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“Artificial humans”: Psychology and neuroscience perspectives on embodiment and nonverbal communication

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ABSTRACT

“Artificial humans”, so-called “Embodied Conversational Agents” and humanoid robots, are assumed to facilitate human–technology interaction referring to the unique human capacities of interpersonal communication and social information processing. While early research and development in artificial intelligence (AI) focused on processing and production of natural language, the “new AI” has also taken into account the emotional and relational aspects of communication with an emphasis both on understanding and production of nonverbal behavior. This shift in attention in computer science and engineering is reflected in recent developments in psychology and social cognitive neuroscience. This article addresses key challenges which emerge from the goal to equip machines with socio-emotional intelligence and to enable them to interpret subtle nonverbal cues and to respond to social affordances with naturally appearing behavior from both perspectives. In particular, we propose that the creation of credible artificial humans not only defines the ultimate test for our understanding of human communication and social cognition but also provides a unique research tool to improve our knowledge about the underlying psychological processes and neural mechanisms.

“The king stared at the figure in astonishment. It walked with rapid strides, moving its head up and down, so that anyone would have taken it for a live human being. The artificer touched its chin, and it began singing, perfectly in tune. He touched its hand, and it began posturing, keeping perfect time [. . .] As the performance was drawing to an end, the robot winked its eye and made advances to the ladies in attendance, whereupon the king became incensed and would have had Yen Shih [Yan Shi] executed on the spot had not the latter, in mortal fear, instantly taken the robot to pieces to let him see what it really was”

(Lie Zi text, China 3rd century, cited after Rosenberg, 2004, p. 37).

1. Introduction

The challenge to create convincing artificial social entities seems to hold a particular fascination for humans and in fact is older than psychology, computer science or cognitive neuroscience. Historical examples to build mechanic humans as well as recent scientific and technological endeavours to implement socially intelligent machines (Fong, Nourbakhsh, & Dautenhahn, 2003), although differing in their starting intuitions, methodologies and goals reveal a common denominator: the urge to unravel the secrets of human communication and social information processing. Be it for the aim of impressing an audience through a skillful machine, the development of useful and acceptable computer agents or robots, or the experimental control of social cues in psychological studies, basically the success of all these efforts relies on the understanding of the most complex and still in many respects enigmatic social cognitive processes related to the production and perception of social behavior and their underlying neural mechanisms.

Research in social cognition, evolutionary psychology and more recently also in social cognitive neuroscience has provided ample evidence that the human mind in contrast to other species holds particular capacities to process and to adapt to complex affordances emerging from our social environment (Moll & Tomasello, 2007; Tomasello, Carpenter, Call, Behne, & Moll, 2005). Equipped by nature with unique prerequisites for social cognition the human cognitive system already in early childhood develops the capability to differentiate self and others (Decety & Chaminade, 2003), to infer emotional and cognitive states of other minds (Frith & Frith, 2003), to form social impressions and to adjust actions and communicative behavior accordingly (Decety & Chaminade, 2003; Frith & Frith, 2003; Vogeley & Roepstorff, 2009). As adults we refer to this ability in everyday life with great ease forming spontaneous

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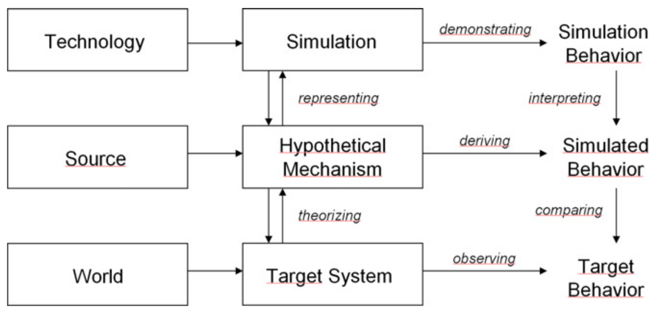

Fig. 1. Taxonomy for technical systems of biological systems.
Source: From Webb, 2001, p. 1035.

impressions of complex psychological matters hardly ever reflecting on the information causing our inferences or the rational of the underlying processes: "Though the full significance of man's relation to man may not be directly evident, the complexity of feelings and actions that can be understood at a glance is surprisingly great" (Heider, 1958, p. 2). Although social cognitive processes such as social perception and interpersonal communication are seemingly automatic in many instances, humans are also prone to reflect on their actions and capabilities, what not only creates an inferential, reflexive counterforce to intuitive, pre-reflexive processes in daily interactions, but also provides the universal cognitive basis for the development of culture, science and technology (Tomasello et al., 2005). Again we encounter a human particularity, i.e. our striving for understanding ourselves through reflections about regularities in the social world, through systematic psychological experimentation, through identifying relevant neural mechanisms and last not least, through simulating the complex reality of the human mind and behavior through technology.

The idea to simulate sensory, cognitive and motor functions of biological systems through technology has been already the key topic of cybernetics, systems theory and robotics and, more recently, of the emergent field of biorobotics (Webb, 2001). The aim to simulate biological systems by creating surrogates which are not only abstract models of the world but result in somehow materialized agents, which can be encountered in the real world or experienced via our senses, poses a particular challenge in theory and practice. Actually we might claim that it is the most critical test for a model of biological systems to put it into action and to expose it to the critical comparison with social reality as created by nature (Hut & Sussman, 1987). The requirements to meet this challenge have been sketched by Webb (2001), comprising different tasks levels which have to be addressed successfully before artificial systems can be expected to pass the real life test (see Fig. 1). These levels include reliable observation of the natural target behavior, appropriate theoretical assumptions about the biological mechanisms underlying this behavior, and efficient algorithms to implement a convincing simulation, which demonstrates the quality of the model.

While in its general form Webb's model holds value as a taxonomy for a broad variety of technical simulations of biological systems, it has to be specified with regard to the topic of this article, which focuses on social behavior of humans, in contrast, for example, to the construction of a robot pet serving as a social toy or an industrial robot performing complex mounting tasks during the "ghost shift" of a car fabric. Specifications are thus required with regard to the behavioral domains and the cognitive processes to be addressed and the simulation approach to be chosen.

2. Simulating social interaction

The domain essentially addressed in this article is embodiment and nonverbal communication (NVC) in social virtual entities. Embodiment as a feature of artificial agents can be preliminarily defined as the presence of human-like physical properties, which enable the transmission of nonverbal signals (Bente, Rüggenberg, Krämer, & Eschenburg, 2008; Ruttkay, Doorman, & Noot, 2002). Embodiment is a constituent of all face-to-face encounters, but can be minimized or might be even absent in mediated communication and in particular in human–technology interactions (HTI). Artificial reconstructions of human beings, such as anthropomorphic agents or robots can be considered as a means of embodying respectively anthropomorphizing technology and are assumed to render HTI more natural, in the sense that humans can intuitively rely on their everyday communication routines and thus perform interactions with greater ease (Duffy, 2008; Krämer & Bente, 2005; Krämer, Bente, & Piesk, 2003; Krämer, Bente, Troitzsch, & Eschenburg, 2009; Krämer, Tietz, & Bente, 2003; Rickenberg & Reeves, 2000; Sproull, Subramani, Kiesler, Walker, & Waters, 1996).

