Neural correlates of social comparison and decision

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Erklärung

Ich erkläre hiermit, dass ich mich bisher keiner Doktorprüfung unterzogen habe.

Michael Lindner

Eidesstattliche Versicherung

Ich erkläre hiermit an Eides Statt, dass ich die vorgelegte Dissertation über "Neural correlates of social comparison and decision“ selbständig angefertigt und mich anderer Hilfsmittel als der in ihr angegebenen nicht bedient habe, insbesondere, dass aus Schriften Entlehnungen, soweit sie in der Dissertation nicht ausdrücklich als solche mit Angabe der betreffenden Schrift bezeichnet sind, nicht stattgefunden haben.

Teile der vorliegenden Arbeit wurden bisher in folgendem Publikationsorgan veröffentlicht:

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Michael Lindner

Danksagung

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Content

Abstract

The comparison of persons is pervasive in social judgement and human decision making and yet its neural substrate is poorly explored. Using functional magnetic resonance imaging we investigated the brain activities of participants comparing other persons with each other (other vs. other comparison - OOC) and with themselves (self vs. other comparison - SOC) as regards psychological (intelligence) and physical (height) characteristics. We found that the comparison of these two person characteristics differ in their neural activation patterns in the OOC as well as in the SOC with higher activity increases for intelligence than height comparison in several areas in medial frontal and orbitofrontal cortex and posterior cingulate cortex suggesting that their activation scales with the demand on person comparison. The person comparison network strikingly overlaps the one commonly described for the classic theory of mind tasks. We interpret this overlap as indicating perspective taking common to person comparison and theory of mind. Furthermore, we suggest that the neural differences between the SOC and the OOC especially in the dorsal part of the medial frontal cortex rely on the different degree of the self involved in the two types of comparisons. The results additionally suggest that the decision directions of self-relevant comparisons, especially in the intelligence comparison of the SOC, resulted in differences in the activation of the medial frontal cortex, which also relies on differences in the reward anticipation and self-relatedness of these decisions.

1. Introduction

Human beings are social beings: we spend our time with friends, and we live together in villages and cities with thousands, even millions of fellow human beings. Most of us work together with other people. We interact with others nearly every day, we are at war with one another, we perform contests at work, sports, and in other fields and of course, we compare other persons with each other and other persons with ourselves. The list of interactions between human beings is endless. Therefore, it is not astonishing that these interactions are in the focus of interest in several areas such as economics, sports, and of course psychology. In the last decades, the basics of social cognition processes and their neural correlates constituted a key issue in social psychology. One of these social cognition processes concerns social comparisons. We behave and decide on the basis of judgements we make in social comparisons in our daily life. Every day we compare ourselves with other people and pass judgements for "is she/he taller/fitter/stronger/more intelligent/better/richer... than I am, or am I taller/fitter/stronger/more intelligent/better/richer... than the other?". These kinds of decisions bear an important influence on our behaviour and our interaction with other people. For example, even decisions about our own marriage are influenced by the people we compare ourselves with (Titus, 1980). Social comparison can provide a reference frame for our own opinions. Although social comparisons are used in our daily life and are in the focus of research, little is known about their neural substrates.

Social comparison is an umbrella term referring to all processes through which people come to know themselves or others by evaluating their own attitudes, abilities, and beliefs in comparison with another person or with a group of others, for example a peer group. For extracting information about the attitudes, abilities or beliefs of other persons for social comparison processes, we have to draw inferences about potentially intelligent beliefs, intentions, and attitudes of one or more persons and take their perspective into account. Taking the perspective of others into account is a specific human ability termed *mentalizing* or Theory of Mind (ToM). Furthermore, a judgement based on a social comparison process requires a decision making process.

This doctoral thesis deals with the neural similarities and differences in specific social comparison processes. In particular, we are interested in neural differences in the comparison of physical and psychological person characteristics. Our person comparisons include the comparison of body height as a physical person characteristic and the comparison of intelligence as a psychological person characteristic. We were moreover interested in neural differences resulting from the differing involvement of the self in these social comparison processes. We performed three experiments using functional Magnetic Resonance Imaging (fMRI) to investigate the neural correlates of person comparison tasks. FMRI is a non-invasive magnetic resonance imaging technique of the brain that relies on intrinsic changes in hemoglobin oxygenation and blood flow to functioning areas of the brain. A short explanation of the blood-oxygen-level dependent signal (BOLD) can be found in Excursus box 1.

In the following parts of the introduction the social comparison processes and the related processes such as decision making and ToM and their neural correlates will be described in more detail. Furthermore, the neural correlates of processes in which the self and others are included will be characterized. The introduction will close upon the foci of interest of the three experiments.

Excursus 1: blood-oxygen-level dependent signal (BOLD)

Every time when nerve cells are firing they consume energy in form of glucose and oxygen. Because of having no internal reserves for these energy sources in the nerve cells, it is necessary to supply them with glucose and oxygen, quickly. The more nerve cells are firing the more the demand on energy source is increasing. A complex regulation mechanism of the blood vessel compensates this demand. The particular details of this mechanism are still unknown. Because of a vascular dilatation in the surrounding of the activated neurons more oxygenic blood is delivered than to inactive neurons (see Figure 1). This process is called hemodynamic response and has a latency of about 5-6 sec. The variation of the blood flow and the oxygen saturation of the blood have influences on the local magnetic field, because oxygenated or deoxygenated blood have different magnetic properties (Hemoglobin is diamagnetic when oxygenated but paramagnetic when deoxygenated). These changes in magnetic fields can be detected with fMRI.

With simultaneous measurements of electroencephalography and BOLD could be shown, that the subliminal fluctuations of local field potentials show higher correlations with BOLD than the firing rate of the neurons with the BOLD (Logothetis, Pauls, Augath, Trinath & Oellermann, 2001). This is seen as a verification that BOLD is an indirect measurement of neural activity.

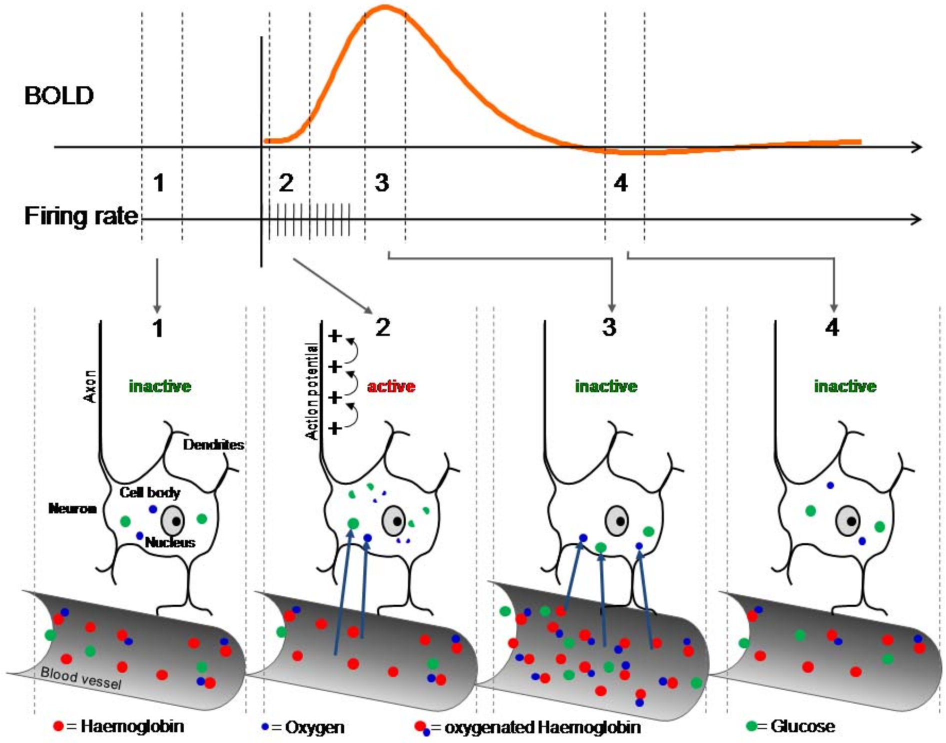

Figure 1: Schematic diagram of the appearance of the BOLD-signal. TOP: BOLD-characteristics and firing rate, BOTTOM: (1): inactive neuron with normal amount of glucose and oxygen, (2): active neuron – glucose and oxygen were spent - shortfall refilled from the blood circulation, (3): Because of vascular dilatation more blood and therefore more glucose and oxygen is delivered in the immediate surrounding of the active neuron, which refills the deficit, (4): neuron is again in inactive state with normal amount of glucose and oxygen.

1.1 Social comparison

As mentioned above, social comparison is a term referring to the process through which people come to know themselves by evaluating their own attitudes, abilities, and beliefs in comparison with others. Two explanations shall first be provided for a better understanding of the further text. First, two directions of social comparisons can be defined: upward and downward comparison. Upward comparison means that people compare themselves with others having higher parameter values concerning the content of the comparison, while downward comparison describes a comparison with people having lower parameter values. Second, in his meta analysis Van Overwalle (2009) divided social processes into two major types of mental inferences: (1) inferences of transitory states (goals and intentions) which are more perceptual and directly related to the observed behaviour of others and (2) inferences of enduring characteristics (personality traits and social scripts), which requires a more mature mentalizing capacity.

The next section will deliver a detailed description of theories of social comparison processes, which are relevant for the comparison tasks in our three experiments, will be given. Subsequently, results of neuroimaging studies are presented which investigated the involvement of brain areas in social comparison processes and dealing with social information.

1.1.1 Theories of social comparison processes

The term “social comparison” was first used by Leon Festinger (1954). He also developed the first systematic theory of social comparison processes in groups. This theory is based on his previous work and theory regarding the power of groups and how individuals use groups to fulfill the information which is needed to evaluate their opinions and abilities.

Festinger’s (1954) theory of social comparison processes includes 5 hypotheses:

1. In the first hypothesis Festinger (1954) postulated the existence of a drive in every human organism to evaluate its own opinions and abilities.

2. In the second hypothesis he claimed that people evaluate their opinions and abilities by comparison with the opinions and abilities of others whenever objective, non-social means are not available.

3. Thirdly, he postulated that the tendency to compare oneself with another specific person decreases as the difference between her/his opinion or ability and one's own increases. Accordingly, the person with the closest opinion or ability to one's own will be chosen for comparison. If no such person is available, meaning that all other possibly comparable persons have a very divergent opinion or ability, a person will not be able to make a subjectively precise evaluation of their own opinion or ability.

   Festinger (1954) made four derivations based on his first three hypotheses. He deduced that …

   a. if the opinions/abilities of the person that we compare ourselves with are close to our opinions/abilities, the subjective evaluation of opinions/abilities will be stable.

   b. if the opinions/abilities of the person to compare with are somewhat different from one's opinions/abilities, a tendency to change one's opinions/abilities will exist.

   c. people do not tend to compare themselves with others who have different opinions/abilities than one's own.

   d. if discrepancies exist in the group concerning the opinions/abilities, members of the group will act to reduce the discrepancy.

4. In a fourth hypothesis, the author postulated the existence of an upward drive so that people tend to improve their own abilities. This upward drive is largely absent in opinions.

5. Finally, Festinger (1954) hypothesized the existence of non-social constraints which make it difficult or even impossible to change one's ability (but not opinions).

Festinger (1954) postulated that the most important reason why we perform social comparisons is to get an as accurate as possible feedback about our own opinions and abilities. In the following years Schachter (1959) extended Festinger's theory to emotional states. For example, he postulated that people are more likely to affiliate when made fearful and that the link between fear and affiliation was partly the result of social comparison processes (Schachter, 1959). Additionally, our motivations influence the direction of social comparisons and decisions. Wheeler (1962) postulated that upward comparisons are preferred if a person has a high level of motivation and if a person believes to be closer in rank to a person above them than to a person below them.

Human beings do not only search for accurate information about themselves but also for information to improve their self-esteem. In this case, social comparisons in downward directions are preferred. For example, if we compare ourselves with a person who performs worse in sports than we do, we will show a tendency to think that we are good at sports. Thornton and Arrowood (1966) were the first to define two different motivations of social comparisons - self-evaluation and self-enhancement. This means that individuals use social comparisons to improve or develop their own abilities by getting self-relevant information for self-improvement. For example, social comparisons in upward directions enable us to get information for self-improvement (Mussweiler, 2006). This means that social comparison processes seem to be strategic and deliberative processes. However, social comparison can also be spontaneous, it can appear without any motives in social interactions and it can lie outside conscious awareness (Mussweiler, 2006). Mussweiler and Rueter (2003) suggested that people may simply compare themselves with those whom they routinely compare with. This tendency may save cognitive resources, thus it would be consistent with the cognitive efficiency principle (Mussweiler, Rueter, & Epstude, 2006).

Social cognition broadly includes the cognitive processes used to understand and store information about other persons. This information comprises facts about the self, interpersonal norms, scripts, and procedures to navigate through the social world efficiently. If one wants to receive these kinds of information, it is necessary to extract, understand, and predict the behavioural motives and stable dispositions of oneself and other persons and/or groups. In doing so, forming trait judgements of others is a helpful tool. Such trait judgements are drawn from a vast array of previous experience, general knowledge, and subjective inferences (Hastie & Park, 1986; Wyer, Srull, & Gordon, 1984). Furthermore, they are critically shaped by comparisons of the target person with other people (Damisch, Mussweiler, & Plessner, 2006; Dunning & Hayes, 1996; Herr, 1986; Higgins & Lurie, 1983). People's fundamental propensity to process social information in a comparative manner has always played a prominent role in social psychological theory and research, especially in research on person judgement (Festinger, 1954; Herr, 1986; Higgins & Stangor, 1988). Person judgements reflect the implications of judgement-relevant knowledge about the person. Hence, these informational judgements can be distinguished from experimental comparisons which are directly based on sensory inputs (Strack, 1992). It is not possible to use all judgement-relevant knowledge for such informational judgements, because on the one hand not all information will be present in certain situations and on the other hand the process will take a very long time. However, social judgements are even performed spontaneously (Mussweiler & Bodenhausen, 2002). Higgins (1996) postulated that the degree to which a particular knowledge unit influences a given judgement depends on its accessibility. Human judgements about personal qualities often involve comparison processes, as research has shown (Dunning et al., 1996; Festinger, 1954; Mussweiler, 2003). In order to answer questions like “How intelligent is Eric Kandel?” people spontaneously use comparison standards to form a judgement (Mussweiler, Rueter, & Epstude, 2004; Gilbert, Giesler, & Morris, 1995). In this respect, a statement like “Kandel is very intelligent” essentially means “Kandel is more intelligent than most of the people coming to my mind right now”. Similarly, characterizing oneself as intelligent implies that one is more intelligent than others, thus the statement is inherently comparative (Huttenlocher & Higgins, 1971).

In general, comparative evaluations involve three major stages: standard selection, target-standard comparison and evaluation. For the stage of standard selection three different mechanisms are described in the literature. Standard selections may be influenced by conversational inferences (e.g. Grice, 1975;

Schwarz, 1994), by the level of accessibility in memory (e.g. Herr, 1986; Wilson, Houston, Etling & Brekke, 1996) and are perhaps guided by normative concerns for selecting a relevant or diagnostic standard (Festinger, 1954).

Once a standard has been selected, it is necessary to determine the particular features of the standard and the target the comparison will be based upon. This feature selection drives the evaluation consequences of the comparison. For example if we compare ourselves with Michael Ballack concerning athletic skills, we may evaluate our skills as poor, but if we compare ourselves with Michael Ballack with regard to academic skills, we may evaluate our skills as high. In contrast, we would probably evaluate our academic skills as poor and our athletic skills as high when comparing ourselves with Albert Einstein. But what happens in the stage of the standard-target comparison? Mussweiler (2003) proposed a model for the selective accessibility process (see Figure 2).

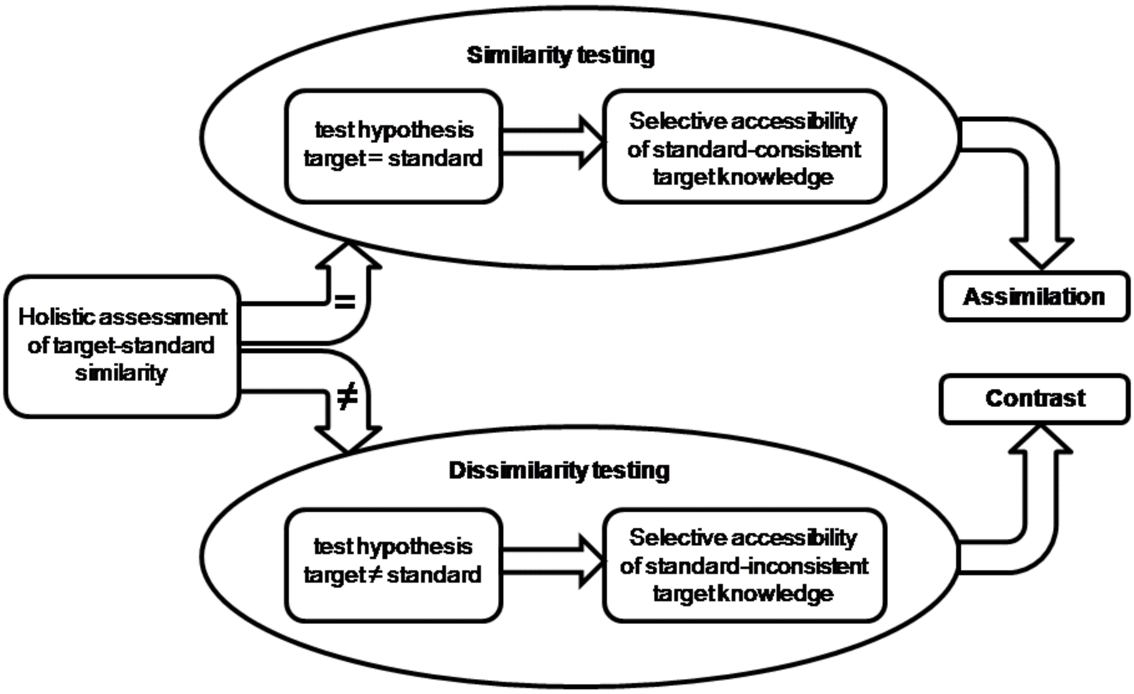

Figure 2: The selective accessibility process (according to Mussweiler, 2003)

As explained above for a comparison, judges have to obtain judgement-relevant knowledge about the target and the standard.

In a first step in the selective accessibility process, judges engage a quick holistic assessment of the target and the standard in which only a small number of features are used to determine whether both are similar or dissimilar in general. Based on the outcome of this initial holistic assessment, two different hypothesis-testing mechanisms assumingly take place. Mussweiler (2003) assumed that if the holistic assessment indicates that the target and the standard are similar, judges will engage in a process of similarity testing and test the hypothesis that the target is similar to the standard. In contrast, if the holistic assessment indicates that the target and the standard are dissimilar, judges will engage in a process of dissimilarity testing and test the hypothesis that the target is dissimilar from the standard. According to relevant literature, once a hypothesis is selected it is often tested by focusing on hypothesis-consistent evidence (Klayman & Ha, 1987; Snyder & Swann, 1978; Trope & Bassok, 1982; Trope & Liberman, 1996). For the selective accessibility process this means that the mechanism of similarity testing selectively increases the accessibility of standard-consistent target knowledge, whereas dissimilarity testing selectively increases the accessibility of standard-inconsistent target knowledge (Mussweiler, 2003). Furthermore, the author claimed that this suggests that the default evaluative consequence of similarity testing is assimilation, whereas dissimilarity testing typically leads to contrast.

In summary, Leon Festinger (1954) developed the first social comparison theory, which was extended and changed several times in the following years. Furthermore, social judgements are performed even spontaneously (Mussweiler et al., 2002), they include comparison processes and depend on the accessibility of stored and understood knowledge which is necessary for the comparison (Higgins, 1996). This information concerns the self, interpersonal norms, scripts and procedures to navigate through the social world efficiently. Comparative evaluations involve three major stages: standard selection, target-standard comparison and evaluation. Standard selections may be influenced by conversational inferences, by the level of accessibility in memory, and they may be guided by normative concerns to select a relevant or diagnostic standard. Mussweiler (2003) proposed a model for the selective accessibility process for standard-target comparisons postulating a first quick holistic assessment of standard and target, followed by two alternative similarity or dissimilarity comparison processes, depending on the first assessment. The default evaluative consequence of similarity testing is assimilation, whereas dissimilarity testing typically leads to contrast.

1.1.2 Neural substrates of social comparison

Regardless of its remarkable psychological importance, little is known about the neural substrates of person comparison. Which brain regions might contribute to comparative person judgements? First, person comparisons necessarily have to be based on semantic person knowledge. Thus, person comparisons should activate those regions that represent semantic person knowledge. Studies investigating the neural representation of abstract person-based knowledge (e.g., Mason, Banfield & Macrae, 2004; Mitchell, Heatherton, & Macrae, 2002) found activation of the medial frontal cortex (MFC) for this type of knowledge. Second, person comparisons may differ from non-comparative person judgements in that they call on neural resources that are involved in comparison processes. Here, the question is whether different types of person comparisons call on different neural resources. For example, do comparisons on physical or psychological dimensions rely on the same neural mechanisms? If different kinds of comparisons draw on similar neural activation patterns, one might assume that brain regions involved in comparing inanimate objects on dimensions such as luminance, size or numerical value, i.e. regions along the intraparietal sulcus (Cohen-Kadosh et al., 2005; Pinel, Piazza, Le Bihan, & Dehaene, 2004) might also be involved in person comparisons. Alternatively, one might assume that comparative judgements and their neural representation are organized along basic content domains into a social and non-social realm. In fact, comparisons in the social realm might be a special case.

Social comparisons are often based on characteristics of the own body (e.g. comparing ourselves with other people concerning body height or weight). When Participants had to compare their own body (active self-comparison condition) or their own home (control comparison condition) with other images and had to rate the level of anxiety that they experienced while exposed to the stimuli, self-comparison activated the lateral fusiform gyrus on both sides, the right inferior parietal lobule, the right lateral prefrontal cortex, and the left anterior cingulate cortex (ACC) (Friederich et al., 2007).

Judgements in social comparison processes involve reward anticipation processes. For example, rating oneself as richer or more intelligent than another can be more satisfying than the opposite decision direction. Reward specific activations in social comparison tasks were found in left and right occipital cortex, left and right angular gyrus, left and right ventral striatum, precuneus (PCun), and two distinct areas in medial orbitofrontal cortex (mOFC) (Fliessbach et al., 2007). The brain activity in ventral striatum increased with the ratio of subjects' rewards. Furthermore, posterior regions and orbitofrontal regions showed higher activation in cases getting a higher or a lower reward than another person. The differential activation in response to the relative payment conditions shows an immediate impact of contextual social information on ventral striatal responses (Fliessbach et al., 2007).

Van Overwalle (2009) showed in his meta-analysis that the MFC is involved in trait inferences, judgements about close others, social scripts, self reference, and interactive games. The dorsal part of the MFC is involved in trait inferences of others especially in tasks requiring enduring traits about actors on the basis of single trait words, sentences, and short stories, whereas the ventral part of MFC is involved in self-reference and trait inferences about close others (familiar people like relatives, friends, etc.) and the self. Knowledge on social scripts involves both parts of the MFC (Van Overwalle, 2009). Owing to the high degree of interconnectivity of the MFC with several brain areas including the dorso-lateral prefrontal cortex, the superior temporal sulcus (STS), the tempoparietal junction, and other brain areas, the MFC has to handle the neural input. This may contribute to the capacity of the MFC to implement more abstract inferences (e.g., Amodio & Frith, 2006). Moreover, neurons in the MFC are oriented to time and they fire over extended periods of time (Huey, Krueger, & Grafman, 2006). The authors suggested that the MFC serves the integration of social information over time.

In summary, the MFC plays an important role in social comparison. The MFC suggestedly serves the integration of social information and handles neural input from the dorso-lateral prefrontal cortex, the STS, and the tempoparietal junction. The dorsal part of the MFC is involved in trait inferences of others especially in tasks requiring enduring traits about actors based on single trait words, sentences, and short stories, whereas the ventral part of MFC is involved in self-reference and trait inferences about close others (familiar people like relatives, friends, etc.) and the self, and in evaluative judgements of famous names. Furthermore, the orbitofrontal cortex (OFC) and ventral striatum were described as reward-specific areas in social comparison tasks and a network including the lateral fusiform gyrus on both sides, the right inferior parietal lobule, the right lateral prefrontal cortex, and the left ACC were active in the slim-body self comparison.

1.2 The "Self"

In social comparison processes, especially when we compare ourselves with other people, the self plays an important role, for instance if self-knowledge and self-reference is required. This paragraph presents a short overview of definitions of the self (1.2.1) and an overview of the neural substrates of the self (1.2.2).

1.2.1 Definitions of the self

The self is a major construct in philosophy as well as in psychology. In psychology, the self refers to the cognitive representation of one's identity. William James (1890) was the first in modern psychology to postulate the distinction between the self as "I", the subjective knower, and the self as "Me", the object that is known. James (1890) divided the self into a physical self, a mental self, and a spiritual self. The view of the self has changed several times since the first definition suggested by James in 1890. One of the current views on the self was described by Damasio (1999). He proposed three levels of self-processing: The proto-self, the core self and the autobiographical self. The recent definitions are very similar to James' definition (1890). The proto-self of Damasio (1999) is associated with sensory and motor domains and corresponds with James' physical self (1890). The concept of the mental self

(James, 1890) is more or less in accordance with the core self of Damasio (1999) - representing the awareness of being the owner of a thought process and being able to act on the content of this process - and the minimal self (Gallagher, 2000; Gallagher & Frith, 2003) - which is characterized by distinguishing between a sense of agency and a sense of ownership for action. Furthermore, the spiritual self suggested by James (1890) corresponds to the autobiographical self (Damasio, 1999), reflecting the memory domain, and the narrative self (Gallagher, 2000; Gallagher et al., 2003) representing the link between past, present and future events. In other definitions of the self, the concept refers to other domains: the emotional self (Fossati, Hevenor, Graham et al., 2003; Fossati, Hevenor, Lepage et al., 2004), the spatial self (Vogeley & Fink, 2003; Vogeley et al., 2004), the facial self (Keenan, Wheeler, Gallup, & Pascual-Leone, 2000; Keenan, Nelson, O'Connor, & Pascual-Leone, 2001; Keenan, Wheeler, Platek, Lardi, & Lassonde, 2003), the verbal or interpreting self (Turk, Heatherton, Macrae, Kelley, & Gazzaniga, 2003) and the social self (Frith & Frith, 1999, 2003).

1.2.2 Neural correlates of the self

In the last decade, social cognitive neuroscience has investigated different aspects of the neural correlates of the self such as self-referential processes, or self-relevance (processes concerning stimuli that are experienced as strongly related to one’s own person) and self-description processes respectively.

Recent research has delineated a network of brain areas involved in representing the self: medial frontal areas (Craik et al., 1999; Frith et al., 1999; Kelley et al., 2002; Vogeley et al. 2001), medial parietal areas including the posterior cingulated cortex (PCC), PCun (Craik et al., 1999; Johnson et al., 2002; Kelley et al., 2002; Kircher et al., 2000), and secondary somatosensory areas including the bilateral insula (Kircher et al., 2000; Seger, Stone & Keenan, 2004).

Particularly the MFC was found in various kinds of studies investigating the self. The MFC is involved in first-person-perspective which is necessary but not sufficient for self-consciousness (Vogeley et al., 2003) and in tasks where subjects had to evaluate the extent to which a series of personality characteristics were self-descriptive (Macrae, Moran, Heatherton, Banfield & Kelly, 2004). The authors could show that the activation of the MFC could predict the memory performance and judgements of self-relevance. Several subregions of the MFC like the ventral, dorsal and posterior parts and the ACC show task specific activation in relation to their different involvement of the self. For instance, self-referential processes where subjects had to pronounce judgements on adjectives targeting the self vs. the other person yielded in activation of the ventral and dorsal anterior MFC (D'Argembeau et al., 2007). Self-related processes where subjects had to reflect about their own personal qualities (Modinos, Ormel & Aleman, 2009) and processes of adopting the other person's perspective showed more activation in the posterior dorsal MFC (D'Argembeau et al., 2007). An interaction between perspective taking and self-referential processes was found in the left dorsal MFC. The authors suggested that this region may be involved in decoupling one's own from other people's perspectives on the self. Another study investigating self-referential judgements in comparison to other judgements also found selective activation in the anterior ventral MFC (Kelley et al., 2002). The authors suggested that self-referential processing is functionally dissociable from other forms of semantic processing within the human brain. Another subregion in the center of the MFC, the ACC, showed higher activation in self- and other-relevance judgements than in case judgements (Kelley et al., 2002) and it proved to be involved in decisions about psychological trait adjectives (Kircher et al., 2000), viewing one's own face (Kircher et al., 2000) and self-related processes (Modinos, Ormel & Aleman, 2009).

Besides the MFC, other areas such as the insula (Ins), the PCC and the temporo-parietal junction (TPJ) were found to be activated in similar tasks. The Ins plays an important role in self-reflection (Modinos, Ormel & Aleman, 2009) and in viewing one's own and other familiar faces (Kircher et al., 2000), whereas the PCC engaged activation in self-referential processing in comparison to other judgements (Kelley et al., 2002). The TPJ is involved in first person perspective and it is crucial for the coding of the self as embodied and as spatially situated within the human body (Arzy, Thut, Mohr, Michel & Blanko, 2006). The TPJ has also been shown to code for several aspects of self-processing, such as agency, self–other distinction, and mental own-body imagery (Maguire et al., 1998; Zacks, Rypma, Gabrieli, Tversky & Glover, 1999; Ruby & Decety, 2001; Vogeley et al., 2003; Blanke & Arzy, 2005). Samson, Apperly, Chiavarino, and Humphrey (2004) have shown that damages in the left TPJ cause selective deficits in judging the contents of others' beliefs.

Seger et al. (2004) investigated the neural correlates of judgements of ones own preferences with judgements of another person's preferences. Participants had to make decisions on food names (self - whether he or she liked the food; other - whether a specific friend liked the food, or letter - whether there were more than two vowels in the food name). In comparison to the letter task, the self and other comparisons activated medial areas of frontal and parietal lobes and the bilateral Ins. When contrasting the two decision types (self and other) the superior medial parietal areas revealed a higher activation in the self condition, whereas activation was higher in the inferior medial parietal and left lateral frontal areas in the other condition.

In addition to the involvement of the self, our experience in a specific domain influences the neural activation pattern in self-descriptive judgements in this domain. Lieberman, Jarcho, and Satpute (2004) found different neural correlates for high- and low experience domain judgements. In this study participants with experience in different domains (soccer and acting) made self-descriptive judgements about words. They had to indicate if a word did or did not describe them. When subjects had to pronounce high-experience domain judgements a network including ventromedial prefrontal cortex, nucleus accumbens (NAcc), amygdala (AMG) and lateral temporal cortex showed activity. In low-experience domain judgements, only the lateral prefrontal cortex was differentially activated.

In a meta-analysis Northoff et al. (2006) summarized the social cognitive neuroscience studies investigating the self. The authors assumed self-referential processing to be at the core of what is called the self. They claimed that self-referential processing accounts for distinguishing stimuli related to one's own self from those that are not relevant to one's own concerns. Based on the results of their meta-analysis, the authors suggested a model of functional specialization within the cortical midline structures (CMS). The authors divided the CMS into ventral, dorsal and posterior subregions postulating specific involvements of these subregions in self-referential processes. Ventral subregions of the CMS including medial orbitofrontal cortex, the ventromedial prefrontal cortex, and the sub- and pregenual part of the ACC are connected with the AMG, the striatum, the NAcc, all primary exteroceptive sensory modalities, and subcortical regions (midbrain and brain stem). Northoff et al. (2006) postulated that the ventral part of the CMS is involved in linking extero- or interoceptive stimuli with respect to their self-relatedness and therefore could be involved in coding the self-relatedness of stimuli thereby representing them as self-referential. The dorsal subregion of the CMS including the dorsomedial prefrontal cortex and the supragenual ACC have been shown to be connected especially with the lateral prefrontal cortex. The authors suggested that the dorsal subregion of the CMS could be implicated in processes of reappraisal and evaluation of self-related stimuli. Finally the posterior subregion of the CMS including the PCC, the retrosplenial cortex, and the medial parietal cortex are densely connected with the hippocampus implicated in encoding and retrieving autobiographical memory. The authors postulated that the posterior CMS are centrally implicated in putting self-referential stimuli within a temporal context (medial parietal cortex also in spatial context) linking them to past self-referential stimuli. Northoff et al. (2006) stated that parts of the proposed model (especially for the posterior CMS) have to be further investigated with appropriately designed studies.

Damasio’s theory (1999) tries to explain the interaction between the areas found in the studies investigating the self. He claimed that the proto-self is non-conscious, represents the current state of the organism and includes the medial parietal cortex, the Ins, and the secondary somatosensory cortices. Furthermore, he stated that the core self consists of a transient, conscious representation of events currently involving the organism. According to Damasio (1999), the core self is related to activations in the cingulate cortex (CC), the thalamus, and the superior colliculi. At last, the author postulated that the autobiographical self represents the past experience of the organism and is supported by activation of medial and lateral temporal areas by retrieving the relevant memories and representing them in core consciousness. The postulated activation in the ACC of the core self in Damasios theory is consistent with the opinion of Frith et al. (1999), who claimed that medial frontal areas represent mental states.

In summary, the several regions of the MFC are involved in tasks concerning the self (for example, in tasks requiring self-knowledge, self-other relevant judgements and self-reference). Depending on the tasks, different combinations of other areas were activated in addition to the MFC. Tasks requiring first-person perspective involved medial parietal areas and the TPJ, while self-other comparison additionally involved medial parietal areas and the Ins. High self-descriptiveness additionally involved NAcc, AMG, and lateral temporal areas. The activation in the MFC also differed in respect to the task. The more dorsal parts of the MFC were activated in processes of reappraisal and evaluation of self-related stimuli, whereas the more ventral parts of the MFC were involved in coding the self-relatedness of stimuli thereby representing them as self-referential. The posterior parts of the MFC are involved in tasks including self-referential stimuli.

1.3 Neural correlates of "Others" and Theory of Mind

When comparing people, particularly on psychological characteristics like intelligence, participants have to draw inferences about potentially intelligent beliefs, intentions, and attitudes of the other persons and take their perspective into account. Hence, they try to understand other people’s behaviour in terms of their mental states – which is a specific human ability termed mentalizing or ToM reasoning (Premack & Woodruff, 1978). The concomitant brain activation would be expected in the neural network responsible for ToM (Gallagher et al., 2003; Saxe, 2006), including bilateral TPJ, the PCun, and especially the MFC. Past research has demonstrated that these areas are activated when participants try to explain and predict other people’s behaviour based on the observation of their intentional actions (Brunet, Sarfati, Hardy-Bayle, & Decety, 2000; Fletcher et al., 1995; Gallagher et al., 2000; Saxe & Kanwisher 2003; Saxe & Wexler, 2005; Walter et al., 2004; Buckner & Carroll, 2007). For example, Saxe et al. (2003) showed that the BOLD response in ToM areas (e.g.

TPJ) was higher when reading stories about mental states of a character relative to non-social control stories. These authors claimed that the TPJ is generally involved in reasoning about another's mind. Such mentalizing is also likely to be at play in person comparisons, the more so when they concern psychological rather than physical characteristics.

Researchers in the domain of social cognitive neuroscience have pointed out several brain areas that support various aspects of social interaction and representation of others (Uddin, Kaplan, Molnar-Szakacs, Zaidel, & Iacoboni, 2005; Iacoboni, 2006; Mitchell et al., 2002). A Network including MFC, ACC, and PCun has been associated with self-processing (Northoff & Bermpohl, 2004) and social cognition (Schilbach et al., 2006). As mentioned above, social comparison could entail mentalizing in tasks involving the self and others and their mental states respectively. It is therefore not surprising that the neural correlates of tasks involving mentalizing and thus the self overlap. For instance, Mitchell, Macrae, and Banaji (2006) examined how perceivers make mental state inferences when the other is similar to oneself or dissimilar from oneself. Whereas mentalizing about a similar other engaged a region of ventral MFC linked to self-referential thought, mentalizing about a dissimilar other engaged a more dorsal subregion of MFC. The authors claimed that perceivers could use knowledge about themselves to infer the mental states of others and that this process might be a basic principle of social comparison processes. Also, evaluative judgements of famous names revealed greater activation in the dorsomedial and ventrolateral prefrontal cortex than non-evaluative judgements (Cunningham, Johnson, Gatenby, Gore, & Banaji, 2003).

For self-referential processes of mentalizing about particular individuals, it was shown that the ventral MFC is suppressed when self-reflections follow either an initial reflection about self or a judgement of a similar but not a dissimilar other (Jenkins, Macrae, & Mitchell, 2008). The authors suggested that thinking about the mind of another person may strongly rely on references to one's own mental characteristics. Gallagher et al. (2003) postulated that the MFC is the unique neural substrate of reasoning about representational mental states. However, Saxe (2006) claimed that the MFC is not specifically recruited for reasoning and showed that two subregions (dorsal and ventral part) of the MFC are implicated in distinct components of social cognition. The ventral MFC is involved in emotional perspective taking, sympathy, and emotional empathy. The dorsal MFC is implicated in monitoring the actions of others, sensations, and personalities, in monitoring one's own social responses and representing shared or collaborative attention and goals (Saxe, 2006). Furthermore, the dorsal MFC is also involved in judgements that combine both self and other (Ochsner et al., 2005) and it also plays a role in triadic attention (relation between me, you, and it). For example, the dorsal MFC is selectively activated while subjects play a game against another human being, versus against a computer (Rilling, Sanfey, Aronson, Nystrom, & Cohen, 2004). The authors suggested that the players probably experienced greater triadic engagement while playing against a human opponent.

Social emotions constitute other aspects of mentalizing: social interactions with other people are always emotionally connected, and we see and hear people expressing their emotions. Mentalizing helps us to identify the emotions of other people. Shamay-Tsoory, Tibi-Elhanany, and Aharon-Peretz (2007) investigated neural activation patterns of social emotions (envy or gloating), which reflect one’s assessment of the consequences of the other’s fortune. Identifying such social competitive emotions is thought to be related to perspective-taking abilities and ToM. The authors found in lesions studies that the ventral MFC is involved in understanding social competitive emotions. While the recognition of gloating (a positive emotion) was impaired in patients with lesions in the left ventral MFC and additionally in the inferior parietal lobule, the recognition of envy (a negative emotion) was more impaired in patients with lesions in the right ventral MFC.

Nevertheless, mentalizing has its limits. Studies of brain lesions (Wood, Knutson, & Grafman, 2005) and autism (Frith et al., 1999) supported the hypothesis that the capacity to mentalize depends on cognitive brain mechanisms that are potentially dedicated specifically to social reasoning.

In summary, a network of the MFC, the PCC, and the TPJ was found for ToM. The dorsal MFC is involved in monitoring others’ actions, sensations, and personalities, in monitoring one's own social responses and representing shared or collaborative attention and goals, combining self and others, and in judgements of similar others. By contrast, the ventral MFC is involved in emotional perspective taking, sympathy and emotional empathy, and in judgements of dissimilar others.

1.4 Common neural substrates

The medial frontal areas and the medial parietal areas were found to be involved in social comparisons (see 1.2), ToM (see 1.3) and in the default mode network (a network of brain areas that are active when human beings are awake but not focused on the outside world). It has been well documented that the ventral and dorsal MFC, the PCun, and the posterior lateral cortices have a high baseline metabolic activity when individuals are left to think to themselves undisturbed. These regions show a decrease in activation during cognitive tasks and goal-directed behaviours. Hence, these areas are thought to represent a ‘default-mode’ of brain function and are characterized by coherent neuronal oscillations at a rate lower than 0.1 Hz).

