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# Toward a second-person neuroscience<sup>1</sup>

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**Abstract:** In spite of the remarkable progress made in the burgeoning field of social neuroscience, the neural mechanisms that underlie social encounters are only beginning to be studied and could—paradoxically—be seen as representing the “dark matter” of social neuroscience. Recent conceptual and empirical developments consistently indicate the need for investigations that allow the study of real-time social encounters in a truly interactive manner. This suggestion is based on the premise that social cognition is fundamentally different when we are in interaction with others rather than merely observing them. In this article, we outline the theoretical conception of a second-person approach to other minds and review evidence from neuroimaging, psychophysiological studies, and related fields to argue for the development of a second-person neuroscience, which will help neuroscience to really “go social”; this may also be relevant for our understanding of psychiatric disorders construed as disorders of social cognition.

**Keywords:** interactor’s point of view; mentalizing network; mirror neuron system; observer’s point of view; “problem” of other minds; second-person neuroscience; social cognition

*“No more fiendish punishment could be devised, were such thing physically possible, than that one should be turned loose in society and remain absolutely unnoticed.”*

— William James (1890/2007, p. 293) *The Principles of Psychology*

## 1. Introduction

The burgeoning field of social neuroscience has begun to illuminate the complex biological bases of human social

cognitive abilities (Frith & Frith 2010; Ochsner & Lieberman 2001). Many investigations have focused, in particular, on the neural correlates of our capacity to grasp the mental states of others. Two neuroanatomically distinct large-scale networks have gained center stage as the neural substrates of social cognition: the so-called *mirror neuron system* (MNS) and the *mentalizing network* (MENT). The former has been taken as evidence for a simulationist account of social cognition and is believed to give us a “*first-person grasp*” of the motor goals and intentions of

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other individuals (Rizzolatti & Sinigaglia 2010). The latter has been seen as providing evidence for a “Theory Theory” account of social cognition believed to give us an inferential, reflective, and what might be called a *third-person* grasp of others’ mental states (Frith & Frith 2006; 2010). The apparent disparity between these sets of results may, however, arise from differences in the experimental paradigms used (cf. Keyser & Gazzola 2007), which run the danger of presupposing the very theoretical frameworks they claim to test. Hence, both of these paradigms are investigating actual but limited domains of social cognition. Both are, in effect, committed to spectator theories of knowledge. They have focused on the use of “isolation paradigms” (Bechio *et al.* 2010), in which participants are required to merely observe others or think about their mental states rather than participate in social interaction with them. Consequently, it has remained unclear whether, and how, activity in the large-scale neural networks described above is modulated by the degree to which a person does or does not feel actively involved in an ongoing interaction and whether the networks might subserve complementary or mutually exclusive roles in this case (Schilbach 2010). After more than a decade of research, the neural mechanisms underlying social interaction have remained elusive and could – paradoxically – be seen as representing the “dark matter”<sup>2</sup> of social neuroscience.

In this target article we propose an approach to the investigation of social cognition focused on *second-person* engagements. This approach, we argue, will help to throw light on this “dark matter” and may help social neuroscience to really “go social.”

### 1.1. Spectator theories of other minds

Spectatorial accounts of social knowing are not restricted to social neuroscience, but have been central to the Western intellectual tradition (Dewey 1950). Psychological accounts of how people make sense of other people have usually shared a common format:

1. Each is a detached observer, rather than actively engaged with the other in some joint project.
2. The information available to each of us about other people is limited and disorganized, and hence, there is a gulf between what we can actually observe about them, and what they themselves feel, intend, or believe.
3. Each of us, therefore, has to engage in some or other intellectual “detour” to bridge the gap between what can be immediately experienced about the other person and that person’s psychological states (see Asch 1952, pp. 144–50).

As Neisser has pointed out, this detached and intellectualist theoretical approach to how people make sense of one another has been built into the research which was supposed to support that very position: namely, people observing video-recordings of other people, and making judgments of what they saw:

The theories and experiments ... all refer to an essentially passive onlooker, who sees someone do something (or sees two people do something) and then makes a judgment about it. He [...] doesn’t mix it up with the folks he’s watching, never tests his judgments in action or interaction. He just watches and makes judgments. ... When people are genuinely engaged with one another, nobody stops to give grades. (Neisser 1980, pp. 603–604)

Modern cognitive psychology has retained “methodological behaviorism” from precisely the psychology it claims to have undermined (see Costall 2006; Garner 1999; Jenkins 1986; Leahey 1992; Neisser 1997). According to the textbooks, psychologists in their research necessarily start from the observation of inherently meaningless, “colorless behavior” (Hull 1943, p. 25) and can only begin to make psychological sense of what they observe on the basis of theorizing. Few modern psychologists, of course, are Cartesian dualists: They rightly insist that they do not make an *ontological* disjunction between behavior and mind.

Nevertheless, psychologists keep framing their methodology, in principle if not in their actual practice, in the old Hullan, reductionist terms, and hence, keep talking themselves into a *methodological* dualism of behavior and mind. In so doing, they resurrect for themselves the traditional dualistic “problem” of other minds. And, when Theory Theorists project this methodology onto other people and how they make sense of one another, they often enough also carry the same insoluble problem with them. In relation to the other domains to which it has been applied, the “Theory Theory” approach has taken for granted that the child has already acquired a substantial practical understanding of the social domain before attempting to systematize his or her existing knowledge (such as friction or collisions in the domain of physics, and reproduction and growth in the domain of biology). This is not the case for “Theory Theory” of Mind (TToM) in its original form, for, according to TToM, it is only *once* children have developed a “Theory of Mind” that they have access to any of the necessary psychological data upon which the theory could be based.

Of course, “Theory of Mind” does not refer to a theory in the scientific sense, but denotes an empirical field of study with (apparently) no particular theoretical commitments (cf. Penn & Povinelli 2008, p. 394). Yet, to the extent that the most important alternative approach, “Simulation Theory,” frames the problem of how people make sense of other people—in terms of how psychologists make a detour from the observation of “mere” behavior to psychological states—they both face the same logical impasse. Indeed, there could be no naturally occurring precursors to “Theory of Mind,” not even evolved ones, if the problem of how we really make sense of one another is framed in terms of this kind of methodological dualism (see Costall *et al.* 2006; Leudar & Costall 2008).

### 1.2. An alternative account of social knowing

Before the rise of recent social cognition research there was already an important body of theory and research proposing that, typically, when relating to one another, people are not engaged in a tortuous process of inferences and theorizing about one another, but immediately experience the other as a subject (see Asch 1952; Heider & Simmel 1944; Runeson & Frykholm 1983; Schutz 1972; Thinès *et al.* 1991). This approach drew upon Gestalt theory and phenomenology. Here is Solomon Asch’s lucid statement of this position:

The quality of their actions imbues persons with living reality. When we say that a person is in pain, we see his body as feeling. We do not need to “impute” consciousness to others if we directly perceive the qualities of consciousness in the

qualities of action. Once we see an act that is skillful, clumsy, alert, or reckless, it is superfluous to go “behind” it to its conscious substrate, for consciousness has revealed itself in the act (Asch 1952, p. 158).

This social perception approach is close to the theoretical perspective we are presenting in this target article. It is not detached; it is not dispassionate. However, it is nevertheless committed to an observer epistemology, a spectator theory of how we relate to other people. Knowing others is limited to perceiving them. In this target article, we argue for an approach to social knowing based on interaction and emotional engagements between people, rather than mere observation. This *second-person* approach has already begun to prove productive within developmental and social psychology and points toward the importance of experiencing and interacting with others as our primary ways of knowing them (see Section 2 for details). Also, preliminary evidence from neuroimaging and psychophysiological studies demonstrates profound differences in neural processing related to the reciprocity of social interaction, which is consistent with our proposal that the second-person approach can make an important contribution to the neuroscientific study of social encounters and could, in fact, lead to the development of a second-person neuroscience (Section 3). In this respect, we provide an outlook for future research by describing key ideas and objectives of a second-person neuroscience and related objectives in other areas of research (Section 4). Finally, we argue that the second-person account may also be relevant for our understanding of psychiatric disorders: Although psychiatric disorders such as autism have been conceptualized as disorders of explicit social cognition, recent evidence suggests that the implicit processes of interpersonal coordination relevant during second-person engagements might be more closely related to the core impairments (Section 5).

## 2. Second-person engagements

### 2.1. Overcoming the spectatorial gap

Spectatorial views of cognition have been developed within the paradigm of standard cognitive science, which understands cognition as information processing in the sense of a passive intake of information provided by a ready-made world. Embodied cognition replaces this view by a concept of perception as an active process executed by an organism situated in the environment, wherein subjects are not isolated from but embedded in and coupled with the perceived world (Thompson 2007). Such coupling brings to the fore new properties—what Gibson (1979) calls “affordances”—which depend on the organism’s specific potential and actual interaction with the environment. In this way, cognition is essentially construed as an activity carried out by an embodied and embedded agent. In addition to hybrid accounts of “Theory Theory” and “Simulation Theory” (e.g., Goldman 2006; see Newen & Schlicht 2009 for a critical discussion), recent debates have, therefore, led to alternatives which emphasize various aspects of embeddedness and embodiedness in social cognition (De Jaegher & Di Paolo 2007; Fuchs 2009; Gallagher 2005; 2008; Hutto 2008; Noë 2009; Reddy 2008; Zahavi 2005).

Spectatorial views construe social cognition as something that could in principle occur in the presence of a one-way mirror, where a detached observer reads out the mental states of another person, who, in turn, is not affected by this and cannot react to it. In contrast to this, our central claims are that *social cognition is fundamentally different when* (sect. 2.1.1) *we are emotionally engaged with someone as compared to adopting an attitude of detachment, and when* (sect. 2.1.2) *we are in interaction with someone as compared to merely observing her* (see Fig. 1).

### 2.1.1. Constituents of a second-person approach: Emotional engagement.

A second-person grasp of other minds, we argue, is, first, closely related to feelings of engagement with and emotional responses to the other. According to this viewpoint, awareness of other minds crucially hinges upon *emotional engagement* and a responsiveness to another person's states or actions as compared to a

detached observer's attitude, which does not include such responding (cf. Reddy 2003; 2008; Rietveld 2008) (Fig. 1). Although emotional responses are also influenced by one's own concerns, they constitute an important way of perceiving and integrating the state of the other by way of experiencing one's own bodily responses to her (e.g. Prinz 2003) (Fig. 1B). Mentality—in this view—is thought to become meaningful as a result of relating new pieces of experience to a pre-existing network of experiences. On a neural level, emotional and embodied responses may play a crucial role in influencing action control networks of the brain by modulating processes of sensorimotor integration, which, in turn, solicit activity and observable behavior (Frijda 1986, p. 469; Keltner & Haidt 1999; Schilbach *et al.* 2008a) (Fig. 1). Consequently, affective responses relying upon proprioceptive afferences from the body and action-based processes are likely to be closely linked and to interact in complex ways. For instance,

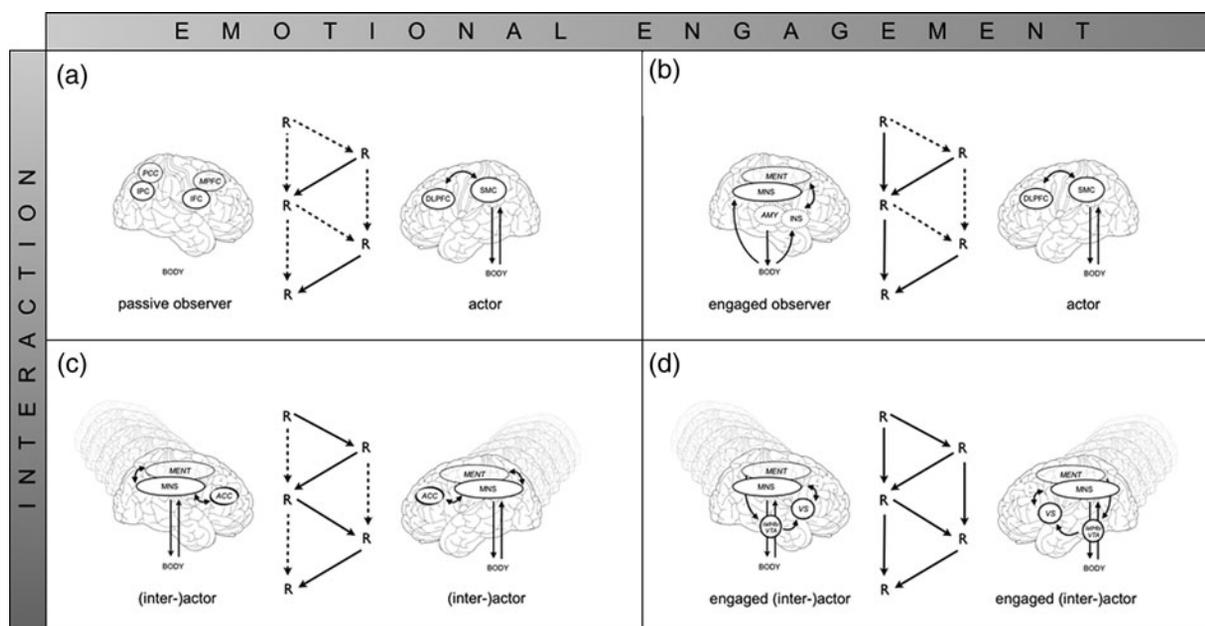


Figure 1. A–D:

**Center:** Schematic depiction of interaction contingencies for situations of (A) no (or little) social interaction and no (or little) emotional engagement, (B) no (or little) social interaction, but emotional engagement of person A with person B, (C) social interaction, but no (or little) emotional engagement, and (D) social interaction and emotional engagement. Dotted lines indicate the absence or relatively decreased influence of actions on oneself (vertical arrows) or the other (oblique arrows), temporal sequence is shown from top to bottom. (Schematic of interaction contingences adapted from Jones & Gerard 1967.) Despite the suggestion of linearity in the interaction sequence, our account also stresses the importance of interaction dynamics, which may be seen as emergent properties of an interaction, and possible inter-brain effects of social interaction (see sects. 2.3 & 3.2.2 for details).