The mere technical feasibility of the creation of realistic virtual characters with real-time communicative capabilities is certainly a relevant catalytic factor for the rapid development in the research field of agents and robots. But this development also seems to be driven by the peculiar interest humans devote to the visual communication channel and the exceptional sensitivity they have developed towards nonverbal cues, such as gestures, postures, movements and facial displays (DePaulo & Friedman, 1998; Fridlund, 1991; Krämer, 2006). In fact psychological research provides ample evidence for the fact that embodiment and NVC serve a number of conversational and socio-emotional functions in human encounters (Bente, Rüggenberg et al., 2008; Bente, Krämer, & Eschenburg, 2008) and thus – given the technical prerequisites – can be influential when humans communicate with or via technology (Biocca & Nowak, 1999, 2001; Blascovich et al., 2002; Burgoon, Buller, & Woodall, 1996; Petersen, 2002; Slater & Steed, 2002). Although this view is shared by many researchers in the field, there is still more speculation than empirical knowledge about the psychological functions of embodiment in HTI and the social–emotional impact of artificial social entities in virtual social encounters. As we will show convincing implementations of artificial social entities do not only require such knowledge but they can also serve as powerful tools to advance this knowledge in experimental communication and social cognitive neuroscience.

Regarding the relevant simulation approaches, i.e. the way our models of the social mind and social behavior are implemented, we extend the perspective from robots to the more general category of "artificial social entities", thus including virtual agents as graphical representations of humanoid actors on a screen or within shared virtual environments (SVEs). With regard to the technical implementation artificial agents and robots share relevant commonalities as both require simulations of an "artificial social intelligence (ASI)" to allow them to process humans' social behavior as well as to produce meaningful social responses and elicit perceptions and attributions in humans comparable to those elicited by other humans. It has to be posited, however, that robots and agents are also different in a fundamental experiential aspect: Robots, in contrast to agents, are situated objects, sharing the physical world with the human agent (Cañamero, 2003; Dautenhahn & Christaller, 1997; Krämer & Bente, 2005). Thus the common reference system for robots and humans is the real physical world in which location, distance, physical properties, collision or touch construct immediate respectively unmediated impressions (Powers, Kiesler, Fussell, & Torrey, 2007). One might argue that in particular in so-called immersive virtual environments (including 3D representations of the world, locomotion and haptic devices) the illusion of an unmediated experience might become so convincing that the difference between real and virtual fades and the distinction between robots and agents becomes obsolete (Sallnäs, Rassmus-Gröhn, & Sjöström, 2000). However, it seems that we still have some way to go to enter this stage of technological development (Kiesler, Powers, Fussell, & Torrey, 2008).

Given this constraint, important aspects of simulation are nevertheless common to both domains of embodied robots and virtual agents, as related to their capacity to produce and process nonverbal behavior (NVB). This commonality justifies that the current paper mainly refers to virtual agents, which we use a research tool to advance our still fragmentary knowledge about the mechanisms of the social mind and unravel the secrets of NVB in interpersonal communication. Two perspectives are relevant to this approach: (1) *the interpersonal perspective*, based essentially on NVB research targeting the structural and functional properties of NVC and (2) *the intrapersonal perspective*, based on research in social cognitive neuroscience, asking for the cognitive processes and neural mechanisms involved in and recruited during the production and perception of NVB.

3. The interpersonal perspective: meanings and functions of nonverbal behavior

Nonverbal cues including facial expressions, gaze behavior, gestures, postures and body movements have a deep impact on the process and outcome of our communication (Argyle, Salter, Nicholson, Wiliams, & Burgess, 1970; Mehrabian & Wiener, 1967; Schneider, Hastorf, & Ellsworth, 1979). Burgoon (1994) summarized relevant findings from NVB research concluding that approximately 60%–65% of social meaning is conveyed via NVC channels (Mehrabian & Ferris, 1967). This rough estimation however ignores the particular complexity (Bente & Krämer, 2003; Poyatos, 1983) and "polysemous nature" (Burgoon & Bacue, 2003, p. 187) of NVB and leaves open the questions which nonverbal cues under which conditions serve which interpersonal functions, respectively which inferences or social behavior they induce. In the following we will explore key functional properties of NVC, which pose particular challenges for basic research as well as applied research focusing on implementations of artificial agents (Bente & Krämer, 2003; Bente, Rüggenberg et al., 2008; Bente, Krämer et al., 2008).

3.1. Context dependency and implicitness

There is consensus that interpretations and effects of nonverbal cues largely depend on the context in which they occur. The so-called Kuleshov effect demonstrates the influence of *situational context* (Pudowkin, 1961; Wallbott, 1988). Showing a movie sequence, in which an actor's neutral face is presented with either a dead woman's body, a little girl playing, or a pot of soup, Lev Kuleshov (a Russian film director) could induce distinct interpretations of the same neutral facial display ranging from terror to joy or contentment (see also the replication of Goldberg, 1951). Conceptualizing communication as a multichannel activity (Poyatos, 1983) it could be further shown that co-occurring behavior can also constitute a context relevant for the interpretation of NVB. Chovil (1991) demonstrated that the interpretation of facial displays (eye brow movements) is heavily dependent on the *verbal context*, leading to such different interpretations of eye brow movements as emphasis, marked questions, offers, surprise or disbelief depending on the simultaneous speech activity. Furthermore, there are numerous examples for the influence of the *nonverbal context* on the interpretation of particular nonverbal cues (Krämer, 2001). In concordance with our everyday experience, Grammer (1990) for example showed that the meaning assigned to laughter is modulated by other nonverbal signals such as posture and bodily movements. These few examples might be sufficient to illustrate the complexity in assigning meaning to NVB and the difficulties arising when analysing the effects of particular cues or implementing an artificial social intelligence.

A further problem derives from the fact that NVB cannot be fully understood as an assembly of discrete cues with clearly defined spatio-temporal characteristics and meanings. The effects of NVB often emerge from dynamic qualities that are implicit to the ongoing behavior and can hardly be identified with the naked eye. Riggio and Friedman (1986) concluded that these subtle dynamics even determine perception and evaluation in the first place. Recent studies confirm this position, showing that dynamic qualities, such as speed, acceleration, complexity and symmetry of body movements and facial expressions, may have a stronger impact on the observers' impressions than so-called semantic aspects, although they might not be consciously identified as a possible cause (Grammer, Honda, Juette, & Schmitt, 1999). For instance, Grammer, Fidova, and Fieder (1997) could demonstrate that very subtle changes in women's movements were provoking attributions of interest and contact readiness in male observers and that the complexity level and speed of movements was dependent on actual levels of estrogen. Male observers did not consciously notice these subtle changes, but they nevertheless differentially responded depending on hormone levels. Similarly, Krumhuber and Kappas (2005) showed that movement quality is equally important when observing facial behavior. Against this background, Grammer et al. (1997) even suggest a new conceptualization of (nonverbal) communication that radically differs from category-oriented or semiotic "body language" approaches stressing a direct coupling between movement production and movement perception and the automaticity and unconscious character of NVB. Accordingly, Choi, Gray, and Ambady (2005) concluded from numerous studies that "because of the need to act quickly in social life" (p. 327) the degree of automation for both encoding and decoding of NVB is fairly high. Consistent with the definition of automaticity by Bargh (1994) NVC can thus be seen as unaware, efficient, uncontrollable and unintentional. Against this background Burgoon, Berger, and Waldron (2000) coined the term *mindlessness,* which, however, leaves open the debate how the human cognitive system determines which NVB to show and which meaning to assign to observations of others' NVB. Definitely there must be some processing going on when humans move in social environments, interpret others' behaviors and adapt accordingly. A computational model relying on higher level inferences and signal detection based on denotative dictionary entries, however, seems inappropriate to tap the subtlety of NVC and the complexity of social information processing.