With respect to the overlap of activation in medial frontal and parietal areas, Buckner et al. (2007) conducted a meta-analysis comparing the activation networks of tasks concerning future perspectives, episodic memory, ToM, navigation, and default mode network, finding that they share similar brain regions especially in the MFC and the posterior cingulated cortex. All these processes rely on memory systems, because past experiences serve as the foundation for alternative perspective taking and thinking about the future. Hence, the authors postulated that all these processes are best understood as part of a larger class of functions that enables flexible forms of self-projection.

In a current meta-analysis of neuroimaging studies using activation likelihood estimation, Spreng, Mar, and Kim (2009) have shown further correspondences between autobiographical memory, prospection, navigation, ToM, and default mode. In addition to the regions (the medial-temporal lobes, medial parietal regions, and the TPJ) found in the meta-analysis of Buckner at al. (2007), Spreng et al. (2009) also found that the lateral prefrontal cortex (which potentially serves to maintain and manipulate information held online) and the occipital cortex (mental imagery processes) are involved in this common network. Furthermore, Spreng et al. (2009) showed that the lateral temporal regions are involved in autobiographical memory, prospection, and ToM. The authors ascribed this further functional correspondence in the lateral temporal regions to involvement of these regions in autobiographical memory, ToM, default mode, and prospection. Spreng et al. (2009) found similar neural activation patterns for autobiographical memory and ToM in the ventrolateral and medial prefrontal cortex, the PCun, posterior cingulate, and retrosplenial cortex, the medial-temporal region, the AMG, and regions from the TPJ, down the STS, and middle temporal gyrus (MTG) to the temporal poles. Hence the authors deduced that autobiographical memory and ToM require meta-representational abilities and therefore knowledge of the past self in relation to the present rememberer. The authors also named evolutionary reasons for believing that autobiographical memory and ToM should be functionally bound. Additionally, they argued that evolution is driven by social selection pressure and that complex social processes needed for social selection like perspective taking require the ability to remember specific social encounters and the changing social conditions which are mainly part of the autobiographical memory. The common neural activation pattern of autobiographical memory and ToM were interpreted as evidence that ToM, reasoning and autobiographical recollection are engaged during story processing (Spreng et al., 2009). Spreng et al. (2009) claimed that the involvement of the medial-temporal lobe in the core network may reflect mnemonic or relational processes and the construction of coherent scenes, events, and mental models.

In summary a core network including the MFC, medial-temporal lobes, medial parietal regions, the TPJ (Buckner et al., 2007), the lateral prefrontal cortex, and the occipital cortex (Spreng et al., 2009) were found to be activated in autobiographical memory, prospection, navigation, ToM, and default mode. As described above, most of these brain areas (the MFC, the TPJ, and the PCC) were also found to be activated in social comparison processes (1.1.2) and processes including the involvement of the self (1.2.2).

1.5 Decision making

In this paragraph decisions in general and their neural substrates (1.5.1) as well as decisions under uncertainty (1.5.2) will be described.

Decision making is the cognitive process of selecting one of two or more alternatives on the likelihood and potential value of possible outcomes. Nearly all decision making processes end in a final choice like an action or an opinion. The decision can either be easy, deciding on what to eat, or difficult, such as ethical or moral decisions. Many decisions can have important social consequences, while others may have a more limited impact on our everyday life. In cases where we have to decide on the basis of what we are actually seeing, feeling, hearing etc. we make perceptual decisions. For example: We have to decide if a person who comes across is a stranger or our boss and connect this decision with an appropriate action like greeting in a very friendly manner, just greeting or ignoring. Decisions can be based on the identification of the correct response, which is intrinsic to the external situation and is actor-independent (veridical decision making). On the other hand decisions can be actor-centered and guided by the actor’s priorities (adaptive decision making). A prediction of the expected outcome or consequence of the decision that is as accurate as possible is critical for all kinds of decision making. Optimal decisions can be made if all necessary information for the decision is available, but many decisions must be made with limited information, which are known as decisions under uncertainty (psychology) or with risk (economics).

In social comparison tasks, no matter whether we compare other persons with each other or other persons with ourselves, we give a judgement in one or the other direction. This means that we decide that one person has a higher or lower value concerning the content of the comparison. While a decision that one number is higher than another is definite, the decision that one person is more intelligent than another is ambiguous, because normally we do not have an exact value for the intelligence of a person. In this case we have to estimate the intelligence on the basis of what we know about the person, but we cannot be absolutely sure about it. Hence, we decide under uncertainty.

Schall (2001) supposed a difference between choices and decisions. In Schall's (2001) point of view, people are choosing when someone has to perform an action to reach a goal or desire because of being confronted with one or more alternatives. Choices refer to the final commitment to one alternative whereas decisions refer to the consideration about the alternatives. When confronted with familiar alternatives you can choose one of them, but when you are confronted with new alternatives you first have to understand them, the differences between them and the relations of the alternatives to your own goals, desires, and preferences, then you can decide which alternative you want. Consequently, decisions require more effort, they take more time, require attention and deliberation, and are more error prone than simple choices.

Rettinger and Hastie (2001) showed that the cover story of a decision making experiment influenced both the strategy and mental representations, by influencing the information processing that underlies the decision process. The authors conducted an experiment in which the same basic decision problem was presented with different cover stories (legal traffic tickets, academic course grades, stock market investments, and casino gambling). The expected values of the decisions were the same in all conditions. The authors defined several strategies on self-reports of participants: numerical strategies like numerical calculation, avoiding the worst (security), choosing the favourite (high aspiration) and narrative strategies like regret-focused, emotion-focused, morality-focused, and story construction. The authors showed that numerical calculations are used in all four story conditions but the other strategies vary systematically, for example morality-focused strategies were used in the legal traffic ticket condition but not in the gambling task condition and avoiding the worst was mostly used in the gambling condition.

1.5.1 Neural correlates of decision making

Recent research has delineated a number of brain areas involved in decision making processes: the dorsolateral prefrontal cortex (DLPFC) (e.g. Kim & Shadlen, 1999; Heekeren, Marrett, Bandettini, & Ungerleider, 2004), the MFC including ACC (e.g. Manes et al., 2002; Walton, Bannerman, Alterescu &

Rushworth, 2003; Fellows, 2006; Rushworth, Walton, Kennerley, & Bannerman, 2004) and the OFC (e.g. Wallis, 2007).

Goldberg and Podell (1999) explored two different types of decision making in healthy individuals and in a variety of brain damaged patients. The first type was the so-called veridical decision making condition, in which the subject was required to look at a target and make a choice between two alternatives which were most similar or different to the target. In this condition the response of the subject was unambiguously defined by the target stimulus and the instruction. The second type was an adaptive decision making condition. In this condition it was up to the subject to make the choice and there was no correct or incorrect response. The authors found no differences in the decision making performance between patients with frontal lesions and healthy people in the first condition. But in the second condition, which required an actor-centered subjective selection between two equal options, Goldberg et al. (1999) found a difference between normal healthy subjects and patients with damages in the frontal lobe. These patients tended to choose the same alternative most of the time, while healthy subjects made arbitrary selections, and likewise patients with damages in other parts of the brain. The authors claimed that these findings suggest that some parts of the brain, especially the left DLPFC, play a crucial role in selection processes of equally appropriate alternatives. The activation in the DLPFC predicted monkey's (Kim et al., 1999) and human beings' (Heekeren et al., 2004) decisions in perceptual decision making tasks. Heekeren, Marret, Ruff, Bandettini, and Ungerleider (2006) found an abstract decision making network (left posterior DLPFC, left PCC, left inferior parietal lobe (IPL), and left fusiform/parahippocampal gyrus) responding more to high- than to low-coherence stimuli independent of the motor system used to express a perceptual decision. The authors speculated that the left posterior DLPFC, which showed the greatest differences in activation, is a critical area in this decision making network and that this brain area appears to perform a comparison of signals from sensory processing areas during perceptual decision making processes. Even the decision directions in tasks requiring intentional decisions could be decoded from the neural activation of the posterior medial prefrontal cortex (Haynes et al., 2007). The DLPFC was also found to be involved in other kinds of decisions. Areas in the prefrontal cortex of monkeys were claimed to play a key role in optimizing decision-making strategies in mixed-strategy games (Barraclough, Conroy, & Lee, 2004). Frontopolar cortex and IPL were also activated during exploratory decisions (Daw, O'Doherty, Dayan, Seymour, & Dolan, 2006). The right DLPFC showed greater activity for low- than high-confidence decisions in episodic retrieval and visual perception tasks (Fleck, Daselaar, Dobbins, & Cabeza, 2006).

Activations in the MFC of human beings and monkeys (Rushworth, 2008), especially the ACC, are often found in neuroimaging studies of decision making and action selection. The ACC is involved in effective action selection when the evaluation of other individuals is important (Rushworth, Buckley, Behrens, Walton, & Bannerman, 2007) and it plays a fundamental role in relating actions to their consequences (Rushworth et al., 2004). Walton et al. (2003) claimed that the ACC is implicated in evaluating how much effort is expended for a specific reward.

In a study with patients with lesions in the OFC, Wallis (2007) suggested that the OFC plays a key role in processing rewards. The authors claimed that the OFC integrates information from other prefrontal areas regarding the reward outcome to generate the valence of a reward.

In summary, areas in the MFC, OFC, and DLPFC were found activated in many different decision making contexts. The involvement of the MFC in decision making was also investigated in lesion studies showing that lesions in the ventral MFC can be associated with strikingly poor decision making (Eslinger & Damasio, 1985; Godefroy & Rousseaux, 1995; Harlow, 1999; Ackerly, 2000; Manes et al., 2002; Fellows, 2006).

1.5.2 Decision making under uncertainty

There are two different kinds of uncertain events. First, decisions are made on the basis of judged probabilities of their possible outcomes. Those decisions under a varying level of probability are called decisions under risk. Second, sometimes the probabilities are uncertain because of missing information. In this case decisions are subject to ambiguity/uncertainty. When we compare two persons with each other or with ourselves concerning the intelligence, we normally do not know an exact value of the intelligence of the other person and/or ourselves, and we have to estimate the intelligence on the basis of our knowledge about the person. Such a judgement would be a decision under uncertainty, thus it would belong to the second category.

As mentioned in the paragraph above, the MFC has been pointed out as an important area in decision making processes. Therefore, decisions under uncertainty - as a special kind of decision making process - also involve the MFC, and human neuroimaging studies have demonstrated that decision under uncertainty evoked increased activation in dorsal MFC as compared to certain decisions (Volz, Schubotz, & von Cramon, 2003, 2004; Critchley, Mathias, & Dolan, 2001). Critchley et al. (2001) used a “nonface” card game with 0% (extreme cards) to 40% (medial cards) uncertainty of outcome, where subjects had to decide if the next card has a higher or lower value than the preceding one. Volz et al. (2003) used pairs of comic figures and let subjects judge which figure would win according to previously learned rules. In such uncertain decisions, activation was typically found in the MFC (Volz et al., 2003) and in the ACC (Critchley et al., 2001). The activation of the posterior parts of the MFC increased with increasing amount of uncertainty independent of the fact that the uncertainty is internally and externally attributed (Volz, Schubotz & von Cramon, 2005). For the internally attributed uncertainty, i.e. uncertainty of knowledge, the authors found, additional to the posterior MFC, areas in the inferior frontal junction, middle frontal gyrus (MFG), and inferior parietal sulcus (IPS) co-varying with increasing uncertainty. Patients with lesions in the ACC are impaired in behavioural control and the ability to evaluate risks involved in seeking rewards (Peru, Pavasi, & Campello, 2004; Walton et al., 2003). Van Veen, Cohen, Botvinick, Stenger, and Carter (2001) claimed that ACC is involved in the mechanisms that help control and select appropriate behaviours.

Also or especially in decisions under uncertainty the reward anticipation is a crucial process, and the direction of the decision depends on it. Hence again the OFC is involved in such decision making processes and its activation occurs with and without combination with the ACC. Numerous studies have shown that the mOFC and the ACC are critically involved in the process of evaluating and choosing between decision options when the outcomes of those decisions are unknown or uncertain (Bechara, Damasio, & Damasio, 2000, 2003; Elliott, Newman, Longe, & Deakin, 2003; Krawczyk, 2002; O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001). Critchley et al. (2001) and Walton et al. (2003) could show that activity in OFC and ACC increases with increasing potential failure of effort associated with a potentially rewarding action. These two regions also show an increasing activation when increasing the risk in decisions (Cohen, Heller, & Ranganath, 2005). In an fMRI experiment Hsu, Bhatt, Adolphs, Tranel, and Camerer (2005) found positive correlations between the levels of ambiguity in a card game and the activation in the AMG and the OFC. Lesion studies support the hypothesis that the OFC is involved in reward anticipation in decision making processes. Patients with lesions or damages in the OFC show deficits or impairments in learning optimal decision making strategies to avoid long-term monetary losses (Bechara et al., 2000, 2003). Rolls (2000, 2004) found that those patients are also impaired in adapting decision making behaviour to changes in stimulus-reward contingencies. Based on these results, the author argued that the OFC maintains stimulus-reward associations.

In summary primarily areas in the MFC and OFC are found to be activate in decision making tasks with different types of uncertainty. Especially the MFC is involved in uncertain decisions. Additionally the inferior frontal junction area, the MFG, and the IPS were activated in decision making when the uncertainty was internally attributed. Dorsal MFC was activated in uncertain decision making processes independent of the reason for the uncertainty. Areas in the OFC and the ACC are involved in ambiguity of decisions and in learning decision strategies. Furthermore, these areas are involved in different kinds of reward anticipation in uncertain and certain decisions.

1.6 Imagery of person

Comparing physical characteristics of persons may additionally involve imagining the person under comparison. If we have to decide which of two persons is taller than the other, we probably imagine the pictures of their bodies side by side to estimate the difference. This paragraph provides a short overview of mental imagery.

In everyday life, mental imagery is a frequently occurring phenomenon. Who has never imagined being on holiday at a favourite location, sitting behind the steering-wheel of a favourite car or spending time with friends? The fact that anyone knows and uses the ability to imagine (consciously or unconsciously) is expressed in a number of colloquial terms like “seeing in the mind`s eye”, ”to see with the inner eye”, “visualisation”, etc. Imagery is not only associated with fantasy and the imaginary, but also, and perhaps more importantly, with prototypically cognitive functions such as memory, perception, and thought. Mental imagery refers to the experience of a perception in the absence of an external physical stimulus – it is a quasi-perceptual experience that can take place in all sensory modalities. Imagery has best been investigated for the visual modality. The processes that are involved in generating, examining, and manipulating visual images are usually referred to as visual imagery (Kosslyn, 1996; Palmer, 1999; Richardson, 1999). Functional similarities between visual perception and visual imagery in terms of activation of common cortical regions have been demonstrated in brain imaging and psychophysical studies (Roland, Eriksson, Stone-Elander, & Widen, 1987; Farah, Peronnet, Gonon, & Giard, 1988; Goldenberg et al., 1989; Ishai & Sagi, 1997; Mohr, Linder, Linden, Kaiser, & Sireteanu, 2009). In an fMRI study O'Craven and Kanwisher (2000) reported category-related activation in the fusiform face area (FFA) and in the ventral temporal cortex during visual imagery of faces and other objects. In addition to face-selective regions, visual imagery of famous faces activated a network of brain regions – bilateral calcarine sulcus, hippocampus, PCun, IPS, and the inferior frontal gyrus (IFG) – in long-term as well as short-term memory tasks (Ishai, Haxby, & Ungerleider, 2002). Focussing on details of the imagined face revealed increased activation of IFG. Two additional regions show selective activations for specific objects. The parahippocampal place area shows category-related activation for places and houses, and the extrastriate body area (EBA) is involved in the analysis of body-related information but not in the assignment of body identity (Hodzic, Muckli, Singer, & Stirn, 2009).

Zacks, Gilliam, and Ojemann (2003a) showed in a single subject study that two classes of task-specific mental spatial transformation can be distinguished: object-based spatial transformation and egocentric perspective transformation (Zacks et al., 1999; Zacks, Mires, Tversky, & Hazeltine, 2000; Zacks, Ollinger, Sheridan, & Tversky, 2002; Zacks et al., 2003a; Zacks, Vettel, & Michelson, 2003b). Object-based spatial transformations are imagined movements of objects, such as mental rotation. Egocentric perspective transformations are imagined changes in one's viewpoint, such as imagining oneself in the position of another person. Electrical stimulation of the right parietal cortex results in interference in an object-based transformation task, while the perspective transformation task and the control for visual encoding and responding were unimpaired by the stimulation. In an fMRI study, Zacks et al. (2003b) found an increase of neural activation in the right parietal cortex and a decrease in the left parietal cortex in an object transformation task, where subjects had to rotate images mentally. On the other hand, the authors found an increase in the left temporal cortex in a perspective transformation task, in which subjects had to imagine themselves rotating around the array of objects. Additionally to secondary visual, premotor, and frontal lobe regions, the left posterior parietal lobe was found to be the most significant area in a self-rotation task (Creem et al., 2001).

In summary, visual imagery results in the activation of category-selective visual areas (FFA, PPA, and EBA). Additionally, several medial and lateral parietal areas were found to be activated in diverse visual imagery tasks and show differences in spatial transformation, egocentric perspective transformation, and object-based transformation.

1.7 Focus of interest

Regardless of their remarkable psychological importance, little is known about the neural substrates of person comparison. This thesis was designed to fill this gap and delineate how, on a neural level, person comparisons (social comparison processes on specific person characteristics) differ from non-comparative person judgements. It is still unclear if different types of person comparison call on different neural resources. For example, do comparisons on physical or psychological dimensions rely on the same neural mechanisms? A second principal aim of the experiments underlying this thesis is to find an answer to this question. Moreover, we are interested in the involvement of the self and its neural substrates in such social comparison tasks. Last but not least, the neural basis of decision directions in these social comparison tasks are a focus of interest here.

In the first fMRI study, we investigated the neural correlates of comparative and non-comparative judgements on the same person material, where comparative judgements were made on both psychological and physical dimensions. In this experiment subjects had to give judgements when comparing two other persons with each other (Other vs. Other Comparison, referred to as OOC in the further text). We expected that the comparative and non-comparative social judgements in our tasks required different degrees of mentalizing/perspective taking, decisions under different levels of uncertainty, mental imagery, and autobiographical memory. Based on the results described earlier, we expect differences between comparative and non-comparative judgements in the areas of the core network described above and in decision- and imagery-specific areas. In addition, we expected ToM areas to be more activated during intelligence comparisons because the comparison of psychological characteristics (intelligence) involves taking the person’s own perspective into account.

In the second fMRI study, we focused on the comparative judgements when subjects had to compare other persons with themselves (Self vs. Other Comparison, referred to as SOC in the further text). In this experiment we expected differences in the activation patterns between the two dimensions of comparative judgements to be similar to the first experiment.

In the third fMRI study, we compared the SOC and the OOC. Additionally, we focused on the differences in the neural pattern of the decision directions. Here we expected the neural activation pattern of the MFC to differ in relation to the different involvement of the self. We further expected the decision directions to show differences in the MFC and the reward anticipation related areas in the OFC.

Further details about the hypotheses of these three experiments are described in the short introduction to the experiments.

2. Experiment 1[1]

2.1 Introduction

In the first fMRI study, we contrasted comparative and non-comparative judgements on the same person material, and comparative judgements on psychological and physical dimensions. Participants were presented with names of two celebrities from sports, politics, entertainment or music. In the non-comparative judgement, participants had to decide whether one of the two celebrities was a musician (or politician). In the two comparative judgements participants were to decide which of the two celebrities was more intelligent and which celebrity was taller (**O**ther vs. **O**ther **C**omparison - OOC). We hypothesized that in comparative person judgement, along with the activation of regions representing semantic person knowledge, comparison specific brain activities should be found. In addition, the use of both psychological (intelligence) and physical (body height) person characteristics in the comparison tasks enabled us to probe our hypothesis of different degrees of activation of the ToM network with different levels of perspective taking. We expected that participants would need to mentalize to a higher degree when comparing intelligence rather than body height. As argued above, a comparison of psychological characteristics involves taking the persons' own perspective into account, whereas the comparison of physical characteristics can be based on evoking mental images of the individuals concerned from long-term memory. As a consequence, ToM areas should be more activated during intelligence comparisons. Our design thus entailed a comparison task with different degrees of perspective taking and a purely semantic non-comparative task as control condition. We did not try to include a control condition with a social but non-

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[1] Parts of this experiment were published in: Lindner, M., Hundhammer, T., Ciaramidaro, A., Linden, D.E. & Mussweiler, T. (2008). The neural substrates of person comparison - An fMRI study. Neuroimage, 40(2), 963-971.

comparative task (e.g., how intelligent is X?), because comparisons are spontaneously engaged even if a person characteristic is judged without explicitly asking for comparison (Dunning et al., 1996; Mussweiler et al., 2004).

2.2 Methods

2.2.1 Participants

Fourteen healthy male, right-handed participants were recruited from an academic environment (mean age 27.93 years, SD 4.67). The Ethics Committee of the Medical School of the Johann Wolfgang Goethe University approved of the study. Written informed consent was obtained from all participants prior to scanning.

2.2.2 Stimuli

Prior to the first fMRI experiment the surnames of 100 celebrities had been tested in a separate study for 100% familiarity on N = 20 male students by the research group of Prof. Mussweiler. (This rating was not part of my thesis.) Only 47 celebrities which were rated as familiar from all students (see Appendix 9.1) were made available for the usage as stimuli in this first fMRI experiment.

A set of 64 pairs of surnames of these 47 celebrities served as stimulus material. Pairs of names were presented in white font (font type: Arial, height: 4.6°) against a black background above and below the centre of the screen. The distance between centre of word and centre of screen was 4.4°. The four cue stimuli had the same colour and font size. Stimulus presentation and recording of response time was controlled by the Presentation 0.9 software (Neurobehavioral Systems, Inc.). During scanning, the computer display was projected onto a mirror mounted on the head coil.

2.2.3 Procedure

The two experimental conditions required comparative judgements on intelligence or body height. Participants had to decide which of the two persons whose name appeared on the screen was more intelligent or taller. In the control conditions participants had to indicate whether the stimulus pair included the name of a musician/politician. In all three conditions, participants were asked to respond as quickly as possible by using a two button fiber-optic response box.

Participants performed the experiment while undergoing fMRI. We used an event-related design. In event-related designs, single stimuli or trials are presented with an appropriate inter-trial interval (ITI). The ITI is necessary for the relaxation of the BOLD signal. Hence, event-related designs allow the description of the neural activation patterns which are induced by the single trials or stimuli.

The experiment was divided into two runs of approximately 17 minutes. Each run started with a 20 s instruction on key-assignment, followed by 64 trials (16 per condition) in a pseudo-randomized order. Each trial began with one of four cues (see Fig. 3) indicating the task instruction, presented for 1000 ms at the centre of the screen. After the cue had disappeared, an “x” was displayed as a fixation point for 1000 ms, a pair of stimuli followed for 1000 ms. The ITI was 10 s (see Figure 3). The experiment was preceded by a training session with eight trials serving to familiarize participants with the timing of the task and the response box.

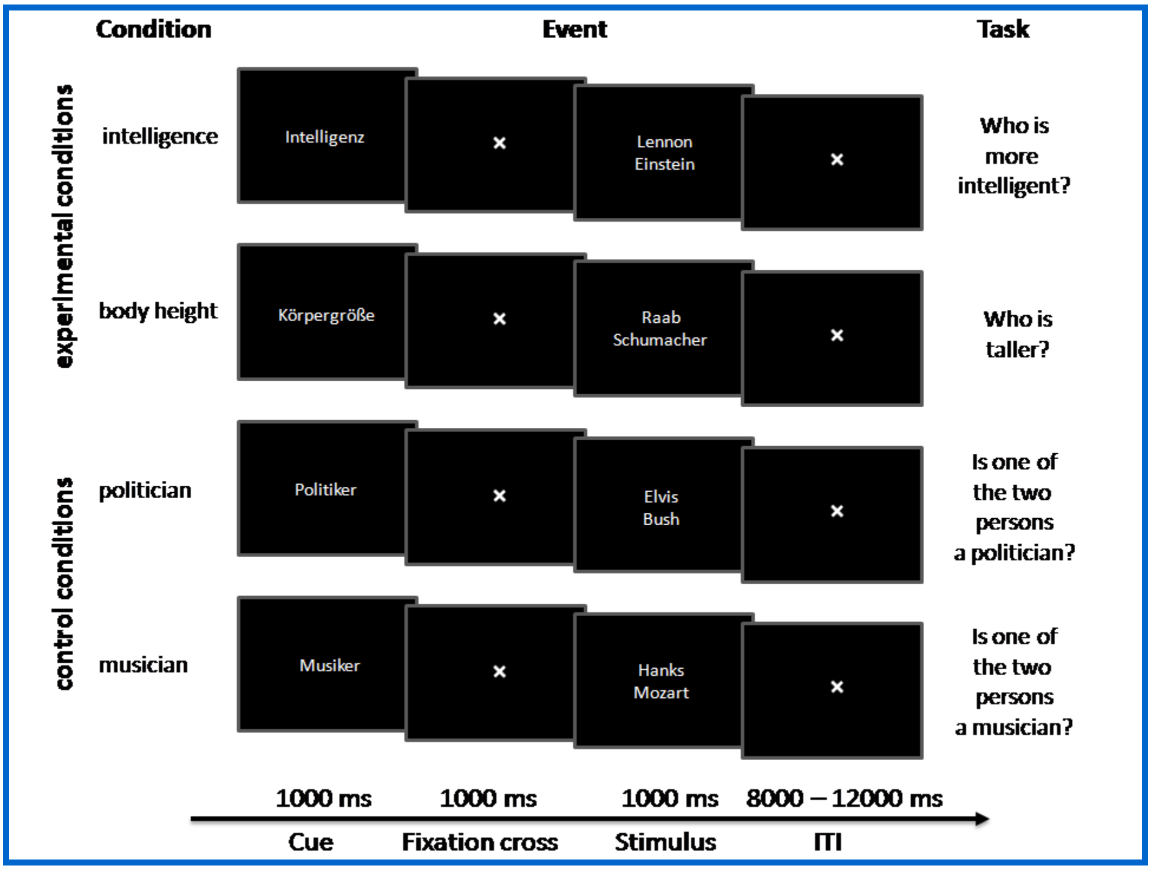

Figure 3: Paradigm design. Four different tasks containing two experimental conditions (body height and intelligence comparison) and two control conditions (musician/politician). Each trial began with the presentation of a cue (1000 ms), followed by a fixation point (1000 ms) and a pair of stimuli (1000 ms). After 10 s (ITI) a new trial began. In the experimental conditions subjects had to decide which person, indicated by the names, was taller or more intelligent. In the control condition they had to decide whether a politician or musician was presented.

2.2.4 Imaging procedure

We collected whole-brain MRI data on a 3T TRIO Magnetom (Siemens, Erlangen, Germany). We acquired echo-planar imaging data for fMRI using standard parameters (field of view, 200 mm; matrix: 64 x 64; 1 volume = 16 axial slices, 5mm slice thickness; in-plane resolution, 3.128 mm; repetition time (TR): 1000 ms, echo time (TE): 30 ms; flip angle: 60°; 1006 volumes per run).

We synchronized stimulus presentation with the fMRI sequence at the beginning of each trial, and acquired four dummy volumes before each run in order to reduce possible effects of T1-saturation. To minimize head motion, we used fixed head pads. We obtained a T1 weighted 3D anatomical scan (1x1x1 mm^3 resolution) for each participant.

2.2.5 Data analyses

We pre-processed and analyzed the fMRI using BrainVoyager^{TM} QX (Brain Innovation, Maastricht, The Netherlands), applying the following pre-processing steps: slice-time correction, motion correction, linear trend removal, highpass temporal filtering with 3 cycles in time course and spatial smoothing using a Gaussian kernel of 8mm full-width at half-maximum. We manually coregistered the fMRI data with the anatomical scans. We transformed the 3D anatomical scans into Talairach space (Talairach & Tournoux, 1988) and subsequently used the parameters for this transformation to transform the coregistered functional data. We then re-sampled the 3D functional data set to a voxel size of 3x3x3 mm^3.

For the statistical analyses the physiological time course of the BOLD signal change of each voxel represents the dependent variable. The variance of the BOLD time-course is analyzed in dependence of the stimulation protocol, which consists of a set of predictors. Each voxel time course of the BOLD signal changes is correlated with a respective reference time course in simple correlation maps, measuring similarities between the physiological changes of the BOLD signal and the a priori conducted reference function, based on the stimulation protocol.

For the stimulation protocol we defined each of the four conditions of the experimental design as a predictor. Owing to technical problems with the fiber-optic response pad, reaction times were partly recorded by button press, and partly by button release. We were consequently unable to define the predictors individually in milliseconds, which would be preferable. Hence, we determined the length of the predictors by assuming a trial duration of one volume (1s) following stimulus onset. All cues and the following fixation points were set as a fifth (2 s per event) and the instruction as a sixth predictor (10 s). The remaining fixation volumes served as baseline. We convolved the predictors with a two-gamma hemodynamic response function (HRF) in order to consider for the hemodynamic response of the measured BOLD signal (Boynton, Engel, Glover, & Heeger, 1996). The typical shape of the two gamma HRF is shown in Figure 4.

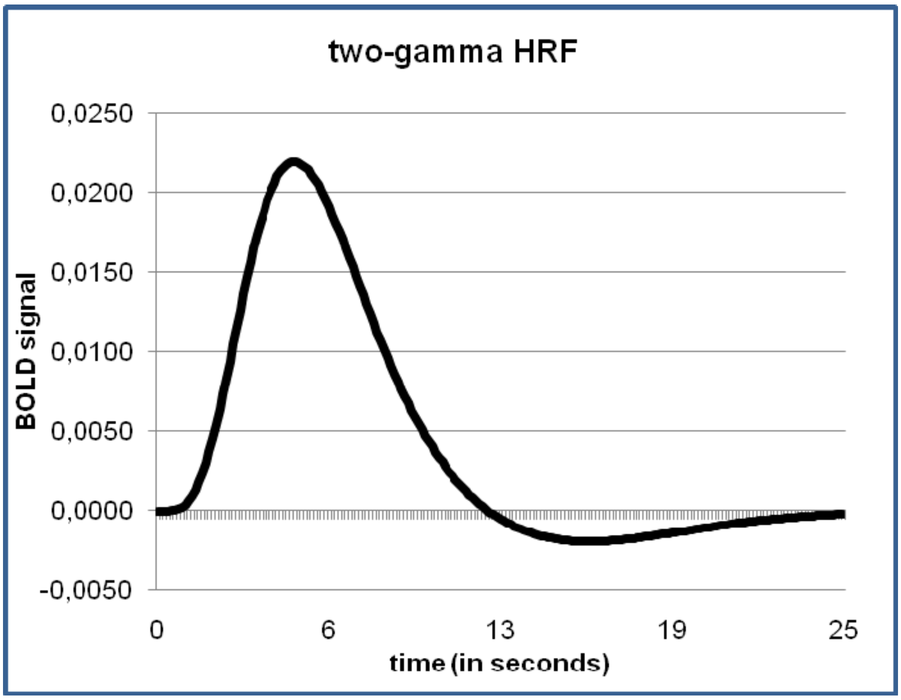

Figure 4: typical shape of a two-gamma hemodynamic response function (HRF)

The principle of computing linear correlations between a set of hypothesis driven predictors and physiological signal change represents an application of the general linear model (GLM). This kind of application of the GLM and respective statistical analyses was introduced by Friston et al. (1995) for the first time. GLM turns out to be a statistical analysis that is highly flexible in analyzing multi-factorial design by determining the contribution of a defined set of predictors to the explanation of the BOLD signal variance. For this reason the statistical analysis of the variance of the BOLD signal was based on applying multiple regression analysis of the time series of task related functional activation. Within multiple regression analyses, a β-value is calculated for each predictor, and for each voxel time course. On the basis of these β-values, comparisons and contrasts between predictors or sets of predictors were calculated.

Because subjects were treated as fixed effects in the standard GLM analysis, the significant results are strictly speaking only valid for the measured and analyzed group. For generalization of the obtained fMRI results to the population level, a random effects (RFX) analysis has to be performed. In this RFX, the sample of subjects is treated as a random selection from the population. Hence we computed a whole-brain RFX-GLM for group data from 28 (2 for each subject) z-normalized volume time courses.

We implemented comparisons of interest as linear contrasts. To find discrete local activation maxima in a large cluster, we identified voxels with minimal p-values in sub clusters of voxels with p<0.0001. Around that putative activation maximum we defined a box with edge lengths of 10 voxels.

In the second step of analyses we investigated differences between the two types of comparison. Therefore we defined all significant voxels of the whole-brain RFX-GLM as a mask and performed a second RFX-GLM only for the masked regions. Here we contrasted the two experimental conditions versus the control condition separately and the two comparison conditions against each other.

We used the False Discovery Rate (FDR) for correction of multiple comparisons of the whole-brain RFX-GLM as for the masked RFX-GLM. The results of the GLMs were then projected on the standard brain of the Montreal Neurological Institute (MNI).

2.3 Results

2.3.1 Behavioural data

Reaction times were highest for intelligence comparison 2125 ms (standard deviation (SD)= 656), followed by body height comparison 1921 ms (SD= 507) and the control condition 1543 ms (SD= 433). Reaction times revealed significant condition effects for comparison vs. control conditions (t (13) = 13.13, p<.0001), intelligence vs. body height comparison (t (13) = 12.101; p<.0001), and intelligence comparison vs. control condition (t (13) = 12.101; p<.0001) (see Figure 5).

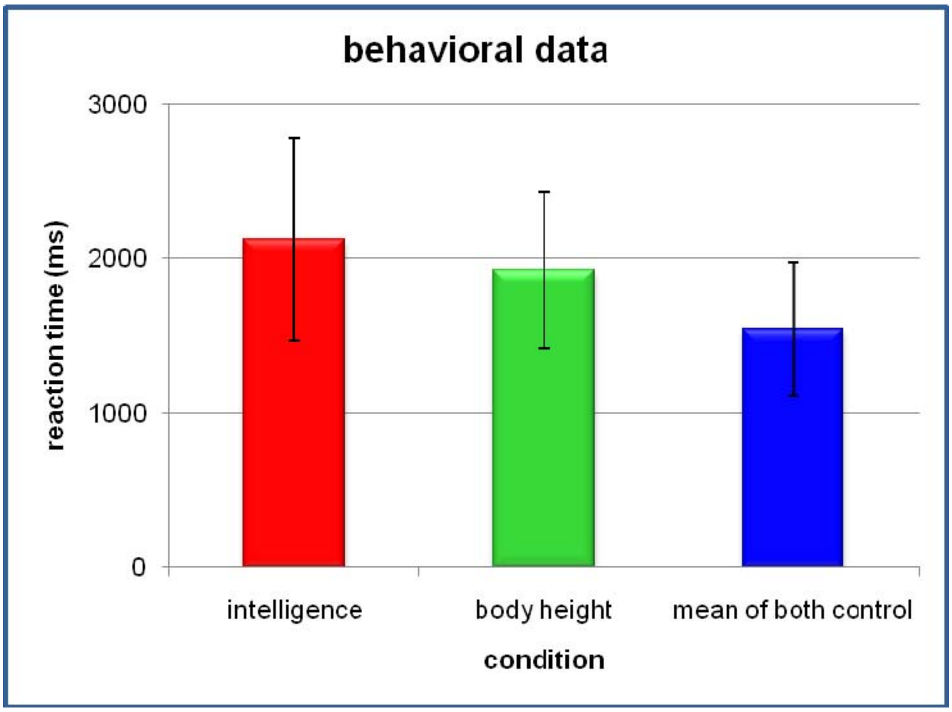

Figure 5: Reaction times: mean reaction times of intelligence comparison (left) and body height comparison condition (centre). The reaction times of the two control condition were averaged (right). Error bars represent standard deviations of means.

2.3.2 fMRI data

We used RFX-GLM for whole-brain and masked RFX-GLM analyses. Maps of both RFX-GLM were thresholded at a FDR < .05 and included only clusters exceeding a cluster size threshold of 50 voxels.

2.3.2.1 Whole-brain GLM

Contrast comparison versus control condition

The t-map for the contrast between comparison and control condition was thresholded at a FDR < .05. Several areas emerged in this contrast with significantly higher activation for the comparison condition, including posterior portion of the right rostral medial frontal cortex (prMFC), left and right TPJ (TPJ), and left and right PCC (see Figure 6 and Table 1). Furthermore, this contrast showed a higher activation for comparison in left and right OFC, right frontal operculum (FO), left and right posterior hippocampus (pH), left AMG, left and right globus pallidus (GP), left MTG, right anterior middle temporal gyrus (aMTG), right occipital gyrus (OcG), and left part of substantia nigra (SN). The comparison conditions additionally revealed a higher activation of a large bilateral cluster in the medial prefrontal cortex including seven discrete local maxima. These maxima were left and right anterior paracingulate cortex (APCC), two areas in the left prMFC, an area in the anterior portion of the rostral medial frontal cortex (arMFC), and two areas in the mOFC. A significantly higher activation for the control condition than for comparison was only observed in left and right IPL and left MFG. Time course plots of some areas are shown in Figure 7. In summary, a network of medial prefrontal, parietal, and limbic areas seems to be recruited for comparing person characteristics.

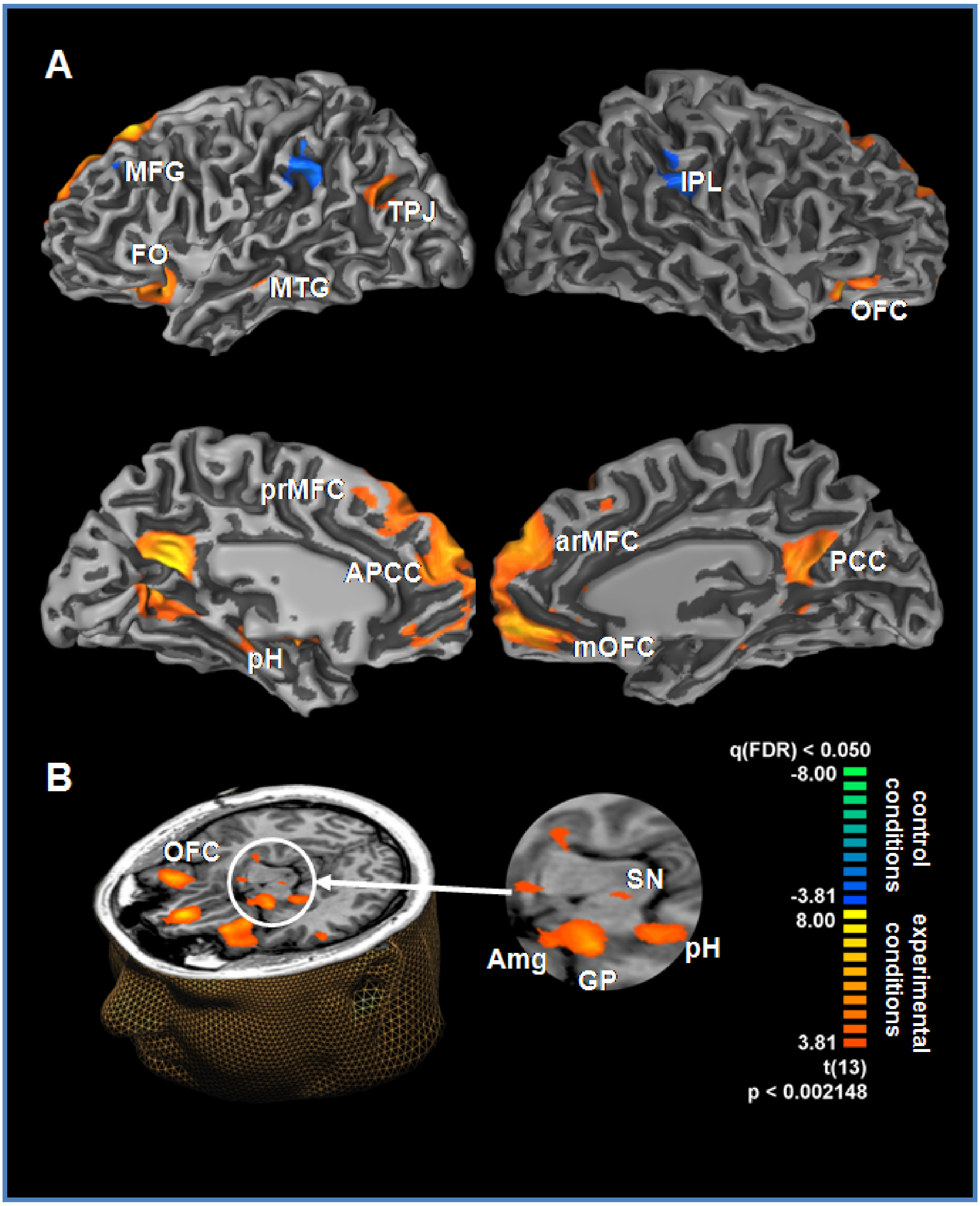

Figure 6: (A): Group analysis of whole-brain GLM. Superposition maps (left: left hemisphere; right: right hemisphere; Top: lateral view; Bottom: medial view) of the contrast between comparison and control condition. Higher activation for comparison is shown in orange and for control condition in blue. Effects were only shown if the associated p-value yielded $p<0.01$ (corrected for multiple comparisons with FDR). The 3D statistical maps were then projected on the folded surface reconstruction of the MNI template brain. Bilateral areas: arMFC, rMFC, TPJ, PCC, OFC, pH, mOFC. Left lateralized areas: FO and MTG, (B): Coronal slice showing areas which are not projected on folded brains in A (left Amg, bilateral pH, left SN and bilateral GP). Additionally a magnification of the activations in the brain stem is presented.