**Left & right:** Schematic depiction of putative differences in the recruitment of brain regions during situations A–D and their functional connectivity (see sect. 3 for details). Brain regions on the medial surface or deep structures of the brain are shown in italics, brain regions on the lateral surface of the brain are shown in normal font.

**Abbreviations:** **R:** (re-) actions performed by agents. **MENT:** The “mentalizing network” is a network of brain regions recruited by tests which tap “the ability to read the desires, intentions, and beliefs of other people” (e.g., Frith & Frith 2008). In line with recent meta-analyses of functional neuroimaging studies which have investigated mentalizing, we see medial prefrontal cortex (MPFC) and the posterior cingulate cortex (PCC) as the most important nodes of this network, sometimes also referred to as the “cortical midline structures” (e.g., Northoff & Bermpohl 2004; Schilbach *et al.* 2012a; Uddin *et al.* 2007). While a large body of literature exists to suggest that these brain regions can be differentially engaged by classical mental state attribution tasks (Figure 1A), much less is known about the interactions within this network and with other brain regions as a function of emotional engagement and social interaction (Figure 1B–D). **MNS:** As introduced in section 1 the so-called “mirror neuron system” is thought to include areas of inferior frontal cortex (IFC) and inferior parietal cortex (IPC) (Rizzolatti & Sinigaglia 2010). Individual nodes of this network are known to become active during the observation of goal-directed actions, but their interplay and, in particular, the interaction with MENT is not well understood (Figure 1B–D; Schilbach 2010). **SMC:** Primary sensorimotor cortex. **DLPPFC:** Dorsolateral prefrontal cortex (separate from MNS regions). **ACC:** Anterior cingulate cortex (here thought to be separate from MENT). **AMY:** Amygdala. **INS:** Insular cortex. **Lathb:** Lateral habenula complex. **VTA:** Ventral tegmental area. **VS:** Ventral striatum.

it would seem plausible that emotional-embodied responses could facilitate more cognitive ways of understanding minds, whereas the absence of such responses could make this a more effortful process. Furthermore, it is important to point out that while emotional engagement may also occur (and could be particularly relevant) during observation (such as watching an emotionally charged movie scene or perceiving to be perceived by someone; Fig. 1B), the opposite may be true for some situations, in which one actually interacts with someone (such as hastily buying a bus ticket from a cashier; Fig. 1C).

**2.1.2. Constituents of a second-person approach: Social interaction.** Second, we see *social interaction* as a key constituent of grasping other minds. Social interactions are characterized by intricate reciprocal relations with the perception of socially relevant information prompting (re-)actions, which are themselves processed and reacted to (see Fig. 1, C & D). These reciprocities might be sequential (as depicted in the schematic of Figure 1), but are often complex, dynamic and nonlinear (Froese & Di Paolo 2010; Port & van Gelder 1995; Thelen & Smith 1994). Being in interaction with someone, we suggest, furthermore relies upon a perception of the environment in terms of the resources held collectively by both interactors rather than those held by each individual alone (Costall 1995; Marsh *et al.* 2009; Richardson *et al.* 2007a; 2007b; Schilbach *et al.* 2012b; Sebanz *et al.* 2006). In social interaction, rather than exercising one's deliberative reflective capacities we exercise our own practical know-how in dealing with others as interactors (Klin *et al.* 2003). Here, interaction and feedback are not only a way of gathering data about the other person, that is, observing effects one may have on the other, but rather, as De Jaegher *et al.* (2010) have argued persuasively, one's knowledge of the other resides – at least in part – in the interaction dynamics “between” the agents. Thus, taking social interaction seriously suggests that there may not be an absolute epistemic gulf between self and other, which would make an inferential detour necessary, but rather, that the dynamics of the social interaction contribute to and – at times – constitute our awareness of other minds (Fig. 1, C & D).

There are at least three different aspects of social interaction that are important for research in social neuroscience. First, interaction involves different roles for the interactors. At the simplest level, one can be an “initiator” or a “responder” in an interaction, that is, the same (or very similar) action can be performed in an attempt to initiate an interaction or as a response to someone else's action. Although such a simple and clear-cut difference in roles may be rare in dynamic real-time encounters, we believe that this distinction is important for neuroscience research, because it implies different motivational consequences and differences in the underlying neural processes: An action by an “initiator” may involve stronger monitoring of the outcome of the interaction, whereas an action by a “responder” may involve closer attention to the emotional effects of the action being responded to; a difference which may be reflected in differential involvement of brain regions (see Fig. 1). Second, shared intentions and motivations are newly created within an interaction, with important consequences for the performance of joint actions and for the progress and continuation of the interaction itself. We argue that these processes are

quite different from those involved in merely observing someone else interact, and must play a crucial role in shaping activity in the neural networks that underlie social cognition (see sects. 3 & 5 for further details). Third, interaction always involves historicity, suggesting that social phenomena must be understood, – at both the psychological and the neural level – within the context of the past and must involve developmental trajectories, which continue to be relevant throughout the life span.

In order to further clarify the central notions of *emotional engagement* and *social interaction* as part of a second-person approach to other minds and to illustrate that this view has already begun to prove productive in shaping research outside the neurosciences, in what follows, we draw on and review evidence from the fields of developmental, social, and cognitive psychology.

**2.2.1. Developing awareness of minds through second-person engagements: Evidence from developmental psychology.** Debates in developmental psychology concerned with the processes through which infants and young children come to recognize the existence and nature of other minds reflect the same assumptions that have beset the traditional philosophical debates. They have most often posited two sources of information for the developing child – that of first-person *experience* and third-person *observation* – or, on occasion, an unconvincing amalgam of the two. The possibility of a difference in awareness in different relations with specific “other minds” – which is the central assumption of a second-person approach to mind knowledge (Reddy 2003; 2008) – was either neglected or explicitly denied (Barresi & Moore 1996). There has, however, been a dramatic surge of interest in second-person explanations within development (e.g., Carpendale & Lewis 2004; Gallagher 2001; Hobson 1991; Hobson 1999; Reddy 1996; 2003; 2008).

Evidence for the second-person argument, namely that an appropriate development of awareness of other minds depends on the infant first experiencing minds which are directed towards her, is scattered throughout the developmental psychological literature. Probably the most impressive evidence of infants' sensitivity to, and preference for, the infant-directedness of interpersonal actions comes from recent studies concerning early responses to gaze. Mutual gaze both reflects one organism's interest in another's gaze and signals this interest to the other, with the potential for creating a situation of intense mutuality. Between 2 and 5 days of birth, human neonates show a preference for looking at faces or pictures of faces with eyes directly looking towards the infant. This preference reveals itself both in terms of longer looking times and in terms of more frequent looks (Farroni *et al.* 2002). Even earlier than this, within minutes of birth, infants show considerable interest in and respond appropriately to self-directed facial actions, primarily more noticeable actions such as tongue protrusion and opening the mouth wide (Kugiumutzakis 1998; Meltzoff & Moore 1977; Nagy & Molnar 2004). Also, there is evidence that by 4 months of age the experimenter's gaze directed toward rather than away from the infant leads to a variety of neural reactions and information processing advantages: higher cortical arousal (Farroni *et al.* 2002), enhanced occipital early gamma response (Grossmann *et al.* 2007), enhanced

neural processing of emotional expressions (Striano *et al.* 2006), facilitated neural processing of objects (Reid *et al.* 2004), and differential processing of words (Parise *et al.* 2008). By 2 months of age infants already show a variety of emotional reactions to attention directed to the self, ranging from pleasure (Wolff 1987) to distress if unable to disengage (Brazelton 1986) to ambivalence in the form of coy smiles (Reddy 2000). A large number of studies have shown that the intricacies of emotional engagement matter from very early infancy and are the source of meaning about self and others. Two- to three-month-olds during face-to-face communication demonstrate intra- and interpersonal coordination (Fogel 1993; Lavelli & Fogel 2002; Stern 1985; Trevarthen 1977), are disturbed by the lack of temporal and affective coordination (Cohn & Tronick 1989; Legerstee & Varghese 2001; Murray & Trevarthen 1985; Nadel & Tremblay-Leveau 1999), are affected in their ability to bid for attention by the history of maternal affective responses (McQuaid *et al.* 2009) and learn to prefer the levels of interactional contingency they are familiar with (Bigelow & Rochat 2006).

Infant awareness of attention in second-person engagements has been argued to have developmental primacy over the awareness of attention in triadic and more temporally extended attentional engagements (Reddy 2003; 2005; 2008). Evidence for the causal role of such engagements in developing triadic and more complex reflective awareness comes from developmental psychopathology (particularly autism) where problems with explicit social cognition (at the level of triadic joint attention or at the level of concepts of self or of other) are heralded by problems in second-person engagements (with establishing mutual attention and mutual responsiveness with self and with other; Leekam & Ramsden 2006; Reddy, 2012; Reddy *et al.* 2010).

The primacy of second-person engagements creates serious conceptual and methodological problems for psychological research: It demands that emotion be taken as central to an awareness of minds and focuses on emotional responses rather than reflections or constructs. We argue that such experiences of mind and mentality are first and most intensely experienced within second-person engagements, where the individual is directly addressed by and responds to an “other” mind. Such second-person experiences of other minds, we argue, are necessary for the typical development of social understanding and continue to influence social understanding throughout life.

**2.2.2. Knowing minds in interaction: Evidence from social and cognitive psychology.** In social psychology and related fields—in spite of a long history and interest in “social presence” effects (e.g., Allport 1924; Biocca *et al.* 2003; Short *et al.* 1976; Triplett 1898; Worryingham & Messick 1983; Zajonc 1965)—the need to allow test subjects to leave the “experimental quarantine” of “isolation paradigms” when studying social processes has only recently been recognized (e.g., Becchio *et al.* 2010; Richardson *et al.* 2007a; 2007b; Sebanz *et al.* 2006). This development appears to be based on the assumption that cognition is grounded in basic perception and action processes and emerges out of the interaction of the organism with its environment, and that—rather than treating it as an experimental confound—a social context and social

interaction can be treated as an independent variable of experimentation. Consistent with this proposal, the second-person approach sees interaction with other agents and the ensuing interaction dynamics as crucial for the knowing of other minds and the expression of that knowledge.

The role of social interaction for cognitive and social development has begun to gain center stage in various scientific discourses (De Jaegher *et al.* 2010): The role of interaction as a vehicle for the acquisition of knowledge has, for instance, been demonstrated in language development. In contrast to the Chomskian idea of a “Language Acquisition Device” (e.g., Chomsky 1979), the perception of structure in social interactions has been shown to guide vocal development and language learning (Bruner 1983; Goldstein & Schwade 2010), both in terms of speech perception (Kuhl 2007a; 2007b; Kuhl *et al.* 2003) or turn-taking (Goldstein & Schwade 2008; Goldstein *et al.* 2010a; Jaffe *et al.* 2001). Whereas children can extract statistical regularities from any structured material without awareness or intention using mere error feedback (Marcus *et al.* 1999; Saffran *et al.* 1997), observation of one’s own behavioral outcomes in interaction may be crucial for such learning to occur (Goldstein *et al.* 2010b). Adults also coordinate turn-taking, implicitly agree upon names for objects (Brennan & Clark 1996; Brennan & Hanna 2009), approach each other’s accents (Giles *et al.* 1992), sway their bodies in synchrony (Shockley *et al.* 2003), and visually coordinate their attention through synchronized eye movements (Richardson *et al.* 2007a), suggesting that communication may be grounded by a shared context, which is actively developed in ongoing encounters (Clark 1996; Garrod & Pickering 2004).