3.2. Interpersonal functions of nonverbal behavior

Opening the visual channel can hardly be understood as adding a specific functionality to communication. In fact, the transmission of nonverbal cues will inevitably and simultaneously affect different levels of social information processing (see below) including aspects of impression formation, interaction control, and emotional rapport. Imagine an adult teaching a child how to handle a tool (e.g. using a hammer to pin down a nail). Demonstrating the action and at the same time keeping eye contact with the child and showing an encouraging smile ("knowing how"), would certainly provide more information than just describing the adequate motor trajectories to perform the action ("knowing that"). The visually perceivable movements of the adult will also carry information about the target of instruction, the emotional attitude of the instructor, his patience or impatience, his own level of expertise, his current mood and other aspects to be inferred from the various aspects of his motor performance. A functional distinction of the various informational layers potentially inherent to motor actions seems most relevant not only with regard to the implementation of embodied communication in virtual actors, but also with regard to the understanding and modeling of specialized processing modules which are able to extract and interpret the relevant cues intermingled in the observable behavior. Extending on previous conceptions (Bente & Krämer, 2003; Bente, Krämer, Petersen, & de Ruiter, 2001; Bente, Petersen, Krämer, & de Ruiter, 2001; Bente, Krämer et al., 2008) we suggest to differentiate at least four functional levels on which NVB operate simultaneously: (1) modeling and coordination functions, (2) discourse functions, (3) dialogue functions, (4) socio-emotional functions.

Modeling and coordination functions of visual behavior are essential for learning and social organization not only in humans (Bandura, 1968), but also in non-human primates (Galef & Laland, 2005; Zentall, 2006). Lion cubs evidently learn to hunt from observing adult lions and later they take their place in the predator group coordinating their movements by observing motion trajectories, attention focus and speed of the other members of the pack. Learning from and adapting to the behavior of others seems to be a particular evolutionary advantage and an indispensible prerequisite for the formation of social groups. Although most likely relying on the same capacities to simulate observed behavior through low level brain mechanisms, putatively the so-called mirror neuron system (MNS) (Gallese & Goldman, 1998; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Iacoboni et al., 1999; Rizzolatti et al., 1996), humans bare evident advantages in regard to processing complex motor activities for the benefit of learning and social coordination. As for example shown by Beck (2005) baboons observing successful tool use in food acquisition exerted by a trained conspecific showed increased handling of the tool but failed to perform the correct actions. As demonstrated by Bandura and his research group higher level cognitive functions such as self-monitoring and symbolic coding are necessary to fully benefit from observations of others' motor behavior (Bandura, Adams, & Beyer, 1977; Carroll & Bandura, 1982). While modeling functions potentially concern all aspects of functional motor behavior directed towards the physical or social environment and are prevalent in most social situations, coordination functions on the other hand are more specific and often relate to a shared environment and common tasks. Common to both is their functional role as "motor contagion" (Blakemore & Frith, 2005) which allows for action prediction and thus enables anticipation or expectation of action outcome and according adjustments. In many cases human action coordination starts before functional operations can be observed in conspecifics. A most relevant nonverbal cue to prepare for imitation and/or coordination before the onset of action is the observed gaze direction of others. It provides the basis for automatic processes of joint attention and higher inferential processes regarding others' intentions. We will elaborate on this most relevant aspect of human interaction below in more detail. Generally speaking, modeling and coordination functions of NVB are ubiquitous in social interaction and it can be hypothesized that the underlying processes and neural mechanisms might provide the basis for higher level mentalizing processes and empathic responses to others (Lieberman, 2007; Santos et al., in press; Vogeley & Roepstorff, 2009).

Discourse Functions are closely related to speech production and understanding. So-called emblems, pointing gestures, illustrative gestures and beat gestures belong to this functional category (Efron, 1941; Ekman & Friesen, 1969, 1972). *Emblems* are conventionalized gestures, which can substitute a word or a phrase, often used when the auditory channel is not available (e.g. during diving) or when social settings do not allow to use the voice (e.g. raising the hand to get the turn in the classroom). Emblems only cover a small range of NVB. They have clear physical properties and a lexical meaning (at least within a culture). *Illustrators* complement and clarify verbal exchange (Efron, 1941; Ekman & Friesen, 1969, 1972): They are frequently used to establish an object reference, e.g. by finger-drawing an object into the air (iconic gestures) or by pointing at it (deictic gestures). So-called *beat gestures* are used to underline rhythm of speech and emphasize certain parts of an utterance (see McNeill, 1992, for a distinction between iconic, metaphoric and beat gestures). Successful implementations of beat gestures in artificial agents have been demonstrated by Cassell (1998) and Cassell et al. (1994). As visible from the literature, hand gestures are the predominant nonverbal subsystem when it comes to discourse functions of NVB, but it has also been shown that facial movements can serve discourse functions (Chovil, 1991).

Dialogue Functions include so-called *turn-taking respectively turn-yielding signals* (e.g. eye contact) and *back-channel signals* (e.g. head nods), which establish the smooth flow of interaction and the exchange of speaker and listener roles (Duncan, 1972, 1974; Duncan & Niederehe, 1974; Duncan, Brunner, & Fiske, 1979). *Turn-taking signals* are often a conglomerate of verbal (e.g. sociocentric sentences as "you know"), paraverbal (e.g. intonation or prolongation of the last syllable) and nonverbal cues (e.g. termination of gestures, head movements). Kendon (1967) further identified changes in head position (raising, rotating towards the listener) as relevant turn-taking cues. *Back-channel signals* such as head nodding confirm the listener status and motivate the speaker to go on (Yngve, 1970). If the listener wants to take the turn she/he indicates this via a so-called *speaker state signal* that might consist of head rotations away from the interlocutor, starting gestural activity and body movement, and averted gaze. The necessity of visual cues within the turn-taking process has been doubted (Rime, 1983), given the observation that interlocutors still are able to lead well organized conversations when they do not see each other, e.g. during a telephone chat. Rutter and Stephenson (1977), however, demonstrated that this channel loss comes at a price as it implies higher workload in supervising the verbal exchange and particular repair strategies (Donaghy & Goldberg, 1991; Rutter, Stephenson, Ayling, & White, 1978).

Socio-emotional functions of NVB include its influence on person perception and impression formation as well as the communication of emotions and interpersonal attitudes. Socio-emotional functions are not independent from dialogue and discourse functions of NVB. A smooth flow of the conversation will be likely to influence mutual person perception and interpersonal climate in a positive way. In an attempt to systematize nonverbal cues according to their socio-emotional functions, Mehrabian (1972) identified three basic dimensions: the *evaluation* dimension (liking), the *activity* dimension, and the *potency* dimension (power).