Table 1: Talairach coordinates, Brodmann areas (BA) and statistical details (cluster size, averaged t-values, and p-values for the cluster) of whole-brain RFX-GLM for areas with significant difference for the contrasts between experimental conditions vs. control conditions after correction for multiple comparisons with FDR (α<.05).

Regions	**Left/ Medial/ Right**	**Talairach coordinates**			**BA**	**Cluster size (voxel)**	**t(avg)**	**p-value**
		x	**y**	**z**				
Comparison > contol								
medial frontal cortex large bilateral cluster with 8 local maxima						30518		
- prMFC	L	-11	29	50	8		5.49588	p < 0.01
	L	-12	48	42	9		6.35006	p < 0.01
	R	19	34	45	8/9		4.36786	p < 0.01
- arMFC	L	-13	56	33	9		5.62926	p < 0.01
- mOFC	M	0	42	-8	11		6.21955	p < 0.01
	R	2	56	-3	11		5.91280	p < 0.01
- APCC	R	2	56	22	10		5.37478	p < 0.01
	L	-3	45	18	10		4.99269	p < 0.01
prMFC	R	17	46	45	8	110	4.03567	p < 0.01
APCC	R	2	32	11	10	49	3.94537	p < 0.01
MTG	L	-60	-17	-8	21	251	4.11598	p < 0.01
aMTG	R	56	-3	-11	21	34	3.91401	p < 0.01
TPJ	L	-45	-63	25	39	1328	4.59237	p < 0.01
	R	50	-62	30	39	655	4.12683	p < 0.01
MFG	L	-26	20	52	8	13	4.04457	p < 0.01
pH	L	-23	-24	-7	35	805	4.31160	p < 0.01
	R	25	-24	-9	35	218	3.95269	p < 0.01
Amg/GP/hippocampal head	L	-12	-5	-7	38	1562	4.52466	p < 0.01
GP	R	10	-4	-4		767	4.35991	p < 0.01
OFC/FO	L	-32	24	-8	11/44	5888	4.61342	p < 0.01
OFC	R	32	30	-6	11	3292	4.77588	p < 0.01
SN	L	-4	-12	-10		92	3.89671	p < 0.01
medial pulvinar nucleus	L	-6	-25	1		35	3.86608	p < 0.01
OcG	L	-9	-84	0	17	18	3.88615	p < 0.01
	R	11	-87	2	17	157	4.03777	p < 0.01
PCC	L/R	-1	-52	15	31	13757	5.10908	p < 0.01
Control > Comparison								
IPL	L	-56	-34	33	40	2097	-4.2472	p < 0.01
	R	55	-34	31	40	1900	-4.1284	p < 0.01
MFG	L	-33	36	37	9	65	-3.9477	p < 0.01

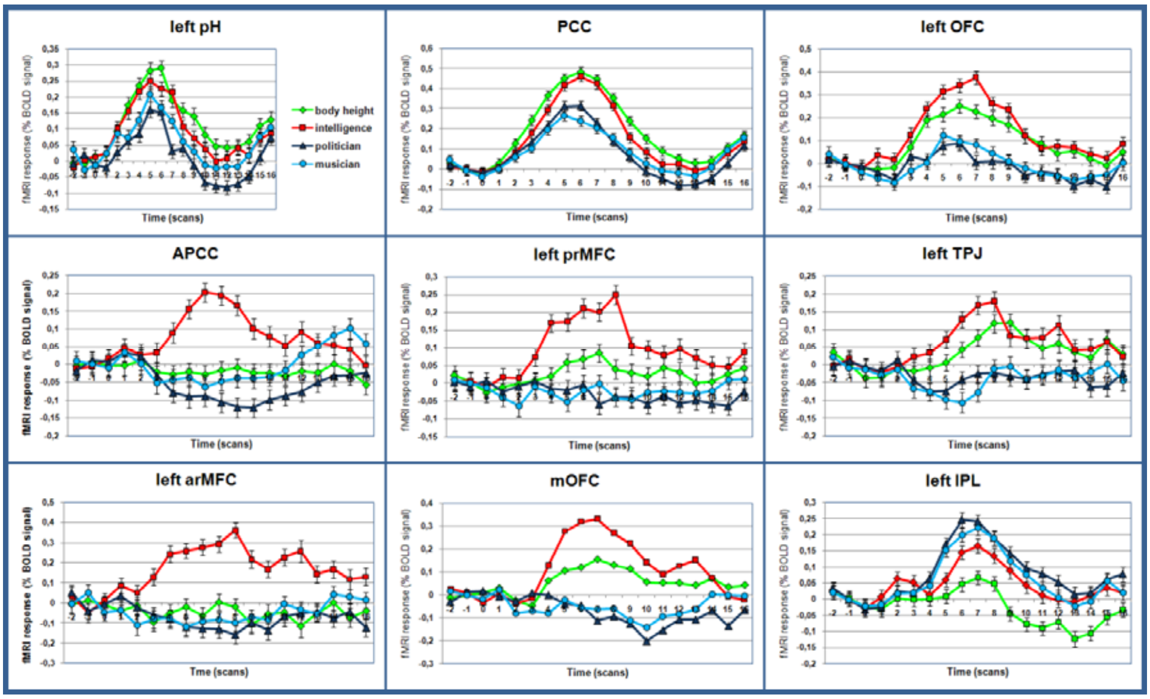

Figure 7: BOLD time courses for all conditions (red=intelligence comparison, blue=body height comparison, dark and bright green=control conditions). Top: areas showing significant differences in comparison versus control (left pH, left PCC, and left OFC); center and bottom left and right: areas showing significant differences in intelligence comparison versus control and in intelligence versus body height comparison (center: left APCC, right prMFC, and left TPJ; bottom: left arMFC and mOFC); bottom right: left IPL showed significantly higher activation for control condition in contrasts intelligence comparison versus control condition and body height versus control condition. Error bars indicate the standard errors.

2.3.2.2 Masked RFX-GLM

In several areas with higher activation for the comparison condition, the time courses of the BOLD showed higher peaks in the intelligence than in the body height comparison condition (see Figure 7). This indicated that, although some neural processes are common to physical and intelligence comparison, the latter may draw on additional neural resources. Therefore, in order to examine the influence of the two comparison conditions separately, we computed a masked GLM including only all significant voxels of the regions of interest (ROI) of the whole-brain GLM (see Table 1). For the following contrasts we used a statistical threshold at a FDR < .05.

Intelligence comparison versus control condition:

All of the areas showing significant differences in the contrast between comparison and control conditions of the whole-brain RFX-GLM also revealed a significant difference in the masked RFX-GLM contrast between intelligence comparison and control condition.

Body height comparison versus control condition:

Relative to the control condition, body height comparison yielded a significant difference of activation in all areas showing significant differences in the whole-brain RFX-GLM. A significantly higher activation in the control condition was again observed bilaterally in the IPL.

Intelligence versus body height comparison:

Contrasting intelligence versus body height comparison revealed significant differences in activation in most of the areas (entire areas or at least portions of them) of the whole-brain RFX-GLM. Significantly higher activation for the intelligence comparison was found in most of the areas including left and right prMFC, left arMFC, mOFC, left APCC, left PCC, left MTG, right aMTG, bilateral TPJ, left FO, right OFC, left GP, and left and right SN. Only the bilateral IPL showed a significantly higher activation for body height comparison in this contrast (see Figure 8 and Table 2). As expected, these differences between the two comparison conditions included classical ToM areas.

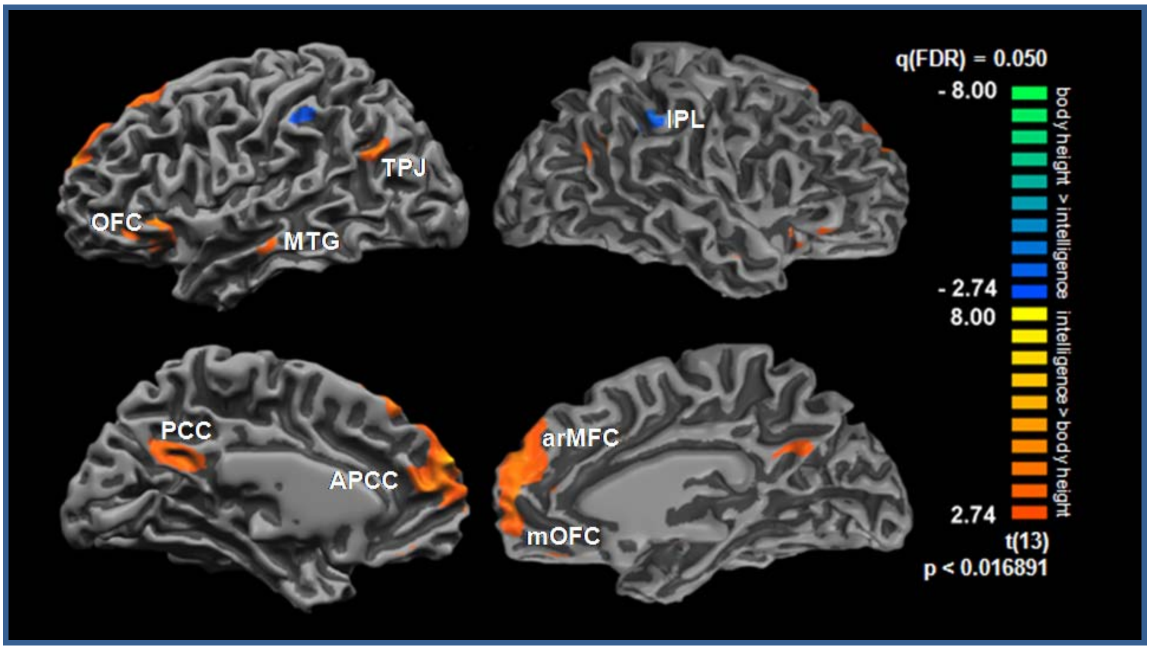

Figure 8: Group analysis with masked RFX-GLM. Superposition maps (left: left hemisphere; right: right hemisphere; Top: lateral view; Bottom: medial view) with areas of masked GLM coloured for significant differences between intelligence and body height comparison. Higher activation for intelligence comparison is shown in orange and for body height condition in blue. Effects were only shown if the associated p-value yielded $p<0.05$ (corrected for multiple comparisons with FDR). The 3D statistical maps were then projected on the folded surface reconstruction of the MNI template brain. Areas: prMFC, arMFC, OFC, mOFC, FO, APCC, PCC, TPJ, and IPL.

Table 2: Talairach coordinates, Brodmann areas (BA), and p-values of masked RFX-GLM for areas that showed a significant difference for the contrasts between intelligence and body height comparison.

Regions	**Left/ Medial/ Right**	**Talairach coordinates**			**BA**	**Cluster size (voxel)**	**t(avg)**	**p-value**
		x	**y**	**z**				
Comparison >Control								
medial frontal cortex large bilateral cluster with 6 local maxima						23872		
- prMFC	L	-10	37	53	8		4.17835	p < 0.01
- arMFC	L	-9	54	41	9		3.88115	p < 0.01
- mOFC	M	0	57	4	11		3.59385	p < 0.01
	M	0	41	-9	11		3.13956	p < 0.01
- APCC	L	-2	56	23	10		4.68213	p < 0.01
	L	-2	45	14	10		4.26309	p < 0.01
prMFC	R	15	32	51	8	489	3,34104	p < 0.01
	R	14	45	47	8	25	2.80987	P < 0.05
MTG	L	-63	-19	-8	21	123	3.10767	p < 0.01
aMTG	R	60	-3	-16	21	7	2,94533	p < 0.01
TPJ	L	-45	-61	28	39	790	3.57199	p < 0.01
	R	52	-61	29	39	858	3,82617	p < 0.01
FO	L	-40	25	-6	44	3350	3,36472	p < 0.01
OFC	R	31	30	-8	11	251	3,05594	p < 0.01
	R	45	31	-5	11	156	3,00819	p < 0.01
SN	L	-7	-8	-6		154	2,96903	p < 0.05
	R	9	-10	-8		22	2,94409	p < 0.01
	L	-5	-22	-13		89	3,14278	p < 0.01
GP	L	-14	-3	-1		10	2,82929	P < 0.05
PCC	L	-3	-52	27	31	2701	3,17537	p < 0.01
Control > Comparison								
IPL	L	-54	-33	42	7	222	-2,9529	p < 0.01
	R	54	-37	38	7	369	-3,3224	p < 0.01

2.4 Discussion

The network of brain areas that are active during person comparisons seems to differ from that involved in comparisons of non-person stimuli, like numbers, or the size and luminance of physical objects (Cohen-Kadosh et al., 2005; Pinel et al., 2004), which mainly comprises parietal and dorsolateral prefrontal areas. Conversely, the tasks of person comparison discussed here were accompanied by activation in several medial frontal, orbitofrontal and limbic areas, and the TPJ. The activation of this network was largely driven by the comparison of mental characteristics (intelligence), with significantly higher activation for intelligence than height comparison in several areas in MFC. As expected, there was a striking overlap of the person comparison network and the one commonly described for classic ToM tasks. The difference between the activation pattern in these person comparison tasks and that observed during size comparisons of inanimate objects may at first seem surprising, because both classes of comparisons can be conceptualised as judgements of magnitudes (numerical values of intelligence quotients or body height in the case of the person comparisons). However, both our person comparison tasks differed from standard physical and numerical comparison tasks in two main respects. First, participants had to draw on their knowledge about the celebrity in question because they were unlikely to have specifically thought about their height or intelligence beforehand. Second, the participants could not be certain of the right answer. We would propose that the second characteristic of the task constituted a similarity to other tasks where participants have to make an active decision under uncertain conditions, whereas the first contributed to the engagement of areas involved in perspective taking and ToM. Several studies of decision making processes in ambiguous or otherwise uncertain situations have described the activation of several of the medial frontal and orbitofrontal areas that were also activated by our comparison tasks, including prMFC, arMFC, mOFC, and OFC (Manes et al., 2002; Bechara et al., 2000; Fellows & Farah, 2007; Haynes et al., 2007). OFC has traditionally been implicated in reward and punishment tasks (Rolls, 1996). Amodio et al. (2006) suggest that the OFC guides behaviour in terms of the value of possible outcomes.

Considering the processes participants had to engage in when solving the comparison tasks, it seems only plausible that areas were activated that typically are involved when facts and arguments are generated, retrieved, weighed, and integrated. Indeed, process models of comparison (Mussweiler, 2003) have emphasized that comparison and decision making involve similar psychological processes. The brain activation pattern observed here provides converging evidence for the procedural similarity between comparison and decision making mechanisms. In accordance with our hypothesis, we found most of the areas that constitute the classical brain network for ToM tasks to be activated during the comparison tasks. These included the TPJ bilaterally, the anterior paracingulate, and dorsomedial prefrontal cortex (Baron-Cohen et al., 1999; Berthoz, Armony, Blair, & Dolan, 2002; Brunet et al., 2000; Calarge, Andreasen, & O'Leary, 2003; Calder et al., 2002; Castelli, Happe, Frith, & Frith, 2000; Fletcher et al., 1995; Gallagher et al., 2000; Gallagher, Jack, Roepsdorff, & Frith, 2002; McCabe, Houser, Ryan, Smith, & Trouard, 2001; Saxe et al., 2003; Vogeley et al., 2001; Walter et al., 2004). ToM research so far has demonstrated that people are most likely to mentalize in situations where their own outcomes depend on other intentional agents (Gallagher et al., 2002; Rilling et al., 2004). Our paradigm is different in that person targets are only mentioned via their name, without any further behavioural information, no interaction is anticipated and there is no direct prompt to try and take their perspective or read their minds. The neural evidence for the activation of ToM that can be derived from the present study may indicate that automatic processes of mentalizing occur in social judgements. Social judgements often involve a spontaneous activation of relevant self-knowledge (Dunning et al., 1996), which in turn has been linked to perspective taking activities (Davis, Conklin, Smith, & Luce, 1996; Galinsky & Moskowitz, 2000). At the same time, our findings suggest that there are clear limits to mentalizing: Specifically, simple categorization tasks like answering questions about the profession of a person do not seem to activate a ToM network.

We did not find any comparison-specific activation in the region around the posterior superior temporal sulcus (pSTS), which is a key component of the putative ToM network. Recent research has implicated the pSTS in the understanding of intentional actions (Pelphrey, Violy, & McCarthy, 2004;

Schultz, Imamizu, Kawato, & Frith, 2004; Saxe, Xiao, Kovacs, Perrett, Kanwisher, 2004; Zacks et al., 2001), the interpretation of goal-directed movements of a human body (Grosbras & Paus, 2006) and the indirect observation of the effects' actions (Ramnani & Miall, 2004). However, we did find activity in TPJ, which seems to be selective for attributions of mental states (Saxe et al., 2003; Saxe & Powell, 2006). Damage in TPJ causes selective deficits in judging the contents of others' beliefs (Samson et al., 2004). In a study of personal characteristics, Mitchell et al. (2002) found activation in TPJ for the person judgements "assertive, energetic, nervous" but not for judgements on objects. The reason that we see activation of TPJ, but not STS, thus seems to be that participants made attributions of mental states, but there was no element of comprehension of goal directed actions where the recruitment of pSTS would have been fundamental.

We found different degrees of activation of the ToM network for comparisons of psychological characteristics (intelligence) versus physical characteristics (body height). When comparing two persons concerning their intelligence, for example, participants have to understand other people's behaviour in terms of their mental states, that is, they have to mentalize. This is the case because judgements about psychological characteristics are inherently subjective. The intelligence of a person, for example, cannot be read off directly. Rather, it has to be inferred from the behaviours and utterances of this person. Conversely, comparisons of physical characteristics of a person are more similar to judging inanimate objects (Mitchell et al. 2002), and accordingly we found less activity in ToM relevant areas in the body height comparison condition, particularly in prMFC. The neural network involved in person comparisons thus appears to vary flexibly according to the ToM required for the dimension of comparison. This finding is also consistent with recent evidence demonstrating that MFC is specifically involved in judgements about psychological states (Mitchell, Banaji, & Macrae, 2005).

Our behavioural data can also be tentatively interpreted as being consistent with the assumption that person judgements about psychological characteristics involve more mentalizing activities. Specifically, the fact that judgements about psychological characteristics of others took longer than judgements about their physical characteristics may be attributed to the added cognitive effort that mentalizing entails. Clearly, however, a variety of other psychological mechanisms may also contribute to this difference in processing time. For example, people tend to define psychological characteristics in a self-serving manner (Dunning & McElwee, 1995). In the present context, this implies that participants may have attributed a particular weight to their own strengths when constructing the definition of intelligence that builds the basis for their judgements of others. More generally speaking, ascribing a psychological characteristic to a person requires sophisticated attribution processes concerning the links between behavioural manifestations and potential causes (Kelley, 1973). This does not apply to physical characteristics, which can be more readily ascertained. As is true for mentalizing, such self-serving constructions of the critical characteristic as well as such attribution processes require an additional cognitive effort which ultimately leads to longer processing times. In light of this ambiguity, our behavioural data should only be interpreted in conjunction with the fMRI data. The bilateral IPL was the only region with higher activation in the control condition. IPL activity has consistently been implicated in semantic categorization, which is the core cognitive process required in the control task. However, many of the other areas found in the literature for semantic categorization (Devlin et al., 2002; Grossman et al., 2002; Koenig et al., 2005) were not differentially activated, probably because the comparison tasks, as well, required some degree of semantic categorization. The present findings have interesting implications for psychological research on social cognition and social judgement. Comparisons on all levels of complexity involve similar psychological mechanisms, many researchers assume (Kahneman & Miller, 1986; Mussweiler, 2003). The present findings, however, suggest that comparison activities may be more multifaceted. First, person and non-person comparisons seem to involve different neural activation patterns and hence probably different psychological processes. Second, person comparisons along psychological vs. physical dimensions involve different levels of perspective taking. These findings suggest that a more detailed analysis of the psychological mechanisms underlying comparisons may be required. In principle, this analysis may lead to one of two conclusions: One possibility is that different types of comparison involve the same core mechanism of knowledge activation that has been identified in previous research (Mussweiler, 2003), but this mechanism is supplemented by different comparison-specific mechanisms such as mentalizing. Alternatively, no such common ground may exist, and different psychological processes underlie different types of comparison (e.g. person vs. non-person comparisons).

There are some critical points and problems in this study:

One possible limitation of the present design is that we did not independently manipulate comparison and mentalizing requirements. However, a great deal of evidence demonstrates the ubiquity and inevitability of comparison processes in social judgements (e.g., Dunning et al., 1996; Gilbert et al., 1995; Mussweiler et al., 2004). This suggests that it is impossible to construct a control condition requiring mentalizing but no comparison. If two processes cannot be dissociated on theoretical grounds, the design chosen here with a graded manipulation of the function in question, the mentalizing requirement in person comparison, is appropriate and it still allows for isolating the specific effects of the manipulated function. This research explored the neural substrates of person comparison — one of the most basic psychological tools that are used to judge ourselves and others. The considerable overlap between the activated areas and the networks commonly observed for ToM (medial prefrontal areas and TPJ) and emotion- and value based decision making (OFC, limbic areas) was the key finding of this study. Within the limitations of reverse inference (Poldrack, 2006), this finding suggests that person comparisons involve perspective taking, especially when psychological dimensions are concerned.

Second, one might argue that we should have used a 2x2 factorial ANOVA to analyse the data but despite two experimental and two control conditions, we do not have a complete 2x2 design. Even though our design comes very close, it is not perfectly factorial, and we decided on performing separate GLMs instead of a 2 factorial ANOVA. The contrast of the whole-brain GLM for the comparison vs. control conditions yields essentially what would be the main effect of comparison in an ANOVA. The situation is slightly more difficult for the „internal states“ effect – it was impossible to design a control condition where subjects had to make a social judgement without comparison, because our theoretical position implies that any social judgement will involve a comparison. We could therefore only assess the ”internal states“ effects in the comparison task, and the contrast “intelligence“ vs. “body height” comparison should reveal areas whose activity is related to these internal states.

The third problem is that in spite of pretesting the names of the celebrities from the first experiment for 100% familiarity on a comparable sample, nearly all of the subjects did not know some of the presented celebrities or only knew them by name. In these cases the subjects reported that they had no idea about the intelligence and/or the body height of these celebrities. This implicates that our predictors include decisions under different conditions and different levels of uncertainty than expected with possibly an influence on the results in reducing the main and interaction effects because of a higher variance in the data. This should be born in mind when generating the stimuli for the further experiments.

3. Experiment 2

3.1 Introduction

The task in the first experiment was to compare two other persons. In our everyday life, we do not only compare other persons with each other but more often we compare other persons with ourselves. In the second fMRI study, we therefore focused on comparative judgements when subjects had to compare other persons with themselves (**S**elf vs. **O**ther **C**omparison - SOC).

Once more, we used comparative judgements on the same psychological and physical dimensions as in the first experiment (intelligence and body height). Participants were presented with names of familiar persons from their social surroundings. By using persons who were familiar to the participants, we intended to reduce the variance of uncertainty in the social judgements that had occurred in the first experiment.

The contents of the social comparison processes in this experiment were the same as in the preceding experiment. Hence, we hypothesized that the same network of brain areas as in the first experiment should be involved in the comparative person judgements and we did not use a semantic control condition here.

We expected the activation of the ToM network with different levels of perspective taking to differ in the same way in the comparison tasks for psychological (intelligence) and physical (body height) person characteristics as in the first experiment.

Different combinations of regions of the MFC with other areas in the brain (TPJ, Ins, NAcc, AMG) are involved in tasks requiring first-person perspective, self-other comparison and self-descriptiveness (see Northoff et al. 2006). While the more dorsal parts of the MFC were activated in processes of reappraisal and evaluation of self-related stimuli, the more ventral parts of the MFC were involved in coding the self-relatedness of stimuli and the posterior parts of the

MFC are involved in tasks including self-referential stimuli (Northoff et al., 2006). Therefore, in contrast to the first experiment we expected additional and different activation patterns especially in the dorsal MFC because the self is involved in different ways in the two tasks.

Furthermore we are interested in the neural correlates of the decision directions. What activation differences occur when we judge ourselves to be more or less intelligent? These kinds of social decision influence our emotions, depending on our relation to the person we compare ourselves with and depending on the direction and the degree of the differences in intelligence. Hence, we expect differences in emotion-related areas (AMG and limbic structures), in the ventral MFC which is involved in emotional perspective taking, sympathy, emotional empathy (Gallagher et al., 2003) and social emotions (Shamay-Tsoory et al., 2007). Additionally, differences in the OFC which integrates information from other prefrontal areas regarding the reward outcome to generate the valence of a reward (Wallis, 2007) could be expected.

3.2 Methods

3.2.1 Participants

Fifteen healthy right-handed participants (9 male, 6 female) were recruited from an academic environment (mean age 29.73 years, SD 5.91, range: 23 – 39 years). The Ethics Committee of the Medical School of the Johann Wolfgang Goethe University approved of the study. Written informed consent was obtained from all participants prior to scanning.

3.2.2 Stimuli

Prior to the experiment the participants had to compile a list of 40 names (first names and surnames) of persons they knew themselves. The minimum requirement for putting a name on the list was at least three face-to-face encounters with the respective person. These names served as stimulus material for the following fMRI-experiment. They were presented in white font (font type: Arial, height: 4.6°) against a black background in the centre of the screen. The cues indicating the task procedure had the same colour and font size. Stimulus presentation and recording of response time was controlled by the Presentation 10.3 software (Neurobehavioral Systems, Inc.). During scanning, the computer display was projected onto a mirror mounted on the head coil.

3.2.3 Procedure

The two experimental conditions again required comparative judgements on intelligence or body height, in analogy to the first experiment.

While subjects had to compare two other Persons indicated by their names in the first experiment, in the second experiment subjects had to compare themselves with another person indicated by their name (SOC). This means that they had to decide if the person whose name appeared on the screen or the participant himself/herself was more intelligent or taller. Participants were asked to respond as quickly as possible by using a two button fiber-optic response box.

Participants performed the experiment while undergoing fMRI. The experiment was divided into four runs of approximately 7 minutes containing 20 trials (10 per condition) in a pseudo-randomized order. Each trial began with one of two cues (see Figure 9) indicating the task instruction, presented for 1500 ms at the centre of the screen. After the cue had disappeared, a “+” was displayed for 1500 ms as a fixation point, followed by a stimulus appearing for 1000 ms. The ITI was jittered between 9 and 12 s (see Figure 9).

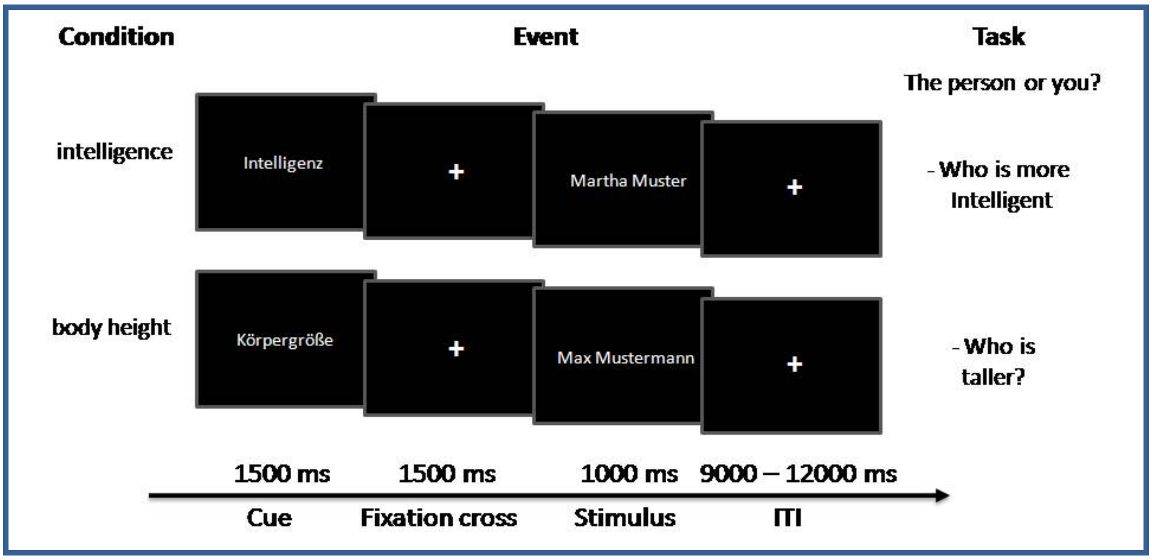

Figure 9: Paradigm design. Two different experimental conditions (body height and intelligence comparison). Each trial began with the presentation of a cue (1500 ms), followed by a fixation point (1500 ms) and a stimulus (1500 ms). After a jittered inter trial interval (ITI) between 9 and 12s a new trial began. The subjects had to decide if the other person, indicated by the names, or themselves was taller or more intelligent.

3.2.4 Imaging procedure

We collected whole-brain MRI data on a 3T ALLEGRA Magnetom (Siemens, Erlangen, Germany). We acquired echo-planar imaging data for fMRI using standard parameters (field of view, 210 mm; matrix: 64 x 64; 1 volume = 27 axial slices, 3mm slice thickness; in-plane resolution, 3.3 mm; TR: 1500 ms, TE: 30 ms; flip angle: 90°; 258 volumes per run). We synchronized stimulus presentation with the fMRI sequence at the beginning of each trial. We acquired four dummy volumes before each run in order to reduce possible effects of T1-saturation. To minimize head motion, we used fixed head pads. We obtained a T1 weighted 3D anatomical scan (1x1x1 mm^3 resolution) for each participant.

3.2.5 Data analyses

We pre-processed and analyzed the fMRI data using BrainVoyager™ QX (Brain Innovation, Maastricht, The Netherlands). We applied the following pre-processing steps: slice-time correction, motion correction, and linear trend removal. For the highpass temporal filtering we used individual adjusted number of cycles in time course. The frequency obtained as the inverse of the time interval is that of the fundamental mode of the slowest BOLD-response (maximal distance between two neighbouring trials of the same condition in the run) in a given fMRI-experiment. This frequency must be preserved upon high-pass filtering. Therefore the high-pass frequency has to chosen well below (see equation 1). This allowed us to filter out only the lower frequencies of the signal that are definitely not generated by the predictors.

$$\textit{cycles in time course} = \frac{\dfrac{\textit{number of volumes per run}}{\textit{max\_dist}}}{2}$$

$$\textit{max\_dist} = \max(\textit{trial}_{i,j+1} - \textit{trial}_{i,j})$$

max_dist = maximal distance (in volume) between two neighbouring trials (*j* and *j*+1) of the same condition/predictors *i* in the run

Equation 1: Calculation of the optimal number of cycles in time course for temporal high-pass filtering.

Additionally we performed spatial smoothing using a Gaussian kernel of 8mm full-width at half-maximum. We manually coregistered the fMRI data with the anatomical scans. We transformed the 3D anatomical scans into Talairach space (Talairach et al., 1988) and subsequently used the parameters for this transformation to transform the coregistered functional data. We then resampled the 3D functional data set to a voxel size of 3x3x3 mm^3. We defined each of the two experimental conditions of the experimental design as a predictor, using the individual reaction times of the trials following stimulus onset for defining the predictor. All cues and the following fixation points were defined as a third predictor (3 s per event). The remaining fixation volumes served as baseline. Again, we convolved the predictors with a two-gamma HRF (Boynton et al., 1996).

In a first analysis we calculated a whole-brain RFX-GLM, using the FDR for correction of multiple comparisons and implemented comparisons of interest as linear contrast.

In a second analysis we once more performed a masked RFX-GLM using the same mask from experiment 1 including only the significant voxels of the contrast between comparison conditions and the control conditions from the whole-brain RFX-GLM of experiment 1. We used the FDR for correction of multiple comparisons and implemented comparisons of interest as linear contrast. To find discrete local activation maxima in a large cluster we identified voxels with minimal p-values in sub clusters of voxels with $p<0.0001$. Around that putative activation maximum we defined a box with edge lengths of 10 voxels.

Afterwards we divided the intelligence and the body height predictor each into two separate predictors concerning the decision direction of the subjects (intelligence: myself>other and other>myself; body height: myself>other and other>myself). The cue predictor remained unchanged. With the new design we performed ROI-RFX-GLMs for each significant area from the previous whole-brain and masked RFX-GLM separately.

3.3 Results

3.3.1 Behavioural data

Reaction times were longer for intelligence comparisons (myself>others: 3502 ms, SD= 851; others>myself: 3633 ms, SD= 881) than for body height comparisons (myself>others: 3248 ms, SD= 858; others>myself: 3343 ms, SD= 1006) (see Figure 10). We performed a 2x2 factorial ANOVA with the first factor "type of comparison" (intelligence and body height) and the second factor "direction of decision" (myself>others and others>myself). Reaction time revealed a significant main effect for the type of comparison (F(1,14)= 4.611, p<0.05). Reaction times did not show a significant main effect for the second factor (F(1,14)= 0.805, p= 0.38), and no significant interaction (F(1,14)= 0.024, p= 0.87).

Subjects rated themselves more often as more intelligent (55.17%) or taller (52.83%) than the other person (see Figure 11). Regardless of these descriptive differences a 2x2 ANOVA showed neither significant main effects (type of comparison (F(1,14)= 1.672, p= 0.217); direction of decision (F(1,14)= 1.173, p=0.297)), nor a significant interaction (F(1,14)= 0.091, p= 0.767).

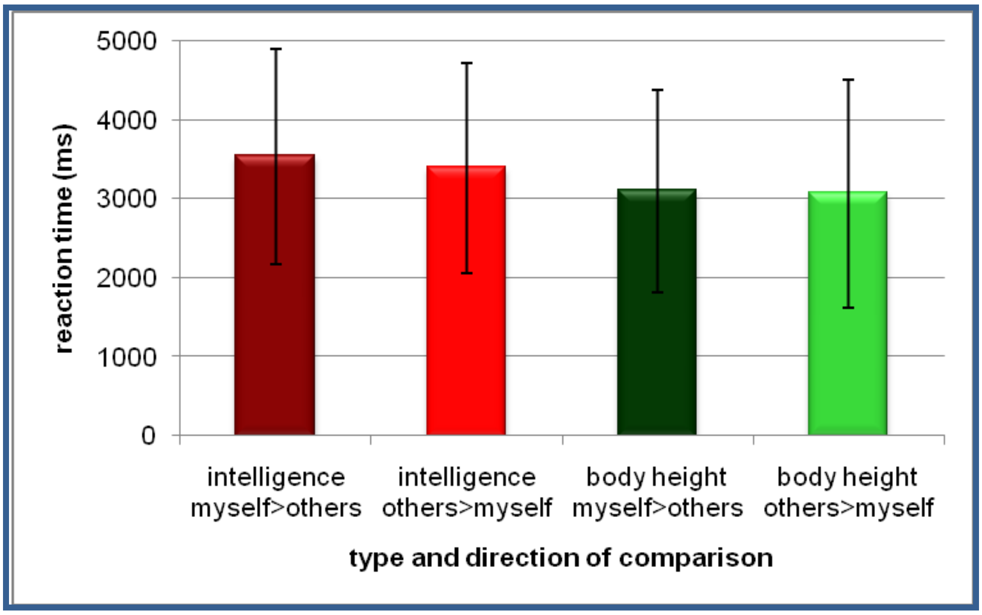

Figure 10: Reaction times for the two types of comparison (red: intelligence; green: body height) and the two directions of decision (dark: myself>others; bright: others>myself). Error bars represent standard deviations of means.

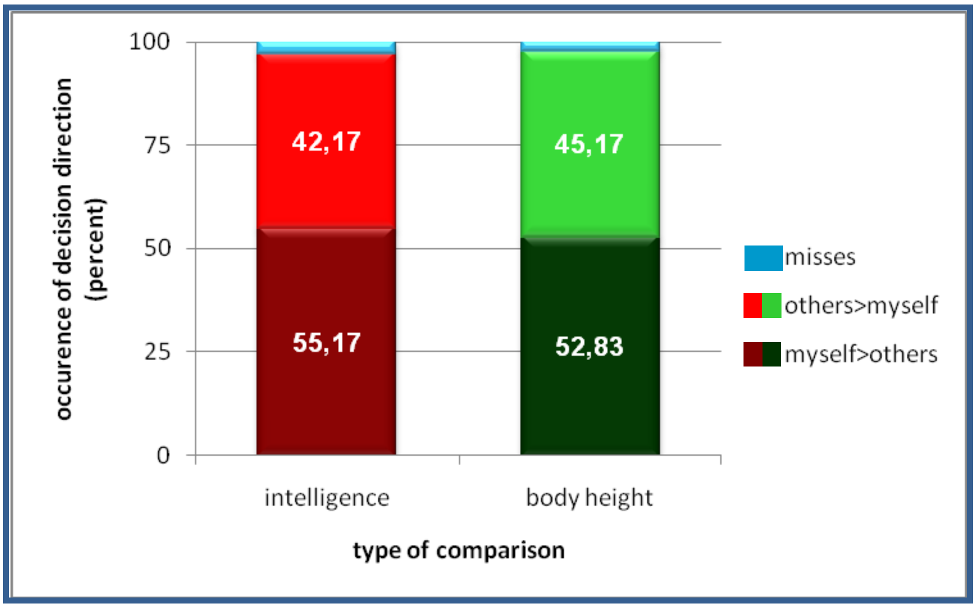

Figure 11: Occurrence of decision direction for the two types of comparison (red: intelligence; green: body height) and the two directions of decision (dark: myself>others; bright: others>myself). Blue parts show the amount of misses, which are less than 3% in both conditions.

3.3.2 fMRI data

We used whole brain RFX-GLM, masked RFX-GLM (including significant areas from the contrast between comparison and control condition from experiment 1) and ROI analyses. Maps of both RFX-GLM were thresholded at a FDR < .05 and included only clusters exceeding a cluster size threshold of 50 voxels.

3.3.2.1 Whole-brain RFX-GLM

Contrast intelligence comparison versus body height comparison

The t-map for the contrast between the two comparison conditions was thresholded at a FDR < .05. Results are shown in Figure 12 and Table 3. A medial frontal cluster emerged in this contrast with significantly higher activation for the intelligence comparison condition, including discrete local maxima in left arMFC, APCC, ACC, and mOFC. OFC/FO, PCC, and MTG also showed a higher activation for the intelligence comparison than for the body height comparison.