In other areas of research “interaction” has been investigated by focusing on processes such as involuntary mimicry (e.g., Chartrand & Bargh 1999; Konvalinka *et al.* 2010; Niedenthal *et al.* 2010; Schmidt *et al.* 1990), which leads to enhanced rapport and liking, but is also influenced by differences in affiliative motives and interdependent self-construal (Van Baaren *et al.* 2003; Baaren *et al.* 2004). Social interaction, however, normally also involves more complex forms of coordination present from early on in life (cf. Harrist & Waugh 2002). In this respect, Knoblich & Sebanz (2008) distinguish between “action simulation” (see also Rizzolatti & Sinigaglia 2010), “joint attention,” and “shared intentionality” (see also Tomasello & Carpenter 2007). The development of a shared perceptual and attentional space within early mutual attentional engagements is crucial, because it paves the way for triadic interactions in which we share our mental states about a third object or person with the other (Tomasello 1995). In turn, such triadic attentional engagements may be crucial for developing complex joint actions (Fiebich & Gallagher 2012; Knoblich & Sebanz 2008; Richardson *et al.* 2007a; Sebanz *et al.* 2006).

In spite of a growing interest in this matter, the bulk of research is still rooted in a mechanistic metaphor of feedback loops that inform individuals about the adequacy of their behavior. In this framework, it is assumed that the sum of two interacting agents can be expressed in terms of processes “within” those agents (however, modified by the external world, in this case each other). We argue that interaction expresses a type of knowledge of other minds that is not entirely reducible to knowledge “inside”

any two individual agents but exists “between” them (see De Jaegher *et al.* 2010). Interestingly, the recently developed “perceptual crossing paradigm” directly addresses this aspect (Auvray *et al.* 2009; Lenay *et al.* 2011): here, two participants interact with each other by moving their mouse cursor in a one-dimensional virtual space. In this space they can encounter three different types of objects indicated by tactile stimulation: a fixed object, a constantly moving object, and the other participant. Their task is to click the mouse only if they believe to have encountered the other person’s cursor. Thus, it is only when they meet each other, that both are stimulated simultaneously. Using the perceptual crossing setup, it has been shown that healthy volunteers exhibit a dissociation between task performance and awareness of this performance with respect to the detection of reciprocity (though not with respect to the detection of animacy): Conscious identification of the other person (by means of clicks) is limited to distinguishing both moving objects from the fixed object (animacy detection), but does not extend to distinguishing the moving object from the other person’s object (reciprocity detection). However, participants’ interaction dynamics allow us to distinguish not only between fixed and moving objects, but *also* between the moving object and the other’s cursor (Auvray *et al.* 2009). Crucially, this demonstrates that unrelated to awareness and strategic processes, people are sensitive to reciprocal interaction,

and furthermore, spontaneously engage in mutual modification of action patterns with an interactor, actively “seeking the other out.” It is only *in this interactive process* that contingencies are simultaneously experienced and acted upon.

Taken together, recent progress in developmental, social, and cognitive psychology indicates a surge of interest in emotional engagement and real-time social interaction as key constituents for knowing other minds. However, although this second-person approach has already begun to prove productive in shaping experimental work, this has occurred largely outside the realm of neuroscience. We suggest that the approach promises to do the same within the field of social neuroscience, thereby leading to the establishment of a second-person neuroscience.

### 3. Toward a second-person neuroscience

After more than a decade of successful research, “dark matter” remains in the field of social neuroscience (Fig. 2). As highlighted above, previous research has often focused on the perception of inert stimuli – consistent with the idea of a detached observer – whereas, in everyday life, making sense of others requires both *emotional engagement* and *interaction* (Fig. 1). Consequently, a second-person neuroscience will help to address

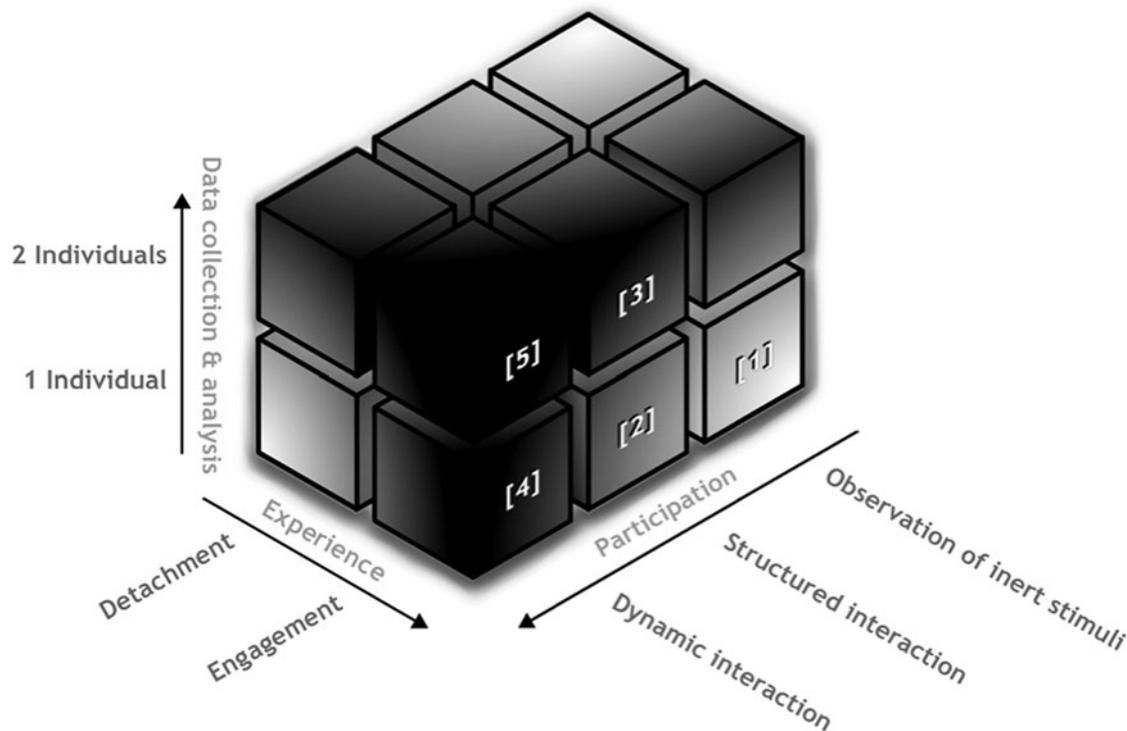


Figure 2. Depiction of the experimental “landscape” of a second-person neuroscience. Cubes shown in this figure represent categories of experimental approaches to the investigation of social cognition in accordance with the second-person account. Here, we highlight cubes 1–5, which in accordance with the text are most informative as to the different aspects of the research landscape: Cube [1], for example, represents studies that target differences between detached observation as compared to emotional engagement (see sect. 3.1.1). Cube [2] represents studies which use paradigms that allow the participant to directly influence the stimulus material, that is, seeing the effect of her actions (e.g., interactive eye-tracking studies; see sect. 3.1.2). Cube [3] represents studies that collect data from two participants who interact by means of a structured task, including hyperscanning studies that, for example, make use of game theory paradigms (see sect. 3.2.1). Cubes [4] and [5] represent studies that allow for the investigation of ecologically valid, real-time interactions (see sect. 3.2.2). More intense shades of grey indicate areas of the landscape that have been left largely unexplored, representing the “dark matter” of social neuroscience.

differences in the neurobiological underpinnings of social knowing related to:

- (i) a person being a detached observer as compared to experiencing a social situation with an attitude of *emotional engagement* (Fig. 2: “experience”)
- (ii) experimental paradigms used to investigate social cognition allowing or not allowing for *interaction* (Fig. 2: “participation”)<sup>3</sup>
- (iii) data collection and analysis taking place at the level of a single or two (or more) individuals (Fig. 2: “data collection & analysis”)<sup>4</sup>

In the following we review evidence from neuroimaging and psychophysiology to demonstrate the relevance and applicability of the first and second dimension of our conception of a second-person grasp of other minds (sect. 3.1). Additionally, we discuss some of the methodological challenges associated with addressing the third dimension and other important milestones in the development of a second-person neuroscience (sect. 3.2).

### 3.1. Preliminary evidence from functional neuroimaging and psychophysiology

**3.1.1. Being addressed as you: The neurobiological correlates of emotional engagement.** Based on the hypothesis of differences in the neural processing of social stimuli depending upon whether or not they are directed toward oneself as compared to being directed toward someone else, we performed a functional magnetic resonance imaging (fMRI) study (Schilbach *et al.* 2006), in which participants were asked to imagine being part of a scenario with three other people, only one of whom was visible (Fig. 3A), and were shown short video sequences depicting this virtual character who exhibited socially relevant facial expressions or arbitrary facial movements. Furthermore, it was varied whether or not the virtual character looked directly at the participant (Fig. 3B) or towards

the right or left in the direction of another agent (Fig. 3C). Participants were asked to rate in all cases whether they felt that the virtual character had expressed an intention to initiate a social interaction.

The behavioral results demonstrated that participants did not have difficulties in differentiating socially relevant from arbitrary mimic behavior. Interestingly, and in spite of the explicit instruction to “put themselves into the shoes of the other,” participants demonstrated a bias towards giving socially relevant facial expressions a significantly higher rating when they were self-directed. In parallel to this, results of the neuroimaging analysis demonstrated significant differences in activation patterns subserving the perception of socially relevant facial expressions, depending upon whether these expressions were self- or other-directed: While self-directed facial expressions led to a differential increase of neural activity in the ventral portion of medial prefrontal cortex (MPFC) and the (superficial) amygdala (AMY) (Fig. 3D), other-directed facial expressions resulted in a differential recruitment of medial and lateral parietal cortex (Fig. 3E). Our findings, therefore, demonstrate that while the perception of socially relevant nonverbal cues from an observer’s point of view recruits brain regions that have been related to visuo-spatial processing, the perception of identical, self-directed stimuli activate brain regions that have been related to emotional and evaluative processing (Schilbach *et al.* 2006).

Indeed, the AMY is known to be a crucial subcortical hub of the limbic system serving various integrative sensory and emotional functions in attaching biological and social significance to stimuli (Gamer & Buchel 2009; Gamer *et al.* 2010; Muscatell *et al.* 2010; N’Diaye *et al.* 2009; Tamietto & de Gelder 2010). The ventral portion of MPFC is also known to be relevant for emotional processing and has been implicated to be involved in “outcome monitoring” (Amodio & Frith 2006). More generally, emotions are known to be an important driving force for interpersonal behavior and a “short hand” that guides decision-making

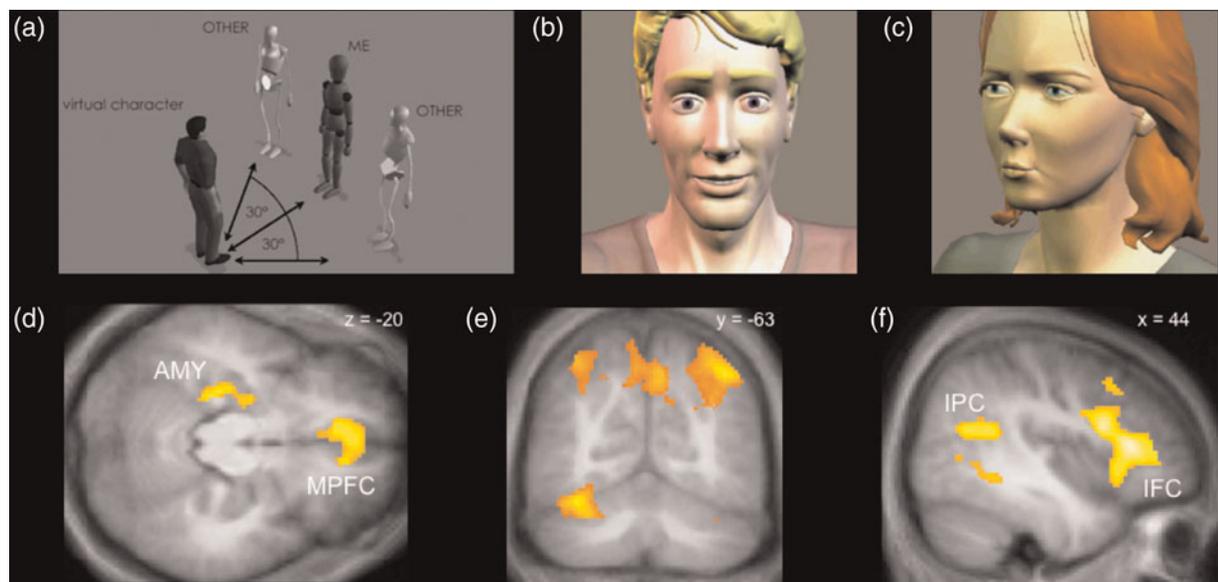


Figure 3. (A) Virtual scenario as shown in the instructions. (B) Self-directed, socially relevant facial expression. (C) Other-directed, arbitrary facial movement. (D) Neural correlates of the perception of self-directed facial expressions. (E) Neural correlates of the perception of other-directed facial expressions. (F) Neural correlates of the perception of arbitrary facial movements. Activation overlays based on reanalysis of data taken from Schilbach *et al.* (2006).

processes (e.g., Damasio 2010; Frijda 1986). Also, emotions are assumed to be of crucial importance for interpersonal perception by allowing the observer to share the feeling state of another individual (Preston & de Waal 2002). Apart from this traditional view of how emotions might contribute to social cognition, our account views emotional responses not only as a way of perceiving emotional states in others, but also as a way of being engaged with others, which could contribute to the understanding of the bodily intentionality of the other in terms of bodily responsiveness (Rietveld 2008). Being responsive to the socially relevant, expressive behavior of others in this way could provide, and bias, possibilities for (inter-)action by motivating behavior and soliciting activity.