According to Mehrabian (1972) *the evaluation dimension* (liking) is affected by the so-called immediacy or "involvement" (Patterson, 1982) cues such as smiling, forward lean, close proximity, touch, relaxed postures, and interpersonal distance (proxemics) (Haase & Tepper, 1972; LaCrosse, 1975; Mehrabian, 1969; Palmer & Simmons, 1995; Patterson, 1982; Rosenfeld, 1966; Schlenker, 1980). Although smiling has been discussed as a submissiveness cue ("appeasement pattern" according to Henley (1977), Keating, Mazur, and Segall (1977) and Patterson (1994) most studies corroborate its evaluative effects, documented as friendliness and affiliation (Brunner, 1979; Carli, LaFleur, & Loeber, 1995; Carli, Martin, Leatham, Lyons, & Tse, 1993; Deutsch, LeBaron, & Fryer, 1988; Graham & Argyle, 1975; Halberstadt & Saitta, 1987; Page, unpublished manuscript). Furthermore, it was demonstrated that head movements and specific head orientations can carry relevant social information (Frey, 1983; Frey, Hirsbrunner, Florin, Daw, & Crawford, 1983; Signer, unpublished manuscript). The literature further provides evidence for the fact that similarities in the NVB of interlocutors are correlated with positive evaluation being a cause and an effect of mutual liking (Bernieri & Rosenthal, 1991; Tickle Degnen & Rosenthal, 1987; Wallbott, 1995). This class of nonverbal phenomena has been addressed in the literature using different terms, such as reciprocity and compensation (Argyle & Cook, 1976), mirroring (Bernieri & Rosenthal, 1991), conversational adaptation (Burgoon, Dillman, & Stern, 1993), simulation patterning (Cappella,

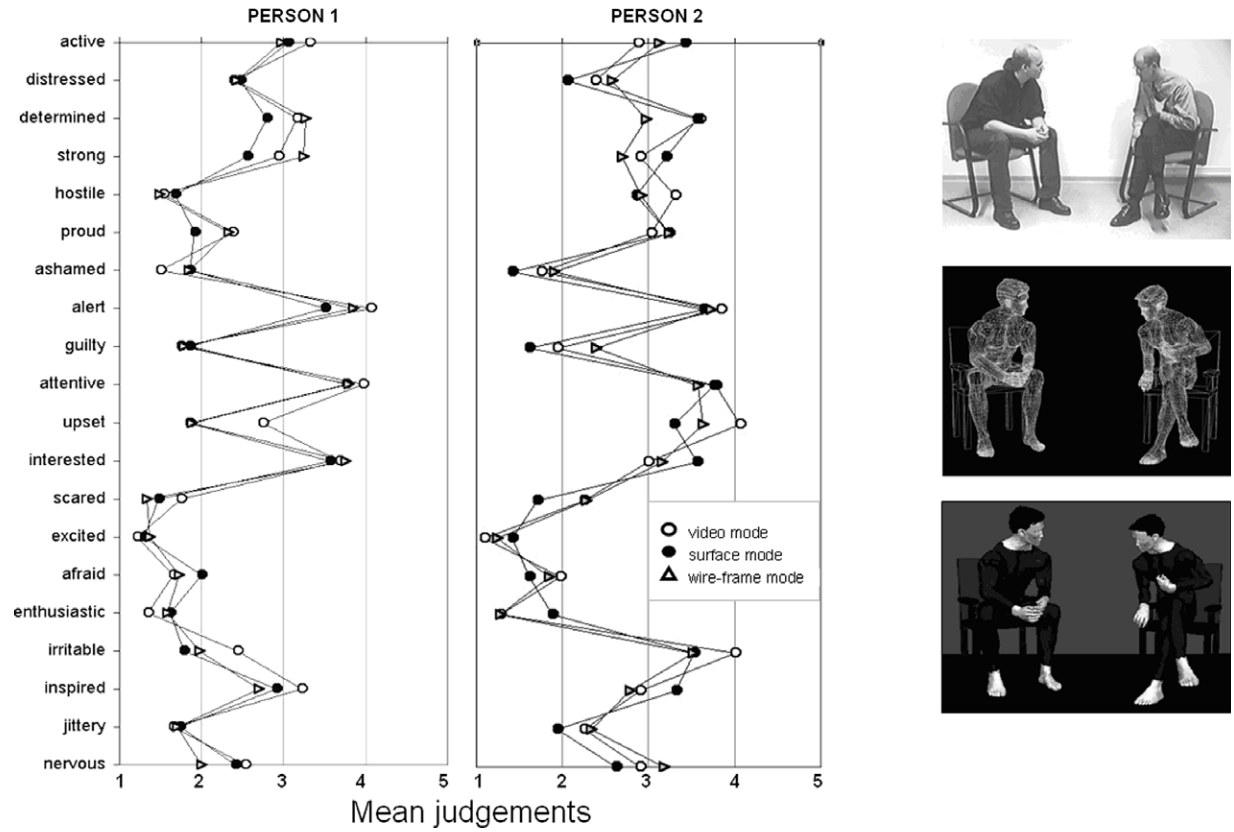

Fig. 2. Profiles of social impressions based on video vs. computer animations. Impression ratings were collected from observers viewing either video sequences or movement behavior reconstructed via computer animation using either wire frame models or surface models of human bodies. High correlations could be established confirming the ecological validity of animated figures.
Source: From (Bente, Krämer et al., 2001).

1991), synchrony (Condon & Ogston, 1966), congruence (Scheflen, 1964), motor mimicry (Bavelas, Black, Lemery, & Mullett, 1987; Lipps, 1907) and accommodation (Giles, Mulac, Bradac, & Johnson, 1987). First experiments using virtual characters have also confirmed the impact of motor mimicry (e.g. Mojzisch et al., 2006; Schilbach, Eickhoff, Mojzisch, & Vogeley, 2008).

The activity dimension is expressed by extensive use of gestures, frequent facial displays, pronounced movements and general responsiveness and expressiveness (DePaulo & Friedman, 1998; Mehrabian, 1969). It has been questioned, whether activity represents an independent impression dimension, since higher activity and responsiveness correlates with positive evaluation (Bentler, 1969). In fact, variations in the general activity level can work as mere amplifiers of immediacy cues. Mehrabian and Williams (1969) state: "In particular, when a relatively high level of activity is combined with other cues which communicate liking, [...] then activity may be seen as a vehicle for the communication of the intensity of liking" (p. 54).

Finally, the *potency dimension* (mostly synonymously used with power, dominance and status) is addressed by so-called relaxation cues such as asymmetry, sideward and backward lean, relaxed extremities, staring or averted gaze and expansive gestures (DePaulo & Friedman, 1998; Mehrabian, 1969; Millar, Rogers, & Bavelas, 1984; Siegel, Friedlander, & Heatherington, 1992). The results on the effects of relaxation cues are equivocal (Aguinis, Simonsen, & Pierce, 1998; Henley, 1977; Schlenker, 1980) showing only consistent results with respect to few cues, such as backward lean (Carli et al., 1993) and touch (Andersen, Andersen, & Jensen, 1979; Henley, 1977; Patterson, 1994; Remland & Jones, 1988). An empirically well established relation exists between dominance and gaze behavior (DePaulo & Friedman, 1998; Dovidio, Ellyson, Keating, & Heltman, 1988; Exline, 1971; Exline, Ellyson, & Long, 1975). Social gaze as a powerful and well defined cue has recently gained particular attention in the development and evaluation of artificial social agents (Bailenson, Beall, Loomis, Blascovich, & Turk, 2005; Bente & Eschenburg, 2007) and constitutes a paradigmatic case for studying interpersonal functions of NVB and the neural mechanisms underlying the processing of visual cues as will be shown in the following chapters.