We observed a significantly higher activation for the body height comparison condition in bilateral MFG, bilateral superior frontal gyrus (SFG), left inferior frontal gyrus (IFG), right inferior temporal gyrus (ITG), right Ins, medial supplementary motor area (SMA), right fusiform gyrus, and an anterior portion of right ventromedial OcG. Additionally, two parietal clusters revealed higher activation for the body height comparison. The left parietal cluster included three local maxima, i.e. two areas in lateral superior parietal lobe (SPL) and PCun. Three areas in the right SPL and an area in the IPL were local maxima in the larger right parietal cluster.

In sum, a network of parietal and lateral frontal areas seems to be recruited in self comparison tasks while performing body height comparisons, whereas the intelligence comparison task activates medial frontal and parietal areas.

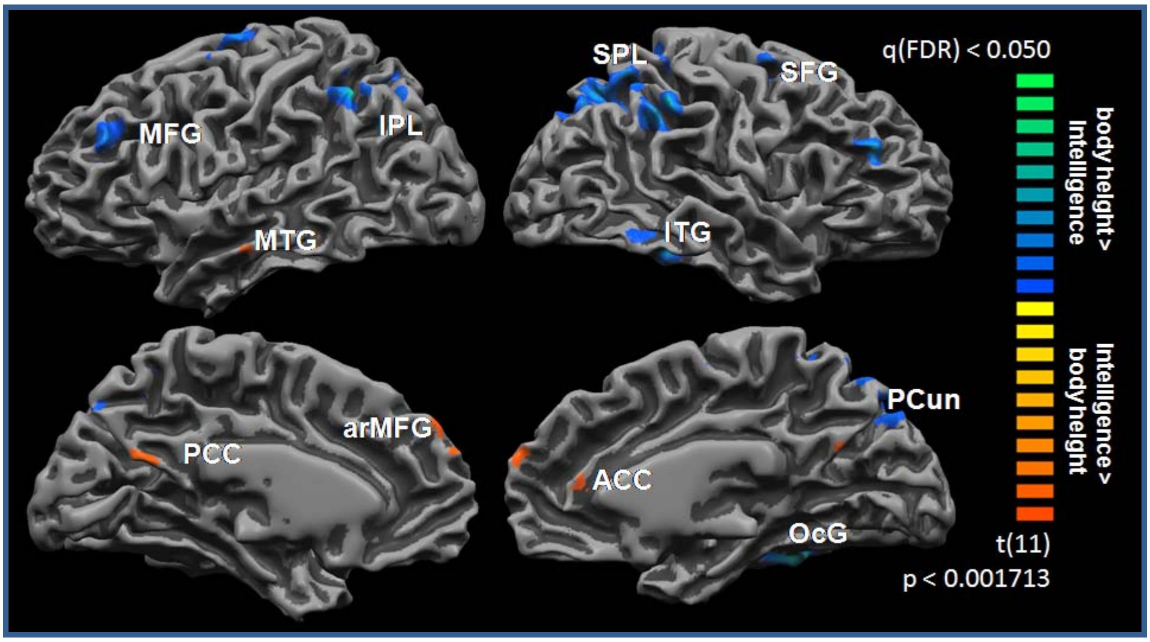

Figure 12: Group analysis with whole-brain RFX-GLM. Superposition maps (left: left hemisphere; right: right hemisphere; Top: lateral view; Bottom: medial view) of the contrast between intelligence and body height comparison. Higher activation for intelligence comparison is shown in orange (areas: left MTG, PCC, right OFC/FO, and a huge medial frontal cluster with local maxima in left arMFC, ACC, APCC, and mOFC) and for body height comparison in blue (areas: bilateral MFG and SFG, right ITG, right OcG, and two parietal clusters – right cluster includes maxima in PCun and two areas in lateral SPL – left cluster includes IPL and three areas in SPL.). Effects were only shown if the associated p-value yielded p<0.01 (corrected for multiple comparisons with FDR). The 3D statistical maps were then projected on the folded surface reconstruction of the MNI template brain.

Table 3: Talairach coordinates (centre of ROIs), Brodmann areas (BA), and statistical details (cluster size and averaged t- and p-values for the cluster) of whole-brain RFX-GLM for areas that showed a significant difference for the contrasts between intelligence and body height comparison after correction for multiple comparisons with FDR (α<.05).

Regions	**L**eft/ **M**edial/ **R**ight	**Talairach coordinates**			**BA**	**Cluster size (voxel)**	**t(avg)**	**p-value**
		x	y	z				
intelligence > body height comparison								
medial frontal cluster with 5 local maxima						5023		
- arMFC	L	-5	53	39	9		4.5523	p < 0.001
- ACC	M	0	46	29	10		4.4055	p < 0.001
	R	2	40	13	10		4.4633	p < 0.001
- APCC	M	0	56	23	10		4.5667	p < 0.001
- mOFC	M	0	55	7	11		4.4010	p < 0.001
PCC	M	0	-61	22	31	779	5.3648	p < 0.001
arMFC	M	0	32	31	10	217	4.8644	p < 0.001
OFC	R	39	26	-5	47	245	5.4448	p < 0.001
	L	-63	-13	-11	47	105	5.1357	p < 0.001
body height > intelligence comparison								
left parietal cluster with 3 local maxima						6394		
- SPL	L	-27	-63	38	7		-5.3660	p < 0.001
	L	-43	-49	45	7		-5.2785	p < 0.001
- PCun	L	-20	-69	20	31		-4.5423	p < 0.001
right parietal cluster with 4 local maxima						12355		
- SPL	R	15	-67	43	7		-5.3260	p < 0.001
	R	36	-55	50	7		-5.6459	p < 0.001
	R	28	-66	43	7		-4.7912	p < 0.001
- IPL	R	51	-43	43	40		-5.1889	p < 0.001
IPL	R	36	-37	28	40	135	-5.0219	p < 0.001
IPL	R	66	-40	25	40	177	-4,8831	p < 0.001
PCun	L	-9	-73	40	31	344	-5.3206	p < 0.001
SMA	M	3	-13	58	4	78	-4.4800	p < 0.001
SFG	L	-21	-10	64	6	1279	-5.7156	p < 0.001
	R	27	-4	52	6	1008	-5.5354	p < 0.001
FG	R	45	-43	-14	37	3107	-8.6443	p < 0.001
OcG	R	15	-40	-8	37	139	-5.9025	p < 0.001
MFG	L	-36	35	28	9	1256	-5.6050	p < 0.001
	R	42	35	22	9	1435	-6.8654	p < 0.001
IFG	L	-36	5	22	9	126	-5.3712	p < 0.001
Ins	R	30	-10	13	13	56	-4.7422	p < 0.001
White matter	L	-24	-13	-37	-	170	-5.9590	p < 0.001

3.3.2.2 Masked RFX-GLM

Contrast intelligence comparison versus body height comparison

We did not apply a control condition in this second experiment, hence we were not able to show comparison specific areas with a contrast between the comparison and a control condition as we had done in the first experiment. Therefore, we examined the comparison specific areas we had found in experiment 1 using the same mask for this masked RFX-GLM. In this masked RFX-GLM, the contrast between the two comparison conditions (intelligence and body height comparison) revealed significant differences in almost all of the areas differing in the first experiment, too. Time course of BOLD signal showed higher peaks for intelligence comparison in left prMFC, APCC, PCC, left MTG, left FO, and right OFC. Again, a huge cluster in the medial prefrontal cortex showed higher activation for intelligence comparison including 5 local maxima in left arMFC, medial prMFC, ACC, APCC, and mOFC. In analogy to the first experiment, bilateral IPL and left MFG revealed a significantly higher activation for the body height comparison than for the intelligence comparison (see Figure 13 and Table 4).

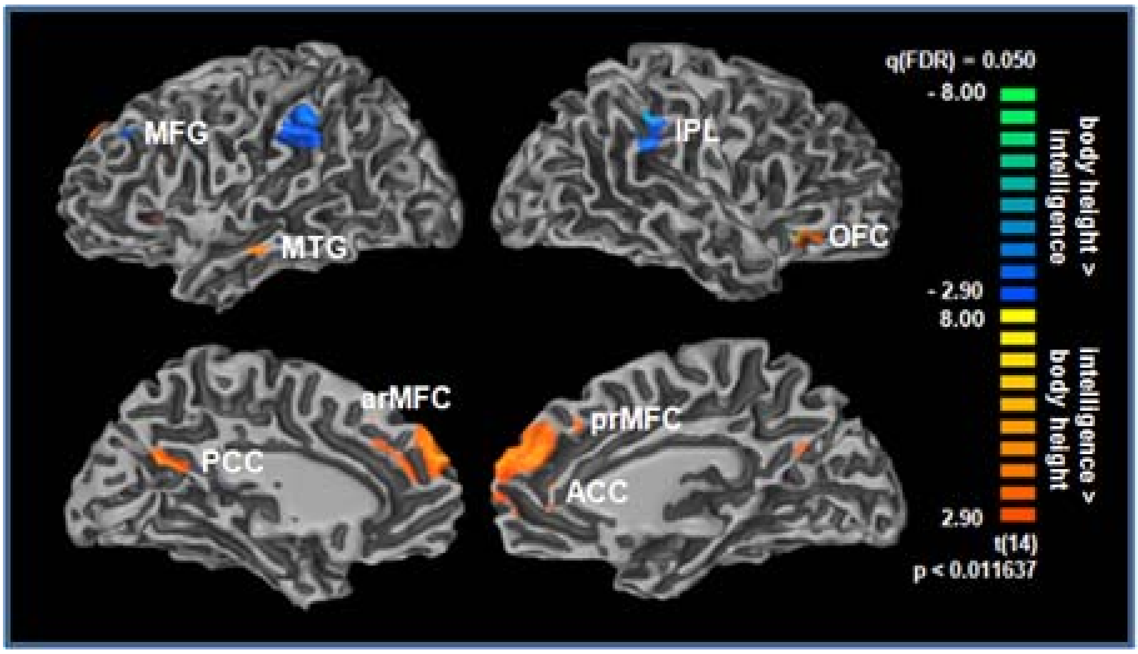

Figure 13: Group analysis with masked RFX-GLM. Superposition maps (left: left hemisphere; right: right hemisphere; top: lateral view; bottom: medial view) of the contrast between intelligence and body height comparison. Higher activation for intelligence comparison is shown in orange and for body height comparison in blue. Effects were only shown if the associated p-value yielded p<0.01 (corrected for multiple comparisons with FDR). The 3D statistical maps were then projected on the folded surface reconstruction of the MNI template brain. Areas: left prMFC, APCC, PCC, left MTG, left FO, right OFC, bilateral IPL, and left MFG. Medial frontal cluster with local maxima in left arMFC, medial prMFC, ACC, APCC, and mOFC.

Table 4: Talairach coordinates (centre of ROIs), Brodmann areas (BA), and statistical details (cluster size and averaged t- and p-values for the cluster) of masked RFX-GLM for areas that showed a significant difference for the contrasts between intelligence and body height comparison after correction for multiple comparisons with FDR (α<.05).

Regions	**L**eft/ **M**edial/ **R**ight	**Talairach coordinates** x	y	z	**BA**	**Cluster size (voxel)**	**t(avg)**	**p-value**
intelligence > body height comparison								
medial frontal cortex large bilateral cluster with 5 local maxima						15515		
- prMFC	M	-1	30	35	9		3.49059	p < 0.01
- arMFC	L	-6	54	31	9		4.77017	p < 0.01
- ACC	M	0	44	27	10		4.05574	p < 0.01
- APCC	R	0	56	23	10		4.38284	p < 0.01
- mOFC	M	0	55	6	11		3.41264	p < 0.01
prMFC	L	-16	34	55	8	98	3.00322	p < 0.01
APCC	M	0	35	12	10	25	3.09399	p < 0.01
MTG	L	-60	-15	-10	21	138	3.78945	p < 0.01
FO	L	-39	25	-3	44	457	3.25151	p < 0.01
OFC/FO	R	39	27	-8	11/44	1151	4.15601	p < 0.01
PCC	M	-2	-56	23	31	1577	3.47120	p < 0.01
body height > intelligence comparison								
IPL	L	-54	-35	35	40	2056	-3.2964	p < 0.01
	R	56	-37	33	40	783	-3.7638	p < 0.01
MFG	L	-34	37	35	9	107	-3.4403	p < 0.01

3.3.2.3 ROI GLMs

Neither in the whole-brain nor in the masked RFX-GLMs did we find any specific areas showing significant differences between the two decision directions after surviving the correction of multiple comparisons. Hence, we performed fixed effects (FX) ROI GLMs for the contrast between the decisions “myself>others” and “others>myself” for each comparison type separately for the ROIs of the whole brain RFX-GLM and the masked RFX-GLM.

ROI-GLMs of whole-brain RFX-GLM - Contrast between decision directions

Two FX-ROI-GLMs for the two comparison types were performed on areas showing significant differences in the whole-brain RFX-GLM. For the intelligence comparison the contrast between the two decision directions revealed a significantly higher activationin ACC, left arMFC, PCC, left PCun, right SPL, right IPL, right SFG, and right Ins. The decision direction of body height comparison revealed a significantly higher neural activation in left and right SPL, right ITG, left SFG, and right MFG. The brain areas left arMFC, mOFC, right SPL, and right IPL showed significant differences between the decision directions in both intelligence and body height comparisons (see Table 5). The decision for rating oneself as more intelligent than another person entailed higher activations in all the areas showing significant differences between the decision directions. While in the body height comparison only the areas found to be more activated for intelligence comparison entailed higher activation for the decision direction myself>others, the areas found to be more activated for body height comparison in general entailed a higher activation for the decision direction others>myself.

Table 5: Talairach coordinates (centre of ROIs) and cluster size of ROIs showing significant differences for the contrast between the direction of decisions (myself > others and others > myself) in intelligence and/or body height comparison of areas of the whole-brain RFX-GLM after correction for multiple comparisons with FDR (α<.05).

Regions	**Left/ Medial/ Right**	**Talairach coordinates**			**Cluster size (voxel)**	**t- and p-values for contrast (myself>others) vs. (others>myself)**	
		x	***y***	***z***		**t-value (+) Intelligence**	**t-value (-) Body Height**
intelligence > body height comparison							
medial frontal cluster with 5 local maxima					5023		
- arMFC	L	-5	53	39		1.975; p < .05	3.182; p < .01
- ACC	M	0	46	29		-	-
	R	2	40	13		2.653; p < .01	-
- APCC	M	0	56	23		-	-
- mOFC	M	0	55	7		1.980; p < .05	2.298; p < .05
PCC	M	0	-61	22	779	2.935; p < .01	-
arMFC	M	0	32	31	217	4.070; p < .01	-
OFC	R	39	26	-5	245	-	-
	L	-63	-13	-11	105	-	-
body height > intelligence comparison							
left parietal cluster with 3 local maxima					6394		
- SPL	L	-27	-61	38		-	-
	L	-43	-51	45		-	-2.684; p < .01
- PCun	L	-20	-69	20		2.634; p < .01	-
right parietal cluster with 4 local maxima					12355		
- SPL	R	15	-67	43		3.072; p < .01	-
	R	36	-55	50		3.193; p < .01	-2.320; p < .05
	R	28	-66	43		-	-2.417; p < .05
- IPL	R	51	-43	43		2.049; p < .05	-2.250; p < .05
IPL	R	36	-37	28	135	-	-
IPL	R	66	-40	25	177	2.283; p < .05	-
PCun	L	-9	-73	40	344	-	-2.383; p < .05
SMA	M	3	-13	58	78	5.745; p < .01	-
SFG	L	-21	-10	64	1279	-	-4.050; p < .01
	R	27	-4	52	1008	2.121; p < .05	-
FG	R	45	-43	-14	3107	-	-
OcG	R	15	-40	-8	139	-	-
MFG	L	-36	35	28	1256	-	-
	R	42	35	22	1435	-	-3.082; p < .01
IFG	L	-36	5	22	126	-	-
Ins	R	30	-10	13	56	3.474; p < .01	-
White matter	L	-24	-13	-37	170	-	-

ROI-GLMs of masked RFX-GLM - Contrast between decision directions

In the FX-ROI-GLM for the areas of the masked RFX-GLM, significant differences between the decision directions for the intelligence comparison condition only were found in PCC, medial arMFC, and right IPL. For body height comparison, we could find significant differences between the decision directions only in the left IPL. In mOFC and left arMFC we found significant differences between the two directions of decision for intelligence comparison as well as for body height comparison (see Table 6). In the ROI-GLMs of the masked RFX-GLMs again all areas showing significant differences for intelligence comparison revealed a higher activation for the decision myself>others. While in the body height comparison only the areas showing a significant difference for both comparison types also revealed a higher activation for decision myself>others, the areas in left IPL entailed a higher activation for the decision direction others>myself. BOLD time course plots are shown for all areas with significant differences in these ROI-GLMs in Figure 14.

Table 6: Talairach coordinates (centre of ROIs) and clustersize of ROIs showing significant differences for the contrast between the direction of decisions (myself > others and others > myself) in intelligence and/or body height comparison of areas of the masked RFX-GLM after correction for multiple comparisons with FDR (α<.05).

Regions	Left/ Medial/ Right	Talairach ccordinates			Cluster size (voxel)	t- and p-values for contrast (myself>other) vs. (other>myself)	
		x	*y*	*z*		t-value (+) Intelligence	t-value (-) Body height
mOFC	M	0	52	3	527	2.071; p < .05	2.052; p < .05
PCC	M	-2	-56	23	1577	3.030; p < .05	-
arMFC	M	-1	30	33	720	4 319; p < .01	-
	L	-16	30	54	119	-	1.980; p < .05
IPL	L	-54	-35	35	2056	-	-2.382; p < .05
	R	56	-37	33	1550	3.320; p < .05	-
MFG	L	-34	37	35	107	2.491; p < .05	-

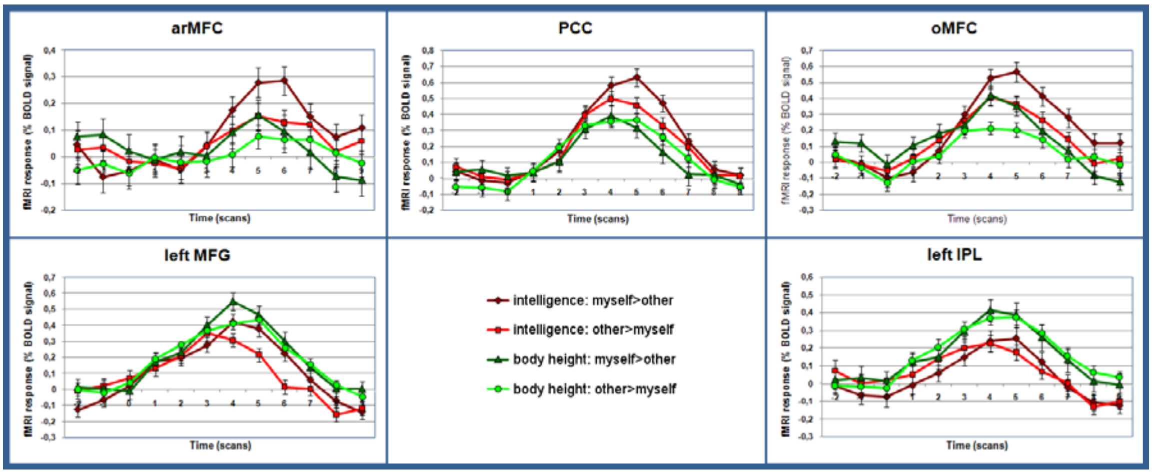

Figure 14: BOLD time courses for the two conditions and for both decision directions (dark red = intelligence comparison: myself>others, bright red = intelligence comparison: other>myself, dark green = body height comparison: myself>other, bright green = body height comparison: other>myself). Top: Areas showing significant differences in intelligence comparison between the decision directions myself>other and other>myself (arMFC, PCC, and mOFC); Bottom left: area showing significant differences in intelligence and body height comparison between the decision directions myself>other and other>myself (left MFG); Bottom right: left IPL showed significant differences only in body height comparison between the two decision directions. Error bars indicate the standard errors.

3.4 Discussion

3.4.1 Physical vs. psychological person comparison

This second experiment investigated whether the comparison between the self and another person recruit two distinct networks of brain activation for the comparative judgements on the psychological and physical dimensions (intelligence and body height) similar to the first experiment.

The whole brain RFX-GLM revealed a large fronto-parietal network (including SPL, IPL, PCun, ITG, OcG, SFG, and MFG) for body height comparison. In contrast, the Intelligence comparison activated more left MTG, PCC, arMFC, ACC, OFC, and mOFC.

Analogous to the first experiment, the network of brain areas which are involved in the comparison of the psychological dimension shows a striking overlap with areas described in ToM and perspective taking, especially ACC and PCC. Hence, we proposed that the social comparison tasks also require decision making under uncertainty, because an objective criterion to estimate the intelligence is missing. The participants had to draw on their knowledge about the respective person in their social environment because it was unlikely they would have specifically thought about their body height or intelligence beforehand and they could not be certain of the right answer. The areas we found in our comparison tasks in the medial frontal and orbitofrontal areas (prMFC, arMFC, mOFC, and OFC) are also found in decision making processes in ambiguous or otherwise uncertain situations (Manes et al., 2002; Bechara et al., 2000; Fellows et al., 2007).

The MFC plays an important role in social comparison and self-related processes, it is considered to be associated with first-person perspective (Vogeley et al., 2003), serving the integration of social information and handling neural input from the dorso-lateral prefrontal cortex, the STS, the tempoparietal junction (Huey et al., 2006), person based knowledge (e.g., Mason et al., 2004; Mitchell et al., 2002), psychological trait judgements (Kircher et al., 2000), and self-relevant judgements (Macrae et al., 2004). The dorsal part of the MFC is involved in trait inferences of unfamiliar others especially in tasks requiring judgements on enduring traits of actors based on single trait words, sentences, and short stories, whereas the ventral part of MFC is involved in self-reference and trait inferences about close others (familiar people like relatives or friends) and the self. The ventral MFC was also found to be involved in evaluative judgements of famous names (Van Overwalle, 2009). A Network including MFC, ACC, and PCun has been associated with self-processing (Northoff et al., 2004) and social cognition (Schilbach et al., 2006). Furthermore, regions of the MFC are engaged in self-referential processes, which are suggested to be functionally dissociable from other forms of semantic processing within the human brain (Kelley et al., 2002). Given that the comparisons of psychological person characteristics included self-references and trait inferences about familiar others and the self, our results suggest that the activation of the ACC and the dorsal regions of the MFC (arMFC and prMFC) are related to these processes.

The involvement of the OFC and mOFC in the intelligence comparison condition can be explained by the postulated involvement of similar psychological processes of comparison and decision making (Mussweiler, 2003) and by the recruitment of the OFC in reward calculation processes in social comparison together with ventral striatum (Fliessbach et al., 2007), in reward and punishment tasks (Rolls, 1996), and in guiding one's behaviour in terms of the value of possible outcomes (Amodio et al., 2006). In their fMRI study, Hare, O’Doherty, Camerer, Schultz, and Rangel (2008) showed that the OFC and the mOFC are recruited in different value-related processes in economic decisions. Goal values are correlated with activity in the mOFC, whereas decision values are correlated with activity in the central OFC. The ventral striatum was found (to be active) in tasks with prediction errors. Considering the processes participants had to engage in when solving the comparison tasks, it seems plausible that areas were activated which are typically involved when facts and arguments are generated, retrieved, weighted and integrated.

Prior to making a decision in a social comparison, it can be helpful to generate a mental image of the compared person, for being certain about the other person independent of the comparison type. On the one hand, in the intelligence comparison task this mental image serves no further purpose regarding the retrieval of specific information needed to estimate the intelligence as the basis of this kind of social judgements. On the other hand, in the body height comparison the mental image of the other person and perhaps a mental image of oneself represents the basis for deciding on differences in physical person characteristics and it therefore has to be much more intensive, and more detailed involving more imagery specific areas. The network (SPL, IPL, PCun, ITG, FG, OcG, SFG, and MFG), which we found for the comparison of physical person characteristics, includes areas of the classical fronto-parietal network of attention (see Posner & Petersen, 1990) as well as of ventral and dorsal visual stream which are evidently activated in visual imagery tasks, too (e.g. Lamm, Windischberger, Leodolter, Moser, & Bauer, 2001; Newman, Lee, & Bates, 2007). The results of the study from Lamm et al. (2001), in which single-trial fMRI and event-related slow cortical potentials were used to achieve a relatively high spatial and temporal resolution, showed that the human lateral and medial premotor cortex (BA 6), the parietal cortex (BA 7), the occipital cortex (BA 18/19), the DLPFC (BA 9), and the anterior Ins cortex are activated in relation to the task at hand approximately 550-650 ms after stimulus presentation in a dynamic visuospatial imagery task. These areas are quite similar to our own findings. Newman et al. (2007) investigated the neural differences and similarities of mental rotation and mental object inspection. While object inspection involved the inferior frontal cortex (BA 47), the left superior frontal cortex, right cerebellum, and the medial occipital cortex to a higher extent than mental rotation, mental rotation rather more involved inferior parietal and the intraparietal sulcal regions), bilateral occipital and temporal regions, the right prefrontal cortex, and premotor cortex as compared to object inspection (Newman et al., 2007). The authors found significant overlaps between object inspection and mental rotation in bilateral visual processing regions (both primary and secondary visual cortex) extending into the ITG, in a small region of the left parietal cortex, and in a region of the left frontal cortex. Knauff, Mulack, Kassubek, Salih, and Greenlee (2002) found a higher activation for relational visual imagery tasks than in conditional imagery tasks in the areas of the medial frontal gyrus (BA6), the superior parietal gyrus, the PCun, the inferior parietal cortex (BA 40), and the extrastriate cortex (BA 19), corresponding to most of the areas we found activated in the body height comparison. Wide areas of the SPL are involved in coordinate and categorical judgements in spatial imagery with lateralisation to the left hemisphere for categorical tasks and to the right for coordinate tasks (Trojano et al., 2002). Furthermore, the SPL is involved in 2D and 3D mental rotations showing a lateralization to the right SPL for 3D mental rotation (Kawamichi, Kikuchi, Noriuchi, Senoob, & Uenoc, 2007). Imagining a person for comparison includes the imagination of his or her face. This is in line with the higher activation for the body height comparison in areas of the right ITG including FFA which was found specifically for the imagination of faces (Ishai, Ungerleider, & Haxby, 2000; O'Craven et al., 2000). The right IPL is involved in self-comparison processes including one's own body and it showed correlations with ACC, AMG, and lateral prefrontal areas (Friederich et al., 2007). Furthermore, several medial and lateral parietal areas were found to be activated in diverse visual imagery tasks and show differences in spatial transformation, egocentric perspective transformation, and object-based transformation (Zacks et al., 1999; Zacks et al., 2000; Zacks et al., 2002; Zacks et al., 2003a; Zacks et al., 2003b). Especially the left and right parietal cortex is involved in object transformation tasks, where the subject has to rotate images mentally (Zacks et al., 2003b). In addition to secondary visual, premotor areas, frontal lobe regions, and the left posterior parietal lobe were also found as the most significant area in a self-rotation task (Creem et al., 2001). The results suggested that the comparison of physical person characteristics, in our case the comparison of body height, requires the retrieval and mental imagery of the compared person and perhaps of oneself. For the comparison itself, the image of the compared person and of oneself had to be born in mind. Participants had to inspect these mental images with respect to their size and decide which of them seems to extend more in the vertical dimension. This might be regarded as a more numerical or physical comparison. In the fMRI study concerning physical, luminance and numerical comparisons, Cohen-Kadosh et al. (2005) found an area in the IPL amongst other areas which was more activated in numerical than in physical and luminance comparisons. This area is also included in our activation pattern of the parietal cortex, indicating that the comparison of physical person characteristics in the SOC task may rely more strongly on numerical physical comparison rather than on social comparison processes, as already expected in the first experiment. The fact that the body height comparison in this second experiment showed a larger network of areas than the body height comparison in the first experiment may result from the higher number of trials in the second experiment. This results in a more powerful analysis, which makes it possible to find smaller effects.

We did not include a control condition in this second experiment, so we were not able to show comparison specific areas in a contrast between comparison and control condition for the SOC tasks. Since the two distinct networks found in the whole brain GLM largely overlap with the areas showing significant activation for the comparison tasks in the first experiment, we focused our second analysis on these "comparison specific areas", using the same mask from the first experiment for the masked RFX-GLM. In this reduced RFX-GLM we found a similar pattern of activation for the two comparison types as in the previous experiment. The IPL and the MFG showed a higher activation for the body height comparison and areas of the arMFC, prMFC, ACC, APCC, PCC, mOFC, MTG, OFC, and FO showed higher activation for the intelligence comparison. Only the TPJ did not reveal any significant differences in the contrast between the two comparison types. However, the results of the masked RFX-GLM of this second experiment clearly replicated the main findings of the first experiment concerning the distinct networks involved in the comparison of psychological and physical person characteristics.

In summary, our results suggest that the participants used a ToM approach to figure out the intelligence-related information of the person under comparison. Additionally the results suggest that for the body height judgement, participants retrieved the body height related information (the image of the person) from their memory and then they tried to visualize mentally the person under comparison and possibly themselves to perform the comparison. In accordance with our first two hypotheses, we found that nearly the same networks of brain areas as in the first experiment are involved in the comparative person judgements, showing different degrees of activation of the ToM network related to different levels of perspective taking in psychological (intelligence) and physical (body height) person characteristics in the comparison tasks although again the two types of comparisons are performed on identical stimulus material. The network of brain areas involved in intelligence comparison showed a particularly large overlap (except for the TPJ) with the results of the first experiment and consequently with the common network of autobiographical memory, prospection, navigation, ToM, default mode, and decision making under uncertainty.

3.4.2 Decision directions

In the decision direction hypothesis, we expected differences in the neural activation pattern of the ventral MFC and in emotion-related areas as regards the decision direction in the comparison tasks.

We did not find any specific areas showing significant differences between the two decision directions after surviving the correction of multiple comparisons, neither in the whole-brain nor in the masked RFX-GLMs. In the FX-ROI-GLMs of areas found in the masked and the whole brain GLMs, we did not find any decision direction specific differences in the ventral MFC or emotion related areas either, but we found other areas revealing significant contrasts between the decision directions.

For the contrast between the decision directions of the FX-ROI-GLMs (based on the whole-brain RFX-GLM), we found significant differences in specific areas for the intelligence comparison only (ACC, left arMFC, PCC, left PCun, right SPL, right IPL, right SFG, and right Ins), for body height comparison only (left and right SPL, right ITG, left SFG, and right MFG), and for both comparison types in common (left arMFC, mOFC, right SPL, and right IPL). Also, the FX-ROI-GLMs of the ROIs of the masked RFX-GLM revealed significant differences between the decision directions in specific areas for the intelligence comparison only (PCC, arMFC, right IPL, and left MFG), for body height comparison only (left IPL and a portion of left arMFC), and for both comparison types in common (mOFC).

Interestingly, we found an additional decision direction specific effect in the FX-ROI-GLMs of both RFX-GLMs: All areas showing significant differences in intelligence comparisons or in both comparison types revealed a higher activation for the decision myself>other, while the areas showing significant differences in body height comparison in the opposite decision direction (other>myself) revealed a higher activation than the other decision direction.

In the intelligence and body height comparison conditions the mOFC showed a higher activation when subjects rated themselves as more intelligent/taller than other persons. In our society, more intelligent and taller (at least to a certain point) persons enjoy higher prestige. Accordingly, the social comparisons in our experiment include high goal values for the decision myself>other in both respects. In line with our results, research has shown that goal values involve regions of the mOFC (see Hare et al., 2008).

The more dorsal parts of the MFC are involved in processes of reappraisal and evaluation of self-related stimuli (Northoff et al., 2006) and in self-referential processes (Kelley et al., 2002) so it is not surprising that these dorsal parts of MFC including the arMFC showed a higher activation for the decision direction myself>other related to a self-referential process resulting in higher self-esteem.

In the intelligence comparison condition, we found significant differences between the decision directions in brain areas (ACC, PCC, and PCun) which are classically related to perspective taking and ToM, these areas are also more activated in myself>other decisions. Hence, we suggested that perspective taking and ToM related areas do not only seem to be involved in this social comparison, but these areas also seem to play a role in the development of decision directions.

The higher activation for the decision other>myself in the body height comparison in the imagination specific areas can be explained by a possibly stronger imagination of the other person than of oneself to access the information necessary to make the decision about the difference in body height.

Because the differences in decision directions are only found in FX-ROI-GLMs we suggested that the GLM approach is not sensitive enough to investigate these small differences in the BOLD signal, as the differences in neural activation between the decision directions will not concern *involvement* and *no involvement* of specific areas or involving different areas. The existing but small differences in the BOLD time courses of the areas showing differences between the decision directions in the FX-ROI-GLMs lead us to expect that both decision directions are involved and that they activate the same areas. We further postulate that the difference of the decision is calculated of slightly different inputs from several areas. In this case only extreme differences in the activation pattern of the decision directions can be found with the GLM approach. On the other hand, areas may be missed that show only small differences in neural activation while they possibly play an important role in social decision making in the one or the other direction.

4. Comparison of experiments 1 and 2

4.1 Introduction

In both preceding experiments subjects had to perform comparisons of psychological characteristics (intelligence) and physical characteristics (body height) of persons. It would be interesting to compare the two different social comparison types OOC and SOC, to investigate the neural similarities and differences of these two comparisons. This comparison of the two experiments was based on the masked RFX-GLMs of both experiments involving the social comparison specific areas found in experiment 1.

While the participants had to compare two different other persons in the first experiment, participants in experiment 2 had to compare one other person with themselves. Hence, three major differences can be expected based on the differences between the tasks in the two experiments.

First, different combinations of several regions of the MFC with other areas in the brain (TPJ, Ins, NAcc, AMG) are shown to be involved in tasks requiring first-person perspective, self-other comparison, and self-descriptiveness. Whereas the more dorsal parts of the MFC were activated in processes of reappraisal and evaluation of self-related stimuli, the more ventral parts of the MFC were involved in coding the self-relatedness of stimuli thereby representing them as self-referential. The posterior parts of the MFC were involved in tasks including self-referential stimuli. The comparative judgements in the first and the second experiment differ in the role of the self in these judgements. Therefore we expected additional and differential activation patterns for the contrast between the comparison of psychological (intelligence) and physical (body height) person characteristics in the MFC between the two experiments.

Second, the task presented in experiment 1 could be expected to require a higher amount of mentalizing than the task performed in the second experiment, because the personal characteristics of two persons had to be estimated. This could result in a higher and/or more widespread activation of the ToM related areas.

Third, while the participants (students of psychology and graduates) of the first experiment had to compare celebrities which maybe represent a more dissimilar group of persons, the participants (also students of psychology and graduates) of the second experiment submitted their own list of stimuli. These lists include persons the participants knew themselves and included mostly family members, friends and colleagues, representing a more homogenous group of people. While mentalizing about a similar other engages a region of ventral MFC linked to self-referential thought, mentalizing about a dissimilar other engages a more dorsal subregion of MFC (Mitchell et al., 2006, Van Overwalle, 2009). Therefore, the comparison process of the first experiment should activate more dorsal regions of the MFC. In the second experiment more ventral regions of the MFC should be involved in the comparison process. Furthermore, the ventral part of the MFC is activated when people make trait inferences about familiar others or others similar to themselves (Van Overwalle, 2009).

4.2 Method

For the comparison of the two different comparison types (SOC and OOC) of psychological characteristics (intelligence) and physical characteristics (body height) of persons, a 2x2 factorial ANOVA would be the preferred statistical analyses.

We measured the two experiments in two different MRI-Scanners (first experiment: 3T TRIO Magnetom (Siemens, Erlangen, Germany); second experiment: 3T ALLEGRA Magnetom (Siemens, Erlangen, Germany)). In addition to the task, the predictors in an fMRI-experiment are linear dependent to the scanners. In case of measuring in two scanners, the effects which could possibly been found with a statistical analysis cannot be clearly assigned to the task itself or the different scanners.

Hence, we only had a descriptive view on the masked-RFX-GLMs while comparing the contrasts between the intelligence and body height comparison from both experiments. Maps for areas showing significant contrasts between the intelligence and body height comparison of both experiments were placed on top of another. Both maps were thresholded at a FDR < .05 and included only clusters exceeding a cluster size threshold of 25 voxels.

4.3 Results

The neural activation patterns of the intelligence comparisons in the SOC and the OOC experiment overlap in a huge medial frontal cluster including ACC, arMFC, mOFC, in several parts of arMFC, ACC, APCC, PCC, mOFC, bilateral OFC, and left STS. Nevertheless, each of the comparison types (SOC and OOC) seems to activate additional areas in its own right (see Table 7 and Figure 15).

The intelligence comparison in the second experiment with the SOC task activated the anterior and dorsal edges of the MFC areas in the left arMFC, the prMFC, an anterior part of the ACC, and a ventral area of the MFC (mOFC). Further areas were activated in the bilateral (more in the right hemisphere) OFC, the superior part of the PCC, the STS, the SN, and anterior thalamic nucleus. Moreover, the bilateral TPJ only seemed to be activated in the OOC of the first experiment.

The intelligence comparison of the OOC specifically activated the lower and posterior regions of the dorsal MFC and areas of the cingulate gyrus and sulcus in the central and ventral MFC including areas in the inferior parts of arMFC and prMFC and the superior parts of the mOFC. Furthermore, a more inferior part of the PCC, the bilateral (more in the left hemisphere) OFC, a region in the left STS, and an area in the medial OcG were involved in the OOC.

The body height comparison showed a similar activation in the IPL for both SOC and OOC. The SOC in the second experiment seemed to show more activation in the IPL and left MFG.

Table 7: Talairach coordinates (centre of Cluster) and cluster size of areas showing similar activation (SOC = OOC) and dissimilar activation pattern (SOC > OOC or OOC > SOC) for both comparison types (intelligence and body height comparison) in the descriptive comparison of both experiments.