Interestingly, our neuroimaging analysis also demonstrated that the perception of arbitrary facial movements recruited the right inferior frontal and inferior parietal cortices (see Fig. 1 & Fig. 3F). These brain regions are commonly described as important nodes of the mirror neuron system (MNS), which has been related to understanding the (motor) intentions that underlie others' actions (Rizzolatti & Sinigaglia 2010). This finding, we think, is interesting in several respects: First of all, it suggests that activity in the MNS is not related to the particular perspective a human observer adopts, but more closely tracks the observed behavior itself regardless of whether it is "my action" or "your action." This seems to be consistent with the dominant interpretation of MNS activity in the literature, suggesting that the MNS may have evolved to represent actions in the same way across subjects and that mirror neurons explain the ability to understand other minds by giving us a "first-person grasp" of the motor goals and intentions of other individuals (Rizzolatti & Sinigaglia 2010). This view has, however, been criticized as over-emphasizing similarities in self- and other-related processes (Schilbach 2010) and under-representing the important question of where mirror neurons actually "come from" (Heyes 2010). Here, an important suggestion has been that mirror neurons may only play a role in situations when the action and its stereotypic context are highly familiar (e.g., Brass *et al.* 2007). In our study, however, brain regions described as corresponding to the MNS respond more strongly to arbitrary facial movements than to socially relevant ones—which appears to contradict the idea that the MNS only plays a role in familiar situations. On the contrary, an arbitrary facial movement—with which one may be less familiar than with socially relevant facial expressions which are directed towards another person more frequently—also leads to the recruitment of the MNS. This finding could be understood in terms of a prediction error signal (Pelphrey *et al.* 2003; Schippers & Keysers 2011) and could be relevant to the associative learning processes recently discussed as an alternative account of the development and modulation of activity in the MNS (Heyes 2010).

In fact, according to the "associative hypothesis" (Heyes 2010), mirror neurons are forged through sensorimotor experience of observing and executing actions, and the MNS, even in adulthood, can be reconfigured through sensorimotor learning. Evidence for this comes from a series of elegant studies which demonstrate that sensorimotor experience can enhance (Press *et al.* 2007), abolish (Heyes *et al.* 2005), and even reverse (Catmur *et al.* 2007; 2008) "mirror" activation in human participants.

Consistent with this finding, a recent simulation study demonstrated that a reinforcement learning based model could account for the development of mirror neurons in gaze following (Triesch *et al.* 2007). With respect to the possible sources of sensorimotor experience that may impact on the MNS, Heyes (2010) has recently emphasized that much of this experience is obtained through interaction with others. We strongly support this position and argue that the investigation of action observation and execution in a more ecologically valid, interpersonal context—as suggested by a second-person neuroscience—will help to investigate these matters further (cf. Kourtis *et al.* 2010). More specifically, we see a role for the MNS beyond mere motor resonance: Rather than suggesting that mirror neuron activity constitutes a simulation routine which gives us a "first-person grasp" of the other (Rizzolatti & Sinigaglia 2010), we contend that an understanding of the MNS on the enactive view of cognition would suggest that activity in these brain regions might be more closely related to the ability to perceive social affordances. Such affordances can thereby be understood as the possibilities for interaction provided by others, in terms of an activation of motor programs that would allow for interpersonal coordination of behavior (cf. Gangopadhyay & Schilbach, 2012). This view is consistent with the idea of social interactions having a profound impact on MNS activity and offers a more plausible account for actions that people perform jointly, as these often involve complementary or incongruent actions rather than imitative or congruent ones (cf. Fuchs & De Jaeger 2009; Gallagher 2007). Indeed, a study by Newman-Norlund *et al.* (2007) found evidence that the MNS is more active during the preparation of complementary actions, while other studies demonstrate that activity in the human MNS can be modulated by social interaction (Kourtis *et al.* 2010; Oberman *et al.* 2007). This is clearly in line with our suggestion that an essential aspect of apprehending other minds lies in the kinds of responses their activity elicits (see Fig. 1).

In a follow-up experiment to our fMRI study, the paradigm was used while recording eye-movements, pupil size, and facial electromyography (EMG). The results show that attention allocation, as assessed by fixation duration, was specifically related to the perception of self-directed stimuli. EMG measurements demonstrated that facial activity was influenced by the perception of socially relevant facial expressions, demonstrating spontaneous, involuntary facial responses that have been described as "facial mimicry" (Mojzisch *et al.* 2006). Although we did not observe a statistically significant interaction effect here, the difference in EMG activity between self- and other-directed facial expressions was noteworthy (see Mojzisch *et al.* 2006; Schilbach *et al.* 2008a for details). Using the temporal information from the EMG study, we re-analyzed the fMRI data to investigate the neural correlates of facial mimicry. This analysis identified a network comprising the face region of the primary motor cortex, but also the posterior cingulate cortex, hippocampus, and the dorsal midbrain. This is suggestive of a close link between the perception of facial expressions and their generation in the observer. Facial expressions might be particularly prone to engaging such mechanisms as they serve important communicative functions. Furthermore, these findings demonstrate that situations which lead to emotional

engagement and invite an element of a motor response, recruit both fronto-parietal areas, as well as the cortical midline structures, and differentially activate the limbic system of the brain (Schilbach *et al.* 2008a; cf. Buck *et al.* 1992; see Fig. 1).

Taken together, the results of these studies demonstrate significant differences in the neurobiological mechanisms of the perception of facial expressions depending upon emotional engagement. When we are personally addressed by others, the perception of their mimic behavior relies, in neurobiological terms, upon tight perception-action coupling with affective and body-based processing feeding into and promoting the preparation of motor responses as a way of picking up and responding to the possibilities for interaction.

**3.1.2. Minds made for sharing: The neurobiological correlates of the reciprocity of social interaction.** As outlined above, interaction loops must be considered as important constituents of second-person relations. Thus, within social interaction, interactors mutually and directly influence each other and may hold different roles during the interaction (as introduced in sect. 2.1; see Fig. 1, C & D). To establish a paradigm that allows participants to be part of a social interaction in the constrained fMRI setting, we have developed a novel technique that makes use of eye-tracking data obtained from participants inside the scanner to control a virtual character's gaze behavior in real-time making it "responsive" to the human observer's gaze (Wilms *et al.* 2010). This setup, therefore, allows participants to experience their own eye-movements to have an effect on the gaze behavior of a (virtual) other, similar to how this occurs in real-life situations. Importantly, such a setup allows for the investigation of cognitive phenomena which are at the interface of automatic and controlled processes, because eye-movements are known to be closely related to both (e.g., Hikosaka & Isoda 2010). Also, the setup allows us to investigate phenomena

whose emergence necessarily depends upon social interaction, its reciprocity; and whose underlying psychological processes and neural mechanisms may differ depending upon the roles interactors hold during interaction, namely those of being "initiator" or "responder" in the interaction.

With respect to the phenomenon of joint attention, that is, attending to something together with someone and being aware that "we both" are attending, the difference between being "initiator" or "responder" in the interaction appears to be highly relevant: Joint attention can occur either as a result of following someone else's gaze toward an object ("responder") or as a result of directing someone else's gaze toward the object ("initiator"). Clinically, children with autism, in fact, show less pronounced impairments in their ability to respond to a person's gaze shifts (by following the gaze) than in their spontaneous drive to initiate the sharing of attention (by trying to make someone look at something; Mundy & Newell 2007).

Based on the hypothesis that differences in the neural basis of joint attention could be related to the reciprocity of social interaction (as compared to previous social neuroscience attempts to investigate the neural correlates of joint attention by means of tasks in which participants are mere observers of gaze cues (e.g., Materna *et al.* 2008; Williams *et al.* 2005; see also sect. 2.1), the setup described above was used to perform an fMRI study, in which participants interacted with the virtual other while undergoing neuroimaging (Schilbach *et al.* 2010b). Experimental variations consisted of initiating versus following the gaze of the virtual character when fixating objects shown on the stimulus screen (Fig. 4A). Our results demonstrate the recruitment of medial prefrontal cortex (MPFC) and posterior cingulate cortex (PCC) for joint attention to an object, regardless of whether or not this was initiated by the participant or the (virtual) other (Fig. 4B). Conversely, looking at an object different from the one inspected by the virtual other led to the recruitment of a lateralized fronto-parietal network (Fig. 4C). While the latter closely

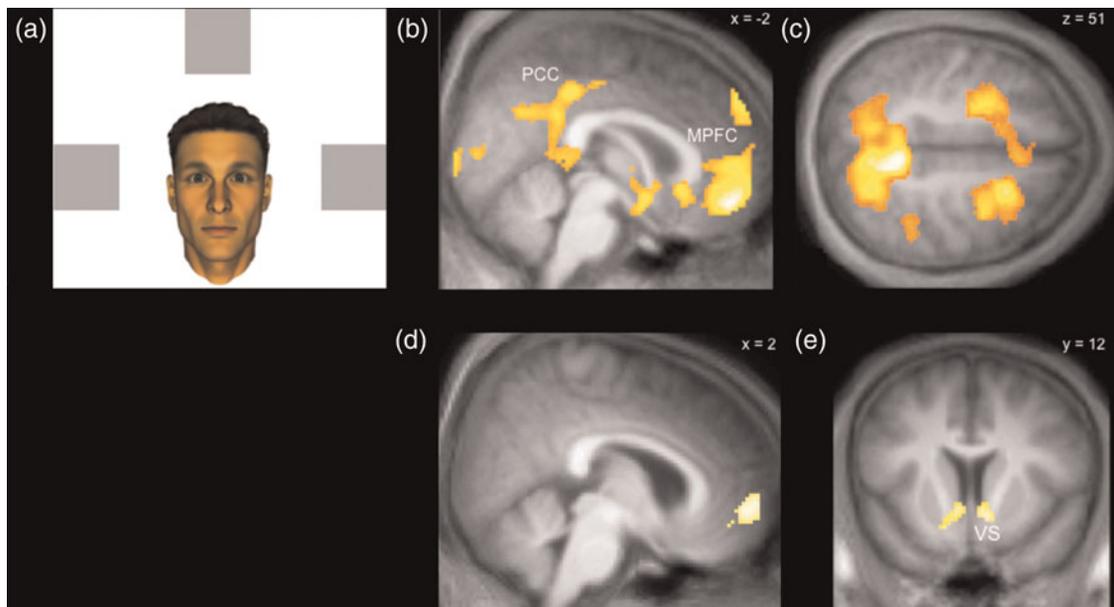


Figure 4. (A) Screenshot depicting an anthropomorphic virtual character and three objects (grey squares). (B) Neural correlates of main effect of joint attention. (C) Neural correlates of non-joint attention. (D) Neural correlates of other-initiated joint attention. (E) Neural correlates of self-initiated joint attention. Activation overlays based on a reanalysis of data taken from: Schilbach *et al.* (2010b).

resembles the neural network which has been related to the control of attention and eye-movements (Corbetta *et al.* 2008; Pierrot-Deseilligny *et al.* 2004), the former regions closely match those which have been described as belonging to the “mentalizing network” (MENT) (Frith & Frith 2006; Kampe *et al.* 2003), overlapping with others that have become known as the “default mode of brain function” (Raichle *et al.* 2001; Schilbach *et al.* 2008b; Schilbach *et al.* 2012a).