As should be evident by now, NVB constitutes a structurally and functionally complex phenomenon which owes its impact to subtle, implicit and rarely consciously processed characteristics. It does not come as a surprise that many secrets are left undiscovered. This is partly due to methodological problems researchers face when trying to manipulate particular effects or functionalities. Advancements in computer animation targeting the creating of believable virtual characters, however, have changed the situation remarkably (Bente, 1989; Bente, Krämer et al., 2001; Bente, Petersen et al., 2001; Bente, Rüggenberg et al., 2008; Bente, Krämer et al., 2008). Computer agents and so-called avatars are increasingly used to study the complex mechanisms of encoding and decoding nonverbal cues allowing for an unprecedented experimental control of embodiment and physical appearance as well as behavioral dynamics. In an early study we could demonstrate that, at least from an observers point of view, computer-animated moving agents in social interactions are able to produce the same impressions as original video recordings from which the animations were derived (see Fig. 2). Based on these experiences virtual characters have now been used in various settings and in particular as an important tool in functional neuroimaging studies which require highly standardized stimulus material as demonstrated in the next paragraphs.

4. Processing embodied social cues: intrapersonal mechanisms

Social cognitive processes have recently become a key topic in cognitive neuroscience and social (cognitive) neuroscience has emerged as a new subdiscipline in neurosciences and recently developed into an autonomous scientific discipline (Adolphs, 2009; Cacioppo, Lorig, Nusbaum, & Berntson, 2004). Generally speaking, social neuroscience focuses on processes that are related to the adequate ascription of mental states to others for the purpose of successful communication or interaction between personal agents. One very important distinction that has been already introduced in the first paragraphs and which we want to emphasize in the following, too, is related to different levels of processing of social information, that can be either implicit or explicit (Frith & Frith, 2008). Whereas implicit information processing refers to a comparably fast, automatic, pre-reflexive mode that is employed for instance during nonverbal behavior, explicit information processing, in contrast, comprises processes in a comparably slow, controlled, reflexive, inferential format such as stereotypes or information processing that is based on explicit rules (Barsalou, 2008; Lieberman, 2007). However, these levels of processing should be conceptualized as a continuum of different levels or formats of processing that allow to make use of different processing modes resulting in a flexible capacity of person perception that is performed either automatically or in a controlled manner. Which level of processing is recruited probably depends to a large amount on the data available (Fiske & Neuberg, 1990). Many of these processes appear to underlie a considerable influence of culture: Gestures can stand for meaningful conventionalized signals, and they can be transferred from culture to culture (Pika, Nicoladis, & Marentette, 2006). They can also be traced back to acculturation processes of individuals and thus appear culture-dependent (Chiao et al., 2008; Efron, 1941). Social cognition therefore needs to be carefully differentiated with respect to cultural influences (Vogeley & Roepstorff, 2009). However, as this is not the main focus here we will conceptualize culture for the purpose of this paper in the following as a "universal" category proposing that social cognitive capacities enabling us to develop language, culture, technology, are relevant for the whole genus of homo sapiens (Tomasello et al., 2005).

4.1. Liveliness detection and attribution of intentionality (animacy and agency)

Like many other animals, humans are able to detect biological motion in their environment, that is movement that is performed by biological organisms, irrespective of the format of displays that present the movement. Phenomenally, biological motion relies on a complex perception that includes data about a wealth of different aspects of the moving objects perceived. This includes, first, the physical properties of the moving object that allow inferences about weight or size, second, its dependency on the physical environment such as gravity or obstacles, third, its interrelation to the social environment that might be described employing concepts of approach and avoidance, and, fourth, its behavioral capacities, for instance related to the degree of efficiency during the performance of motor tasks. A very prominent example are displays of graphically reduced representations of moving objects, for instance simple geometric figures or point-light walkers (e.g. Heider & Simmel, 1944). They offer sufficient variations in their movement patterns so that an object can be perceived as a biological "being" and often enough even a human being that is alive and allows for meaningful inferences (Blake & Shiffrar, 2007; Johansson, 1973).

The different aspects of movement that influence our ability and our disposition to ascribe and attribute mental states to moving objects have been explored in the literature extensively, and they appear to be independent from the environment of the moving objects (Abell, Happe, & Frith, 2000; Barrett, Todd, Miller, & Blythe, 2005; Heider & Simmel, 1944; Rochat, Morgan, & Carpenter, 1997; Santos, David, Bente, & Vogeley, 2008; Tremoulet & Feldman, 2006). Specific movement features that have been empirically shown to contribute to the experience of animacy include self-propelled motion as initiation of movement without an external cause (Leslie, 1984; Stewart, 1984), motion contingency based on both spatial and temporal synchrony between objects (Bassili, 1976; Blakemore et al., 2003; Johnson, 2003; Johnson, Booth, & O'Hearn, 2001), or responsiveness to the motion by any component in the environment (Abell et al., 2000; Castelli, Happe, Frith, & Frith, 2000; Leslie, 1984; Michotte, 1946; Schultz, Friston, O'Doherty, Wolpert, & Frith, 2005). In an own study, we developed a paradigm that allowed to induce the experience of animacy in a parametric fashion by the systematic variation of movement parameters of two balls presented in animated video sequences. The experience of perceiving animated objects increased with enrichment of the animations by any of the three different movement cues (a break in an otherwise smooth movement trajectory, an approach movement of one object to the other, responsiveness from the addressed object to the actively moving object) or combinations of these movement cues (Santos et al., 2008).

On a neural level, movement patterns of geometrical figures can elicit activation in brain regions that have been already formerly shown to be crucially involved in social cognitive processes including "mindreading", "mentalizing" and "theory of mind" (ToM) as the capacity to adequately attribute mental states to others in order to explain or predict their behavior. This commonality supports the hypothesis that cognitive processes that are involved during the attribution of animacy and during mentalizing or ToM rely on the same – or at least on substantially overlapping – neural mechanisms. Empirical neuroimaging studies that made use of this type of animated material have consistently shown that brain areas are recruited that belong to the so-called "social neural network" (SNN). The SNN essentially comprises the medial prefrontal cortex (MPFC), the superior temporal sulcus (STS), the insula, the amygdala, and the anterior temporal poles (TP) (Lieberman, 2007; Vogeley & Roepstorff, 2009). Making use of animations showing geometric figures – similar to those developed by Heider and Simmel (1944) – Castelli et al. for example reported increased neural activations in a PET study in the ventral portion of the MPFC and basal temporal regions (fusiform gyrus, TP) during the perception of complex "socially" appearing animations in contrast to random motion animations (Castelli et al., 2000). This finding was corroborated more recently by Gobbini, Koralek, Bryan, Montgomery, and Haxby (2007) who made use of the same animations and compared them with false belief stories, as commonly used in ToM experiments, and point-light displays of human actions. They again found increased activity in the anterior cingulate cortex as part of the MPFC, both during the presentation of animations and of ToM stories and ToM animations, but not during the observation of point-light displays of human motion per se. The authors hence proposed that the ACC plays a crucial role in the representation of the social intentions of actions. The STS has also been shown to be critically involved in the processing of movement kinematics of such geometrical figures, in particular related to those properties that are strongly tied to animacy perception such as goal-directed motion (Schultz, Imamizu, Kawato, & Frith, 2004), and interactivity (Schultz et al., 2005).