Regions	**L**eft/ **M**edial/ **R**ight	**Talairach coordinates**			**Cluster size (voxel)**
		x	**y**	**z**	
SOC = OOC					
intelligence comparison					
Cluster including					
arMFC,ACC,APCC	M	-3	51	25	15719
PCC	M	-3	-52	26	1902
OFC	R	43	29	-6	128
	R	33	20	-10	64
	L	-33	26	-6	65
	L	-44	23	-3	405
mOFC	M	-3	44	-3	27
STS	L	-62	-18	-11	43
body height comparison					
IPL	R	54	-37	38	288
	L	-54	-34	41	173
OOC > SOC					
intelligence comparison					
Cluster including:					
ACC/arMFC/prMFC	L	-13	42	42	4764
arMFC	R	9	51	30	702
	R	12	52	18	47
mOFC	R	4	54	-3	613
	M	-2	40	-9	437
prMFC	R	15	31	51	450
OFC	R	26	20	-7	98
	L	-40	25	-8	2601
PCC	M	-3	-56	31	347
	M	-2	-43	24	64
	R	-12	-52	28	40
TPJ	R	51	-61	29	736
	L	-46	-62	27	689
STS	L	-62	-21	-8	40
SN	L	-5	-23	-14	87
anterior thalamic nucleus	L	-8	-10	-7	107
SOC > OOC					
intelligence comparison					
ACC	M	1	32	11	130
arMFC	R	4	58	30	2044
	L	-7	65	23	109
mOFC	M	-2	43	1	1228
prMFC	R	20	37	46	177
	M	-3	34	33	3211
	L	-9	32	58	127
	L	-19	26	53	81
OFC	R	36	26	-8	659
	R	45	28	-8	40
PCC	M	-1	-57	20	1926
STS	L	-61	-14	-11	46
OcG	R	12	-88	4	37
body height comparison					
MF G	L	-35	36	35	87
IPL	R	56	-37	30	1283
	L	-56	-35	35	1703

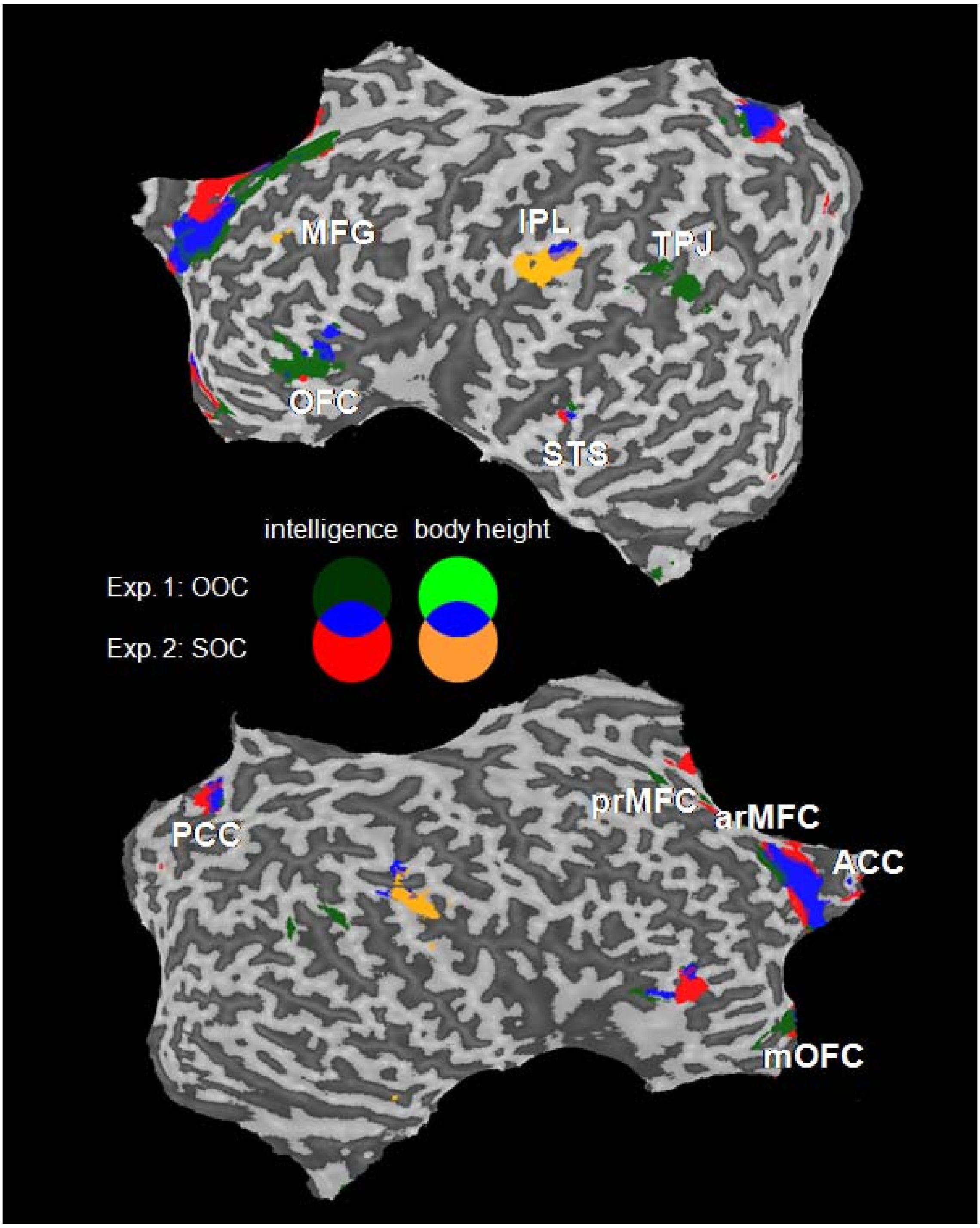

Figure 15: Comparison of group analysis of masked RFX-GLMs of experiments 1 and 2. Superposition maps with areas involved in both SOC and OOC (blue) and with areas showing specific differences. Red colours indicate areas only activated by SOC in the first experiment, green colours indicate areas only activated by OSOC in the second experiment (dark colours = intelligence; bright colours = body height). Effects were only shown if the associated p-value yielded $p<0.05$ (corrected for multiple comparisons with FDR). The 3D statistical maps were then projected on the flatmap reconstruction of the MNI template brain. Areas: arMFC, prMFC, ACC, mOFC, MFG, IPL, TPJ, OFC, STS, and PCC.

4.4 Discussion

The similarities and the differences between the OOC and the SOC we found in the descriptive comparison of the data can only be interpreted very carefully, and cannot be generalized.

In this comparison between the SOC and OOC we were mainly interested in the differences of neural substrates caused by the involvement of the self in the social comparison process in the second experiment. However, the comparisons of these two experiments are problematic for several reasons. First, knowledge of the participants about the celebrities and the familiar persons differed, i.e. participants can more easily estimate the intelligence and body height of personal acquaintances than of dissimilar celebrities. Furthermore, the comparison of familiar persons used as stimuli in the second experiment could be more self-relevant and the retrieval of the information about them may require a higher degree of autobiographical memory than the comparisons of two celebrities used as stimuli in the first experiment. Also, the participants’ knowledge about the celebrities differed as such, both with respect to the group of familiar persons as well as regards the celebrities as such – the participants were well acquainted with some of the celebrities, while they did not know others at all, or only by name. This results in different degrees of perspective taking and different levels of decision under uncertainty between the two groups of subjects as well as within the group of subjects taking part in the first experiment, comparing the celebrities.

Nevertheless, the two social comparison processes showed similarities of neural activation for the physical as well as for the psychological person characteristics.

Neural activation pattern in the two intelligence comparisons overlapped in arMFC, ACC, APCC, PCC, and OFC.

The OFC is involved in reward calculation (Rolls, 1996; Fliessbach et al., 2007), in value-related processes (Hare et al., 2008), and in guiding one's behaviour in terms of the value of possible outcomes (Amodio et al., 2006). Hence, it could be expected that in both intelligence comparison processes value- and reward processes are used. The SOC seems to activate a larger area of the right OFC. If this activation of the OFC is related to reward processes, this larger activation could be explained by a higher reward anticipation of the SOC task. The decision whether I am more or less intelligent than another person is more self-relevant and therefore linked with a higher reward outcome than comparing two other persons with one another. On the other hand the OFC was found in decision making processes in ambiguous or otherwise uncertain situations (Manes et al., 2002; Bechara et al., 2000; Fellows et al., 2007). The OFC shows an increasing activation when increasing the risk in decisions (Cohen, Heller, & Ranganath, 2005) and shows positive correlations with the levels of ambiguity in a card game (Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005). Lesions in the OFC result in deficits or impairments in learning optimal decision making strategies to avoid long-term monetary losses (Bechara et al., 2000, 2003). Hence, it could be expected that in both intelligence comparison processes value- and reward processes are used and base upon ambiguity. The OOC seems to activate a larger area of the left OFC. If the activation of the OFC is related to the uncertainty, this larger activation could be explained by a higher uncertainty of the OOC task. It could be argued that these differences in the OFC are based on the different kinds of stimuli in the two experiments. The estimation of the intelligence of unfamiliar persons like the celebrities in the first experiment is based on less accurate information than for the personally known persons in the second experiment. It could be expected, that the differences in the activation of the OFCs between the two experiments rely on the different kinds of stimuli in the two experiments

As expected in the intelligence comparison of both OOC and SOC, ToM related areas (ACC, APCC, and PCC) were involved. In both tasks the personal characteristics of at least one person had to be estimated but there is a major divergence in the neural activation pattern of psychological person comparison between the two experiments. Unlike the first experiment, the intelligence comparison in the second experiment did not show an involvement of the TPJ. Differences of activation in the TPJ may be due to a reduced amount of perspective taking in the second experiment. For two reasons, the SOC-task may require a lower degree of perspective taking and mind reading: First, the intelligence of only one other person has to be estimated and second, the persons to compare with are familiar to the participants. Assuming that the estimation of intelligence is based on the knowledge about the other person, we may expect that it is much easier to estimate the intelligence of a familiar person than of a stranger as the knowledge about familiar persons is more present and comprehensive and we normally have no problem in judging whether someone we know well is intelligent or not. On the other hand, the information necessary to estimate the intelligence of a celebrity, as far as it is available, has to be assembled from different parts of memory which may be inadequate for an accurate estimation of their intelligence.

More dorsal and ventral areas of the MFC were shown to be involved in self-referential processing tasks (D’Argembeau et al., 2007). Hence, the higher activation for the more dorsal part of arMFC and prMFC and the more ventral part of the MFC including mOFC in SOC than in OOC could be explained by a higher number of self-referential processes in the SOC task. This higher number of self referential processes in the SOC task could be related to the involvement of the self in the comparison as well as to the familiar persons under comparison. Judging the intelligence of a familiar person can be more self-relevant because the social relationship with familiar persons is more important than relating to dissimilar celebrities. Depending on the decision direction, judging familiar persons’ intelligence can be related with different outcome perspectives and expected consequences while judging a celebrity normally has no consequences independent of the decision direction.

Furthermore, while the activation of the inferior dorsal parts of MFC in OOC with respect to the SOC could be explained by the dissimilarity of the celebrities the subjects had to compare with (Mitchell et al., 2006), the activation in ventral parts of the MFC in SOC could also be explained by comparing with more similar others (Mitchell et al., 2006).

The activation of the more superior part of the PCC in the OOC and the more inferior part of the PCC in the SOC are in accordance with the results from Seger et al. (2004).

The body height comparison showed common activation in IPL which could be explained by the participants’ imagination of the persons under comparison (e.g. Friederich et al., 2007; Knauff et al., 2002; Lamm et al., 2001; Newman et al., 2007; Zacks et al., 1999; Zacks et al., 2000; Zacks et al., 2002; Zacks et al., 2003a; Zacks et al., 2003b; Zimmer, 2008).

The differences of neural activation patterns especially in the comparison of psychological person characteristics cannot be unambiguously ascribed to an expected different amount of the "self" included in the SOC- and the OOC-tasks, but we used this descriptive comparison of the two experiments to formulate the following hypothesis for a new experiment, in which the stimulus material has to be identical for both comparison types:

- The OOC and the SOC differ in their scope of mentalizing, resulting in higher activation in ToM related areas, spatially in the TPJ, in OOC.

- The OOC and the SOC show differences in the activation of MFC which is related to the involvement of the self in the social comparison process of personal characteristics.

5. Experiment 3

5.1 Introduction

Based on the results and the comparison of the preceding experiments, this third experiment is designed to investigate the differences and similarities of neural activations between the two types of comparison (SOC and OOC) as well as the neural correlates of the decision directions in both comparison types.

In addition to the classical analysis approach for fMRI (GLM), this study is designed to use a multivariate pattern analysis (MVPA) approach.

In this experiment, we investigate the neural substrates of intelligence comparison, because of methodological reasons regarding the combination of the used methods. On the one hand, we are once more using an event-related design. This results in trials of up to 3s and an ITI of 9-12 seconds after each trial for relaxation of the BOLD signal (see Excursus 1), so we have approximately 11 sec per trial. On the other hand, we want to use MVPA for analyzing the data concerning the decision directions of a participant's response. In general, this MVPA requires a vast number of trials, with a minimum of 60 trials per condition. However, we cannot explicitly define the decision directions of the subject prior to the experiment as it is up to the participants to decide, thus we need about 80 trials per condition. Two conditions (decision directions) in two comparison types (SOC and OOC) result in 320 trials and about 2 hours for the experiment.

The following hypotheses are tested by this experiment :

- OOC and SOC differ in the amount of mentalizing, resulting in higher activation in ToM related areas, spatially in the TPJ, in OOC?

- The OOC and the SOC show differences in the activation of MFC which is related to the involvement of the self in the social comparison process of personal characteristics.

- The decision directions differ in the neural activation pattern especially in the MFC.

5.2 Methods

5.2.1 Participants

Six healthy right-handed participants were recruited from an academic environment (4 female; mean age 25.17 years, SD 4.17). The Ethics Committee of the Medical School of the Johann Wolfgang Goethe University approved the study. Written informed consent was obtained from all participants prior to scanning.

5.2.2 Stimuli

Prior to the experiment the participants had to rate a list of 250 names (first names and surnames) of celebrities. First they had to rate these names for familiarity using a rating scale with 4 levels ("I do not know the person", "I have only heard the name of the person", "I have an idea about the person" and "I know the person well"). If the participants had an idea about the respective persons or knew them well, the participants had to guess the person's intelligence on the basis of their knowledge about the person. At the end of the rating scale, the participants had to estimate their own intelligence (see complete celebrity rating scale in Appendix 9.2).

These names served as stimulus material for the following fMRI-experiment. The List was "analyzed" twice. For the SOC 80 names which were rated with a higher intelligence and 80 with a lower intelligence than the participants own self-rated IQ-value were used as stimuli. For the OOC the 80 names with highest and the 80 names with the lowest rated intelligence were used as stimuli. Additionally, eight names (one for each run) with an individually medium rated intelligence were used as a reference, where subjects had to compare all other stimuli with.

Stimuli were presented in white font (font type: Arial, height: 4.6°) against a black background in the centre of the screen. The cues indicating the task procedure had the same colour and font size. Stimulus presentation and recording of response time was controlled by the Presentation 10.3 software

(Neurobehavioral Systems, Inc.). During scanning, the computer display was projected onto a mirror mounted on the head coil.

5.2.3 Procedure

In this third experiment, the two experimental conditions required comparative judgements. In contrast to the first two experiments, only comparative judgements on intelligence had to be performed.

Subjects had to perform both SOC and OOC. In the SOC condition, subjects had to compare themselves with one person indicated by their name, i.e. they had to decide whether the person whose name appeared on the screen or the participant himself/herself was more intelligent. In the OOC condition, subjects had to compare two other persons. Prior to each functional run, the name of a so-called reference person was presented. In the following run each person indicated by their name during the task had to be compared with this reference person, i.e. participants had to decide whether the person whose name appeared on the screen was more intelligent than the reference person ('other>ref') or the reference person was more intelligent ('ref>other'). In both conditions, participants were asked to respond as quickly as possible by using a two button fiber-optic response box.

Participants performed the experiment while undergoing fMRI. The experiment was divided into two sessions. Each of these sessions included eight runs of approximately 6 minutes containing 20 trials (10 per condition) in a pseudo-randomized order. Each trial began with a cue (fixation cross turned red) presented for 1500 ms at the centre of the screen (see Figure 16). This attention capturing cue served only to denote that the next task was about to start. After the cue the fixation cross turned white again and appeared for 1500 ms, followed by a stimulus appearing for 1000 ms. The ITI was jittered between 9 and 12 s (see Figure 16).

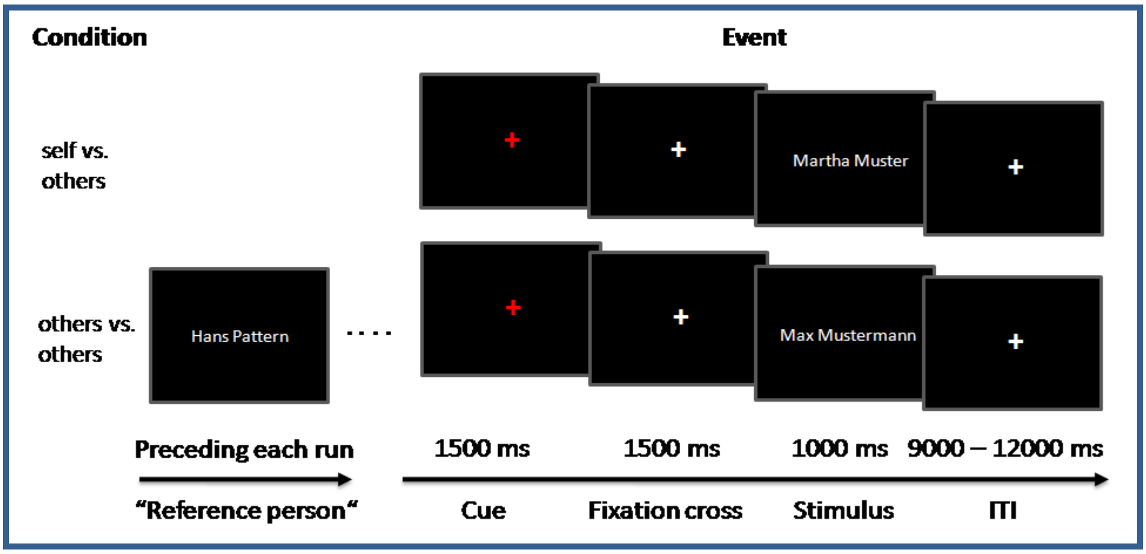

Figure 16: Paradigm design. Two different experimental conditions of intelligence comparison: Top: self vs. other comparison. The subjects had to decide if another person, indicated by the names, or themselves was more intelligent. Bottom: other vs. other comparison. The subjects had to decide if another person, indicated by the names, or the "reference person", which was presented prior to each run, was more intelligent. Each trial began with the presentation of a cue (1500 ms), followed by a fixation point (1500 ms) and a stimulus (1500 ms). After a jittered inter trial interval (ITI) lasting between 9 and 12s, a new trial began.

5.2.4 Imaging procedure

We collected whole-brain MRI data on a 3T TRIO Magnetom (Siemens, Erlangen, Germany). We acquired echo-planar imaging data for fMRI using standard parameters (field of view, 210 mm; matrix: 64 x 64; 1 volume = 28 axial slices, 5mm slice thickness; in-plane resolution, 3.3 mm; TR: 1500 ms, TE: 30 ms; flip angle: 90°; 237 volumes per run). We synchronized stimulus presentation with the fMRI sequence at the beginning of each trial. We acquired four dummy volumes before each run in order to reduce possible effects of T1-saturation. To minimize head motion, we used fixed head pads. We obtained a T1 weighted 3D anatomical scan (1x1x1 mm^3 resolution) for each participant.

5.2.5 Data analyses

For the analyses with GLM we pre-processed and analyzed the fMRI using BrainVoyager^{TM} QX (Brain Innovation, Maastricht, The Netherlands). We applied the following pre-processing steps: slice-time correction, motion correction and linear trend removal and highpass temporal filtering with 2 cycles in time course. Additionally we performed spatial smoothing using a Gaussian kernel of 8mm full-width at half-maximum. We manually coregistered the fMRI data with the anatomical scans. We transformed the 3D anatomical scans into Talairach space (Talairach et al., 1988) and subsequently used the parameters for this transformation to transform the coregistered functional data. We then resampled the 3D functional data set to a voxel size of 3x3x3 mm^3.

We defined each of the two decision directions (myself>other and other>myself, respectively ref>other and other>ref) for the two experimental conditions (SOC and OOC) as four predictors. For defining the predictors, we used the individual reaction times of the trials following stimulus onset. All cues and the following fixation points were defined as a fifth predictor (3 s per event). The remaining fixation volumes served as baseline. Again, we convolved the predictors with a two-gamma HRF (Boynton et al., 1996).

In a first GLM-analysis we calculated a whole-brain FX-GLM, using the FDR for correction of multiple comparisons and implemented comparisons of interest as linear contrast.

In a second masked FX-GLM-analysis we again used the mask including the social comparison specific areas found in the first experiment.

5.3 Results

5.3.1 Behavioural data

Subjects rated the person under comparison more often as more intelligent than themselves (52.50%) or the reference person (50.10%) (see Figure 17). A 2x2 ANOVA showed neither significant main effects (type of comparison (F(1,5)= 1.689, p= 0.250); direction of decision (F(1,5)= 0.343, p= 0.584)) nor a significant interaction (F(1,5)= 0.273, p= 0.623).

Reaction times were higher for OOC conditions (ref>other: 1687 ms, SD= 458; other>ref: 1734 ms, SD= 516) than for SOC conditions (myself>other: 1586 ms, SD= 410; other>myself: 1705 ms, SD= 526) (see Figure 18).

We performed a 2x2 factorial ANOVA for repeated measurements with the first factor "type of comparison" (SOC and OOC) and the second factor "direction of decision" (myself>other and other>myself for the SOC conditions and ref>other and other>ref for the OOC conditions). Reaction time revealed no significant main effects (F(1,5)= 0.82, p= 0.141 and F(1,5)= 1.715, p= 0.255) and no significant interaction (F(1,5)= 1.172, p= 0.19).

The directions of the participants’ decisions were consistent with the expected decision direction based on the relation between the individual ratings of the stimuli ranging from 76.04% to 81.66% (see Figure 19). A 2x2 factorial ANOVA did not show any significant main effects (F(1,5)= 0.40, p= 0.55) and F(1,5)= 0.41, p= 0.55) and no significant interaction (F(1,5)= 0.24, p= 0.64) for the decisions consistent with the hypothesis.

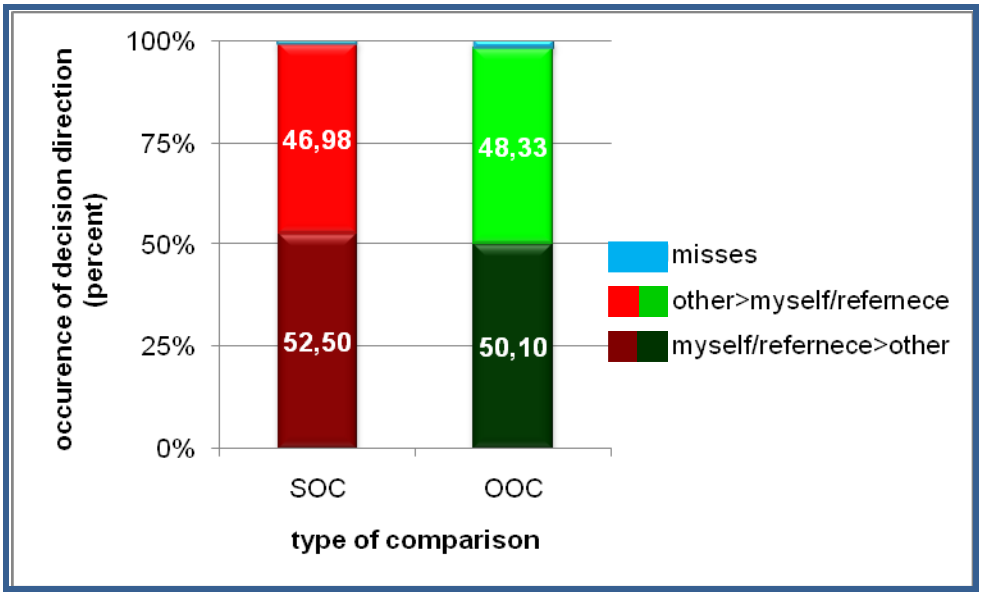

Figure 17: Occurrence of decision direction for the two types of comparison (red: SOC; green: OOC) and the two directions of decision (dark: SOC: myself>other; OOC: ref>other; bright: SOC: other>myself; OOC: other>ref). Blue parts show the amount of misses, which are less than 2% in both conditions.

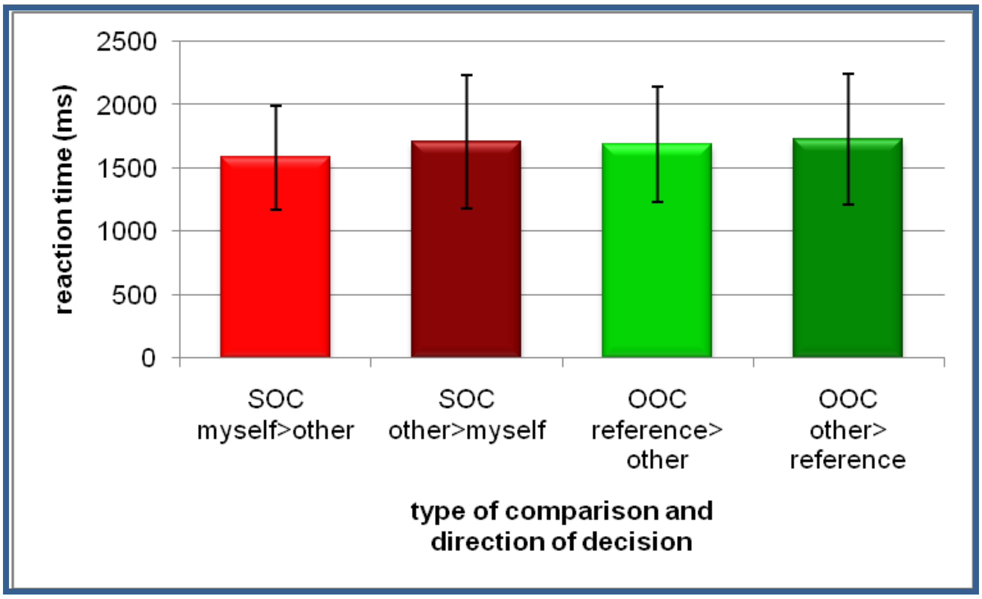

Figure 18: Reaction times for the two types of comparisons and the two decision directions (red: self vs. other comparison (SOC); green: other vs. other comparison (OOC)) and the two directions of decision (bright: myself>other in SOC respectively reference person>other in OOC; dark: other>myself in SOC respectively other>reference person in OOC). Error bars represent standard deviations of means.

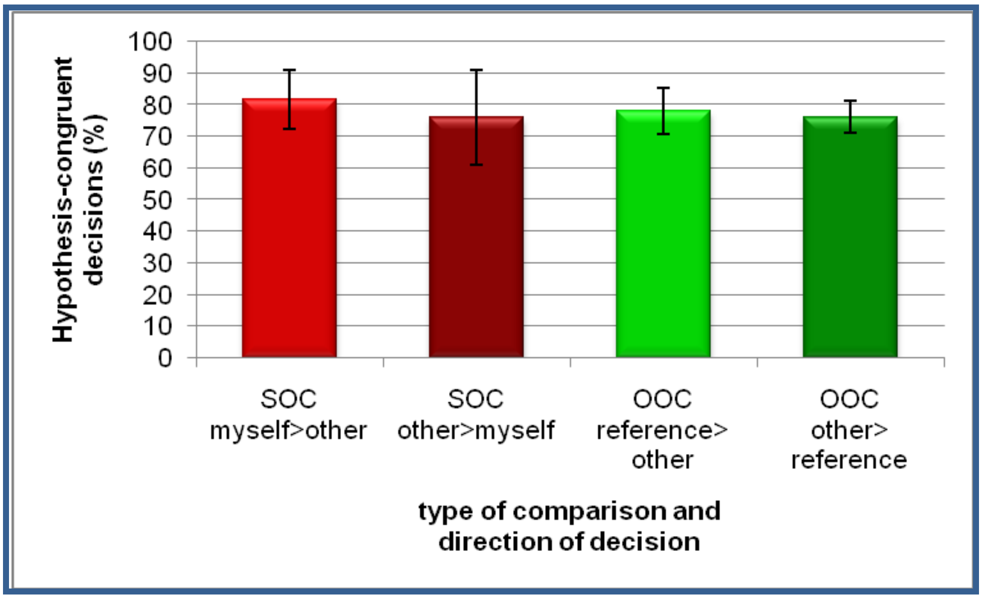

Figure 19: Hypothesis-congruent decisions (in percent) for the two types of comparison and the two decision directions (red: self vs. other comparison (SOC); green: other vs. other comparison (OOC)) and the two directions of decision (bright: myself>other in SOC respectively reference person>other in OOC; dark: other>myself in SOC respectively other>reference person in OOC). Error bars represent standard deviations of means.

5.3.2 fMRI data

We used a whole brain FX-GLM and a masked FX-GLM to analyse the data.

5.3.2.1 whole brain FX-GLM

SOC vs. OOC

The t-map for the contrast between the two comparison types was thresholded at a FDR < .05. A widespread of areas including large regions in the parietal, frontal, temporal and occipital lobes showed higher activation for the SOC than for OOC. OOC showed only higher activation in three clusters in bilateral IPL (Talairach-coordinates: 38,-73,28; -39,-74,34, and -51,-65,34). After thresholding the t-maps with Bonferroni <.05 and a cluster size threshold of 25 voxel several areas still show a significantly higher activation for SOC than for OOC (postcentral gyrus (PoCG), SMA, SFG, MFG, CC, ACC, OcG, supramarginal gyrus (SMG), OFC, MTG, STS, FO, hippocampus (Hi), a cluster including Hi, Tectum (Tec), and Pons. Results are shown in Table 8 and Figure 20. BOLD time courses of some of these areas are shown in Figure 21.

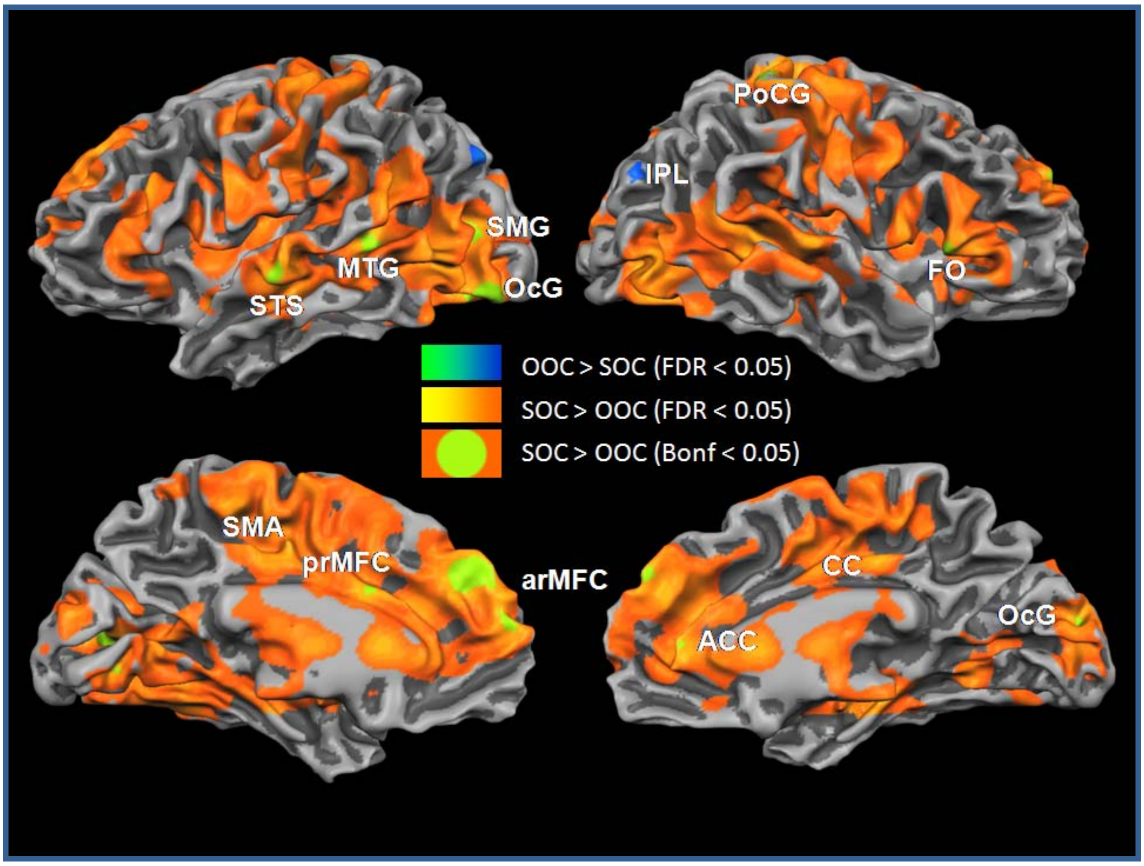

Figure 20: Results of the group analysis with a whole brain FX-GLM. Superposition maps (left: left hemisphere; right: right hemisphere; Top: lateral view; Bottom: medial view) of the contrast between SOC and OOC. Higher activation for SOC is shown in orange and for OOC in blue. Effects were only shown if the associated p-value yielded p<0.01 (corrected for multiple comparisons with FDR). Green colours in the SOC areas represent significant contrast corrected for multiple comparisons with Bonferroni correction. The 3D statistical maps were then projected on the folded surface reconstruction of the MNI template brain. Areas: PoCG, SMA, SFG, MFG, CC, ACC, OcG, SMG, OFC, MTG, STS, FO, Hi, a cluster including Hi, Tec, and Pons.

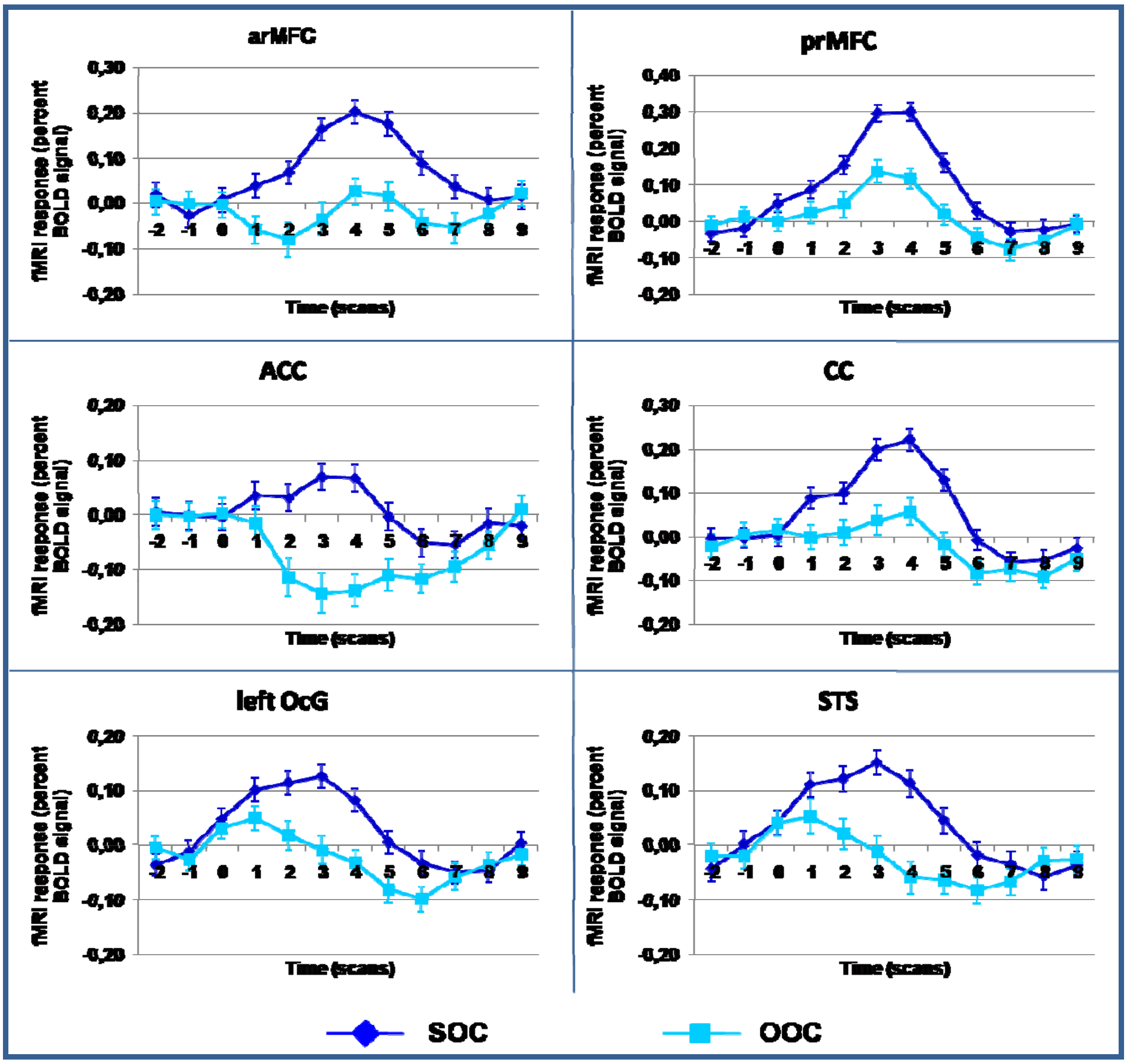

Figure 21: BOLD time courses for areas showing significant differences between the SOC (dark blue) and the OOC (light blue) after correction for multiple comparison with Bonferroni (<.05). The time courses of the SOC and the OOC each represent averages of both decision directions. Error bars indicate the standard errors.

Table 8: Talairach coordinates (centre of ROIs) and statistical details (cluster size and averaged t- and p-values for the cluster) of FX-GLM for areas that showed a significant difference for the contrasts SOC and OOC after correction for multiple comparisons with Bonferroni (α<.05).

Regions	**Left/ Medial/ Right**	**Talairach coordinates**			**Cluster size (voxel)**	**Averaged t- and p-values for contrast (myself>others) vs. (others>myself)**	
		x	**y**	**z**		**t-value**	**p-value**
SOC > OOC							
PoCG	R	37	-36	56	370	5.227851	< 0.0001
SMA	M	0	-29	50	65	4.952286	< 0.0001
	M	0	-19	39	127	4.941959	< 0.0001
SFG	L	-24	44	40	107	4.969591	< 0.0001
arMFC	R	15	52	29	661	5.120808	< 0.0001
	L	-5	46	31	1756	5.204811	< 0.0001
prMFC	L	-4	54	18	411	5.161613	< 0.0001
CC	M	-3	16	29	424	5.121597	< 0.0001
ACC	M	1	39	8	302	5.090835	< 0.0001
OcG	R	6	-87	18	65	4.928834	< 0.0001
	L	-32	-73	-1	3391	5.373530	< 0.0001
	R	39	-68	-3	96	4.953944	< 0.0001
SMG	R	45	-46	17	91	5.006118	< 0.0001
OFC	R	26	36	-1	49	4.976359	< 0.0001
MTG	L	-45	-38	7	172	5.040084	< 0.0001
STS	L	-60	-10	-2	271	5.113631	< 0.0001
FO	R	52	15	5	109	5.073191	< 0.0001
Hi	L	-27	-17	-11	48	4.990326	< 0.0001
Hi/Tec /Pons	R	17	-22	-7	693	5.249225	< 0.0001

Contrast between the decision directions

The contrast between the decisions ref>other and other>ref in the OOC condition revealed no significant differences. However, the contrast between myself>other and other>myself yielded a higher activation in mOFC for the decision myself>other and a higher activation in PoCG, SPL, IPL, precentral gyrus (PreCG), SMA, inferior frontal gyrus opercular part (IFGOp), OcG, Ins, and cerebellum for the decision other>myself (see Table 9 and Figure 22). Again, a cluster size threshold of 25 voxels was used.

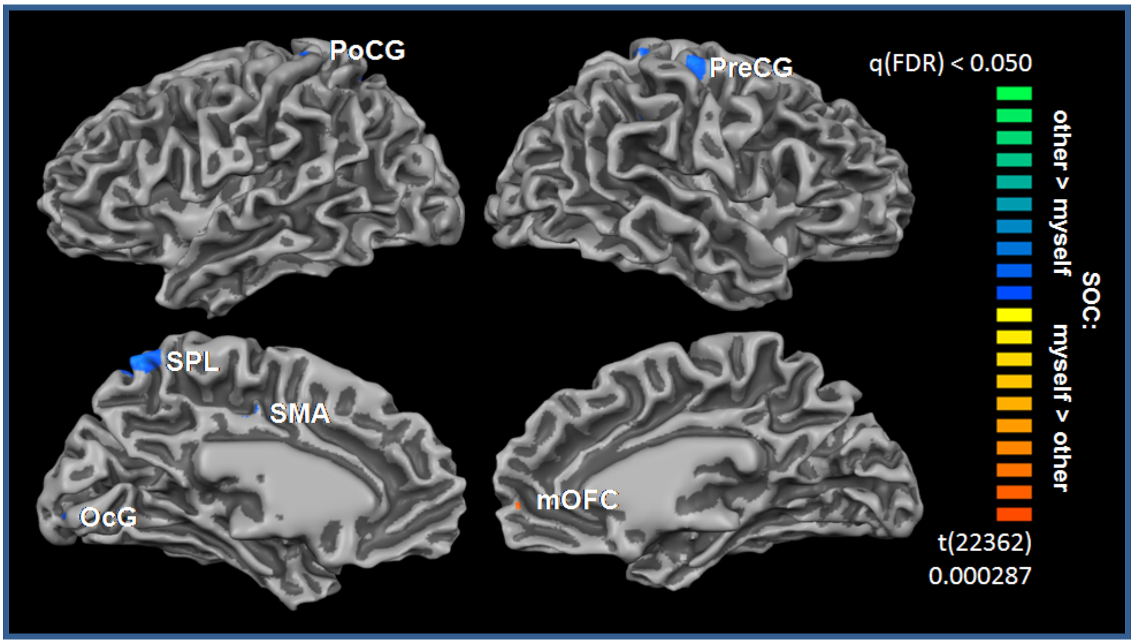

Figure 22: Group analysis with FX-GLM. Superposition maps (left: left hemisphere; right: right hemisphere; Top: lateral view; Bottom: medial view) of the contrast between myself>other decisions and other>myself decisions for the SOCs. Higher activation for myself>other decisions is shown in orange and for other>myself decisions in blue. Effects were only shown if the associated p-value yielded p<0.01 (corrected for multiple comparisons with FDR). The 3D statistical maps were then projected on the folded surface reconstruction of the MNI template brain. Areas: mOFC, PoCG, SPL, PreCG, SMA, SMG, OcG.