In spite of participants always fixating on an object on the stimulus screen, the underlying brain activity appears to be markedly different depending upon whether or not the participant is doing this “together” with a virtual other. Doing so in coordination with the virtual character resulted in a differential increase of neural activity in a network which has been related to the human ability for grasping another person’s mental states and her communicative intentions, and for using an internally oriented mode of cognizing to contextualize aspects of a situation (Amodio & Frith 2006; Bar 2007; Buckner & Carroll 2007; Kampe *et al.* 2003; Schilbach *et al.* 2008b). Here, it is important to stress that the MENT was activated as a result of participants simply and naturally coordinating their gaze with that of the other *without* any explicit instruction to assess the mental states of the virtual other. This is consistent with the observation of activations of dorsal MPFC when study participants were addressed by their first names or by faces looking directly at them (Kampe *et al.* 2003). Our findings, therefore, seem to contradict the proposal that the MENT is responsible for reflective and more explicit social cognition (Keysers & Gazzola 2007). In essence, we are able to show that this network is activated as a result of interpersonal coordination in social interaction, which was also experienced as more pleasant and less effortful than doing the opposite of what the virtual character was doing (cf. Schnell *et al.* 2011). Follow-up studies using modifications of our novel paradigm will investigate putative connectivity differences between areas of the MENT during social interaction and observation, and will explore how a cooperative or competitive context influences the neural mechanisms of a gaze-based interaction (Fig. 1; see sects. 3.2 and 5 for further details).

Our findings, therefore, raise the intriguing possibility that activity changes in the MENT can occur as a result of (gaze-based) social interaction (cf. Allen & Williams 2011). To us it is tempting to think of this finding as paralleling the suggestions of Heyes (2010) with respect to the MNS, giving rise to the hypothesis that similar associative mechanisms might play a role in the case of the MENT. In a similar line of thought, Behrens and colleagues have demonstrated that social prediction error signals – when learning from the behavior of or advice provided by others – are coded by MENT components, which they describe as evidence for the argument that higher-order social cognitive mechanisms may rely on simple associative processes (Behrens *et al.* 2009). Crucially, the elegant computational approach taken by Behrens *et al.* to investigate reward-based learning and decision-making uses a generative model, allowing the consideration of the learning history to predict changes in neural activity over time. Similarly, we suggest, future research in social neuroscience should investigate the development and changes in neural networks, that is, the neural plasticity related to and induced by real-time social interactions, thereby helping

to understand how particular functions actually develop in particular areas of the brain or in brains of interactors (cf. Westermann *et al.* 2007; see Fig. 1 and sect. 5 for more details).

Furthermore, our neuroimaging finding of a differential increase of neural activity in the MENT is particularly relevant, because it is observed during joint attention: Ontogenetically, joint attention is known to be a most important precursor of explicit social cognitive abilities and predates these conceptual abilities by years: A recent study was, indeed, able to show that children have an implicit “know how” of what others experience when they encounter them in joint engagement, long before passing false-belief tasks (Moll *et al.* 2007). Based on our findings, it can be assumed that joint attention in social interaction already relies upon the brain regions of the MENT before children pass tasks that require an explicit knowledge of others’ mental states (cf. Grossmann & Johnson 2010). Rather than being a network that is exclusively devoted to *reflective* social cognition, this network might, therefore, be trained up by participation in social interaction in terms of basic mechanisms which allow the use of analogies and associations to generate predictions (Friston 2008; Mitchell 2009). During later stages in development this network may then be brought into the service of *explicit* social cognition (Frith & Frith 2008; Knops *et al.* 2009), which – at the level of the brain – could be reflected in differences in the functional or effective connectivity between individual brain regions, rather than functionally segregated effects (e.g., Daunizeau *et al.* 2010a; 2010b; Sporns *et al.* 2004). In these terms, the progression from *perceiving* and being motivated to respond to relevant social stimuli to *understanding* them may be a result of the matching of top-down and bottom-up expectations. Importantly, bi-directional relationships between different levels of neural processing may remain relevant throughout life (Teufel *et al.* 2010; see Fig. 1).

Returning to the results of the fMRI study on joint attention, it is of crucial importance that differences in the neural correlates were also observed depending upon joint attention being self- or other-initiated: While following someone else’s gaze to engage in joint attention resulted in the recruitment of the anterior portion of MPFC (aMPFC; Fig. 4D), known to be involved in the enhancement of stimulus-oriented attending (Burgess *et al.* 2007), directing someone else’s gaze towards an object activated the ventral striatum (VS), a part of the functional neuroanatomy of reward processing (Fig. 4E). In light of ratings of subjective experience also obtained from participants during a post-scan questionnaire – which indicated that they enjoyed looking at objects more “together with” the virtual other – the latter finding, indeed, appeared to be related to the hedonic aspects of experiencing self-initiated joint attention (Schilbach *et al.* 2010b). This seems to be in line with the idea that social interaction may involve collaborative and affiliative motives, the realization of which is experienced as rewarding, possibly relying upon an “intrinsic” motivation of humans for sharing of experiences (Tomasello 2009; Trevarthen 1980). Furthermore, these findings demonstrate how basic motivation- or reward-related signals may play a key role in the establishment and maintenance of social relations (e.g., Panksepp *et al.* 1980), which appears to be a crucial area for future research in social neuroscience

(see sect.5.2 for further details). Most importantly, our results provide clear evidence that the neural circuitry used during social interaction differs from the circuitry recruited during “individual” social cognition, when one’s behavior does not have effects on the “object” of one’s cognition (cf. Materna *et al.* 2008; Schilbach *et al.* 2010b; Williams *et al.* 2005).

### 3.2. Methods for a second-person neuroscience

Advancing research in social neuroscience as suggested by a second-person approach requires both – upon a refinement of conceptual issues – the derivation of concrete hypotheses, as well as the development of adequate methods to address these questions. It is to the discussion of the latter that we turn in the following section. Concrete ideas for experiments based upon our conception of the constituents of a second-person approach as outlined in section 2 are discussed in detail in section 4.

**3.2.1. Top-down and bottom-up investigations of social interaction.** In the joint attention paradigm, participants interact with anthropomorphic virtual characters, who they believe are controlled by other human participants (Wilms *et al.* 2010). In this paradigm, we are in a position to investigate the behavioral and neural correlates of interaction contingencies and responses that are characteristic of various forms of social encounters (see Figs. 1 & 2). Future studies will make use of this setup to explore the interaction of explicit and implicit processes in social cognition and how this may depend upon being able to “get into the action.” Here, one could specifically ask whether the difference between social cognition from an interactor’s as compared to an observer’s point of view merely adds an action component or whether this actually changes other psychological processes. In terms of the underlying neural substrates such differences might be characterizable in terms of overlapping versus distinct neurocircuits or could be related to differences in connectivity between “social brain” regions (Fig. 1). Also, the question could be addressed whether ostensive cues exchanged between interactors (e.g., mutual gaze; Csibra & Gergely 2009) are equally effective from an observer’s point of view as compared to situations when one is personally addressed.

Furthermore, paradigms are being developed in our laboratory which will help to understand differences between social cognition from an interactor’s as compared to an observer’s point of view with respect to reward-based interactions (cf. Pessoa & Engelmann 2010). Based on the assumption that social interaction per se may be experienced as motivating and rewarding, it appears plausible to devise paradigms that implement a social context, in which task performance may be modulated depending upon whether or not the motivation to interact socially is parallelized with or contrasted with performing the task (see sect. 5.1.1 for further details). Another extension of the above described joint attention paradigm could consist in using virtual characters whose facial expressions and whole-body movements could also be manipulated. This setup would allow the investigation of how participant-directed gaze behavior of the virtual character would influence the perception of, for example, reaching or grasping movements in peri- and extrapersonal space (cf. Caggiano *et al.* 2009). Here, an interesting possibility would

be to parametrically vary the degree to which a virtual character is responsive to a human observer’s gaze in real time to investigate how this may lead to differential recruitment of the MNS and MENT of the brain (Brass *et al.* 2007; de Lange *et al.* 2008; Santos *et al.* 2010; Wheatley *et al.* 2007). Also, the presentation of real-world objects that can be attended to both by the virtual character and the participant could be helpful to manipulate neural activity in those large-scale neural networks.

Another fundamental question for a second-person neuroscience – closely related to the “problem” of other minds – consists in asking which factors actually determine that we perceive an interaction as an exchange, with a mindful rather than a machine-driven agent. To this end, a “nonverbal Turing test” can be devised, in which participants engage in gaze-based interaction with an anthropomorphic virtual character, whose gaze behavior is either controlled by another participant or by a computer (Fig. 2; Pfeiffer *et al.* 2011). These investigations are likely to be informative with respect to the impact of valence (whether or not an interaction subjectively feels positive or rewarding) as compared to contingency (the degree to which the virtual character objectively follows or does not follow one’s gaze). Furthermore, one can address the question of the congruency of the behavior shown by the virtual character during the interaction – that is, whether following or not following the participant’s gaze has an impact on ratings of sympathy and trustworthiness, as well as subsequently evoked prosocial behavior shown towards the person one has interacted with.

**3.2.2. From interaction loops to interaction dynamics.** In the early years of social neuroscience, attempts had already been made to investigate two brains in interaction through “hyperscanning,” which was hailed as a break-through technology (Montague *et al.* 2002). Although the application of this method has, indeed, provided invaluable insights into the neural basis of social cognition in conditions of health and pathology (e.g., King-Casas *et al.* 2005; 2008), the approach never really caught on. At least in part this is due to the fact that using it to its full potential would have required establishing more ecologically valid ways for two or more participants to interact (cf. Redcay *et al.* 2010). Most hyperscanning studies, however, have relied upon experimental paradigms from game theory, which allow for a highly structured, tit-for-tat kind of interaction. The latter can be elegantly formalized mathematically, but can also be criticized for not recreating the interaction dynamics of everyday-life social encounters (Engemann *et al.* 2012). Also, paradigms from game theory are deeply entrenched in a cognitivist view of the subject as a (rather) rational and (rather) passive recipient of information, which may not fully capture many aspects of naturalistic social interaction, including the ways in which interactors co-regulate their behavior (cf. Bacharach 2006; Hertwig & Erev 2009; Schonberg *et al.* 2011).

However, first steps are now being taken to investigate the neural mechanisms of interaction dynamics (Fig. 2: cubes [4] & [5]). Similar to our approach of using gaze behavior to allow for direct social interaction (Schilbach *et al.* 2010b; Wilms *et al.* 2010), the recent work of Saito *et al.* (2010) capitalizes on the idea that inter-subject synchronization at the neural level might occur during eye contact. Using a similarly minimalist and yet naturalistic setup

allows the experimental control of bandwidth, that is, the degree of complexity of the interaction, which may be helpful in focusing on its temporal dynamics (cf. Auvray *et al.* 2009). For their ground-breaking study Saito *et al.* have devised a setup in which they not only use hyperscanning, but also allow participants to interact in real-time by exchanging gaze behavior. To this end two MRI scanners were equipped with infrared eyetracking systems and video cameras. Thereby a live video image of the respective interaction partner's face could be broadcast into the respective other scanner to generate a mediated face-to-face situation (Fig. 5).

In a simple task, participants were instructed to either look at (or away from) targets (blue or red balls) when a change in color indicated to do so or to follow (or not follow) the interactor's gaze toward a target. Using this setup for neuroimaging purposes, it was shown that "paired" subjects showed higher correlations than "non-paired" subjects in an area of the MNS, as assessed by performing an inter-brain correlation analysis of the blood-oxygen-level-dependent (BOLD) signal time courses as a measure of functional connectivity. Future investigations could use measures of effective connectivity to systematically explore both models of eye-movement control as well as measures of inter-brain synchronization (e.g., Anders *et al.* 2011; Schippers *et al.* 2010). While we appreciate that the exploratory study by Saito *et al.* had to rely on a highly structured task, we see a significant number of possibilities for modifying and extending the paradigm and ingenious setup used by the authors.

Indeed, it is only very recently that researchers in social neuroscience have moved on to investigate (relatively) unconstrained real-time social interaction while measuring neural activity in both interactors (Fig. 1, C & D; Fig. 2: cube [5]). Dumas *et al.* (2010) set out to investigate the inter-brain correlates of mutual adaptation processes in social interaction by recording with a dual-video and dual-EEG setup while interactors were asked to spontaneously imitate each other's hand movements. Results demonstrated that states of "interactional synchrony," that is, states during which the hands of the two participants started and ended a movement simultaneously, correlate with a synchronized inter-brain network in the alpha-mu band in centro-parietal cortex. Interestingly, the alpha-mu band has been considered as an electrophysiological correlate of MNS functioning, and specific frequencies of this band have been discussed as a marker of social coordination (Tognoli *et al.* 2007).