Employing our own paradigm that employs a design involving systematic variations of motion parameters previously shown to successfully induce and parametrically vary the experience of animacy (Santos et al., 2008) we were able to show that during the perception of animacy brain regions involved in the so-called "social neural network" (SNN; (Lieberman, 2007)) were recruited including the ventral portion of MPFC, the insula, superior temporal gyrus, fusiform gyrus, and the hippocampus. Decreased animacy experience was associated with increased neural activity in the superior parietal and premotor cortices as key constituents of the human MNS. A particularly interesting finding in this context was presented by Wheatley, Milleville, and Martin (2007) who showed that animations of the same object moving in different "contexts" lead to the interpretation of animacy – and activation of the SNN – only under circumstances in which objects were animated in social contexts. Related to this finding is a study in which the attended aspect of two animated figures was the focus. The SNN was activated only if subjects had to focus on the social interaction but not during conditions in which they had to attend to motion properties only (Tavares, Lawrence, & Barnard, 2008).

These results suggest that the human MNS is recruited during an early stage of processing representing a basic disposition to detect the salience of movements whereas SNN appears to be a high level processing component serving evaluation and mental inference (Santos et al., in press). The MNS, formerly being shown to be recruited during action observation, imitation or imagination, is putatively a complementary system compared to the SNN that is also considerably involved in social information processing (Gallese et al., 1996; Iacoboni et al., 1999; Keysers & Gazzola, 2007).

4.2. Inferring mental states: "theory of mind"

In contrast to this "basic", intuitive or implicit capacity of reading out animacy induced by systematic variations of movement parameters of geometric figures (e.g. Santos et al., 2008) or their context (e.g. Wheatley et al., 2007) or read out by different instructions (e.g. Tavares et al., 2008), the capacity of "theory of mind" (TOM) is based on an inferential, rule-based processes. TOM also referred to as "mindreading" (Baron-Cohen, 1995) or "theory of mind" (TOM) (Premack & Woodruff, 1978) is defined as the capacity to ascribe mental states to others in order to predict or explain their behavior. This ability to read another persons mind can be reliably assessed in classical TOM paradigms, originally designed for studies in primates and further developed in developmental psychology of humans. In a typical TOM paradigm, a subject has to model the knowledge or propositional attitudes of an agent with respect to a particular set of information or propositions that are provided either on the basis of a cartoon or a short story (e.g. "Person A knows, believes, etc., that p."). According to ST, the capacity of TOM is based on taking someone else's perspective, and projecting one's own attitudes on someone else (Harris, 1992). By contrast, according to TT, the TOM capacity is a distinct body of theoretical knowledge acquired during ontogeny different from one's own previous experiences (Gopnik & Wellman, 1992; Perner & Howes, 1992). On a purely behavioral level, an independent cerebral implementation of the two capacities could only be inferred on the basis of a double dissociation. Arguments based on information of simultaneous or subsequent development of the two differential cognitive capacities have been non-conclusive with regard to their putative differential cerebral implementation which is reflected by the current controversial debate (for more detail see e.g. Carruthers, 1996; Gopnik, 1993; Gopnik & Wellman, 1992).

A number of functional imaging studies using PET and fMRI have successfully delineated brain regions involved in "reading other minds" (Fletcher et al., 1995; Gallagher et al., 2000; Vogeley et al., 2001). These studies have repeatedly and convincingly demonstrated increased neural activity associated with TOM conditions in the MPFC to which we have referred to in the previous paragraphs already (Amodio & Frith, 2006; Frith & Frith, 2003). However, it is interesting to note, that another brain region, the posterior superior temporal sulcus (pSTS) is also crucially involved not only in the perception and interpretation of socially salient bodily or facial cues (Allison, Puce, & McCarthy, 2000; Keysers & Perrett, 2004), but has also been described as a key node of the neural network involved in the ability to infer other person's mental states (Frith & Frith, 2003). Functional MRI studies have shown increased neural activation in the region of the pSTS during a number of mentalizing tasks (Brunet, Sarfati, Hardy-Bayle, & Decety, 2003; Gallagher & Frith, 2004; Gallagher et al., 2000; Schulte-Ruther, Markowitsch, Fink, & Piefke, 2007; Vogeley et al., 2001; Völlm et al., 2006), viewing stimuli of other persons' intentions or expressive gestures and faces (Gallagher & Frith, 2004; Narumoto, Okada, Sadato, Fukui, & Yonekura, 2001), observing other persons' actions (Pelphrey, Morris, & McCarthy, 2004; Saxe, Xiao, Kovacs, Perrett, & Kanwisher, 2004), and – as already mentioned – viewing biological motion (Bonda, Petrides, Ostry, & Evans, 1996; Grossman & Blake, 2002). Studies of humans with lesions to pSTS show that its structural integrity is necessary for representing others' beliefs in video- and story-based false belief tasks (Apperly, Samson, Chiavarino, & Humphreys, 2004; Samson, Apperly, Chiavarino, & Humphreys, 2004) as well as for discriminating eye gaze direction (Akiyama et al., 2006).

5. Coordinating minds and actions: the case of gaze

Integrating both interpersonal functions and intrapersonal mechanisms social gaze defines a paradigmatic case, which allows to exemplify the multifunctionality of NVB and the multiple cognitive processes and neural mechanisms involved in social information processing. Everyday experience as well as extensive research in social psychology and social cognitive neuroscience confirm the crucial role of human gaze behavior in social interactions and its impact on cognitive, affective and motivational processes (Argyle & Cook, 1976; Gueguen & Jacob, 2002; Hood & Macrae, 2007; Vuilleumier & Pourtois, 2007). It allows to coordinate attention and activities with others (Argyle & Cook, 1976) and also influences processes of person perception and evaluation (Argyle, Lefebvre, & Cook, 1974; Kleinke, 1986; Mason, Tatkow, & Macrae, 2005; Mirenda, Donnellan, & Yoder, 1983). Understanding the ostensive function of eye gaze is closely linked to the ability to infer mental states of others (Baron-Cohen, 1995; Eskritt & Lee, 2007). During ontogeny the capacity to recognize that people can perceive an event differently depending on their position in space and, hence, their gaze direction may support the capacity to switch perspectives at later ages (Gopnik, Slaughter, & Meltzoff, 1994). Inferential knowledge about the relations and causes of mental states helps to interpret gaze information in a complementary fashion (Eskritt & Lee, 2007). Mentalizing processes are particularly important during the perception of direct gaze (Gibson & Pick, 1963; von Grunau & Anston, 1995): it initiates social encounters and conveys interpersonal attitudes (Kampe, Frith, & Frith, 2003; Kleinke, 1986; Mirenda et al., 1983; Valentine & Ehrlichman, 1979; Wicker, Michel, Henaff, & Decety, 1998). Another aspect of direct gaze is its inherent reward value. Evidence for this reward potential can be shown already during early ontogeny as even very young infants preferentially attend to faces presenting with direct gaze (Farroni, Csibra, Simion, & Johnson, 2002; Symons, Hains, & Muir, 1998). Direct gaze is a considerable motivational factor from the end of the first postnatal month onwards by positively influencing affect regulation and suckling behavior of newborn babies (Blass, Lumeng, & Patil, 2007).

5.1. Information and processing layers in gaze behavior

In addition to the mere direction of another persons' gaze, gaze duration as compared to gaze direction represents an even more complex source of social information because it requires more sophisticated mentalizing abilities in order to reach an adequate interpretation of another persons' gaze (Eskritt & Lee, 2007). In tasks requiring inferences about other persons' desires based on the simple detection of their gaze direction, 4 year olds were already successful in passing this task (Baron-Cohen, 1995). However, advanced levels of understanding gaze cues based on their relative duration were not yet present at this age (Montgomery, Bach, & Moran, 1998). In contrast, the performance of 5 and 6 year olds was comparable to that of adults. These data indicate that during later developmental stages relative gaze duration towards different test objects are highly informative and that they can be efficiently used to infer others persons' preferences (Einav & Hood, 2006; Montgomery et al., 1998).

