
20	4,23	1,36	4,59	1,26	3,66	1,31	3,80	1,47	1,64	0,99
21	4,09	1,52	4,52	1,28	3,41	1,42	3,32	1,25	1,43	0,90
22	3,73	1,77	5,02	1,19	3,50	1,36	4,41	1,62	1,50	1,09
23	4,41	1,26	4,84	1,20	4,02	1,45	3,48	1,41	1,70	1,17
24	4,50	1,30	5,36	1,01	4,23	1,16	3,61	1,33	1,75	1,10
25	4,39	1,56	4,55	1,34	3,59	1,26	3,64	1,56	1,59	1,02
26	3,11	1,54	5,34	1,27	3,52	1,41	4,64	1,54	1,59	0,95
27	4,48	1,66	4,75	1,38	3,64	1,54	3,36	1,57	1,86	1,25
28	4,23	1,48	4,73	1,30	3,57	1,23	3,48	1,50	1,50	0,95
29	4,57	1,44	4,59	1,26	3,18	1,54	3,48	1,56	1,73	1,19
30	4,23	1,71	5,34	1,12	4,41	1,50	4,05	1,49	1,75	1,37