Table 9: Talairach coordinates (centre of ROIs) and statistical details (cluster size and averaged t- and p-values for the cluster) of FX-GLM for areas that showed a significant difference for the contrasts between myself>other and other>myself in the SOC condition.

Regions	**Left/ Medial/ Right**	**Talairach ccordinates**			**Cluster size (voxel)**	**Averaged t- and p-values for contrast (myself>others) vs. (others>myself)**	
		x	***y***	***z***		**t-value**	**p-value**
myself>other							
mOFC	M	2	54	4	250	3.807730	< 0.001
Other>me							
PoCG	L	-32	-34	61	76	-3.796959	< 0.001
	L	-34	-42	53	140	-3.759390	< 0.001
	R	23	-39	61	220	-3.801840	< 0.001
SPL	M	-3	-58	59	1659	-4.026281	< 0.001
IPL	R	49	-38	33	53	-3.723143	< 0.001
PreCG	R	39	-19	53	400	-3.844350	< 0.001
SMA	M	-3	-16	41	410	-3.841588	< 0.001
IFGOp	R	40	10	16	33	-3.730503	< 0.001
OcG	M	-7	-87	1	100	-3.727480	< 0.001
	R	19	-44	-9	87	-3.713447	< 0.001
Ins	R	49	5	4	205	-3.738062	< 0.001
Ins	R	35	7	-6	61	-3.671982	< 0.001
Cerebellum	L	-17	-55	-14	41	-3.728268	< 0.001

5.3.2.2 Masked FX-GLM

When contrasting SOC and OOC, all areas showed a higher activation for SOC. The contrast between the decision directions in the OOC did not reveal any significant differences but the contrast between the decision directions in the SOC showed a higher activation for the decision myself>other in arMFC and mOFC and a higher activation for the decision other>myself in IPL (see Table 10 and Figure 23).

Table 10: Talairach coordinates (centre of ROIs) and statistical details (cluster size and averaged t- and p-values for the cluster) of masked FX-GLM for areas that showed a significant difference for the contrasts between myself>other and other>myself in the SOC condition.

Regions	**Left/ Medial/ Right**	**Talairach ccordinates**			**Cluster size (voxel)**	**Averaged t- and p-values for contrast (myself>other) vs. (other>myself)**	
		x	*y*	*z*		**t-value**	**p-value**
myself>other							
arMFC	M	5	48	38	83	3.67416	< 0.001
mOFC	M	2	54	3	871	4.18137	< 0.001
Other>myself							
IPL	R	51	-38	33	72	-3.48448	< .001

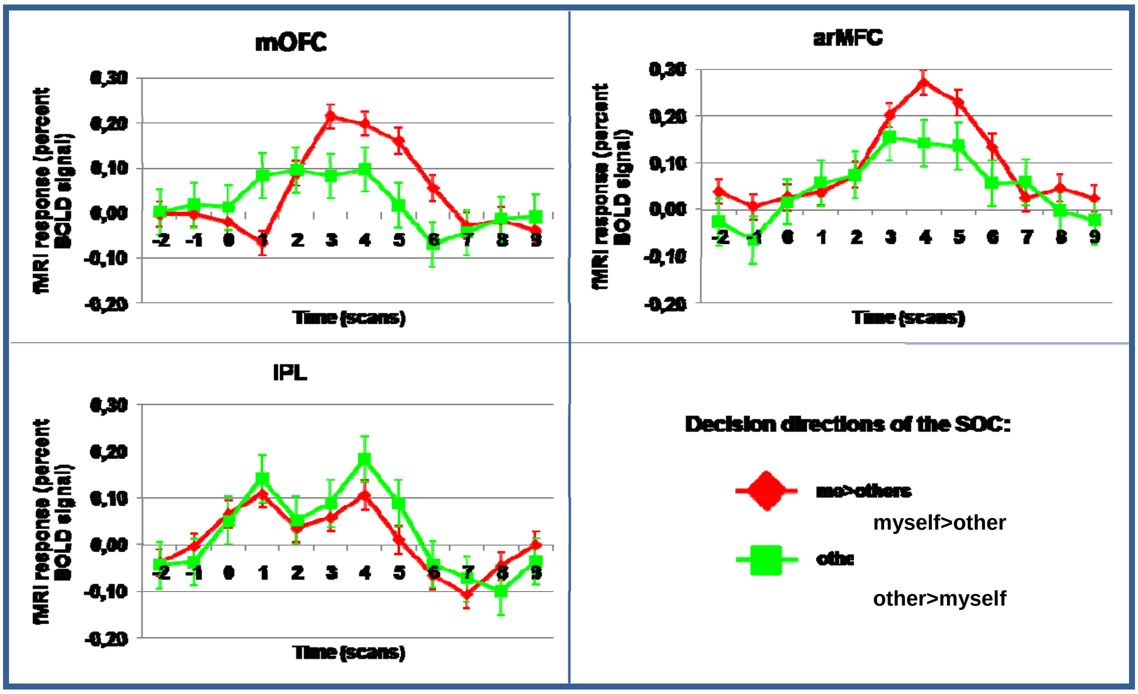

Figure 23: BOLD time courses of the areas showing significant differences between the two decision directions of the SOC in the masked FX-GLM (red=myself>other, green=other>myself, dark and bright green=control conditions). Top: mOFC and arMFC shows higher activation for the decision myself>other; Bottom: IPL shows higher activation when another person was rated as more intelligent than oneself. Error bars indicate the standard errors.

5.4 Discussion

5.4.1. OOC vs. SOC

Referring to the hypothesis generated from the descriptive comparison of the neural activation pattern between the OOC in the first experiment and the SOC in the second experiment, we first investigated the neural differences between the SOC and the OOC using the same stimulus material and stimulus presentation for both comparison types. As we only analyzed preliminary data of 6 subjects, using a FX-GLM, the results can not be generalized to the population. We therefore focus on the areas revealing significant differences after correction for multiple comparisons with Bonferroni. Further measurements of up to 20 more subjects are planned to perform RFX-GLMs of the group data.

We found a higher activation for SOC in several areas including PoCG, SMA, SFG, arMFC, prMFC, CC, ACC, OcG, SMG, OFC, MTG, STS, FO, Hi, and a small cluster including Hi/Tec/Pons.

The decision and lateralization of the button presses did not show any significant differences between the decision directions nor between the OOC and SOC. Moreover, the numbers of button presses were equal for SOC and for OOC. Hence, the higher activation of the SMA is not related to the button presses. The SMA has shown to be involved in decision making; Ikeda et al. (1999) concluded that pre-SMA is involved in cognitive motor control which involves sensory discrimination and decision making or motor selection for the action after stimuli, whereas SMA-proper is one of the main generators of readiness potential preceding self-paced, voluntary movements. Readiness potential was found by (Libet et al. 1983) describing the effect of an activation of the SMA during the preparation of a motor task preceding the actual movement. Because the samples of the third and the preceding experiments are recruited from an academic environment, intelligence assumingly plays an important role in the ideal self of these participants. We could further generally expect these persons to prefer a decision for rating oneself as more intelligent than another person. This can cause a readiness potential in the SOC leading to an activation of the SMA and the hand-related areas in the motor cortex in the task preceding the button press. This additional activation in these areas can cause the difference between the SOC and the OOC in the SMA and motor areas. In this case, the ipsilatersal motor cortex of the hand used for the prefered response should show a higher activation because of a response conflict (Cohen-Kadosh et al., 2007). This could be tested by calculating the lateralization index of the motor areas. Since we counterbalanced the key assignment of the button presses over the subjects, it is not possible to perform this test in this group analysis. Therefore the lateralization index of the motor areas should be calculated after increasing the sample size of this experiment by splitting the group concerning the key assignment.

A network including the lateral fusiform gyrus on both sides, the right inferior parietal lobule, the right lateral prefrontal cortex and the left ACC was found to be activated in self-comparison processes concerning the (own) body shape (Friederich et al., 2007). The two different comparison tasks of our experiment include a direct comparison with oneself only in the SOC. Therefore the areas found activated in self-comparison processes about the (own) body shape should be only or more activated in the SOC than in the OOC. In fact, areas of the network showed higher activation for SOC than for OOC. The lateral fusiform gyri and the left ACC revealed a significantly higher activation for the SOC even after Bonferroni correction; the right lateral prefrontal cortex showed significant differences only after correction for multiple comparison using FDR (<.05). Only the right IPL did not show any higher activation in the SOC.

Again, in analogy to the preceding experiments, we proposed that the social comparison tasks require decision making under uncertainty, perspective taking and ToM. The participants had to draw on their knowledge about particular persons from their social environment because they would have been unlikely specifically to have thought about their height or intelligence beforehand and they could not be certain of the right answer. The regions we found in our comparison tasks in the medial frontal and orbitofrontal areas (prMFC, arMFC, and OFC) were also found in decision making processes in ambiguous or otherwise uncertain situations (Manes et al., 2002; Bechara et al., 2000; Fellows et al., 2007). The comparison between the two preceding experiments has already revealed a stronger activation of the OFC/FO in the right hemisphere for the OOC overlapping with the cluster in the right lateral OFC (including FO), showing differences between the SOC and the OOC in this third experiment. The differences in the activation of the OFC between the two preceding experiments seem to be based on the different stimuli and especially the different amount of uncertainty and reward anticipation in the two experiments. In the third experiment we used the same stimulus material for both comparison types SOC and OOC, hence the differences in the OFC cannot be explained by different amount of ambiguity/uncertainty. As the OFC is recruited in reward calculation processes in social comparisons, together with ventral striatum (Fliessbach et al., 2007), in reward and punishment tasks (Rolls, 1996), and in guiding one's behaviour in terms of the value of possible outcomes (Amodio et al., 2006) in value related processes (Hare et al., 2008), we conclude that the higher activation of the OFC is related to the more reward-related process in the SOC. The decision whether I am more or less intelligent than another person is more self-relevant and therefore linked with a higher reward outcome than comparing two other persons with one another.

The posterior dorsal MFC was also found to be involved in decision making as well as in the process of adopting another person’s perspective and the left part of the dorsal MFC showed an interaction between perspective taking and self-referential processes (D’Argembeau et al., 2007). The authors suggested that this region may be involved in decoupling one’s own from other persons’ perspectives on the self. The left dorsal MFC actually showed a higher activation for the SOC and also belong to the core network including the MFC, medial temporal lobes, medial parietal regions, and the TPJ which are activated in autobiographical memory, prospection, navigation, ToM, and default mode (Buckner et al., 2007). As mentioned above, the authors suggested that all these processes rely on memory systems, because past experiences serve as the foundation for alternative perspective taking and thinking about the future. Hence, Buckner et al. (2007) postulated that all these processes are best understood as part of a larger class of functions that enables flexible forms of self-projection.

Based on the differences in the ToM-areas in the preceding experiment, we hypothesized that the OOC and the SOC differ in the amount of mentalizing, resulting in higher activation in the ToM related areas in the OOC. The results of this third experiment showed that the medial-temporal lobes and the medial parietal areas (PCC and PCun) did not show any significant differences between the SOC and the OOC. Based on the differences in the activation of the TPJ in the preceding experiments, we expected the TPJ to show a higher activation in the OOC. But on the contrary, the TPJ revealed a higher activation for the SOC after thresholding with FDR.

Why then did we find a higher activation in the ToM-related areas for SOC than for OOC, especially in the TPJ and parts of the MFC?

One might suggest that the differences in the activation of the ToM-related areas are related to the differences in the two comparison tasks. The decisions in the SOC are assumingly more important and self-relevant than decisions made in the OOC. The pure comparison of two celebrities in our task has normally no effect or consequences on the participant whereas the SOC includes a comparison with oneself. Hence, the self-reference is much stronger in the SOC than in the OOC. In addition to this self-reference, the decisions in the SOC entail reward expectations such as being content, satisfied, encouraged to be more intelligent than another or dissatisfied, disappointed, crestfallen, etc. about the decision to be less intelligent than another person. Reward-related areas in the OFC showed a higher activation in the SOC. This higher self-relatedness of the decision in the SOC may lead to more effort in performing the task that comes along with a higher degree or more detailed perspective taking. This stronger effort could be the reason for the higher activation of the SOC in widespread areas. Also, the higher activation of the OcG in the SOC may result from this stronger effort and from a more detailed imagery of the person under comparison.

Our second prediction was that the OOC and the SOC would show differences in the activation of the MFC relating to the involvement of the self in the social comparison process of personal characteristics. Although the same stimulus material was used in both comparison types, the third experiment showed higher activation in dorsal and posterior regions of the MFC (arMFC and prMFC) for the SOC in relation to the OOC. A more considerable difference between the SOC and the OOC was found in the ACC. While the ACC showed an increase of activation for the SOC, a decrease of activation was found for the OOC in this area. The ACC has been associated with self-processing (Northoff et al., 2004), social cognition (Schilbach et al., 2006), and in self-related processes (Modinos, Ormel, & Aleman, 2009). Hence, the higher activation of ACC in the SOC seems to indicate a higher involvement of the self or a higher self-related process of the SOC. Therefore, as expected in our second hypothesis, one might also suggest that the differences regarding the involvement of these medial frontal areas in the two tasks result from the different degree of self involvement in these comparison processes.

5.4.2 Decision directions

In a second step of our analysis, we investigated neural differences in the decision directions in both comparison tasks. While the whole brain FX-GLM did not reveal any significant differences between the decision directions in the OOC, the decision directions in the SOC differed in several brain areas. The decision myself>other showed higher activation in the mOFC. The common activation of the ventral area of the MFC and the mOFC could be explained by the combination of the stronger involvement of the self and a higher expected reward for this decision (Wallis, 2007; Van Overwalle, 2009). As explained above, the participants (especially those from an academic environment, chosen for these experiments) may prefer the decision as to be more intelligent than another person, relating to a higher degree of self-reference or rather self-relatedness and a higher reward expectation. The contrary decision direction other>myself revealed a higher activation in SMG, SPL, OcG, MFG, IFGOp, and Ins. The higher activation of the SPL and the OcG could be explained by a stronger imagination of the other person in relation to a process of controlling or checking the decision.

The results of the masked FX-GLM are in accordance with the whole brain FX-GLM and with the comparison of the two preceding experiments. The contrast between the two decision directions of the SOC revealed a higher activation for the decision myself>other in the arMFC and the mOFC, whereas the opposite decision direction other>myself showed a higher activation in IPL only. In accordance with the whole brain FX-GLM results, we explained the higher activation of the mOFC and additionally of the arMFC for the decision myself>other with a higher degree of self-reference or self-relatedness and a higher reward expectation. The BOLD time course of the IPL showed two peaks. While the first peak is identical with the BOLD time course of the SOC, the second peak showed a slightly higher activation for the OOC and therefore these differences drive the significant contrast between the two comparison types in this area. It could be argued that the two peaks represent the imagination of the two persons under comparison. The first peak being identical in both conditions, it could represent the imagination of the participants' own body, whereas the second peak may represent the imagination of the other person. The decision other>myself in SOC could implement a more intensive or enduring imagination process related to a control process of the decision. A probably more enduring imagination could also result in the (not significantly) longer reaction time for this decision direction in SOC.

Keeping in mind that the results are based on a FX-GLM, a further discussion of the results has to be postponed until the sample of participants has been increased and the calculation of an RFX-GLM has been performed.

As mentioned in the introduction, this experiment was designed for using a multivariate pattern analysis to analyze the data. Despite obtaining results with the classical analysis approach with GLM, we assumed that the GLM is not sufficient or sensitive enough to detect differences in the brain pertinent to decision direction. Assumingly, the decision directions of the social comparison processes investigated in this experiment are not calculated in form of involvement or lack of involvement of evolutionary developed brain areas, which are specified for these kinds of comparison. Rather, the decision directions are assumed to be "calculated" by a combination of activations and non-activations of several areas relating to comparison, self and reward. Information from these areas is integrated in a social context and handled in the MFC (see Amodio et al., 2006), resulting in a kind of "decision direction pattern" in one or more discrete areas in the MFC. A difference in the activation pattern within the areas involved in these comparison processes, which are relevant for forwarding the information to the MFC and therefore necessary for the calculation of the decision direction, is also conceivable. In both cases, it is equally impossible to perform a GLM to find the areas responsible for the decision direction. An approach such as the MVPA will be more sensitive regarding these kinds of differences in neural activation pattern because it is designed to find pattern differences. Further developments of the algorithms are required for its use with our data, which will go beyond the scope of this doctoral thesis.

6. General discussion

In this doctoral thesis, the neural correlates of social comparison processes were investigated by three experiments.

6.1 Physical vs. psychological person comparison

The first main result of these three experiments was that neural activation patterns differ in the contrast between comparing physical and psychological person characteristics. Even though it has often been assumed that comparisons on all levels of complexity involve similar psychological mechanisms (Kahneman et al., 1986; Mussweiler, 2003), they recruit significantly different networks at the brain level.

The results suggest that the comparison of physical person characteristics, in our case the comparison of body height, requires the retrieval and mental imagery of the person being compared and perhaps an imagery of oneself. The comparison of physical person characteristics showed a higher activation mainly in the IPL (experiments 1 and 2) and additional areas in SPL, PCun, ITG, FG, OcG, SFG, and MFG (experiment 2). These areas (especially the IPL) were found to be activated in several visual imagery tasks (e.g. Lamm et al., 2001; Newman et al., 2007) showing differences in spatial transformation, egocentric perspective transformation, and object-based transformation (Zacks et al., 1999; Zacks et al., 2000; Zacks et al., 2002; Zacks et al., 2003a; Zacks et al., 2003b), in mental rotation (Newman et al., 2007), in spatial transformations and mental rotation (Zimmer, 2008), in images of slim-idealized bodies (Friederich et al., 2007), and in relational visual imagery (Knauff et al., 2002). Frontopolar cortex and IPL were also found to be activated during exploratory decisions (Daw et al., 2006). On the other hand, the comparison of psychological person characteristics involves areas of the core network (MFC, PCC, TPJ, OcG) which were activated in autobiographical memory, prospection, navigation, ToM, and default mode (Buckner et al., 2007; Spreng et al., 2009). The activation of these areas in our tasks was not surprising as the social comparison tasks, especially the comparison of psychological person characteristics, in our experiment involved perspective taking by drawing on knowledge about the celebrity in question, since it was unlikely that they would have thought about their height or intelligence beforehand, as well as autobiographical memory in terms of retrieving information about the person under comparison from long-term memory. Spreng et al. (2009) argue that complex social processes needed for social selection such as perspective taking require the ability to remember specific social encounters and the changing social conditions which are mainly part of autobiographical memory. Furthermore, the MFC is suggested to serve the integration of social information and to handle the neural input from the DLPFC, the STS, and the TPJ (Huey et al., 2006).

The comparison of psychological person characteristics seemed to include a higher degree of decision making under uncertainty and reward anticipation than the body height comparison and it is attended by a higher activation of the mOFC and the lateral OFC. These areas are related with reward calculation processes in social comparison together with ventral striatum (Fliessbach et al., 2007), in reward and punishment tasks (Rolls, 1996; Wallis, 2007), and in guiding one's behaviour in terms of the value of possible outcomes (Amodio et al., 2006). Additionally, combinations of the activation of the OFC and the MFC (especially the ACC) are found in decision making tasks with different types of uncertainty (e.g. Critchley et al., 2001; Walton et al., 2003; Cohen et al., 2005). The tasks in our experiment, particularly the intelligence comparison, include decisions under uncertainty because the intelligence of the persons under comparison is not explicitly known and thus had to be estimated on the basis of the participants’ knowledge.

Another account for an increase in the recruitment of the ToM network in response to intelligence comparison is that intelligence comparison is more relevant and more socially meaningful than body height particularly for the participants we assessed as participants of all three experiments were recruited from an academic environment. It can be assumed that intelligence plays a more important role for the professional career of academics than body height (e.g. Albert Einstein), whereas perhaps for other occupational groups the body height is much more important than for academics (e.g. basketball players). This second explanation cannot be investigated in these experiments. Further experiments would have to be conducted in the future to investigate possible different influences of personal importance regarding social comparisons and judgements.

6.2 SOC vs. OOC

A second interesting finding is that the neural activation patterns differ between the SOC and OOC. As discussed in chapter 4, despite fundamental differences between the used stimuli (experiment 1: dissimilar, possibly unknown celebrities; experiment 2: more similar, familiar persons), the two social comparison processes showed similarities of neural activation for the physical as well as for the psychological person characteristics. The overlap in the comparison of the physical person characteristics is strictly limited to the IPL which probably refers to the more imagery based comparison process discussed above. The intelligence comparison showed more widespread overlaps mainly in parts of the core network and respectively the OFC, which may represent the involvement of perspective taking, the usage of autobiographical memory and respectively decision making and reward anticipation. A wide range of differences occurred in the activation pattern including ventral and dorsal parts of the MFC, the PCC, and the TPJ. Notwithstanding the possibility that these differences of activation may result from using two different MR-scanners, the differences show meaningful and interpretable activation patterns referring to the content of the involved cognitive processes. The SOC seems to activate more dorsal areas of the MFC. The descriptive results of the comparison between the first two experiments are supported by the Bonferroni corrected preliminary results of the third experiment also showing more activation in widespread brain areas including dorsal parts of the MFC (arMFC). Northoff et al. (2006) suggested that these dorsal regions of the MFC are implicated in processes of reappraisal and evaluation of self-related stimuli. It could be suggested that the comparison concerning the intelligence of one person with oneself is more important and self-relevant than a comparison of two other persons. Hence, the more self-relevant judgements of the SOC may imply more evaluation processes activating the dorsal MFC. This is in line with the results of Northoff et al. (2006). The higher activation of the ACC for the SOC than for the OOC task also points to a higher involvement of the self (Craik et al., 1999; Frith et al., 1999; Kelley et al., 2002; Vogeley et al. 2001). The ACC in combination with the anterior MFC is involved in self-related processes (Modinos et al., 2009). One might further argue that these more important intelligence comparisons also imply more reward anticipating processes than an unimportant comparison or judgement. More reward anticipation processes involve OFC (see Wallis, 2007); we correspondingly found a higher activation in SOC than in OOC in both the descriptive comparison of the first two experiments and in the third experiment. The results of the three experiments lead to the conclusion that the SOCs are more important and self-relevant in general. The comparison of two celebrities in our task has normally no effect or consequences on the participant, whereas the comparison of oneself with another person entails reward and self-evaluation processes.

In chapter 4 we discussed that the differences in the activation of the TPJ between the SOC and the OOC of the first two experiments may rely either on the degree of mentalizing in the two comparison types or on the differences in the used stimuli. While in the first experiment celebrities were used as persons to compare with, in the second experiment the participants had to compare themselves with familiar persons and again celebrities in the third experiment. In this latter experiment we did not find any differences in the activation of the TPJ between the SOC and the OOC using the same stimulus material. Although the results of the third experiment concern preliminary data only using an FX-GLM, it can be assumed that the differences between the activation of the TPJ in the first two experiments rely on the differences of the used stimuli or rather on the induced cognitive process. Retrieving the information about strange and unfamiliar persons like celebrities may require stronger mentalizing than retrieving information about familiar persons. It could be argued that the information about a familiar person is more present, whereas the comparison specific information about unfamiliar others must be extracted in a more exhausting way. This would also be consistent with Schall's (2001) point of view about decisions of familiar and non-familiar alternatives. Schall (2001) claimed that you can choose one of several familiar alternatives, but when you are confronted with new alternatives you first have to understand them, the differences between them and how the alternatives relate to your own goals, desires and preferences. Consequently, decisions are more effortful, take more time, require attention and deliberation, and are more error prone than simple choices.

6.3 Decision directions

The contrast between the two decision directions of the SOC in the third experiment revealed a higher activation for the decision myself>other in the arMFC and the mOFC; and the opposite decision direction other>myself showed a higher activation only in IPL. In accordance with the suggested involvement of the arMFC in self-relatedness and of the OFC in reward-related processes, we explained the higher activation of the mOFC and additionally of the arMFC for the decision myself>other with a higher self-reference or rather self-relatedness and a higher reward expectation.

6.4 Future Perspective

As only preliminary data are available for the third experiment, a more detailed discussion of the data should be deferred to the time after increasing the sample and reanalyzing the data with an RFX-GLM.

Additional analyses with MVPA are required as the MVPA is more sensitive to finding differences in neural activation patterns. In recent years, MVPA approaches have been used in a widespread of neuroscientific studies. In functional brain mapping, pattern recognition methods allow detecting multivoxel patterns of brain activation which are informative with respect to a subject's perceptual (e.g. Haxby et al., 2001) or cognitive state (e.g. Polyn, Natu, Cohen, & Norman, 2005). In addition to decoding and categorization of neural activity inferred from stimulus inspection in various perceptual tasks (e.g. orientation of striped pattern, categorization of objects, direction of movements), MVPA approaches can also be used to characterize these cognitive states as to how they are presented in the brain. Therefore, the MVPA is based on the assumption that cognitive states consist of multiple aspects and different values of these aspects or dimensions are represented by different patterns of neural activation (Norman, Polyn, Detre & Haxby, 2006). MVPA has also been used in mind reading tasks, and to investigate intentional decision making processes. In an fMRI experiment, neural differences related to the decision directions in intentional decision making tasks could be found with MVPA, but not with the classical GLM approach (Haynes et al., 2007). By using MVPA to analyze the data in experiment 3, we expect to decode more detailed information about the social comparison process and especially about the directions of the related decisions.

Further experiments will have to be conducted in the future to investigate possible different influences of personal importance attributed to social comparisons and judgements. Further experiments would also have to investigate the influence of the persons under comparison on the induced cognitive processes and therefore on the neural activation pattern. Personality traits should be included by means of corresponding questionnaires and/or psychological test batteries, in order to investigate the individual decision behavior of participants and the influence of the stimuli used for the social comparison tasks, and of the differences between SOC and OOC.

The process to infer the engagement of a specific cognitive process on basis of a particular neural activation pattern is called “reverse inference” (Poldrack, 2006). The author showed that the usefulness of this approach is limited by the selectivity of the neural activation. If a specific region is only activated by one cognitive process the reverse inference is relatively powerful. The common network described above is involved in several cognitive processes (autobiographical memory, prospection, navigation, ToM, and default mode) and therefore it does not fulfill the condition of being selectively activated.

Furthermore, selective neural activations are absent in most complex cognitive processes and also in social processes. Hence the strategy of reverse inference should be used with caution. Due to the fact, that our task - like most of all social cognitive processes - included several low- and high-level cognitive processes (e.g. low-level: perception, attention, memory, etc; high-level: comparison, decision making, perspective taking, etc) the activation of particular brain regions cannot be taken as a marker of engagement of a particular cognitive process. In general, reverse inference should not be used as an ad hoc means to explain the occurrence of an activation pattern (Poldrack, 2004). Rather it should be used to generate new hypotheses that are tested in new experiments, like we did in the comparison of the experiments 1 and 2. Well-designed psychological neuroimaging experiments should be performed in which the reverse inference approach may be justified such as in our third experiment. Further to our last experiment, future studies should investigate the particular influences of the different cognitive processes involved in the social comparison process separately and by manipulating the amount of these processes in the task to get more precise information about the coherency between the cognitive processes and their neural correlates.

In the first experiment we measured only male subjects, because the stimuli were rated only by male subjects on familiarity in a preceding experiment by the group of Prof. Mussweiler. Thus, a generalization of the results to women is not possible, and therefore we measured only male subjects. In the second and the third experiment we measured both female and male subjects. This was possible, because here the stimuli were chosen or adaptive individually for each subject. It could be argued that the gender of the subjects and that gender of the persons to compare with could have an influence on the comparison and decision processes and hence on the neural activation patterns. For example: If we assume that the mean body height of women is lower than of men, the comparison and the associated decision direction on the body height could be systematically influenced by the usage of male and female subjects in form of a higher amount of decisions that the other person is taller than the subject. However, we did not find significant differences in the neural activation between female and male subjects in our experiments. However our experiments were not designed to investigate gender differences. In future experiments a possible gender effect on the comparisons and the decisions should be explored in detail. For such studies the gender of the participants and the persons to compare with should be counterbalanced. Furthermore the expected decision directions should also be counterbalanced. For the example above: the stimuli sample should be individually selected (concerning the body height) for each subject choosing an equivalent number of taller and of smaller persons to compare with than the subject.

Social cognitive neuroscience is an interdisciplinary field combining the well established models, theories and methods from the social psychology with the methods of neuroscience. Whereas social psychology studies the social interaction between and within groups on the social and the cognitive level, social cognitive neuroscience additionally tries to find the neural correlates of the social processes. Identifying the neural bases of social processes will help social psychology research to define and understand social processes and to generate new ideas and hypotheses (Lieberman, 2007). Furthermore, the integration of neurophysiological, cognitive and social levels of research and analysis provided by the social cognitive neuroscience is important to develop more comprehensive explanations of the human mind and behavior. This is exemplified in the current study: We showed that the two seemingly similar comparison processes of two person characteristics we investigated here involve two different neural networks. Only with the further knowledge of the social psychology that the comparison of psychological person characteristics is seen as a social comparison, whereas the comparison of physical person characteristics is a more non-social one, the neural differences between the two types of comparisons can be ascribed to their different contents – the two different kinds of person characteristics. The example of our study shows that the interdisciplinary perspective of social cognitive neuroscience combining the research methods of neuroscience and the theories and constructs of social psychology complementary enables a better understanding of the brain activation as well as of the underlying social cognitive process.

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8. Lists

8.1 List of abbreviations

In alphabetical order:

ACC	anterior cingulate cortex
AMG	amygdala
aMTG	anterior medial temporal gyrus
APCC	anterior paracingulate cortex
arMFC	anterior portion of the rostral medial frontal cortex
BA	Brodmann area
BOLD	blood-oygen-level dependent signal
CC	cingulate cortex
CMS	cortical midline structures
DLPFC	dorsolateral prefrontal cortex
EBA	extrastriate body area
FDR	False Discovery Rate
FFA	fusiform face area
fMRI	Functional Magnetic Resonance Imaging
fMRT	funktionelle Magnetresonanztomographie
FO	frontal operculum
FX	fixed effects
GLM	general linear model
GP	globus pallidus
Hi	hippocampus
HRF	hemodynamic response function
IFGOp	inferior frontal gyrus opercular part
Ins	insula
IPL	inferior parietal lobe
IPS	Inferior parietal sulcus
ITG	inferior temporal gyrus
ITI	inter trial interval
MFC	medial frontal cortex
MFG	middle frontal gyrus
mOFC	medial orbitofrontal cortex
MNI	Montreal Neurological Institue
MTG	middle temporal gyrus
NAcc	Nucleus accumbens
OcG	occipital gyrus
OFC	orbitofrontal cortex
OOC	other vs. other comparison
PCC	posterior cingulate cortex
PCun	Precuneus
pH	posterior hippocampus
PoCG	postcentral gyrus
PreCG	precentral gyrus
prMFC	posterior portion of the rostral medial frontal cortex
pSTS	posterior superior temporal sulcus
RFX	random effects
ROI	region of interest
SD	standard deviation
SFG	superior frontal gyrus
SMA	supplementary motor area
SMG	supramarginal gyrus
SN	substantia nigra
SOC	self vs. other comparison
SPL	superior parietal lobe
STS	superior temporal sulcus
TE	echo time
Tec	tectum
ToM	Theory of Mind
TPJ	temporo-parietal junction
TR	repetition time

8.2 List of tables

8.3 List of figures

9. Appendix

9.1 Stimuli of experiment 1

9.1.1 Stimuli of experiment 1 in alphabetical order

Surnames of celebrities for the trainings session:

Clinton
Clooney
DeVito
Eminem
Goethe
Jagger
Sinatra
Struck
Tappert
Wussow

Surnames of celebrities for the main experiment:

Agassi
Becker
Biolek
Blair
Bohlen
Brandt
Bush
Carrell
Chirac
Cruise
Drews
Einstein
Elvis
Falko
Fischer
Gates
Genscher
Ghandi
Grass
Hanks
Heino
Hoeneß
Jackson
Jauch
Jordan
Juhnke
Kahn
Kohl
Lenin
Lennon
Loriot
Maffay
Mozart
Otto
Pitt
Powell
Putin
Raab
Rau
Schröder
Schumacher
Sting
Strauß
Trittin
Tyson
Vogts
Völler

9.1.2 Stimuli pairs of the 4 conditions

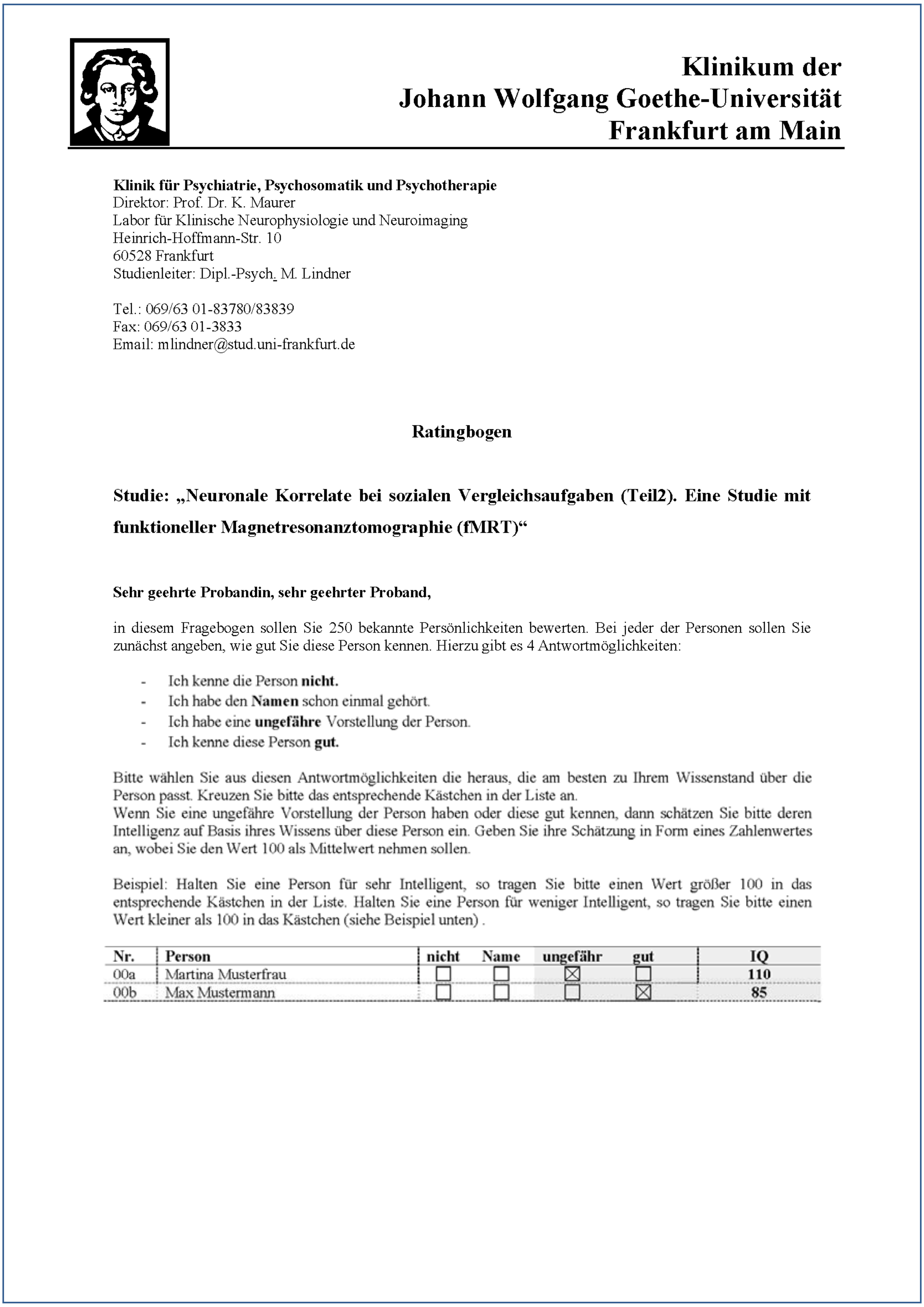
Training session

intelligence		body height		musician		politian	
Wussow	Clinton	DeVito	Jagger	Sinatra	Wussow	DeVito	Tappert
Clooney	Eminem	Clinton	Clooney	Goethe	Eminem	Struck	Jagger

Main Experiment

intelligence		body height		musician		politian	
Bohlen	Putin	Becker	Drews	Vogts	Ghandi	Jackson	Lenin
Putin	Lennon	Juhnke	Heino	Brandt	Genscher	Cruise	Biolek
Bush	Schröder	Cruise	Schumacher	Heino	Jordan	Agassi	Elvis
Sting	Hanks	Bohlen	Becker	Ghandi	Mozart	Cruise	Carrel
Carrel	Schumacher	Brandt	Kohl	Becker	Rau	Lennon	Genscher
Hoeneß	Juhnke	Kahn	Juhnke	Heino	Kahn	Heino	Juhnke
Heino	Einstein	Kohl	Schröder	Bohlen	Becker	Agassi	Völler
Grass	Falko	Biolek	Trittin	Schumacher	Carrel	Falko	Pitt
Agassi	Völler	Fischer	Gates	Raab	Hanks	Trittin	Biolek
Hanks	Raab	Loriot	Grass	Grass	Falko	Bush	Tyson
Juhnke	Gates	Elvis	Maffay	Powell	Trittin	Powell	Biolek
Trittin	Powell	Sting	Raab	Schröder	Kohl	Kahn	Kohl
Mozart	Einstein	Genscher	Brandt	Drews	Becker	Hoeneß	Fischer
Genscher	Lennon	Vogts	Jordan	Mozart	Vogts	Heino	Schröder
Pitt	Drews	Maffay	Jordan	Bush	Otto	Hoeneß	Juhnke
Drews	Chirac	Raab	Lenin	Strauß	Chirac	Strauß	Jauch
Pitt	Falko	Maffay	Völler	Bush	Schröder	Drews	Chirac
Maffay	Ghandi	Elvis	Agassi	Pitt	Sting	Fischer	Gates
Bohlen	Jackson	Schumacher	Vogts	Sting	Hanks	Cruise	Schumacher
Fischer	Brandt	Carrel	Powell	Maffay	Ghandi	Chirac	Jauch
Mozart	Vogts	Chirac	Strauß	Drews	Pitt	Jackson	Bohlen
Völler	Elvis	Ghandi	Grass	Einstein	Heino	Tyson	Kahn
Biolek	Cruise	Pitt	Sting	Strauß	Blair	Vogts	Schumacher
Kahn	Tyson	Kahn	Heino	Agassi	Falko	Juhnke	Gates
Jauch	Strauß	Putin	Genscher	Ghandi	Grass	Juhnke	Kahn
Agassi	Grass	Cruise	Powell	Brandt	Fischer	Lenin	Raab
Fischer	Hoeneß	Carrel	Cruise	Hoeneß	Jackson	Loriot	Grass
Rau	Becker	Hoeneß	Jackson	Vogts	Jordan	Maffay	Elvis
Vogts	Ghandi	Heino	Jordan	Maffay	Jordan	Putin	Lennon
Schröder	Heino	Ghandi	Mozart	Mozart	Einstein	Elvis	Völler
Lenin	Jackson	Rau	Chirac	Fischer	Kohl	Genscher	Gates
Kohl	Kahn	Tyson	Bush	Putin	Genscher	Carrel	Powell

9.2 Celebrity rating scale from experiment 3



Klinikum der
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Ratingbogen

Studie: „Neuronale Korrelate bei sozialen Vergleichsaufgaben (Teil2). Eine Studie mit funktioneller Magnetresonanztomographie (fMRT)“

Sehr geehrte Probandin, sehr geehrter Proband,

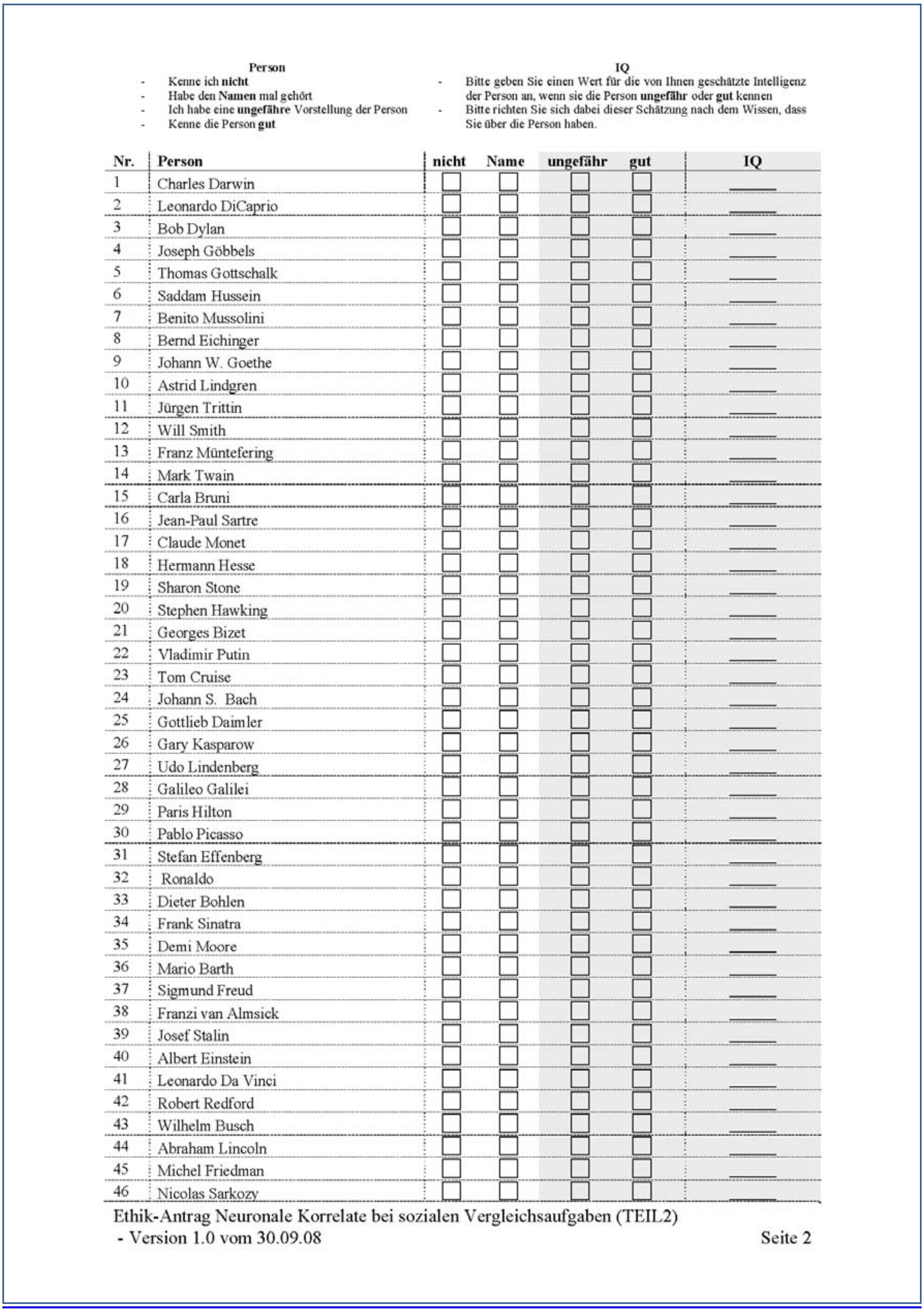
in diesem Fragebogen sollen Sie 250 bekannte Persönlichkeiten bewerten. Bei jeder der Personen sollen Sie zunächst angeben, wie gut Sie diese Person kennen. Hierzu gibt es 4 Antwortmöglichkeiten:

- Ich kenne die Person **nicht.**
- Ich habe den **Namen** schon einmal gehört.
- Ich habe eine **ungefähre** Vorstellung der Person.
- Ich kenne diese Person **gut.**

Bitte wählen Sie aus diesen Antwortmöglichkeiten die heraus, die am besten zu Ihrem Wissenstand über die Person passt. Kreuzen Sie bitte das entsprechende Kästchen in der Liste an.
Wenn Sie eine ungefähre Vorstellung der Person haben oder diese gut kennen, dann schätzen Sie bitte deren Intelligenz auf Basis ihres Wissens über diese Person ein. Geben Sie ihre Schätzung in Form eines Zahlenwertes an, wobei Sie den Wert 100 als Mittelwert nehmen sollen.