Against this background, we posit that a crucial achievement of future research in social neuroscience will consist



Figure 5. Illustration of the combined hyperscanning and dual eyetracking setup used by Saito and colleagues (Taken from: Saito *et al.* 2010).

in the investigation of the neural correlates of mutual adaptation and the reciprocity of human-human social interaction at the intra- as well as the inter-brain level (see Figs. 1 & 2). Beyond the specific methodological challenges regarding synchronized collection and integrated data analysis, a most fundamental challenge involved in this endeavor concerns the implementation of ecologically valid and at the same time highly controllable experimental settings, suitable both for behavioral and neural investigations (cf. Wilms *et al.* 2010; Zaki & Ochsner 2009). The state of the art in neuroimaging provides severe limitations to studying free-running interactions using the full range of verbal and nonverbal channels. Most likely successful studies will need to identify and isolate salient communicative subsystems. As referenced throughout this article, human gaze is certainly a most interesting candidate for this type of approach as it is a highly social cue, it can be unobtrusively measured and processed in real-time using modern eyetracking technology, and it can be easily experimentally controlled and dynamically displayed via artificial characters. Advantages of using virtual representations of human interlocutors in computer animations instead of real-life-interactions or video have long been discussed (see Bente 1989; Blascovich *et al.* 2002). Early studies using computer-animated characters in observational studies concerned with nonverbal behavior confirmed their external validity, for example, when comparing impressions of animated characters with video recordings of real people (Bente *et al.* 2001), and also demonstrated the enormous degrees of freedom in experimental control: for example, when overlaying the same nonverbal behavior on actors of different gender (Bente *et al.* 1996) or neutralizing cultural stereotypes by using standardized animation "dummies" (Bente *et al.* 2010). However, it is only recently that the advent of sophisticated capture devices for gaze, facial expressions, and body movement, as well as real time animation tools, allow for full character control in the framework of truly interactive research paradigms (Bailenson *et al.* 2003; Bente *et al.* 2008b). Using these technologies in such an interactive paradigm, Bente *et al.* (2007a; 2008a) used motion capture devices, data gloves, and eyetracking devices to capture the nonverbal behavior of two interlocutors and transmit this information in real time to the partner's screen where it was executed by an animated character. The whole setting thus established a "virtual video conference" (see Fig. 6).

Although movement was left unmodified, gaze was controlled by a computer program that systematically varied the duration of direct gaze. This kind of "blended interaction" allows for most realistic and lively displays of interaction while exerting strict experimental control over the specific cues under investigation. Furthermore, the computer program can be used to show specific responses conditional on the partner's behavior (e.g., to follow the partner's gaze or not, as in Schilbach *et al.* [2010b], to nod after sentence completion, and to show averted or directed gaze after specific key words or nonverbal signals). Beyond these unprecedented possibilities, animated characters are open for experimental manipulation and they also help to solve problems that arise from the application of complex technologies: Showing the interaction partner lying in a scanner or wearing an EEG cap, carrying reflectors for movement or face tracking, might decrease ecological validity more than meeting an avatar



Figure 6. Basic version of an avatar-based interaction platform (screen shot during calibration; virtual characters shown on screen are mirroring the interlocutors own behavior).

in a virtual environment. Measurement devices, however, do not only obscure our view of the interlocutor and provide an awkward image of the other; they also restrict the behavioral repertoire of the actors; for example, the locomotion radius when using a remote eye tracker or the mobility of extremities and head in the fMRI scanner, where actions are often limited to simple key presses. By providing options for an elaborate action repertoire within the constraints of neuroimaging settings, virtual reality or augmented reality setups are, therefore, likely to advance the investigation of the neural underpinnings of joint actions (Knoblich & Sebanz 2008; Kokal *et al.* 2009; Newman-Norlund *et al.* 2007; 2008). On the other hand, the use of (more) mobile data-collection devices, such as low-density EEG setups or methods such as functional near infra-red spectroscopy (fNIRS), could also help to overcome some of the bandwidth problems and create more ecologically valid situations, in which participants can use the full range of communicative behavior (e.g., Suda *et al.* 2010; 2011). Further, using mobile data collection and analysis devices could help to provide real-time visualizations of brain states and investigate how such interactionally presented neuromarkers might contribute to and impact on ongoing social interactions. Finally, another important matter is to investigate which insights can be gleaned from quantifying inter-brain effects of social interactions and to assess whether two interacting brains provide more information about the interaction than the sum of the individual brains (cf. Hasson *et al.* 2012; Konvalinka & Roepstorff 2012).

Taken together, our review highlights the importance and potential of exploring the neurobiology of social cognition from an interactor's point of view and stresses that the use of more ecologically valid, truly interactive setups will help to address the neural bases of interpersonal coordination and responsiveness in interaction, which may underlie our seemingly effortless ability to apprehend other minds.

#### 4. Key topics and objectives for future research

The characterization of differences in social cognition from an interactor's point of view as compared to from an

observer's point of view, the differential recruitment of underlying processes and neural mechanisms, and the investigation of interacting individuals appear as key targets of a second-person neuroscience (Figs. 1 & 2). In section 3.2 we have focused on the methods necessary for this. The current section highlights how a second-person neuroscience may spark important new questions and can help to shed new light on well-known issues. Here, developing approaches for data collection and analysis from two interacting persons (and possibly two brains) is relevant, as is revisiting and modifying established experimental paradigms to incorporate an emotionally engaged, interactive perspective (see sect. 2). This means that, in our view, a second-person account does not replace first- and third-person accounts, but bookends them to a large degree. Consequently, the resulting research questions are concerned with the degree to which the accounts differ, and how they interact with each other (see sect. 4.1). Furthermore, how is it that largely automatic, implicit forms of interaction develop into explicit social cognitive capacities and how does explicit mind knowledge contribute to ongoing interactions (see sects. 4.2.1 & 4.2.2)? Also, if one considers interaction as developmentally prior to mentalizing or mirroring, then the question remains: What drives interaction? Here, we focus on the importance of reward signals and motivational processes relevant for participation in social interaction (see sect. 4.2.3). Finally, we address how insights from a second-person account could be put to use in future research using computational neuroscience techniques and in the emerging field of social neuroendocrinology (see sect. 4.3). Overall, the section 4, therefore, serves to consider potential new avenues that research might take by embracing a second-person approach.

##### 4.1. Addressing differences between social interaction and observation

The comparison of processes involved during social cognition from an interactor's versus from an observer's point of view is a central target of a second-person neuroscience. Basically we see three options to address this within the context of measuring a single brain: (1) studies contrasting

the information one can obtain when *being in interaction with* versus *observing* someone (learning studies); (2) studies contrasting the effects of being in interaction with versus observing someone on subsequent judgments and behavior (priming studies); and (3) studies that establish whether we are susceptible to different contextual influences when we are interacting versus observing.

One way to address the first and perhaps the second type of studies is to look at whether being in an engaged interaction provides the same information as observation, and if not, how this differs. For instance, one could imagine people interacting with a virtual character whereby they have to make judgments on the character or adapt their behavior to her. The question would then be whether differences in participants' learning rates and behavior exist depending upon interacting with the virtual character themselves as compared to seeing someone else interact with the virtual character, and what the neural bases of such differences could be. Here, an important hypothesis to pursue is that neural plasticity differences could exist in task-specific neural networks, based on one's own involvement in interaction as compared to situations when we merely observe others (cf. Cooper *et al.* 2012). Also, it is conceivable that different routes may lead to the activation of a neural network: For example, in the case of high-functioning autism, patients have failed to show activation differences as compared to healthy controls (Gilbert *et al.* 2009), which might be related to their ability to activate "social brain" areas when asked to make a conscious effort to do so. Nonetheless, important differences could exist in situations of naturalistic, fast-paced social encounters and can only be assessed by providing such situations as a test bed. Another important future extension of interactive paradigms will consist in making it possible for two participants to engage in a task and to interact in an experimentally controllable way in a mediated environment. Such a paradigm would enable one to control and change the bandwidth of the interaction and could help to systematically perturb an ongoing interaction, for example, by replaying responses of the other interactor from a previous interaction, and to investigate participants' ability to tell apart "whether the other can see me (or not)." One way, we suggest, this could be done would be to make use of a dual eyetracking setup, in which two interactors can be virtually present and perform a task together (e.g., Carletta *et al.* 2010; Jermann *et al.* 2010). Furthermore, such dual eyetracking paradigms might help to assess intra- and inter-subject parameters during real-time interactions, which could be used to analyse neuroimaging data obtained from one or two brains.

Concerning the second type of studies, we suggest that using the established possibility of exploring joint attention in the scanner may help to understand the neural underpinnings of other (possibly more explicit) social cognitive tasks: For instance, it has been suggested that being actively engaged in triadic interaction may have an impact both on the perception of the other person (e.g., her trustworthiness and attractiveness), as well as on the perception of an object (e.g., its value) that may be jointly attended (Heider 1958). To the best of our knowledge, there are no neuroimaging studies that have targeted the neural correlates of the perception of jointly attended objects. Such studies might be extremely informative, however, with respect to identifying the neural correlates of different formats or

varying degrees of shared intentionality and could also shed light on the complex relationship between implicit and explicit processes involved in social cognition (Frith & Frith 2008; see also the next subsection). Other applications of the method could include investigations of how interactive gaze cues shown by a virtual character impact upon object-related decision-making or memory performance. Furthermore, the gaze-based interaction setup could enable us to investigate how being involved in an interaction, during which an agent has a high probability of reacting congruently to my gaze behavior by following my gaze, impacts on subsequently presented social cognitive tasks: One particularly intriguing case would be to explore how interaction-based experiences modulate performance during a subsequently presented task, in which the mental states of the agent one has interacted with (e.g., her desires or beliefs), have to be assessed or explicitly reported. Also, exploring the impact of minimal forms of social interaction on self- and other-related person judgments and the tendency to show prosocial behavior would be particularly relevant and interesting. Apart from asking which processes and tendencies might be primed or enhanced by social interaction, it is also important to investigate which cognitive capacities might be perturbed or which processes are interfered with during social interaction. Here, an interesting avenue to pursue is how being a participant of a social interaction might lead to differential effects on mnemonic processes, such that associative components might be favored as compared to declarative memory.

In order to address the third type of studies, i.e. those dealing with contextual influences, one may ask how the situational constraints of a social situation may interact with more abstract rules that one can acquire as illustrated by high-functioning autism (HFA). When performing social cognition from an observer's standpoint, one might be more inclined to take into consideration cues that inform us about the psychological traits or dispositions of other persons, which may be less closely related to the person's current psychological state and to what the person is actually doing in the precise moment of observation (cf. Jones & Nisbett 1971). On the other hand, the integration requirements of direct social interaction may be such that—while trying to form an impression of the other—we simultaneously have to adjust and respond to the other person's actions; which means responding to the concretely given and pragmatically relevant aspects of the current situation. While social cognition from an observer's point of view is, therefore, likely to rely more upon situation-independent formats of information (e.g., stereotypes), social cognition from an agent's point of view might rely more on making use of situational information in order to make sense of the other's behavior.

## 4.2. Social interaction and the relationship of implicit and explicit processes in social cognition

### 4.2.1. From implicit interaction to explicit mentalizing?

In establishing the relationship between social cognition from an interactor's as compared to an observer's point of view, the question of implicit and explicit processes in social cognition gains further importance. Till now it is largely unclear what the neural signatures of implicit as compared to explicit social cognition are (Frith & Frith 2008). There

is a theoretical as well as an empirical side to this issue, both of which can potentially be elucidated within a second-person account. In theoretical terms, it is not always clear what is meant by “implicit social cognition” and how this is actually related to awareness, on the one hand, and automaticity versus control, on the other. It is never spelled out whether “implicit social cognition” is just what we reason consciously about, minus awareness, or, if this is not the case, how exactly the former relates to the latter. For instance, social interaction may be conceptualized as a prime example of implicit learning, as is language, the development of both being closely intertwined (see sects. 2.2 and 2.3). As with implicit language learning, an important question is how we develop an explicit and symbolic, or rule-based grasp of language and social interaction based on implicit, predominantly associative learning of statistical regularities. If indeed such explicit knowledge is the result of exposure to increasingly complex social contexts, it remains unexplained how, and what the neural bases of such changes could be. For instance, how do behavioral precursors to TToM develop into a capacity to pass classic TToM tasks?