On a neural level, evidence from functional neuroimaging has demonstrated that processing gaze-related information is consistently associated with activation in the pSTS, a region that has been introduced already as being recruited during TOM tasks (Akiyama et al., 2006; Hoffman & Haxby, 2000; Hooker et al., 2003; Pelphrey et al., 2004; Puce, Allison, Bentin, Gore, & McCarthy, 1998; Wicker et al., 1998). Moreover, direct gaze in particular has been shown to recruit additional neural regions associated with complex social cognitive processing including the amygdala, the fusiform gyrus and the prefrontal cortex (Conty, N'Diaye, Tijus, & George, 2007; George, Driver, & Dolan, 2001; Kawashima et al., 1999). The latter region of the MPFC, again, is in accordance with other neuroimaging studies that consistently suggest a specific role of this brain region for social cognition (Amodio & Frith, 2006). Thus, the result reported by Kampe et al. (2003) confirms the proposed link between direct gaze and understanding self-relevant intentions of others. Furthermore, differential involvement of the MPFC during processing of direct gaze has also been observed in combination with communicative facial expressions (Schilbach et al., 2006).

In an own recent study we were able to distinguish two different subprocesses in the evaluation of social gaze, namely "gaze detection" and "gaze evaluation" (Kuzmanovic et al., 2009) by the systematic variation of the experience of being gazed at by virtual characters with different gaze durations ranging from 1 s to 4 s. Whereas the mere feeling of being gazed at, irrespective of gaze duration, was associated with activity in the fusiform and temporoparietal cortices, that are assumed to be responsible for biological motion detection ("gaze detection"), the judgment of social gaze with increasing gaze duration was associated with recruitment of the MPFC ("gaze evaluation"). On the basis of this study, gaze detection can be interpreted as an early stage of processing that is essentially depending on the sensory input to the unimodal association cortex of the visual system. In contrast, gaze evaluation can be understood as comparably late stage of processing that is performed in the MPFC.

5.2. Methodological advancements: truly interactive paradigms

True interaction is of course the central challenge when integrating interpersonal functions and intrapersonal mechanisms (Reddy, 2003; Singer, 2006). How far are the neural mechanisms of perceiving social interactions altered by being personally engaged in social interaction ("on-line") versus being only a passive observer who watches others while they are interacting ("off-line")? To address this question in an experimentally feasible way virtual characters are useful instruments. Mediated environments have the potential to elicit a sense of "being there" or a sense of "presence" in the virtual environment (Heeter, 1992; Ijsselsteijn & Riva, 2003; Moore, Wiederhold, Wiederhold, & Riva, 2002; Reeves & Nass, 1996; Steuer, 1992). Furthermore, it has been demonstrated that virtual characters not only convey social information to human observers, but are in turn also perceived as social agents thus exerting social influence on human interactants (Bailenson, Blascovich, Beall, & Loomis, 2003; Pertaub, Slater, & Barker, 2001). It is by now unclear to what extent human social understanding of others – particularly in everyday-life situations – relies on actual on-line involvement in a given situation or on inferential, off-line mode. Neuroimaging studies have only recently begun to target aspects of on-line interactions that require personal involvement in social communication (Gallagher, Jack, Roepstorff, & Frith, 2002; McCabe, Houser, Ryan, Smith, & Trouard, 2001; Rilling et al., 2002; Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). Thus far, however, the differential effects of self-involvement on the neural correlates have only been addressed, to the best of our knowledge, by two studies of our own group (Schilbach et al., in press, 2006).

Consequently this method has recently begun to be used in social and environmental psychological research (Blascovich et al., 2002; de Kort, Ijsselsteijn, Kooijman, & Schuurmans, 2003). Social cognitive neuroscience also benefits considerably by using mediated environments and dynamic stimuli of animated virtual characters (Adolphs, 2003; Pelphrey et al., 2004). However, a crucial prerequisite for the employment of virtual characters in research settings is the assurance that these artificial entities evoke the same experiences and reactions as stimuli depicting human beings. Here, a considerable number of recent studies have yielded consistent evidence that not only experience (e.g. person perception: Bente, Krämer et al., 2001; Bente, Petersen et al., 2001) but also social reactions are strikingly equivalent in social encounters with virtual characters as compared to direct face-to-face interactions between humans (Garau, Slater, Pertaub, & Razzaque, 2005). Virtual characters have for instance been shown to elicit social facilitation (Hoyt, Blascovich, & Swinth, 2003), proxemic behavior (Bailenson, Blascovich, Beall, & Loomis, 2001) and impression management (Sproull et al., 1996). In sum, they have been shown to evoke a sense of "social presence" (Biocca, Harms, & Burgoon, 2003) — especially if the appearance of the virtual characters is anthropomorphic (Nowak & Biocca, 2003). As the virtual character's morphology, outward appearance and movements in space and time can be varied systematically, virtual agents and environments have now become a powerful tool for experimental psychology (Loomis, Blascovich, & Beall, 1999).

To characterize the neural correlates of the experience of being personally involved in social interactions as opposed to being merely a passive observer of social interaction between others, we performed an own fMRI study in which participants were gazed at by virtual characters or observed them looking at someone else. In dynamic animations virtual characters were presented showing socially relevant facial expressions or arbitrary movements as control condition. Results of this study showed that activation of MPFC underlies both the perception of social communication indicated by facial expressions and the feeling of personal involvement indicated by eye gaze. Moreover, this study showed that distinct regions of MPFC contribute differentially to social cognition. Whereas the ventral MPFC was recruited during the analysis of social content as accessible in interactionally relevant mimic gestures, differential activation of a more dorsal part of MPFC was shown to be recruited during the detection of self-relevance and may thus establish an intersubjective context in which communicative signals are evaluated (Schilbach et al., 2006).

A more recent study was focusing on the induction of the experience of "joint attention" referring to the capacity to manipulate another person's attention to an object thereby establishing triadic relations between self, others and objects (Argyle & Cook, 1976; Moore & Dunham, 1995). The ability and motivation to share attention is a unique aspect of human cognition. Ontogenetically, joint attention has been considered an important

Fig. 3. Typical virtual character with which participants can "interact" based on the virtual characters' gaze behavior that is made contingent on the participants' gaze behavior. Participants are instructed in the target condition to make the others follow their own gaze to one of the gray squares as objects to initiate a triadic relation between self, others and object ("joint attention").
Source: From (Schilbach et al., in press).