Beispiel: Halten Sie eine Person für sehr Intelligent, so tragen Sie bitte einen Wert größer 100 in das entsprechende Kästchen in der Liste. Halten Sie eine Person für weniger Intelligent, so tragen Sie bitte einen Wert kleiner als 100 in das Kästchen (siehe Beispiel unten) .

Nr.	**Person**	**nicht**	**Name**	**ungefähr**	**gut**	**IQ**
00a	Martina Musterfrau	☐	☐	☒	☐	**110**
00b	Max Mustermann	☐	☐	☐	☒	**85**



Person

- Kenne ich **nicht**
- Habe den **Namen** mal gehört
- Ich habe eine **ungefähre** Vorstellung der Person
- Kenne die Person **gut**

IQ

- Bitte geben Sie einen Wert für die von Ihnen geschätzte Intelligenz der Person an, wenn sie die Person **ungefähr** oder **gut** kennen
- Bitte richten Sie sich dabei dieser Schätzung nach dem Wissen, dass Sie über die Person haben.

Nr.	Person	nicht	Name	ungefähr	gut	IQ
1	Charles Darwin	☐	☐	☐	☐	______
2	Leonardo DiCaprio	☐	☐	☐	☐	______
3	Bob Dylan	☐	☐	☐	☐	______
4	Joseph Göbbels	☐	☐	☐	☐	______
5	Thomas Gottschalk	☐	☐	☐	☐	______
6	Saddam Hussein	☐	☐	☐	☐	______
7	Benito Mussolini	☐	☐	☐	☐	______
8	Bernd Eichinger	☐	☐	☐	☐	______
9	Johann W. Goethe	☐	☐	☐	☐	______
10	Astrid Lindgren	☐	☐	☐	☐	______
11	Jürgen Trittin	☐	☐	☐	☐	______
12	Will Smith	☐	☐	☐	☐	______
13	Franz Müntefering	☐	☐	☐	☐	______
14	Mark Twain	☐	☐	☐	☐	______
15	Carla Bruni	☐	☐	☐	☐	______
16	Jean-Paul Sartre	☐	☐	☐	☐	______
17	Claude Monet	☐	☐	☐	☐	______
18	Hermann Hesse	☐	☐	☐	☐	______
19	Sharon Stone	☐	☐	☐	☐	______
20	Stephen Hawking	☐	☐	☐	☐	______
21	Georges Bizet	☐	☐	☐	☐	______
22	Vladimir Putin	☐	☐	☐	☐	______
23	Tom Cruise	☐	☐	☐	☐	______
24	Johann S. Bach	☐	☐	☐	☐	______
25	Gottlieb Daimler	☐	☐	☐	☐	______
26	Gary Kasparow	☐	☐	☐	☐	______
27	Udo Lindenberg	☐	☐	☐	☐	______
28	Galileo Galilei	☐	☐	☐	☐	______
29	Paris Hilton	☐	☐	☐	☐	______
30	Pablo Picasso	☐	☐	☐	☐	______
31	Stefan Effenberg	☐	☐	☐	☐	______
32	Ronaldo	☐	☐	☐	☐	______
33	Dieter Bohlen	☐	☐	☐	☐	______
34	Frank Sinatra	☐	☐	☐	☐	______
35	Demi Moore	☐	☐	☐	☐	______
36	Mario Barth	☐	☐	☐	☐	______
37	Sigmund Freud	☐	☐	☐	☐	______
38	Franzi van Almsick	☐	☐	☐	☐	______
39	Josef Stalin	☐	☐	☐	☐	______
40	Albert Einstein	☐	☐	☐	☐	______
41	Leonardo Da Vinci	☐	☐	☐	☐	______
42	Robert Redford	☐	☐	☐	☐	______
43	Wilhelm Busch	☐	☐	☐	☐	______
44	Abraham Lincoln	☐	☐	☐	☐	______
45	Michel Friedman	☐	☐	☐	☐	______
46	Nicolas Sarkozy	☐	☐	☐	☐	______

Ethik-Antrag Neuronale Korrelate bei sozialen Vergleichsaufgaben (TEIL2)
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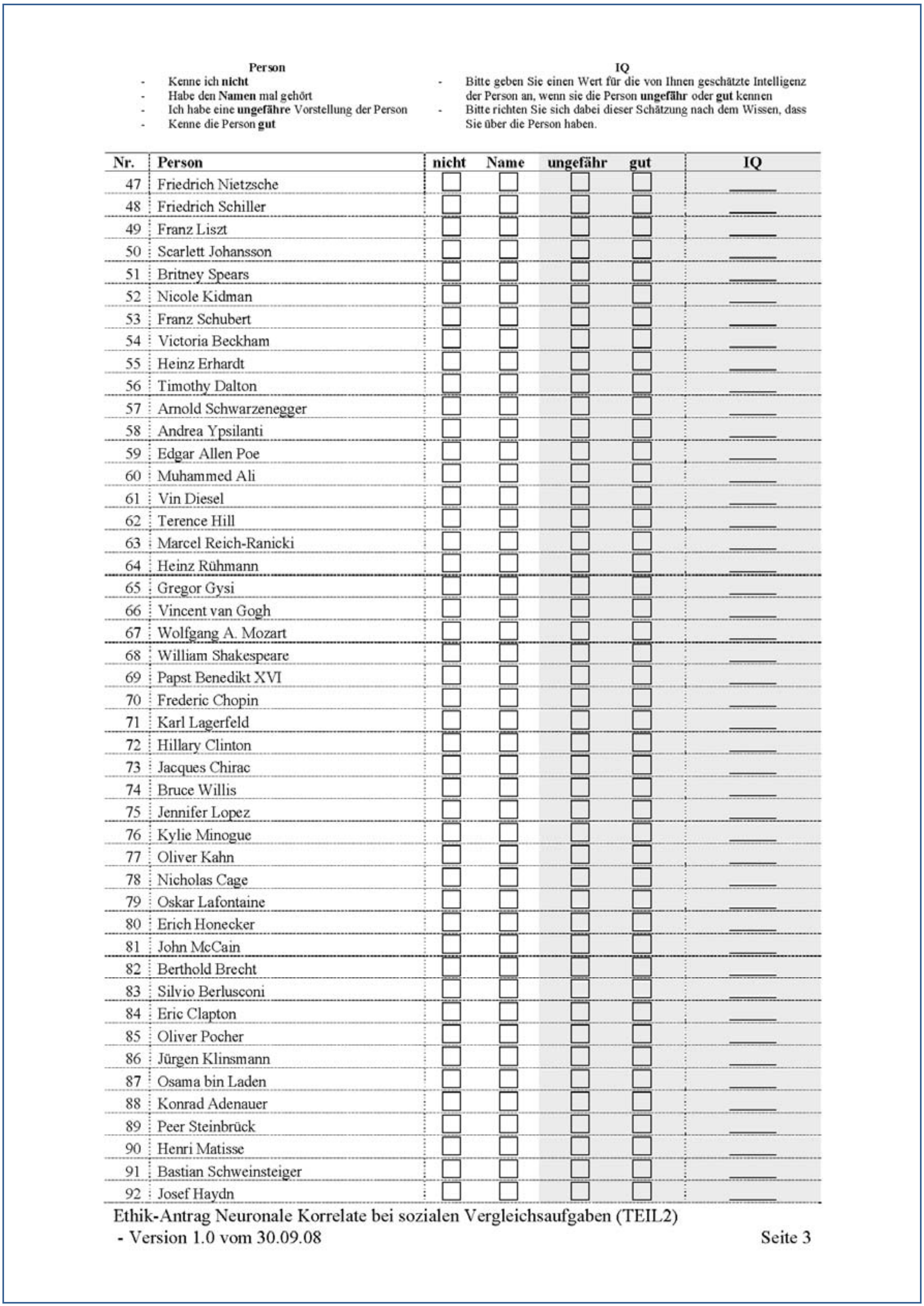

Person
- Kenne ich **nicht**
- Habe den **Namen** mal gehört
- Ich habe eine **ungefähre** Vorstellung der Person
- Kenne die Person **gut**

IQ
- Bitte geben Sie einen Wert für die von Ihnen geschätzte Intelligenz der Person an, wenn sie die Person **ungefähr** oder **gut** kennen
- Bitte richten Sie sich dabei dieser Schätzung nach dem Wissen, dass Sie über die Person haben.

Nr.	Person	nicht	Name	ungefähr	gut	IQ
47	Friedrich Nietzsche	☐	☐	☐	☐	______
48	Friedrich Schiller	☐	☐	☐	☐	______
49	Franz Liszt	☐	☐	☐	☐	______
50	Scarlett Johansson	☐	☐	☐	☐	______
51	Britney Spears	☐	☐	☐	☐	______
52	Nicole Kidman	☐	☐	☐	☐	______
53	Franz Schubert	☐	☐	☐	☐	______
54	Victoria Beckham	☐	☐	☐	☐	______
55	Heinz Erhardt	☐	☐	☐	☐	______
56	Timothy Dalton	☐	☐	☐	☐	______
57	Arnold Schwarzenegger	☐	☐	☐	☐	______
58	Andrea Ypsilanti	☐	☐	☐	☐	______
59	Edgar Allen Poe	☐	☐	☐	☐	______
60	Muhammed Ali	☐	☐	☐	☐	______
61	Vin Diesel	☐	☐	☐	☐	______
62	Terence Hill	☐	☐	☐	☐	______
63	Marcel Reich-Ranicki	☐	☐	☐	☐	______
64	Heinz Rühmann	☐	☐	☐	☐	______
65	Gregor Gysi	☐	☐	☐	☐	______
66	Vincent van Gogh	☐	☐	☐	☐	______
67	Wolfgang A. Mozart	☐	☐	☐	☐	______
68	William Shakespeare	☐	☐	☐	☐	______
69	Papst Benedikt XVI	☐	☐	☐	☐	______
70	Frederic Chopin	☐	☐	☐	☐	______
71	Karl Lagerfeld	☐	☐	☐	☐	______
72	Hillary Clinton	☐	☐	☐	☐	______
73	Jacques Chirac	☐	☐	☐	☐	______
74	Bruce Willis	☐	☐	☐	☐	______
75	Jennifer Lopez	☐	☐	☐	☐	______
76	Kylie Minogue	☐	☐	☐	☐	______
77	Oliver Kahn	☐	☐	☐	☐	______
78	Nicholas Cage	☐	☐	☐	☐	______
79	Oskar Lafontaine	☐	☐	☐	☐	______
80	Erich Honecker	☐	☐	☐	☐	______
81	John McCain	☐	☐	☐	☐	______
82	Berthold Brecht	☐	☐	☐	☐	______
83	Silvio Berlusconi	☐	☐	☐	☐	______
84	Eric Clapton	☐	☐	☐	☐	______
85	Oliver Pocher	☐	☐	☐	☐	______
86	Jürgen Klinsmann	☐	☐	☐	☐	______
87	Osama bin Laden	☐	☐	☐	☐	______
88	Konrad Adenauer	☐	☐	☐	☐	______
89	Peer Steinbrück	☐	☐	☐	☐	______
90	Henri Matisse	☐	☐	☐	☐	______
91	Bastian Schweinsteiger	☐	☐	☐	☐	______
92	Josef Haydn	☐	☐	☐	☐	______

Ethik-Antrag Neuronale Korrelate bei sozialen Vergleichsaufgaben (TEIL2)
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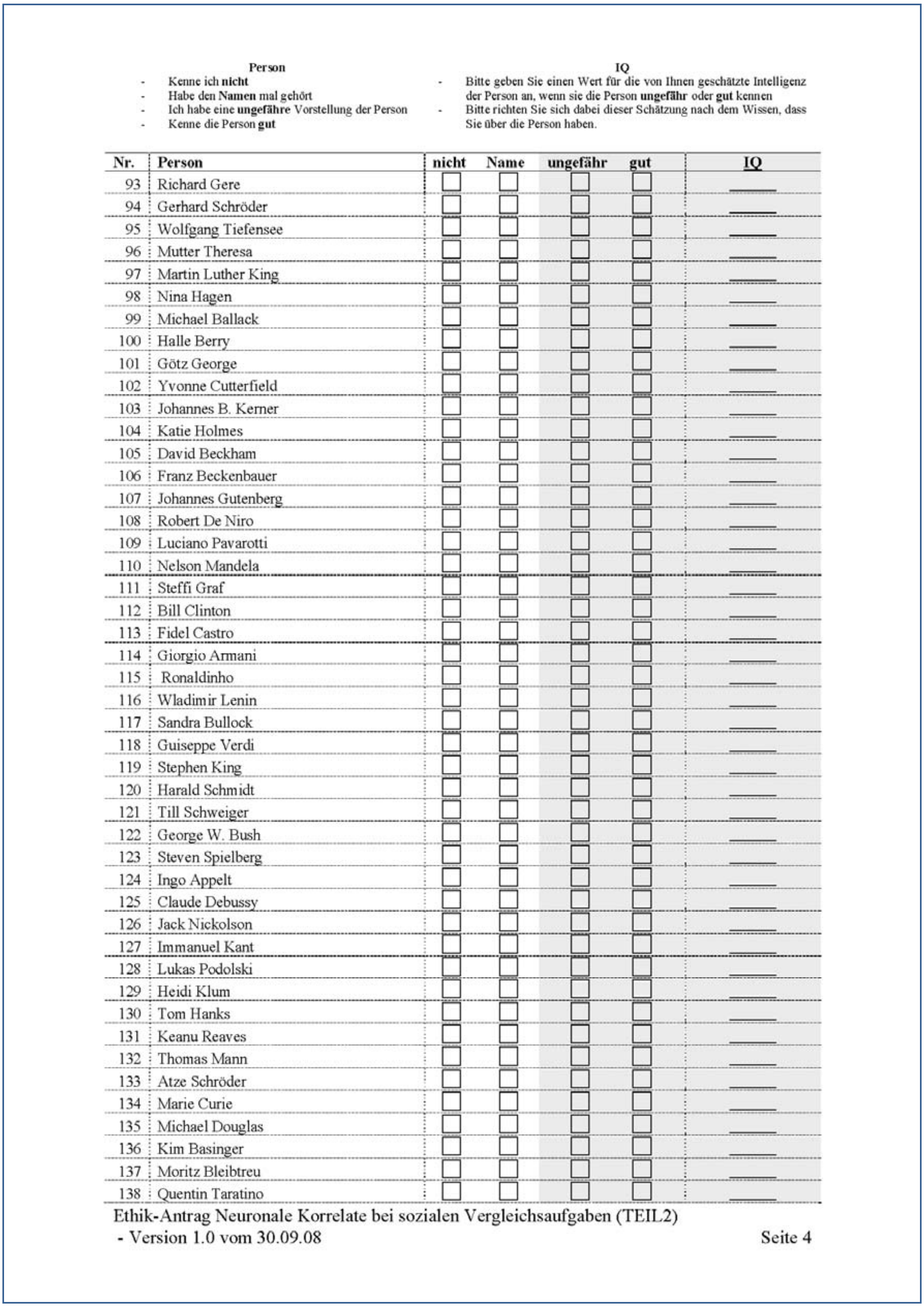

Person
- Kenne ich **nicht**
- Habe den **Namen** mal gehört
- Ich habe eine **ungefähre** Vorstellung der Person
- Kenne die Person **gut**

IQ
- Bitte geben Sie einen Wert für die von Ihnen geschätzte Intelligenz der Person an, wenn sie die Person **ungefähr** oder **gut** kennen
- Bitte richten Sie sich dabei dieser Schätzung nach dem Wissen, dass Sie über die Person haben.

Nr.	Person	nicht	Name	ungefähr	gut	IQ
93	Richard Gere	☐	☐	☐	☐	____
94	Gerhard Schröder	☐	☐	☐	☐	____
95	Wolfgang Tiefensee	☐	☐	☐	☐	____
96	Mutter Theresa	☐	☐	☐	☐	____
97	Martin Luther King	☐	☐	☐	☐	____
98	Nina Hagen	☐	☐	☐	☐	____
99	Michael Ballack	☐	☐	☐	☐	____
100	Halle Berry	☐	☐	☐	☐	____
101	Götz George	☐	☐	☐	☐	____
102	Yvonne Cutterfield	☐	☐	☐	☐	____
103	Johannes B. Kerner	☐	☐	☐	☐	____
104	Katie Holmes	☐	☐	☐	☐	____
105	David Beckham	☐	☐	☐	☐	____
106	Franz Beckenbauer	☐	☐	☐	☐	____
107	Johannes Gutenberg	☐	☐	☐	☐	____
108	Robert De Niro	☐	☐	☐	☐	____
109	Luciano Pavarotti	☐	☐	☐	☐	____
110	Nelson Mandela	☐	☐	☐	☐	____
111	Steffi Graf	☐	☐	☐	☐	____
112	Bill Clinton	☐	☐	☐	☐	____
113	Fidel Castro	☐	☐	☐	☐	____
114	Giorgio Armani	☐	☐	☐	☐	____
115	Ronaldinho	☐	☐	☐	☐	____
116	Wladimir Lenin	☐	☐	☐	☐	____
117	Sandra Bullock	☐	☐	☐	☐	____
118	Guiseppe Verdi	☐	☐	☐	☐	____
119	Stephen King	☐	☐	☐	☐	____
120	Harald Schmidt	☐	☐	☐	☐	____
121	Till Schweiger	☐	☐	☐	☐	____
122	George W. Bush	☐	☐	☐	☐	____
123	Steven Spielberg	☐	☐	☐	☐	____
124	Ingo Appelt	☐	☐	☐	☐	____
125	Claude Debussy	☐	☐	☐	☐	____
126	Jack Nickolson	☐	☐	☐	☐	____
127	Immanuel Kant	☐	☐	☐	☐	____
128	Lukas Podolski	☐	☐	☐	☐	____
129	Heidi Klum	☐	☐	☐	☐	____
130	Tom Hanks	☐	☐	☐	☐	____
131	Keanu Reaves	☐	☐	☐	☐	____
132	Thomas Mann	☐	☐	☐	☐	____
133	Atze Schröder	☐	☐	☐	☐	____
134	Marie Curie	☐	☐	☐	☐	____
135	Michael Douglas	☐	☐	☐	☐	____
136	Kim Basinger	☐	☐	☐	☐	____
137	Moritz Bleibtreu	☐	☐	☐	☐	____
138	Quentin Taratino	☐	☐	☐	☐	____

Ethik-Antrag Neuronale Korrelate bei sozialen Vergleichsaufgaben (TEIL2)
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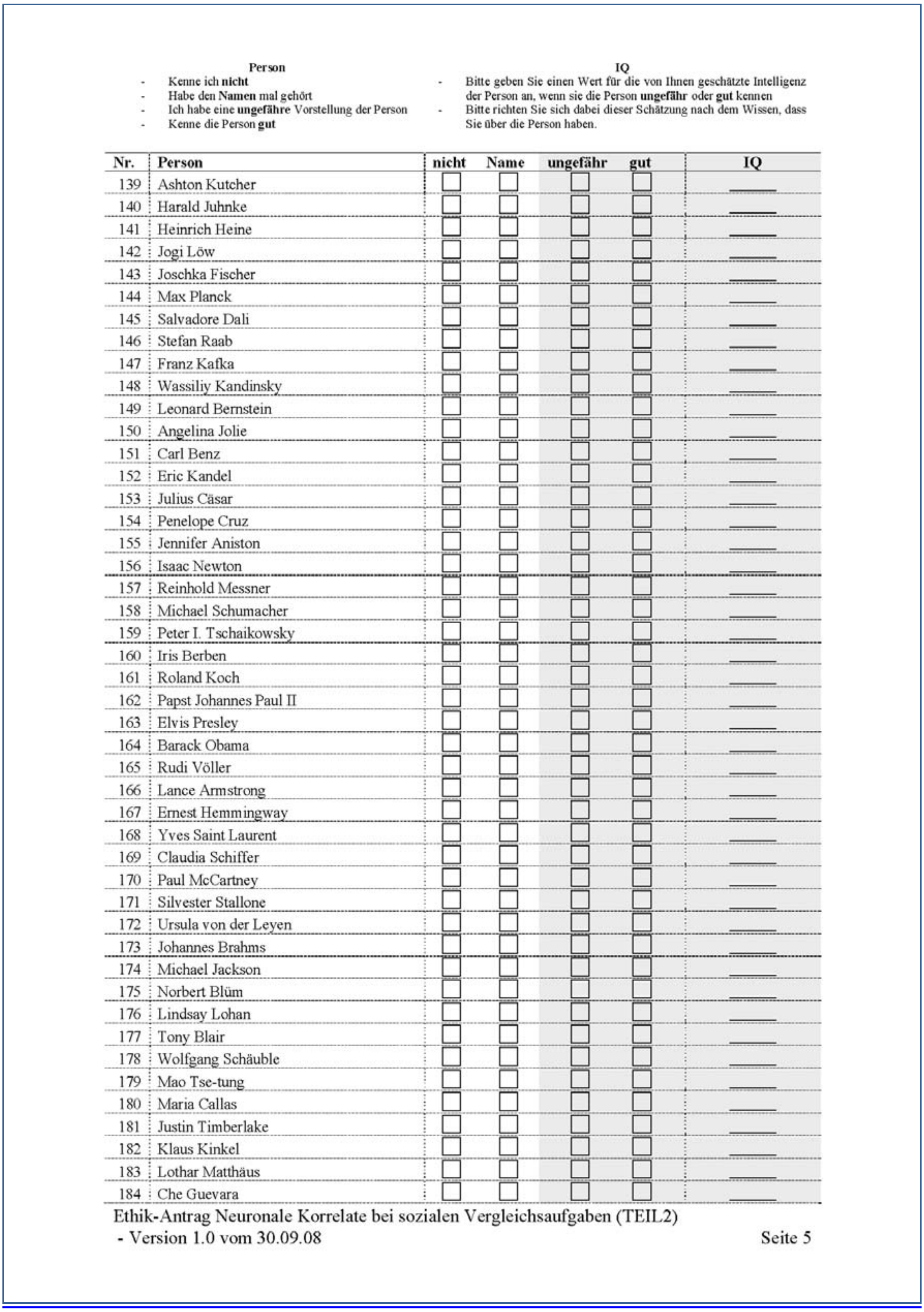

Person

- Kenne ich **nicht**
- Habe den **Namen** mal gehört
- Ich habe eine **ungefähre** Vorstellung der Person
- Kenne die Person **gut**

IQ

- Bitte geben Sie einen Wert für die von Ihnen geschätzte Intelligenz der Person an, wenn sie die Person **ungefähr** oder **gut** kennen
- Bitte richten Sie sich dabei dieser Schätzung nach dem Wissen, dass Sie über die Person haben.

Nr.	Person	nicht	Name	ungefähr	gut	IQ
139	Ashton Kutcher	☐	☐	☐	☐	______
140	Harald Juhnke	☐	☐	☐	☐	______
141	Heinrich Heine	☐	☐	☐	☐	______
142	Jogi Löw	☐	☐	☐	☐	______
143	Joschka Fischer	☐	☐	☐	☐	______
144	Max Planck	☐	☐	☐	☐	______
145	Salvadore Dali	☐	☐	☐	☐	______
146	Stefan Raab	☐	☐	☐	☐	______
147	Franz Kafka	☐	☐	☐	☐	______
148	Wassiliy Kandinsky	☐	☐	☐	☐	______
149	Leonard Bernstein	☐	☐	☐	☐	______
150	Angelina Jolie	☐	☐	☐	☐	______
151	Carl Benz	☐	☐	☐	☐	______
152	Eric Kandel	☐	☐	☐	☐	______
153	Julius Cäsar	☐	☐	☐	☐	______
154	Penelope Cruz	☐	☐	☐	☐	______
155	Jennifer Aniston	☐	☐	☐	☐	______
156	Isaac Newton	☐	☐	☐	☐	______
157	Reinhold Messner	☐	☐	☐	☐	______
158	Michael Schumacher	☐	☐	☐	☐	______
159	Peter I. Tschaikowsky	☐	☐	☐	☐	______
160	Iris Berben	☐	☐	☐	☐	______
161	Roland Koch	☐	☐	☐	☐	______
162	Papst Johannes Paul II	☐	☐	☐	☐	______
163	Elvis Presley	☐	☐	☐	☐	______
164	Barack Obama	☐	☐	☐	☐	______
165	Rudi Völler	☐	☐	☐	☐	______
166	Lance Armstrong	☐	☐	☐	☐	______
167	Ernest Hemmingway	☐	☐	☐	☐	______
168	Yves Saint Laurent	☐	☐	☐	☐	______
169	Claudia Schiffer	☐	☐	☐	☐	______
170	Paul McCartney	☐	☐	☐	☐	______
171	Silvester Stallone	☐	☐	☐	☐	______
172	Ursula von der Leyen	☐	☐	☐	☐	______
173	Johannes Brahms	☐	☐	☐	☐	______
174	Michael Jackson	☐	☐	☐	☐	______
175	Norbert Blüm	☐	☐	☐	☐	______
176	Lindsay Lohan	☐	☐	☐	☐	______
177	Tony Blair	☐	☐	☐	☐	______
178	Wolfgang Schäuble	☐	☐	☐	☐	______
179	Mao Tse-tung	☐	☐	☐	☐	______
180	Maria Callas	☐	☐	☐	☐	______
181	Justin Timberlake	☐	☐	☐	☐	______
182	Klaus Kinkel	☐	☐	☐	☐	______
183	Lothar Matthäus	☐	☐	☐	☐	______
184	Che Guevara	☐	☐	☐	☐	______

Ethik-Antrag Neuronale Korrelate bei sozialen Vergleichsaufgaben (TEIL2)
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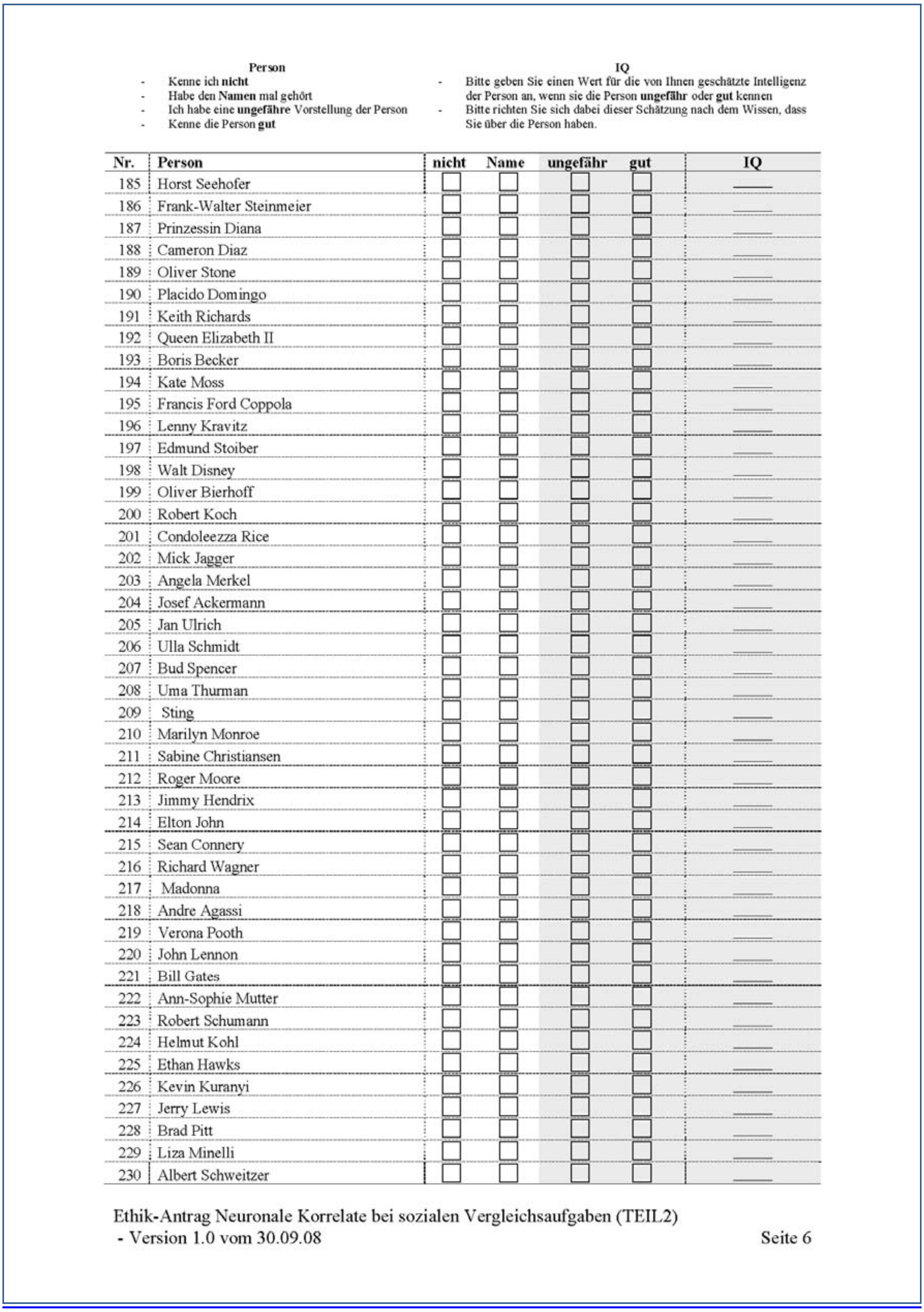

Person

- Kenne ich **nicht**
- Habe den **Namen** mal gehört
- Ich habe eine **ungefähre** Vorstellung der Person
- Kenne die Person **gut**

IQ

- Bitte geben Sie einen Wert für die von Ihnen geschätzte Intelligenz der Person an, wenn sie die Person **ungefähr** oder **gut** kennen
- Bitte richten Sie sich dabei dieser Schätzung nach dem Wissen, dass Sie über die Person haben.

Nr.	Person	nicht	Name	ungefähr	gut	IQ
185	Horst Seehofer	☐	☐	☐	☐	____
186	Frank-Walter Steinmeier	☐	☐	☐	☐	____
187	Prinzessin Diana	☐	☐	☐	☐	____
188	Cameron Diaz	☐	☐	☐	☐	____
189	Oliver Stone	☐	☐	☐	☐	____
190	Placido Domingo	☐	☐	☐	☐	____
191	Keith Richards	☐	☐	☐	☐	____
192	Queen Elizabeth II	☐	☐	☐	☐	____
193	Boris Becker	☐	☐	☐	☐	____
194	Kate Moss	☐	☐	☐	☐	____
195	Francis Ford Coppola	☐	☐	☐	☐	____
196	Lenny Kravitz	☐	☐	☐	☐	____
197	Edmund Stoiber	☐	☐	☐	☐	____
198	Walt Disney	☐	☐	☐	☐	____
199	Oliver Bierhoff	☐	☐	☐	☐	____
200	Robert Koch	☐	☐	☐	☐	____
201	Condoleezza Rice	☐	☐	☐	☐	____
202	Mick Jagger	☐	☐	☐	☐	____
203	Angela Merkel	☐	☐	☐	☐	____
204	Josef Ackermann	☐	☐	☐	☐	____
205	Jan Ulrich	☐	☐	☐	☐	____
206	Ulla Schmidt	☐	☐	☐	☐	____
207	Bud Spencer	☐	☐	☐	☐	____
208	Uma Thurman	☐	☐	☐	☐	____
209	Sting	☐	☐	☐	☐	____
210	Marilyn Monroe	☐	☐	☐	☐	____
211	Sabine Christiansen	☐	☐	☐	☐	____
212	Roger Moore	☐	☐	☐	☐	____
213	Jimmy Hendrix	☐	☐	☐	☐	____
214	Elton John	☐	☐	☐	☐	____
215	Sean Connery	☐	☐	☐	☐	____
216	Richard Wagner	☐	☐	☐	☐	____
217	Madonna	☐	☐	☐	☐	____
218	Andre Agassi	☐	☐	☐	☐	____
219	Verona Pooth	☐	☐	☐	☐	____
220	John Lennon	☐	☐	☐	☐	____
221	Bill Gates	☐	☐	☐	☐	____
222	Ann-Sophie Mutter	☐	☐	☐	☐	____
223	Robert Schumann	☐	☐	☐	☐	____
224	Helmut Kohl	☐	☐	☐	☐	____
225	Ethan Hawks	☐	☐	☐	☐	____
226	Kevin Kuranyi	☐	☐	☐	☐	____
227	Jerry Lewis	☐	☐	☐	☐	____
228	Brad Pitt	☐	☐	☐	☐	____
229	Liza Minelli	☐	☐	☐	☐	____
230	Albert Schweitzer	☐	☐	☐	☐	____

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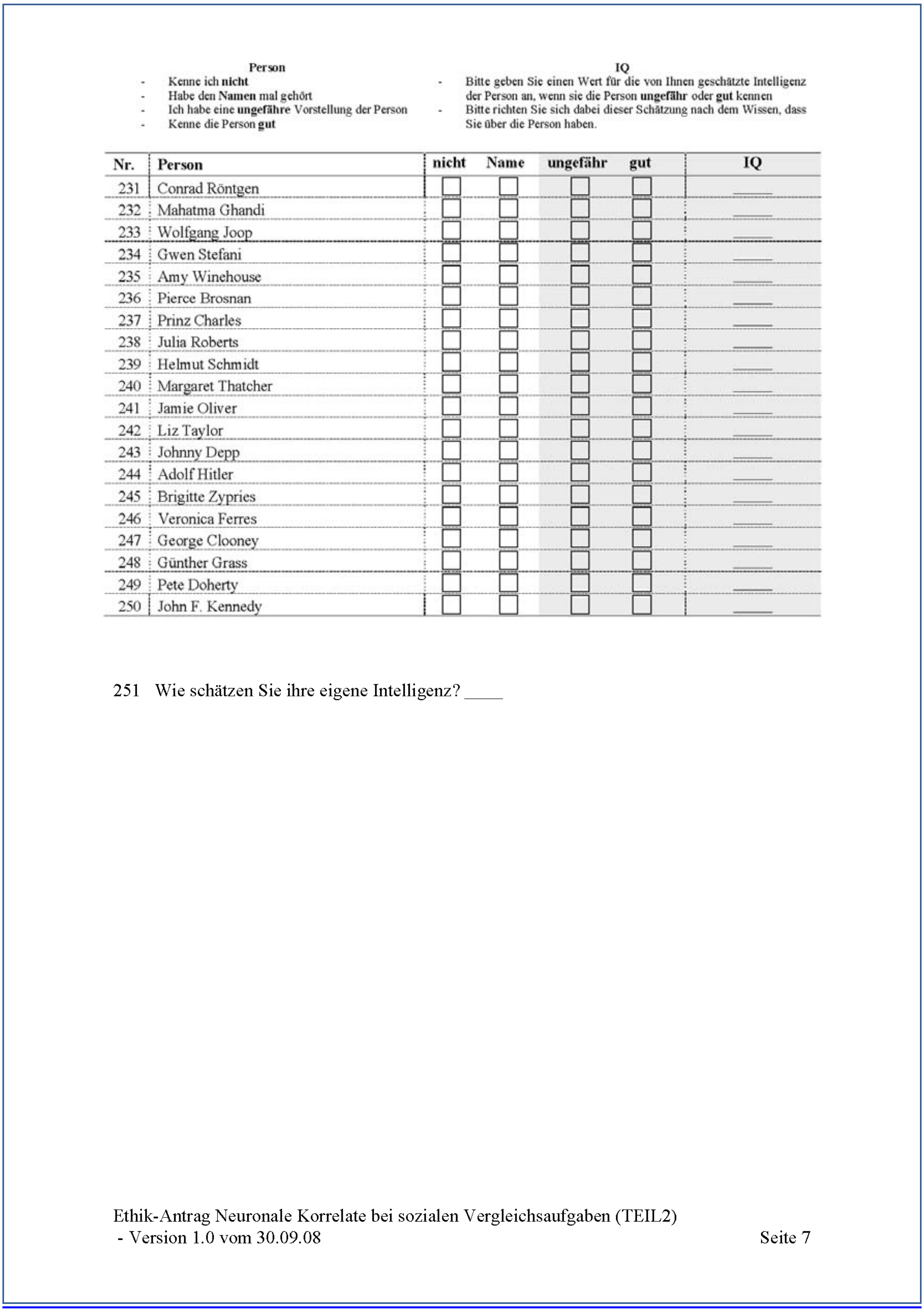

Person

- Kenne ich **nicht**
- Habe den **Namen** mal gehört
- Ich habe eine **ungefähre** Vorstellung der Person
- Kenne die Person **gut**

IQ

- Bitte geben Sie einen Wert für die von Ihnen geschätzte Intelligenz der Person an, wenn sie die Person **ungefähr** oder **gut** kennen
- Bitte richten Sie sich dabei dieser Schätzung nach dem Wissen, dass Sie über die Person haben.