Ontogenetically, becoming an “expert” in social cognition may be, we suggest, primarily a question of social interaction, whereas later competencies of more detached, reflective social cognition might be a result of reactivating the networks forged during social interactions and re-describing these interaction-based capacities (cf. Cleeremans 2008; Cleeremans *et al.* 2007; Karmiloff-Smith 1992; Timmermans *et al.* 2012). In this respect, our proposal links up with theories about the functional structure of the brain, which take the “re-use” of neural circuitry for various cognitive purposes to be a central organizational principle (e.g., Anderson 2010). According to these theories, it is common for neural circuits to be established for one purpose and then to be put to different uses. Crucially, rather than seeing such a re-description as an internally generated, qualitatively different representation of discrete knowledge about the world, our second-person approach frames such a re-description as an ongoing learning process driven by increasingly complex interactive contexts, for example, when moving from dyadic to triadic interaction, which creates the possibility and need to somehow communicate with respect to an external, third object or person (see also Carpendale & Lewis 2004). Furthermore, the involvement of reward signals closely related to ongoing social interaction might also be relevant in this respect (Pasley *et al.* 2004). In the light of section 2.3, language in this context might not only be shaped by social interaction, but the other way around as well, with the gradual development of language providing a scaffolding that allows implicit social know-how to develop in explicit social knowledge. Indeed, as Hutto (2008) suggests, the development from early nonverbal responding to others’ mental states—which, according to Hutto, is essentially non-contentful—into explicit, contentful thinking about others’ mental states is probably linguistically mediated. Future research in social neuroscience will have to find ways to systematically investigate how activity *both* in the parieto-frontal cortex and the so-called mentalizing network may be shaped and modulated by the degree to which human observers perceive themselves as participants of social encounters, and by actual exposure to social interactions; and to understand how this relates to recruiting

these networks during observation (Schilbach 2010, cf. Wang *et al.* 2011).

Apart from investigations of real-time dyadic and triadic interaction in healthy persons, we also see great potential for investigating real-time social interaction during development and in diagnostic groups. In spite of the importance of joint attention in ontogeny and a growing number of neuroimaging studies in this respect, the neural correlates of this significant phenomenon and how it unfolds in real-time are incompletely understood. Given that our paradigm does not rely upon verbal information and higher-order reasoning about others’ mental states, but relies upon naturally occurring social behavior, it might prove to be particularly useful in this respect and could help to address how human infants come to enjoy the sharing of experiences. Furthermore, a characterization of the neural signature of mutual and joint attention in infancy could be related to the development and neural bases of other social cognitive abilities that develop later in life, to investigate commonalities and differences in a longitudinal setup. Such an approach could help to directly test whether interaction-based network modulations are later co-opted and reused for higher-order, explicit processes.

A litmus test for the second-person approach in ontogeny would be to investigate infants’ responses to acts of mentality (e.g., intentional actions, attention, emotional facial expressions), depending upon the infant’s ability to respond to them when they receive them. Contrary to a simulationist reading, which would predict that infants need to be able to do the actions themselves, and to “mind-reading” accounts, which hold that the infant needs to be able to observe and conceptualize patterns in order to be able to grasp actions meaningfully, the second-person approach suggests that acts of mentality should be meaningful to infants depending on the infant’s ability to respond to them when they receive them, regardless of whether the infants can do the actions themselves.

Thus, a second-person neuroscience is concerned with the question of how direct social interaction with others—and the implicit processes inherent to this—may inform and modulate more detached, explicit perspectives on them. Evidence from developmental psychology has been taken to suggest that reflective (or “meta-cognitive”) competence emerges through the infant’s social interactions with others by relating one’s own states with those of others (e.g., Rochat & Striano 2002). However, a more radical approach holds that it may be only via social interaction and in virtue of the fact that we are constantly trying to model other minds in interaction that we learn to be conscious and develop both an understanding of ourselves and a conscious percept of the world at all (Cleeremans 2011; Timmermans *et al.* 2012). A study by Bahrami *et al.* (2010) further indicates that such interaction-based improvements of introspective abilities continue to be effective during adulthood.

**4.2.2. From mentalizing and mirroring to automatic interaction?** A question equally important to an ontogenetic account is how we manage to engage in interaction on a daily basis, without referring to explicit knowledge. Instead, we interact and “go with the flow,” all the while retaining the capacity to reflect upon our interlocutor and ourselves afterward. It is exactly here that neurobiological

evidence of TToM-related activations has given rise to the idea of “implicit TToM” or “implicit social cognition.” But if this “implicit TToM” is essentially something different than, say, what we consciously deploy in False Belief tasks, then what does it represent? It is here that the most immediate empirical questions may be raised: Are the implicit and explicit processes that occur in interaction actually the same processes as those that occur during observation? We suggest that this may not be so, in that interaction-based processes involve at least two aspects. First, they involve an automatic inference component based on previously acquired knowledge, which is also present during observation, and which is largely impervious to explicit modification. Second, they also require an action-control component, which can be fast (<350msec) and based on the previously acquired knowledge, or slightly slower (>350msec) and potentially available to control (Khan *et al.* 2003; Pisella *et al.* 2000; Rossetti *et al.* 2003; Sartori *et al.* 2009). As such, whereas during interaction implicitly activated knowledge seems to be immune to explicit interference (Ambady *et al.* 2000; Choi *et al.* 2005), automatic processes are – due to their action component – susceptible to explicit modification, or interference (you drive a car or play a musical instrument without thinking about particular movements contributing to it, but you can to some degree bring them under conscious control – which under normal circumstances will hamper fluent performance). However, such awareness of action is related not only to action preparation (motor signal), but is additionally prone to strong reconstructive effects of the sensory consequences of one’s actions (Haggard 2009; Haggard & Tsakiris 2009; Pacherie 2008; Sarrazin *et al.* 2008; Sato & Yasuda 2005). In an observational context such factors simply do not come into play, whereas in an interactive context, this means that the reactions of the other co-determine the degree to which one becomes conscious of one’s actions, to which anyone who ever committed a serious gaffe in public will readily testify.

An illustration of how the reasoning described above might lead to novel approaches lies in psychiatric disorders: For instance, autistic persons have been described as having problems with implicit or intuitive social cognition. However, in terms of elementary processes, several studies have been unable to find problems with implicit learning (Brown *et al.* 2010), action representation (Sebanz *et al.* 2005), or even mirroring (Southgate & Hamilton 2008). Thus, one empirically verifiable possibility would be that, at least in HFA, both low-level and high-level processes are relatively intact, but that the application of this implicit know-how versus explicit knowledge is disturbed, in that persons with HFA apply explicit, high-level TToM in situations where healthy controls “trust a gut feeling.” This then could lead to the hypothesis that HFA persons lack the know-how or knowledge that would subtend such a gut feeling (their explicit knowledge not being rooted in interactive know-how), or, alternatively, that they fail to recognize and trust such a gut feeling and instead, in any task allowing explicit reasoning, will opt for such explicit rules instead (failure of automatic application of knowledge, whether know-how or explicit knowledge). Crucially, the notion of how these potentially different capacities, implicit learning and automatic behavior contribute to autism – and healthy controls – remains elusive in passive spectatorial settings.

**4.2.3. Motivation and the spark to interaction: Putting reward signals into social cognition.** Another important feat will be to address how motivation- and reward-related signals could be differentially engaged during participation in social situations as compared to observation of others’ interaction and might interact with brain regions relevant for action control (cf. Oullier & Basso 2010; Pessoa & Engelmann 2010; Schonberg *et al.* 2011; Fig. 1). This directly follows from our conception of “active” social perception strongly relying upon affective and reward-based contingencies that result from being personally addressed and from prompt responses which feed into ongoing social interaction. Being in the presence of someone, human beings cannot help but interact with each other (e.g., Zwickel & Vo 2010), which may be due to an evolutionary heritage of depending upon others for survival; possibly having rendered social interaction “intrinsically” rewarding (Coan 2008; Tomasello 2009). Consequently, being a participant (as compared to being an observer) of social interaction, we speculate, might also lead to an expectation of reciprocation that is more in line with cooperative than competitive behavior and motives (Pfeiffer *et al.* 2011). Furthermore, human beings appear to be extremely sensitive to having an impact on conspecifics and seem to enjoy exerting such influence from early on in life (Fiske & Dépret 1996; Gergely & Watson 1996; Schilbach *et al.* 2010b). Relatedly, human beings not only enjoy being imitated by others (as long as this is done covertly), but this also increases feelings of affiliation and rapport (Chartrand & Bargh 1999). Consistently, experiences or even hints of social exclusion (even third-party exclusion) increases affiliative imitation (Over & Carpenter 2009). One of the factors that makes exerting an influence on other persons so rewarding, might be their agentive nature: First, it vastly increases the action possibilities of the other, and hence, the uncertainty of what the effect of my action will be (compared to when I interact with, say, a vending-machine); second, it might be that simply knowing that the other is an independent agent having other options than reacting to you, makes a contingent response very rewarding.

To investigate interactions of motivation- and reward-related signals with activity in action control and social cognition networks during participating in social interaction, we have devised a non-verbal Turing test, which is based on the interactive eyetracking paradigm used to investigate joint attention described in sect. 3.1.2. In this setup participants engage in gaze-based interaction with an anthropomorphic virtual character, whose gaze behavior is said to be controlled by another participant or by a computer, while, in fact, it is always controlled by a computer algorithm. Using this setup, the character’s gaze reactions were systematically varied along a continuum from a maximal probability of gaze aversion to a maximal probability of gaze-following during brief interactions, thereby varying congruency and contingency of the reactions. We investigated how these variations influenced whether participants believed the character to be controlled by a person or a computer. In a series of experiments, the confederate was either introduced as “naïve” to the task, “cooperative” or “competitive.” Results demonstrate that the ascription of agency increases with higher congruency of gaze reactions when participants are interacting with a “naïve” partner. In contrast, agency ascription was driven

by the degree of contingency (i.e., the probability of the virtual other reacting) irrespective of congruency (whether or not the behavior shown in response was the same or different than the participant's) reactions when the confederate was introduced as "cooperative." Conversely, during interaction with a "competitive" confederate, judgments were neither based on congruency, nor on contingency (Pfeiffer *et al.* 2011). These results offer important insights into what renders the experience of an interaction truly social: Humans appear to have a default expectation of reciprocation as evidenced by the naïve condition, which can be influenced drastically by the presumed disposition of an interactor to cooperate or compete. This finding, we assume, could be related to our neuroimaging results, which were accrued by making use of the same kind of paradigm, and highlight the involvement of reward-related neurocircuitry during congruent interactions (Schilbach *et al.* 2010b). The use of the Turing test paradigm for neuroimaging purposes is likely to advance our understanding of the neural bases of social interaction: For example, it can be hypothesized that gaze-based interactions with a naïve confederate might lead to an increase in neural activity in areas of the so-called mentalizing network, whereas conditions with highly congruent reactions might lead to an increase in reward-related brain areas. Although competitive interactions might also lead to an increase of neural activity in mentalizing areas, it will be interesting to investigate whether a competitive context could lead to a decrease of activity in reward-related neurocircuitry. Moreover, the question can be targeted whether the presence of a shared goal (as in the cooperative context), leads to a decrease of activity in the mentalizing system, while concomitantly an increase of activity might be observed in regions that have been implicated in coordinated behavior. Furthermore, it will be interesting to investigate whether changes in activity of the brain's reward system in response to positively contingent gaze-reactions could generalize to contingent reactions irrespective of their valence depending on the situational context. Finally, neuroimaging studies, which make use of this paradigm, may help to investigate putative connectivity differences between relevant brain areas during social interaction (Fig. 1). This could help us to understand the neural bases of opposing effects between imitative behavior and understanding of others' minds (Stel *et al.* 2009).

Recent evidence suggests that different reward types recruit the reward system of the brain, which has given rise to the suggestion of a "common neural currency" for rewards (Izuma *et al.* 2008). The neural mechanisms of differences in the susceptibility for different types of reward, however, remain unclear. Also, it is not well known how different reward types may compete and can act as a surrogate for one another (e.g., using food rewards when other rewards are unavailable) or how social influences may serve as a control mechanism to reward dependency. In order to probe the reward system of the brain while at the same time allowing for the use of different reward stimuli, the interactive eyetracking paradigm could be adapted to serve as a reward-based saccade paradigm. In such a paradigm, participants would be asked to generate and be rewarded for successfully completing saccades to visual targets. Rewards could be varied to include monetary, food, and social rewards (congruent gaze reactions of an anthropomorphic virtual character

also shown on the stimulus screen). On the behavioral level, higher reward probability for a given target is expected to lead to a decrease in saccade latencies (e.g., Milstein & Dorris 2007), the magnitude of which may depend upon the specific reward type. On the neural level, the correlates of this reward-related bias and possible reward type-specific differences in controls and patient groups characterized by social impairments (such as patients with autism and schizophrenia) are not well known. Research in nonhuman primates suggests that mid-brain dopamine neurons involved in motivated saccade tasks receive inputs from many brain areas including the ventral and dorsal striatum, the subthalamic nucleus, the amygdala, the lateral hypothalamus, the dorsal raphe nucleus, and the lateral habenula (Bromberg-Martin *et al.* 2010; Matsumoto & Hikosaka 2009). A comparison of different reward types could not only allow us to investigate overlap and differences in the underlying neural correlates, but could also enable the calculation of a scaling factor (i.e., an "exchange rate") between social, monetary, and food rewards for each subject.