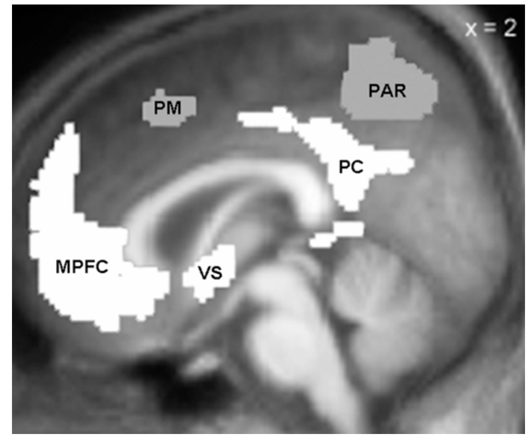

Fig. 4. Brain regions of increased neural activity during social interaction ("joint attention") in contrast to situations without ongoing social interaction ("nonjoint attention"), based on gaze-contingent or non-gaze-contingent behavior (Group mean overlay of functionally activated brain regions on mean structural brain image; "Joint attention": white regions; "Nonjoint attention": light gray regions; MPFC: medial prefrontal cortex, PAR: parietal cortex, PC: posterior cingulate cortex, PM: premotor region, VS: ventral striatum).
Source: From Schilbach et al., in press.

precursor for the emergence of social cognitive capacities (Charman, 2003). Consistently, it has been suggested that it might be the motivation to spontaneously engage in triadic relations which constitutes a unique element of (typically developing) human cognition and influences cognitive development by promoting engagement in shared, social realities (Moll & Tomasello, 2007).

In spite of its significance the neural basis remains elusive. To investigate the neural correlates of joint attention we developed a novel, interactive research paradigm in which participants' gaze behavior – as measured by an eyetracking device – was used to contingently control the gaze of a computer-animated character (Wilms et al., 2010).

Instructed that the character on screen was controlled by a real person outside the scanner, 21 participants interacted with the virtual character while undergoing functional magnetic resonance imaging (fMRI). Experimental variations focused on leading vs. following the gaze of the character when fixating one of three objects also shown on the screen (Fig. 3). In concordance with our hypotheses, results demonstrate, firstly, that following someone else's gaze to engage in joint attention resulted in recruitment of the anterior portion of MPFC known to be involved not only in social information processing, but also in the supramodal coordination of perceptual and cognitive processes. Secondly, directing someone else's gaze towards an object activated the ventral striatum which – in light of ratings obtained from participants – appears to underlie the hedonic aspects of sharing attention (Fig. 4).

The data supports the idea that other initiated joint attention relies upon recruitment of MPFC previously related to the 'meeting of minds'. In contrast, self-initiated joint attention leads to a differential increase of neural activity in reward-related brain areas which might contribute to the uniquely human motivation to engage in the sharing of experiences (Schilbach et al., in press).

6. Conclusions and future prospects

The current paper aimed to demonstrate the complexity of nonverbal phenomena in social interaction both with regard to its functions as well as the psychological processes and neural mechanisms supporting its interpretation. Observing NVB of others involves information processing on various levels and recruits different cognitive and neural processes. What humans evidently learn in ontogeny during early interaction with seemingly great ease are not at all trivial which becomes apparent when endeavours are approached to implement social cognitive capacities in "artificial humans" such as virtual agents or physically embodied robots. Against this background the challenges of implementation social cognitive functions appear to be not only a technological problem but at the same time also a problem of our lack of basic understanding of communicative skills and social cognitive capacities of humans. Artificial or "artificial humans", however, provide unique opportunities to tackle this problem and to advance this knowledge as demonstrated for a series of nonverbal phenomena in communication research and social cognitive neuroscience.

With regard to new and innovative research frontiers, there are a number of new research fields to be approached. Beyond necessary methodological improvements there are numerous questions to be answered related to the perception of artificial humans, requiring more systematic research efforts. Although we have emphasized commonalities between ECAs and robots regarding the production and interpretation of NVB it has to be stressed again that the type of embodiment is different, on one hand being a visual perceivable graphical representation and on the other hand a physical object which is tangible and present in the real world. It has to be further explored how touch and "spatial co-presence" as the experience to participate in a virtual environment might influence our feeling of "social presence" as shared social experience and enforce attributions of agency and anthropomorphism of artificial humans. Further questions concern the level of realism necessary to create the illusion of social interactions with artificial social entities. Behavioral realism here seems more relevant than form realism of the outer appearance (Bailenson, Yee, Merget, & Schroeder, 2006).

Moreover, it is questionable whether the effects of form and behavior on social presence and anthropomorphization are additive or complex in nature. The roboticist Mori (1970, cited after MacDorman, 2005) postulated the so-called "uncanny valley" effect which claims a non-linear relation between form and behavioral realism and perceived anthropomorphism (see also Duffy, 2008). First systematic investigations of this effect by Chaminade, Hodgins, and Kawato (2007) show that computer animations of human movement were less likely to be perceived as biological movement when combined with higher form realism suggestive of an interference process between form and behavioral realism. Beyond the use of interactive paradigms and broader variations of form and behavioral realism current research also should pay more attention to dispositional and situational factors influencing the prevalent human tendency to anthropomorphize non-human entities (Heider & Simmel, 1944). Recent work by Epley, Waytz, and Cacioppo (2007); Epley, Waytz, Akalis, and Cacioppo (2008) suggest that perceived anthropomorphism is not only dependent on object properties, but it also heavily depends on the motivation for sociality and effectance of the human observer or interactant. These results strongly motivate the inclusion of moderator variables when analysing the effects of artificial social entities on humans.

Cognitive neuroscience has revealed that two different systems are recruited during social cognitive processes, namely (i) the "social neural network" (SNN) including the MPFC, the temporoparietal cortex or pSTS, and the temporal pole, respectively, and (ii) the MNS. Empirical studies show that attribution of mental states to others requires SNN activation, whereas the MNS is recruited when a (real or virtual) motor component is involved, e.g. in actions, simulations or imaginations thereof. Although the empirical data on the differential functional roles of the SNN and the MNS are not yet fully understood, it appears that activation of the MNS correlates with the "early" detection of motor expertise and putatively also underlies the fast processing of "first impressions" which are often made on the basis of facial expressions or gestures. NVC that is rooted in our culture might be "part of a universally recognized and understood code" (Burgoon et al., 1996) and is therefore potentially important for intercultural communication and for perception of persons coming from other cultures including our standardized gestures and our judgments (Matsumoto, 2006). In contrast to the MNS, the SNN is suggested to be recruited as a comparably "late" stage of evaluation of socially relevant information.

Summarizing the evidence on neural mechanisms, it appears particularly interesting that a number of topics at the core of social psychology appear to constitute a "natural kind" of domains that have a common neural basis as suggested by Mitchell (2009). He summarizes that seemingly different cognitive phenomena (including thinking about oneself, accessing one's attitudes, experiencing emotions, inferring other person's mental states) are all correlated with increased neural activity in one brain region, namely the MPFC. Mitchell concludes that all these processes can be "distinguished from other kinds of cognitive processing by the dependence on a qualitatively distinct class of mental representations" (Mitchell, 2009, 249). This plausible and empirically justified speculation thus clearly shows that the identification of a functional core of social cognition, here: the "fuzzy", probabilistic, internally generated cognition can stimulate the understanding of its underlying basic neural mechanisms. Empirical evidence presented here suggests that social psychology is a "natural kind" that relies on a basic process or at least on a group of processes that share the same neural basis.

So far the predominant paradigm using artificial humans is relying on mere observation. Truly interactive paradigms as introduced above, which are usable also in functional neuroimaging studies have to be extended to allow for inclusion of broader bandwidth in NVB to include gestures and facial displays. Recent studies using motion capture devices to record and transmit complete body movement behavior in real time while controlling particular nonverbal cues have proven successful (Bente & Eschenburg, 2007) to contextualize specific experimentally controlled cues within otherwise natural behavior. Such paradigms would allow to answer questions about temporal dynamics of NVB, e.g. with regard to the perception of latencies and contingencies in social interactions and explore cross channel interactions within the nonverbal system (e.g. between gaze behavior and facial expressions within and across interlocutors).

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