Nr.	Person	nicht	Name	ungefähr	gut	IQ
231	Conrad Röntgen	☐	☐	☐	☐	____
232	Mahatma Ghandi	☐	☐	☐	☐	____
233	Wolfgang Joop	☐	☐	☐	☐	____
234	Gwen Stefani	☐	☐	☐	☐	____
235	Amy Winehouse	☐	☐	☐	☐	____
236	Pierce Brosnan	☐	☐	☐	☐	____
237	Prinz Charles	☐	☐	☐	☐	____
238	Julia Roberts	☐	☐	☐	☐	____
239	Helmut Schmidt	☐	☐	☐	☐	____
240	Margaret Thatcher	☐	☐	☐	☐	____
241	Jamie Oliver	☐	☐	☐	☐	____
242	Liz Taylor	☐	☐	☐	☐	____
243	Johnny Depp	☐	☐	☐	☐	____
244	Adolf Hitler	☐	☐	☐	☐	____
245	Brigitte Zypries	☐	☐	☐	☐	____
246	Veronica Ferres	☐	☐	☐	☐	____
247	George Clooney	☐	☐	☐	☐	____
248	Günther Grass	☐	☐	☐	☐	____
249	Pete Doherty	☐	☐	☐	☐	____
250	John F. Kennedy	☐	☐	☐	☐	____

251 Wie schätzen Sie ihre eigene Intelligenz? ____

Ethik-Antrag Neuronale Korrelate bei sozialen Vergleichsaufgaben (TEIL2)
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10. Deutsche Zusammenfassung

Einleitung

Da bisher wenig über die zugrunde liegenden neuronalen Korrelate von sozialen Vergleichen bekannt ist, bestand das Ziel dieser Doktorarbeit darin, Gemeinsamkeiten und Unterschiede der neuronalen Aktivierungsmuster bei sozialen Vergleichen von Personeneigenschaften mit Hilfe funktioneller Magnetresonanztomographie (fMRT) zu untersuchen. Weiterhin gibt es keine Befunde darüber ob und inwiefern sich Vergleiche unterschiedlicher Personeneigenschaften auf neuronaler Ebene unterscheiden, z.B. wie unterscheiden sich Vergleiche von physikalischen und psychologischen Personeneigenschaften voneinander. Auch die Beantwortung dieser Frage war ein Ziel dieser Doktorarbeit. Außerdem interessierte uns die Frage, ob es für die unterschiedliche Involvierung des Ichs bei den verschiedenen Arten von sozialen Vergleichen unterschiedliche neuronale Korrelate gibt. Abschließend sollte untersucht werden, ob es neuronale Unterschiede zwischen den Entscheidungsrichtungen bei den oben genannten sozialen Vergleichen gibt.

Experiment 1

Im ersten fMRT-Experiment haben wir komparative und nicht-komparative Urteile miteinander verglichen. Für die komparativen Urteile wurden zwei Arten verwendet – der Vergleich von psychologischen und physikalischen Personencharakteristika. Es wurde die Hypothese überprüft, ob komparative Urteile über Personen im Rahmen sozialer Vergleichsaufgaben zu Aktivierungen von vergleichsspezifischen Arealen und Arealen, die mit dem Abruf von personenbezogenem semantischem Wissen in Verbindung gebracht werden, führen. Darüber hinaus erwarteten wir, dass der Vergleich von psychologischen Personencharakteristiken eine Perspektivenübernahme der zu vergleichenden Personen ("mentalizing") beinhaltet. Die Fähigkeit, eine Annahme über Bewusstseinsvorgänge in anderen Personen vorzunehmen, wird in der Psychologie und anderen Kognitionswissenschaften mit dem Begriff Theory of Mind (ToM) bezeichnet.

Der Vergleich von physikalischen Personencharakteristiken basiert mehr auf einem Vergleich von mentaler Imagination der Personen. Folglich sollten die ToM Areale bei dem Intelligenzvergleich stärker aktiviert werden.

Zu Beginn jeder Versuchsaufgabe wurde den Probanden die Aufgabe mit einem von vier, je eine Sekunde langen, Schlüsselreizen ("Intelligenz", "Körpergröße", "Musiker" oder "Politiker") angekündigt. Nach einer weiteren Sekunde wurden den Probanden jeweils zwei Namen berühmter Personen aus den Bereichen Sport, Politik, Musik und Unterhaltung präsentiert. Diese 47 berühmten Personen wurden mir von Prof. Mussweiler als das Ergebnis (100% Bekanntheit bei 20 männlichen Sudenten) eines Ratings von 100 berühmten Personen als Stimuli zur Verfügung gestellt. Dieses Rating war nicht Teil meiner Doktorarbeit. Bei den nicht-komparativen Urteilen sollten die Probanden entscheiden, ob einer der beiden berühmten Personen ein Politiker (oder Musiker) war. Bei den komparativen Urteilen sollten die Probanden entscheiden, welche der beiden Personen intelligenter oder größer war - Other vs. Other Comparison (OOC). Die Probanden sollten ihr Urteil bzw. Entscheidung mittels eines Knopfdruckes so schnell wie möglich bekannt geben.

Ergebnisse von Experiment 1

Die Ergebnisse des RFX-GLMs (korrigiert für multiple Vergleiche mit False Discovery Rate (FDR) < .05) zeigten, dass bei den komparativen Urteilen viele Areale des medial frontal cortex (MFC) – vor allem der anterior cingulate cortex (ACC), die anterioren und posterioren Teile des rostralen medial frontal cortex (arMFC und prMFC) und der medial orbitofrontal cortex (mOFC) eine stärkere Aktivierung aufwiesen als bei den nicht-komparativen Urteilen. Weiterhin zeigten sich stärkere Aktivierungen für die sozialen komparativen Vergleiche in folgenden Arealen: posterior cingulate coretex (PCC), temporo-parietal junction (TPJ), orbitofrontal cortex (OFC), rechtes frontal operculum (FO), posterior hippocampus (pH), linke amygdala (Amg), globus pallidus (GP), middle temporal gyrus (MTG), occipital gyrus (OcG) and substantia nigra (SN). Nur der inferior parietal lobe (IPL) zeigte eine stärkere Aktivierung für die nicht-komparative Aufgabe.

Im zweiten Analyseschritt – maskiertes GLM über alle signifikanten Areale aus dem ersten RFX-GLMs – kontrastierten wir die beiden Dimensionen der sozialen Vergleiche (psychologische vs. physikalische Personeneigenschaften). Alle Areale, die eine stärkere Aktivierung für die komparativen Bedingungen im ersten RFX-GLM zeigten, zeigten hier eine stärkere Aktivierung für den Vergleich psychologischer Personeneigenschaften (Intelligenz). Nur der IPL zeigte eine stärkere Aktivierung für den Vergleich physikalischer Personeneigenschaften.

Diskussion Experiment 1

Das neuronale Netzwerk, das bei sozialen Vergleichen involviert war, unterscheidet sich anscheinend von dem Netzwerk, dass bei nicht-sozialen bzw. nicht personenbezogen Vergleichen wie z.B. Nummern, Größen oder Helligkeiten physikalischer Objekte (Cohen-Kadosh et al., 2005; Pinel et al., 2004) involviert ist. Das neuronale Netzwerk für nicht personenbezogene Vergleiche beinhaltete überwiegend parietale und dorsolaterale präfrontale Areale. Im Gegensatz dazu aktivierte der Personenvergleich medial frontal, orbitofrontale und limbische Areale als auch den TPJ. Die Aktivierung dieses Netzwerkes kam hauptsächlich durch den Vergleich der psychologischen Personencharakteristik (Intelligenz) zustande. Wie erwartet, zeigten sich Unterschiede zwischen den beiden Arten des Vergleichs von Personencharakteristika (Intelligenz und Größe). Obwohl man beide Vergleiche konzeptuell als Vergleich von Werten ansehen könnte (Intelligenzquotient bzw. Körpergröße als Zahlen), unterscheiden sie sich dennoch in ihren neuronalen Aktivierungsmustern.

Gemäß unserer Hypothese fanden wir bei den Personenvergleichen - speziell bei den Intelligenzvergleichen - Areale, die zu dem klassischen ToM-Netzwerk gezählt werden. Zu diesen gehören der TPJ, der ACC und dorsale MFC (Baron-Cohen et al., 1999; Berthoz et al., 2002; Brunet et al., 2000; Calarge et al., 2003; Calder et al., 2002; Castelli et al., 2000; Fletcher et al., 1995; Gallagher et al., 2000; Gallagher et al., 2002; McCabe et al., 2001; Saxe et al., 2003; Vogeley et al., 2001; Walter et al., 2004). Die ToM-Forschung konnte bisher zeigen, dass Menschen sich Perspektivenübernahmen in Situationen bedienen, in denen die eigenen Folgen von anderen Personen und deren Intentionen abhängen, (Gallagher et al., 2002; Rilling et al., 2004). In dieser Studie wurden keine Situationen sondern nur die Namen von Personen dargeboten - ohne weitere Angaben über das Verhalten, ohne die Erwartung einer Interaktion und ohne eine direkte Aufforderung zur Perspektivenübernahme. Unsere Ergebnisse der Involvierung der ToM-Areale bei sozialen Vergleichen deuten darauf hin, dass soziale Urteile automatisch mentalizing-Prozesse beinhalten.

Soziale Urteile involvieren oft die spontane Aktivierung von relevantem Selbstwissen (Dunning et al., 1996), was wiederum mit der Perspektivenübernahme in Verbindung gebracht wird (Davis et al., 1996; Galinsky et al., 2000). Unsere Resultate zeigen jedoch auch klare Grenzen für mentalizing. Einfache Kategorisierungen, wie die Frage nach den Berufen von Personen, aktivierten nicht das ToM-Netzwerk.

Da die Probanden die genauen Angaben über Intelligenz und Körpergröße der berühmten Persönlichkeiten nicht explizit kannten und diese somit schätzen mussten, basierten die Vergleiche in unserem Paradigma auf Unsicherheit über die Vergleichsinhalte. Einige Studien über Entscheidungen unter Unsicherheit oder in unsicheren Situationen beschreiben Aktivierungen im MFC und OFC (Manes et al., 2002; Bechara et al., 2000; Fellows et al., 2007; Haynes et al., 2007). Unsere Ergebnisse (stärkere Aktivierung des prMFC, arMFC, mOFC und OFC bei den komparativen Bedingungen) konnten die Befunde bestätigen. Eine Aktivierung des OFC wurde bei Belohnungs- und Bestrafungsaufgaben gefunden (Roll, 1996). Amodio und Frith (2006) gehen davon aus, das der OFC bei der Verhaltensregulierung auf Basis der Werte für mögliche Folgen beteiligt ist. In Anbetracht der in sozialen Vergleichen beteiligten Prozesse, macht es Sinn, dass Areale aktiviert werden, die typischerweise involviert sind, wenn Fakten und Argumente generiert, erinnert, gewichtet und integriert werden. Das von Mussweiler (2003) erstellte Prozessmodell von Vergleichen hebt hervor, dass Vergleiche und Entscheidungsfindungen die gleichen psychologischen

Prozesse involvieren. Die Ergebnisse dieser Studie liefern interessante Implikationen für die psychologische Forschung im Bereich sozialer Kognition und sozialer Urteile. Es wurde oft angenommen, dass bei allen Komplexitätsgraden von Vergleichen die gleichen psychologischen Prozesse beteiligt sind (Kahneman et al., 1986; Mussweiler, 2003). Unsere Resultate lassen vermuten, dass Vergleiche vielfältiger sind als angenommen. Erstens unterscheiden sich personenbezogene und nicht-personenbezogene Vergleiche hinsichtlich ihrer neuronalen Aktivierungsmuster und somit wahrscheinlich auch hinsichtlich der involvierten psychologischen Prozesse. Zweitens, beinhalten die Vergleiche von psychologischen und physikalischen Personeneigenschaften einen unterschiedlichen Grad an Perspektivenübernahme der zu vergleichenden Personen.

Trotz der Vortestung der Stimuli erkannten die Probanden die eine oder andere berühmte Persönlichkeiten nicht oder nur deren Namen. Dies impliziert, dass in den Entscheidungen ein unterschiedlicher Grad an Unsicherheit vorhanden war. Dies kann Auswirkungen auf unsere Ergebnisse haben und sollte in folgenden Experimenten kontrolliert werden.

Experiment 2

Im zweiten fMRT-Experiment untersuchten wir komparative Urteile, in denen die Probanden sich selbst mit einer anderen Person vergleichen sollten - Self vs. Other Comparison (SOC). Wir verwendeten wiederum die gleichen komparativen Urteile über psychologische und physikalische Personeneigenschaften (Intelligenz und Körpergröße) wie im ersten Experiment. Die 15 Probanden in diesem Experiment sollten vor dem Experiment eine Liste von 40 Namen ihnen persönlich bekannten Personen erstellen. So wurde sichergestellt, dass die Probanden alle zu vergleichenden Personen kennen. Diese Namen wurden als Stimuli für das Experiment verwendet. Zu Beginn jeder Aufgabe wurde einer der beiden Schlüsselreize ("Intelligenz" und "Körpergröße") präsentiert, der die Art des Vergleiches für die folgende Aufgabe ankündigte. Nach einer Pause von 1,5 Sekunden wurde den Probanden einer der Namen präsentiert. Die Probanden hatten die Aufgabe, die

Person mit sich selbst bzgl. der Intelligenz oder der Körpergröße zu vergleichen und zu entscheiden wer intelligenter bzw. größer war. Da die Inhalte der sozialen Vergleiche in diesem Experiment die gleichen wie im vorhergehenden Experiment waren, erwarteten wir, dass das gleiche Netzwerk von Hirnarealen bei den komparativen Personenurteilen involviert ist und verzichteten auf eine semantische Kontrollbedingung in diesem Experiment. Weiterhin erwarteten wir die gleichen Unterschiede in der Aktivierung des ToM-Netzwerkes mit einem höheren Grad an Perspektivenübernahme bei den Intelligenzvergleichen als bei den Körpergrößenvergleichen.

Areale im MFC und weitere Areale (TPJ, insula (Ins), nucleus accumbens (NAcc), AMG) wurden bei Aufgaben gefunden, die Ich-Perspektive, Vergleiche zwischen selbst und anderen und Selbstbeschreibungen enthalten (z.B. Northoff et al. 2006). Während die dorsalen Areale des MFC vermehrt bei Prozessen der Neubewertung und Evaluation von selbstbezogenen Stimuli aktiviert werden, sind die ventralen Areale bei der Bestimmung der Selbstreferenz oder Selbstbezuges von Stimuli involviert. Zudem sind posteriore Areale des MFC bei Aufgaben mit selbstreferentiellen Stimuli involviert (Northoff et al., 2006). Wir erwarteten für den Kontrast zwischen den beiden sozialen Vergleichen (psychologisch vs. physikalisch) unterschiedliche Aktivierungsmuster im dorsalen und ventralen MFC.

In diesem Experiment waren wir zusätzlich an den neuronalen Korrelaten der Entscheidungsrichtungen interessiert. Abhängig von der Beziehung, zu der wir zu der zu vergleichenden Personen stehen, hat diese Art von Vergleich Einfluss auf unsere Emotionen. Demzufolge war ein Unterschied in der Aktivierung sowohl in emotionsbezogenen Arealen (AMG und limbisches System), als auch im ventralen MFC, der bei emotionalen Perspektivenübernahmen und emotionaler Empathie (Gallagher et al., 2003) und sozialen Emotionen (Shamay-Tsoory et al., 2007) beteiligt ist, zu erwarten.

Weiterhin waren Unterschiede im OFC, der für die Integration von Informationen aus anderen präfrontalen Arealen hinsichtlich der Valenz von Belohnungen der zu erwarteten Folgen einer Entscheidung beteiligt ist, zu erwarten (Wallis, 2007).

Ergebnisse Experiment 2

Der Kontrast zwischen den beiden Arten von Vergleichen (psychologische vs. physikalische Personeneigenschaften) in dem RFX-GLM über das ganze Gehirn zeigte eine stärkere Aktivierung für den Körpergrößenvergleich in einem Netzwerk von parietalen und lateralen frontalen Arealen (SPL, IPL, PCun, ITG, OcG, SFG und MFG). Für den Intelligenzvergleich wurden mediale frontale und mediale parietale Areale stärker aktiviert (linker MTG, PCC, arMFC, ACC, OFC und mOFC).

Da wir keine Kontrollbedingung verwendeten, war es nicht möglich für diesen Vergleich (SOC) spezifische Areale zu identifizieren. Deshalb untersuchten wir die vergleichsspezifischen Areale die wir im ersten Experiment gefunden haben, indem wir die gleiche Maske für ein maskiertes RFX-GLM verwendeten. Der Kontrast zwischen den beiden Dimensionen der Vergleiche (psychologische vs. physikalische Personeneigenschaften) in diesem maskierten RFX-GLM zeigte eine stärkere Aktivierung für die Intelligenzvergleiche in den Arealen arMFC, prMFC, ACC, PCC, mOFC, linker MTG, linker FO und rechter OFC. Die bilateralen IPL und der linke MFG zeigten eine stärkere Aktivierung für die Körpergrößenvergleiche.

In den Entscheidungsrichtungen der Intelligenz- bzw. Körpergrößenvergleiche zeigten sich für die FX-ROI-GLMs signifikante Unterschiede in den Arealen der maskierten RFX-GLM. Für die Entscheidungsrichtungen der Intelligenzvergleiche wurden signifikante Unterschiede im PCC, medialen arMFC und rechten IPL gefunden. Im mOFC und linken arMFC zeigten sich sowohl für die Entscheidungsrichtung der Intelligenz- als auch der Körpergrößenvergleiche signifikante Unterschiede. Für die Entscheidungsrichtung der Körpergrößenvergleiche zeigte sich nur im linken IPL ein Unterschied. Alle Areale, die einen Unterschied für die Intelligenzvergleiche zeigten, wiesen eine stärkere Aktivierung für die Entscheidung "ich bin intelligenter/größer als der/die Andere" auf. Nur der linke IPL zeigte ein stärkere Aktivierung für die Entscheidung "ich bin größer als der/die Andere" bei den Körpergrößenvergleichen.

Diskussion Experiment 2

Analog zum ersten Experiment aktivierten die Vergleiche von psychologischen Personencharakteristika wiederholt Areale die auch bei Aufgaben mit ToM und Perspektivenübernahme zu finden sind (ACC und PCC).

Wir gehen auch im zweiten Experiment von einer Unsicherheit in der Entscheidungsfindung aus, da auch hier den Probanden keine genauen Angaben über Intelligenz und Körpergröße der zu vergleichenden Personen zur Verfügung standen. Hierzu passend fanden wir auch Areale, die bei Entscheidungen mit Unsicherheit gefunden wurden - prMFC, arMFC, mOFC und OFC (Manes et al., 2002; Bechara et al., 2000; Fellows et al., 2007).

Der MFC spielt eine wichtige Rolle bei sozialen Vergleichen und wurde mit Erste-Person-Perspektive (Vogeley et al., 2003), mit der Integration sozialer Informationen aus anderen Arealen (Huey et al., 2006), mit personenbezogenem Wissen (e.g., Mason et al., 2004; Mitchell et al., 2002), mit Urteilen über psychologische Eigenschaften (Kircher et al., 2000) und mit selbstrelevanten Urteilen (Macrae et al., 2004) in Bezug gebracht. Weiterhin wurden Teile des MFC mit sozialen Kognitionen (Schilbach at al., 2006), mit selbstreferentiellen Prozessen (Kelley et al., 2002), mit Rückschlüssen über Personeneigenschaften anderer Personen – dorsaler MFC und mit bewertenden Urteilen über bekannte Personen – ventraler MFC (Van Overwalle, 2009) in Verbindung gebracht.

Da der Vergleich von psychologischen Personeneigenschaften selbstreferentielle Urteile und Rückschlüsse über Personeneigenschaften anderer Personen und sich selbst beinhaltet, lassen unsere Ergebnisse vermuten, dass die Aktivierungen im ACC und im dorsalen MFC mit diesen Prozessen in Verbindung stehen.

Die Aktivierungen im OFC und mOFC bei den Intelligenzvergleichen können äquivalent zum ersten Experiment mit Belohnungsantizipation (Fliessbach et al., 2007; Rolls, 1996; Amodio et al., 2006) und Generierung, Gewichtung und Integration von Fakten und Argumenten erklärt werden (Hare et al., 2008).

Vor dem eigentlichen Vergleich der Personen in unserem Task kann, unabhängig von der Vergleichsaufgabe, eine visuelle Imagination der zu vergleichenden Personen hilfreich sein, um Gewissheit über diese Person zu haben. Während bei Intelligenzvergleichen die Imagination von Personen allein nicht für den Vergleich und die Entscheidung ausreicht, erfolgt der Körpergrößenvergleich auf Grundlage der Imagination von Personen. Die Aktivierungen des Netzwerkes (SPL, IPL, PCun, ITG, FG, OcG, SFG and MFG), welches wir bei den Körpergrößenvergleichen gefunden haben, beinhalten sowohl Areale des fronto-parietalen Aufmerksamkeitsnetzwerkes (z.B. Posner et al., 1990) als auch Areale, die bei diversen visuellen Imaginationen gefunden wurden (z.B. Lamm et al., 2001; Newman et al., 2007), z.B. bei mentaler Rotation (Kawamichi et al., 2007), relationaler visuelle Imaginationen (Knauff et al., 2002) und räumlicher Transformationen (egozentrische vs. objektbasierte) der visuellen Imaginationen (Creem et al., 2001, Zacks et al., 1999; Zacks et al., 2000; Zacks et al., 2002; Zacks et al., 2003a; Zacks et al., 2003b). Die Ergebnisse lassen vermuten, dass der Vergleich von physikalischen Personeneigenschaften wie erwartet visuelle Imaginationen der zu vergleichenden Personen erfordert.

Außerdem konnten wir mit dem Kontrast zwischen den beiden Vergleichsarten des maskierten GLMs die Hauptergebnisse des ersten Experimentes bzgl. der distinkten Netzwerke für die beiden Vergleichsarten replizieren.

Vergleich von Experiment 1 und 2

Ein inferenzstatistischer Vergleich in Form einer 2x2 ANOVA der beiden Experimente wäre wünschenswert, um die neuronalen Unterschiede zu untersuchen, die auf die unterschiedliche Involvierung des Ichs in den beiden Vergleichen zurückzuführen ist. Da die Experimente an zwei verschiedenen Magnetresonanztomographen gemessen wurden und die BOLD-Signale der Versuchsbedingungen von den Messgeräten abhängig sind, kann das Ergebnis einer Inferenzstatistik nicht eindeutig auf die Aufgaben und deren Unterschiede zurückgeführt werden. Aus diesem Grund haben wir die Ergebnisse der beiden

Experimente nur deskriptiv miteinander verglichen, um Hypothesen für ein weiteres Experiment zu generieren.

Die neuronalen Aktivierungsmuster der Intelligenzvergleiche von OOC und SOC zeigten Überlappungen in einem großen medial frontalen Cluster (ACC, arMFC, mOFC) und weiteren Arealen (arMFC, ACC, APCC, PCC, mOFC, OFC und linker STS).

Unterschiede zwischen OOC und SOC waren für die Intelligenzvergleiche in folgenden Arealen zu finden: Für OOC waren zusätzlich Areale im ventralen und anterioren dorsalen MFC (linker arMFC, prMFC, anteriorer Teil des ACC, mOFC), im OFC, im superioren Teil des PCC, im STS, in der SN und im anterioren nucleus talamicus involviert. Zusätzlich waren die bilateralen TPJs nur bei OOC aktiviert. Für SOC waren mehr Areale im zentralen MFC (inferiore Teile des arMFC und prMFC und superiorer mOFC), im inferioren PCC, im lateralen OFC, im linken STS und Areale im medialen gyrus occipitalis involviert.

Für den Körpergrößenvergleich zeigten sich zwischen OOC und SOC Überlappungen im IPL, die wie oben beschrieben auf die für den Vergleich verwendete Imagination zurückgeführt werden können, wobei SOC größere Teile des IPL und zusätzlich ein Areal im linken MFG involvierte.

Die beiden Intelligenzvergleiche zeigten Überlappungen der neuronalen Aktivierungsmuster im arMFC, ACC, APCC, PCC and OFC, die wie bereits oben beschrieben mit Perspektivenübernahmen und Belohnungsantizipationen in den Aufgaben erklärt werden können.

Sowohl SOC als auch OOC aktivierten ToM-Areale, da in beiden Vergleichen Personeneigenschaften anderer Personen geschätzt werden mussten. Allerdings zeigte SOC keine Aktivierungen im TPJ. Dies kann damit erklärt werden, dass sich die Stimuli bzw. die zu vergleichenden Personen in beiden Experimenten unterschieden. Einerseits mussten im Experiment 2 die Eigenschaften nur einer Person geschätzt werden. Andererseits ist es vorstellbar, dass der Vergleich der persönlich bekannten Personen im zweiten Experiment einfacher war als bei den berühmten Personen im ersten Experiment, da die für den Vergleich notwendigen Informationen leichter verfügbar waren und deshalb weniger Perspektivenübernahme nötig war. Weiterhin können die Vergleiche mit uns bekannten Personen eine höhere Selbstrelevanz aufweisen als Vergleiche mit fremden Personen, einhergehend mit mehr Belohnungsantizipationen und einer stärkeren Involvierung des Ichs. Dies kann eine Erklärung für die stärkeren Aktivierungen im anterioren dorsalen arMFC und prMFC im SOC sein.

Wir verwendeten den deskriptiven Vergleich zur Formulierung folgender Hypothesen für ein weiteres Experiment: (1) OOC und SOC unterscheiden sich in dem Bedarf an Perspektivenübernahme, einhergehend mit stärkeren Aktivierungen in ToM spezifischen Arealen, vor allem im TPJ. (2) Durch die unterschiedliche Involvierung des Ichs in den beiden Vergleichsarten unterscheiden sich OOC und SOC in ihren Aktivierungsmustern im MFC.

Experiment 3

Basierend auf den Ergebnissen des Vergleichs der ersten beiden Experimente führten wir ein drittes Experiment durch, um OOC und SOC als „within“-Faktor und die Entscheidungsrichtungen bei Intelligenzvergleichen zu untersuchen. Folgende Arbeitshypothesen wurden untersucht:

(1) OOC bedarf mehr Perspektivenübernahmen, einhergehend mit einer höheren Aktivierung in ToM-Arealen. (2) OOC und SOC zeigen Unterschiede in den Aktivierungsmustern im MFC, die auf die unterschiedliche Involvierung des Ichs in den Vergleichen zurückzuführen sind. (3) Die Entscheidungsrichtungen zeigen ebenfalls ein unterschiedliches Aktivierungsmuster im MFC.

Ergebnisse

Es handelt sich hier nur um vorläufige Daten mit einer kleinen Stichprobe von 6 Versuchspersonen. In einem FX-GLM über das ganze Gehirn zeigten eine Vielzahl von Arealen eine stärkere Aktivierung für SOC als für OOC (PoCG, SMA, SFG, MFG, CC, ACC, OcG, SMG, OFC, MTG, STS, FO, Hi, Tec und Pons). Bei SOC wies die Entscheidungsrichtung „ich > andere“ stärkere

Aktivierungen im mOFC auf, während für die entgegengesetzte Entscheidungsrichtung stärkere Aktivierungen im PoCG, SPL, IPL, PreCG, SMA, IFGOp, OcG, Ins und Cerebellum beobachtet wurde.

Im maskierten GLM, bei Verwendung der gleichen Maske wie in den beiden vorherigen Experimenten, zeigten alle Areale stärkere Aktivierungen für SOC. Der Kontrast zwischen den Entscheidungsrichtungen zeigten bei OOC keine Unterschiede. Bei SOC wies die Entscheidungsrichtung „ich > andere" stärkere Aktivierungen im arMFC und mOFC auf und für die entgegengesetzte Entscheidungsrichtung eine erhöhte Aktivierung im IPL.

Diskussion Experiment 3

SOC aktivierte zum einen Areale die bei der Imagination des eigenen Körpers involviert sind. Weiterhin zeigten sich bei SOC stärkere Aktivierungen in Arealen, die ebenfalls bei Belohnungsantizipationen (OFC), bei Perspektivenübernahmen und bei unsicheren Entscheidungen (arMFC, prMFC und ACC) involviert werden.

Entgegen der Erwartung, dass der TPJ eine stärkere Aktivierung bei OOC haben sollte, wie man aus dem Vergleich der beiden ersten Experimente hätte schließen können, zeigte der TPJ hier eine stärkere Aktivierung für SOC. Dies kann dadurch erklärt werden, dass die Entscheidungen in der SOC Bedingung ein deutlich höhere Selbstrelevanz hat als in der OOC Bedingung. Folglich kann es sein, dass die Probanden sich hier deutlich mehr angestrengt haben, und somit auch mehr detailierte Perspektivenübernahmen durchgeführt haben. Die stärkeren Aktivierungen im dorsalen MFC sprechen auch für unsere zweite Hypothese, in der wir einen Unterschied in der Aktivierung im MFC in Relation zur Involvierung des Ichs in SOC postulierten.

Die stärkeren Aktivierungen im mOFC und arMFC für die Entscheidung „ich >andere" lassen sich wiederum mit einer höheren Involvierung des Ichs und einer höheren Belohnungserwartung erklären. Die Aktivierungen der entgegengesetzten Entscheidungsrichtung lassen sich durch einen höheren

Bedarf an Imaginationen der anderen Person erklären, z.B. der zur Kontrolle der Entscheidung nötig ist.

Zusammenfassende Diskussion

Die Hauptbefunde der drei Experimente sind zum einen die Unterschiede der involvierten neuronalen Netwerke zwischen den Vergleichen von physikalischen und psychologischen Personeneigenschaften. Während der Vergleich von physikalischen Personeneigenschaften mehr auf der Basis von Imaginationen vorgenommen wird, erfolgen die Vergleiche der psychologischen Eigenschaften durch Perspektivenübernahmen und unterliegen einer größeren Unsicherheit bei den Entscheidungen.

Ein weiterer interessanter Befund ist der Unterschied der involvierten neuronalen Areale zwischen SOC und OOC, der durch eine höhere Selbstrelevanz und den damit einhergehenden stärkeren Anstrengungen bei der Bearbeitung in Form von Perspektivenübernahmen und höheren Belohnungsantizipationen zu erklären ist.

Das dritte wichtige Ergebnis dieser Studie ist der Unterschied zwischen den Entscheidungsrichtungen. Die Entscheidung, dass man selbst intelligenter ist als ein anderer weist ebenfalls eine höhere Selbstrelevanz auf und führt zu einer höheren Belohnungserwartung als die entgegengesetzte Entscheidungsrichtung.

Im ersten Experiment haben wir nur männliche Versuchspersonen gemessen, da die Stimuli nur an Männern bzgl. der Bekanntheit eingestuft wurden. Eine Generalisierung der Ergebnisse auf Frauen ist hier nicht möglich. Im zweiten und dritten Experiment haben wir sowohl Männer als auch Frauen gemessen, da wir hier individuelle Stimulisets verwendet haben. Man könnte annehmen, dass das Geschlecht der Versuchspersonen und das Geschlecht der zu vergleichenden Personen einen Einfluss auf die Vergleichs- und Entscheidungsprozesse und damit auch auf die neuronalen Aktivierungsmuster haben. Z.B. Wenn wir von einer kleineren Körpergröße bei Frauen als bei Männern ausgehen, könnten die Vergleiche und die dazugehörigen

Entscheidungsrichtungen bzgl. der Körpergröße einem systematischen Einfluss des Geschlechts der Versuchsperson unterliegen. Wir haben keinen Unterschied zwischen der neuronalen Aktivität von Männern und Frauen in unseren Experimenten gefunden - vielleicht weil unsere Experimente nicht explizit für den Vergleich zwischen Männern und Frauen ausgelegt wurde. In weiteren Experimenten sollte der mögliche Einfluss des Geschlechts auf die Vergleiche und Entscheidungen detailiert untersucht werden. In solchen Experimenten sollte sowohl die Anzahl von weiblichen und männlichen Versuchspersonen als auch die Anzahl von verwendeten weiblichen und männlichen Vergleichspersonen (Stimuli) gleichverteilt sein. Für das oben genannte Beispiel sollten die Vergleichspersonen individuell für jede Versuchsperson bzgl. der Körpergröße ausgewählt werden – eine gleiche Anzahl kleinerer und größerer Vergleichspersonen als die Versuchsperson.

11. Curriculum Vitae

Angaben zur Person

Name: Lindner

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Geburtsdatum: 25.09.1973

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63225 Langen

Familienstand: verheiratet seit 30.06.1993

Schulische Ausbildung

01.08.1986 - 30.06.1993	Leibnizschule in Offenbach (Gymnasium)
18.06.1993	Abitur (3,3)

Studium

01.10.2000	Aufnahme des Psychologiestudiums an der Johann Wolfgang Goethe-Universität in Frankfurt am Main
22.02.2006	Diplom in Psychologie (1,67)

Auslandsaufenthalt

13.02.2004 - 28.06.2004	Auslandssemester in Maastricht/Niederlande

Berufliche Tätigkeiten

22.06.2002 - 02.09.2002	Praktikum in der Forschungsgruppe Neurophysiologie und Neuroimaging in der Klinik für Psychiatrie und Psychotherapie I der Johann Wolfgang Goethe-Universität Frankfurt am Main unter Anleitung von Prof. Dr. K. Maurer und Dr. Dr. D. Linden
15.09.2002 – 31.12.2003	studentische Hilfskraft von Prof. Maurer in dem Labor für Neurophysiologie und Neuroimaging in der Klinik für Psychiatrie und Psychotherapie I der Johann Wolfgang Goethe-Universität in Frankfurt am Main (Planen, Durchführen, Auswerten und Berichtlegung psycho-physikalischer und funktioneller neuroimaging Experimente)
04.08.2003 - 12.09.2003	klinisches Praktikum in der Klinik für Psychiatrie und Psychotherapie I der Johann Wolfgang Goethe-Universität
01.01.2004 – 30.09.2005	wissenschaftlicher Mitarbeiter von Prof. Maurer in dem Labor für klinische Neurophysiologie und Neuroimaging in der Klinik für Psychiatrie und Psychotherapie I der Johann Wolfgang Goethe-Universität in Frankfurt am Main (Durchführung sowie computergestützte Aufbereitung und Auswertung funktioneller neuroimaging Verfahren)

05.07.2004 - 13.08.2004	klinisches Praktikum in der Klinik für Kinderheilkunde III – Pädiatrische Hämatologie, Onkologie und Hämostaseologie der Johann Wolfgang Goethe-Universität in Frankfurt am Main
01.10.2005 - 31.03.2006	studentische Hilfskraft von Prof. Dr. Walter in der Abteilung für biologische Psychiatrie in der Klinik für Psychiatrie, Psychosomatik und Psychotherapie der Johann Wolfgang Goethe-Universität in Frankfurt am Main (Planen, Durchführen, Auswerten und Berichtlegung psycho-physikalischer und funktioneller neuroimaging Experimente)
01.04.2006 – 30.06.2009	Angestellt als wissenschaftliche Hilfskraft mit Abchluss im Labor für klinische Neurophysiologie und Neuroimaging in der Klinik für Psychiatrie, Psychosomatik und Psychotherapie der Johann Wolfgang Goethe-Universität in Frankfurt am Main.
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Stipendien

24.06.2003	Erasmus-Socrates-Stipendium für das Auslandssemester in Maastricht

01.04.2008 – 31.05.2009	Stipendium vom Labor für klinische Neurophysiologie und Neuroimaging der Klinik für Psychiatrie, Psychosomatik und Psychotherapie der Goethe-Universität gefördert durch die Alzheimer Forschungsinitiative e.V.

Publikationen

Oertel, V., Knöchel, C., Rotarska-Jagiela, A., Schönmeyer, R., **Lindner, M.**, van de Ven, V., Haenschel, C., Uhlhaas, P., Maurer, K., Linden, D.E.J. Reduced laterality as a trait marker of schizophrenia - evidence from structural and functional neuroimaging”. *Journal of Neuroscience,* (submitted).

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Sack, A., **Lindner, M.** & Linden, D.E. (2007). Object- and direction-specific interference between manual and mental rotation. *Perception & Psychophysics*, 69(8), 1435-1449.

Uhlhaas, P.J., Linden, D.E., Singer, W., Haenschel, C., **Lindner, M.**, Maurer, K. & Rodriguez, E. (2006). Dysfunctional long-range coordination of neural activity during Gestalt perception in schizophrenia. *Journal of Neuroscience*, 26(31), 8168-75.

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Oertel, V., Knöchel, C., Rotarska-Jagiela, A., Schönmeyer, R., **Lindner, M.**, van de Ven, V., Haenschel, C., Uhlhaas, P., Maurer, K. & Linden, D.E.J. (2008, September). *Reduced laterality as a trait marker of schizophrenia - evidence from structural and functional neuroimaging.* Poster präsentiert auf 5th INSNIP & ECNS Joint Conference, Frankfurt, Germany.

Oertel, V., Rotarska-Jagiela, A., **Lindner, M.**, Van de Ven, V.G., Altmann, C., Knöchel, C., Haenschel, C., Maurer, K. & Linden, D.E.J. (2007, Dezember). *Changes in auditory speech areas in schizophrenia patients and their unaffected family members.* Poster präsentiert auf Symposium des Max-Planck-Instituts für Hirnforschung, Frankfurt / Main.

Lehrerfahrung

Seminar: Forschungsorientierte Vertiefung in der Biopsychologie. „Von der Wahrnehmung zur mentalen Imagination“. WS 07/08. Johann Wolfgang Goethe-Universität Frankfurt

6 Kurse zur Einführung in die Datenverarbeitung von fMRT-Daten mit Brainvoyager QX für Anfänger im Labor für klinische Neurophysiologie und Neuroimaging in der Klinik für Psychiatrie, Psychosomatik und Psychotherapie der Johann Wolfgang Goethe-Universität in Frankfurt am Main

Betreuung von 2 Diplomanden und mehreren Praktikanten im Labor für klinische Neurophysiologie und Neuroimaging in der Klinik für Psychiatrie, Psychosomatik und Psychotherapie der Johann Wolfgang Goethe-Universität in Frankfurt am Main

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