### 4.3. An applied second-person neuroscience

**4.3.1. Computational social neuroscience.** Although computational neuroimaging studies inspired by game theory and other approaches that use generative models for data analyses have already taken up the investigation of competitive scenarios and are beginning to address cooperative games (e.g., Yoshida *et al.* 2008), human beings' unparalleled abilities for cooperation in real-time social interaction have largely been left unexplored. Here, extending computational social neuroscience approaches to reciprocal and adaptive two agent-interactions holds great potential for future research and may enable us to investigate how differences in perspective towards others, that is, social cognition from an agent's versus from an observer's point of view, may influence the reliance on different computational mechanisms. For example a study by Hampton *et al.* (2008) demonstrates the importance of representing the possible influence one may have on others in direct interaction. Similarly, recent findings from model-based neuroimaging studies already do provide evidence for differences in the neural mechanisms of experienced as compared to observational learning (activity changes in ventral striatum being selective to instrumental actions; Cooper *et al.* 2012). Computational approaches are particularly powerful in helping to address the history of an ongoing social interaction, how learning may occur and how it could be related to a social reward prediction error. In doing so, model-based analysis of neuroimaging data could help to investigate the development of neural networks and their structural and neurofunctional underpinnings during social interaction, thereby helping us understand how particular functions develop in particular areas of the brain or, specifically, the brains of interacting minds. One example of how a computational social neuroscience paradigm may help to assess and quantify the impact of (gaze-based) social interactions is the following: By combining a cooperative game such as the "stag hunt" game developed by Yoshida *et al.* (2008) with a gaze-based social interaction manipulation (Schilbach *et al.* 2010b), it becomes feasible to test computational models under more ecologically valid conditions. In light of our

hypothesis and preliminary findings, which suggest that social interactions may prompt collaborative motives, we expect that congruent gaze behavior exhibited by the virtual character in our joint attention manipulation may promote cooperative behavior in the “stag hunt” game, whereas gaze aversion of the virtual character may have the opposite effect. Using fMRI while participants are involved in gaze-based interactions and in the stag hunt game may also allow to use correlational approaches and multi-variate pattern analysis to predict the level of cooperation in the stag hunt from neural activity observed during gaze-based interaction.

Alternatively, future studies could use more elaborate models to control the behavior of a virtual character (conversational agents) in more complex ways (e.g., Broz *et al.* 2013; Kelso *et al.* 2009; Triesch *et al.* 2006; 2007; Fairhurst *et al.* 2012). The meaningful use of conversational agents (i.e., completely computer generated artificial social entities) in interaction studies, in contrast to avatars, would require the implementation of basic social skills in the agents, serving the perception, processing and production of interactive behavior (see Vogeley & Bente 2010). Such implementations are feasible if the scope of behavior is constrained with regard to channel bandwidth (e.g., to eye gaze), as well as with regard to the task affordances (e.g., fixation of objects, gaze following, etc.). However, the available technologies are far from allowing for broadband interactions in open conversational situations. Using such an approach might provide a most informative complementarity to recent investigations, which have focused on using computational models to predict neural responses in a human observer or interactor (e.g., Behrens *et al.* 2009; Cooper *et al.* 2012) and could help in exploring the explanatory power of mutually adaptive modeling approaches.

**4.3.2. Genotype-specific effects and hormonal influences of the neural basis of social interaction.** Recent evidence suggests that important hormonal influences exist which can specifically affect social behavior and its underlying neuroanatomical and neurofunctional correlates (e.g., Chura *et al.* 2010; Hermans *et al.* 2010; Volman *et al.* 2011), giving rise to the notion of a field of “social neuro-endocrinology” (cf. Bos *et al.* 2012). Interestingly, it has been suggested that certain hormonal responses only occur in ecologically valid situations (e.g., Henckens *et al.* 2009), which is consistent with the assumptions of the here proposed second-person approach. Therefore, it seems likely that using the types of interactive and ecologically valid paradigms endorsed by the second-person account may also help to advance the investigation of the complex interplay and influence of hormones on the “social brain.” In addition, efforts are also being undertaken to understand genotype-specific differences in prosocial hormones and brain anatomy and how they impact on social behavior (e.g., Chen & Johnson 2012; Tost *et al.* 2010). Furthermore, we see great potential in elucidating how such genotype-specific differences might be related to differences in reward-based processing (e.g., Chakrabarti & Baron-Cohen 2011) and could predict differential responses to pharmacological challenges or therapeutic interventions. In the following, we therefore go on to discuss the possible implications of a second-person approach to other minds for our understanding of psychiatric disorders.

## 5. Impact

### 5.1. Psychiatric disorders as disorders of social cognition

It has increasingly been recognized that we can conceive of psychiatric disorders as disorders of social cognition (e.g., Crespi & Badcock 2008; Vogeley & Newen 2009).<sup>5</sup> While there is great merit to be found in this endeavour, the above-described conceptual and empirical developments may be taken to suggest that previous research inspired by this assumption may have over-emphasized explicit forms of social cognition, whereas recent work, we suggest, indicates that related impairments might be more closely linked to difficulties in skillfully engaging in social interaction (Schilbach *et al.* 2012b).

### 5.2. The case of high-functioning autism

*“Direct interaction always leads to complications.”*  
— Patient M. V.<sup>6</sup>

#### 5.2.1. The impact of social gaze on action control and interpersonal coordination in high-functioning autism.

Autism is characterized by qualitative impairments of social interaction and communication. Here, the distinction between implicit and explicit processes has recently been emphasized: Contrary to popular explanations, what seems to be impaired in high-functioning autism (HFA) is not the ability to use explicit mentalistic inference, but rather, the implicit processes that contribute to participating in social interaction and that allow us to orient towards, and automatically integrate, relevant social cues in more complex situations (Becchio *et al.* 2007; Kuzmanovic *et al.* 2011; Senju *et al.* 2009). Individuals with HFA are neither impaired in explicit social cognition—as they, in fact, consciously remind themselves to think about the mental states of others in an attempt to compensate for interaction difficulties—nor in their capacity of implicit learning in general (Brown *et al.* 2010). Instead, they may lack the more basic skills to respond intuitively to socially relevant information by generating “adaptive actions upon salient aspects of the environment” (Klin *et al.* 2003). The discrepancy between the ability to solve explicit social cognitive problems and the inability to meet the demands of everyday life social interactions in HFA has been highlighted by methods which enable probing involuntary aspects of behavior. The difference between explicit and implicit social cognition is also nicely captured by descriptions of subjective experiences that persons with HFA provide. Here, individuals with HFA emphasize a preference for being in an observational stance towards others as this allows them to “logically compute,” “contemplate,” and “think through” aspects of the situation in a conscious and cognitively effortful way. Furthermore, being an observer also allows one to think about what one may know about a given situation and the constraints this may entail for a person who is actually in it. On the contrary, the situation becomes remarkably different and more complicated for a person with HFA when the person she has quietly been observing turns towards her and tries to engage her in interaction. Here, patients describe “being flooded” by information, an “inability to keep up,” and “not knowing when and how” to respond to what others do possibly

due to the imperfect contingencies inherent in social interaction (Klin *et al.* 2009).

We suggest that the impairments of being able to respond intuitively to socially relevant information could be closely related to the ability to perceive social affordances, that is, the possibilities for interaction provided by others. In order to investigate the impact of social cues on mechanisms of action control, we therefore made use of a stimulus-response compatibility (SRC) paradigm, in which control and HFA participants were asked to generate spatially congruent or incongruent motor responses to changes in a face, and to a face-like and an object stimulus (Schilbach *et al.* 2012b). Results demonstrate that whereas in control participants being looked at by a virtual other leads to a reduction of reaction-time costs associated with generating a spatially incongruent response, this effect is not present in the HFA group. We suggest that this modulatory effect of social gaze on action control in control participants might be related to social cues triggering motor preparatory programs that may help to coordinate one's actions with those of someone else, rather than providing a mere "resonance" mechanism. It is conceivable that participants thereby automatically adjust to the "perspective" of the virtual agent by making sense of the situation in pragmatic terms (Sebanz *et al.* 2006). Hereby, an action that is deemed spatially "incongruent" from an allocentric observer's point of view might end up being "complementary" to an action that the participant perceives the (virtual) other perform. In other words, being in the presence of someone else (even a virtual other) may change our perception of the environment towards perceiving it in terms of the resources or possibilities for actions held collectively ("we-space"), rather than individually (e.g., Krueger 2010).

Indeed, consistent with this interpretation of social cues leading to a recruitment of motor-preparatory and action-monitoring-related processes, an fMRI study from our lab using an abridged version of the social SRC paradigm in a group of healthy participants demonstrated that performing incongruent actions in the presence of a virtual other (as compared to performing them in response to a nonsocial stimulus) leads to a differential increase of neural activity in the brain regions known to be involved in action monitoring and response inhibition (anterior cingulate cortex and inferior frontal gyrus), and also in areas previously implicated in social cognition (dorso-medial prefrontal cortex; see Schilbach *et al.* [2010a] for details). Furthermore, reaction time differences between the social and nonsocial condition appear to be closely related to activity changes in the reward system of the brain as measured by BOLD fMRI: Participants who demonstrated more pronounced activations of the ventral striatum – often related to hedonic or rewarding experiences – also found it more difficult to disengage from the face stimulus in order to generate incongruent motor responses, which is consistent with suggestions of an important influence of reward-related processes on mechanisms of action control (cf. Pessoa & Engelmann 2010). Taken together, these results highlight that performing actions in a – albeit minimal – social context significantly affects mechanisms of action control (Schilbach *et al.* 2010a; Schilbach *et al.* 2012b; Gangopadhyay & Schilbach 2012).

Our findings are consistent, therefore, with the proposed difficulties in the automatic integration of social information in HFA, whereas more explicit measures of social

cognition may be intact as a result of compensatory strategies (Senju *et al.* 2009; Kuzmanovic *et al.* 2011). Whereas control participants respond to the virtual agent's gaze by recruiting motor-based processes, which lead to a performance benefit as and by recruiting the brain's reward system, which is likely relevant for the hedonic experience of social stimuli, our results seem to suggest no such differences in HFA. In other words, individuals with autism may not lack a theory of how other minds work ("knowing that"), but the relevant know-how for dealing with others in direct interaction (cf. Zahavi & Parnas 2003). Also, important differences are likely to exist in the degree to which social interactions can evoke comparable responses in reward-related neurocircuitry in patients with HFA (cf. Schultz 2005).

In line with the second-person approach, future research should, therefore, investigate impairments of social cognition in autism as reflecting difficulties in skillfully interacting with others, as those might be at the very heart of the problems faced by patients in everyday social encounters. We suggest that the investigation of the neural mechanisms underlying these clinically relevant differences in high-functioning autism will benefit substantially from using more ecologically valid paradigms that look at how people actively engage and interact with one another in social encounters. Furthermore, it will be important to relate known differences in structural (Catani *et al.* 2008) and functional connectivity in autism (Kennedy *et al.* 2006) to interaction abilities. Here also, connectivity differences in the mentalizing or default mode network (see sect. 3) and the anti-correlated fronto-parietal network, as well as interactions of both networks with the reward system of the brain (Camara *et al.* 2008), appear as primary candidates for such studies. Using paradigms that enable control of the bandwidth of the social interaction may help to titrate levels of perceptual complexity and differences in the temporal structure of an interaction, in order to adapt to the differences in functional and structural connectivity and concomitant interaction requirements. Also, using mediated social interactions could help to provide additional cues for patients, which help them to engage in interaction.

**5.2.2. Language use in high-functioning autism.** According to the view of "language-as-action" or of language as a "tool for social interaction" (Tylén *et al.* 2010), language processing can be regarded as a joint activity which results in entrainment and synchronization between partners on various levels (Pickering & Garrod 2004). Furthermore, this "grounding" view of language suggests that words do not contain their meaning, but that linguistic labels can be highly negotiable and that interlocutors flexibly seek to understand them against the background of a "common ground" (Clark 1996). To this end interlocutors produce and monitor paralinguistic cues and one another's instrumental behavior to ensure that they, indeed, understand each other. This view of language processing in dialogue – whereby a partner's contribution plays a dual role by providing the other person with evidence of how the previous utterance has been understood – resonates with our proposal of a second-person approach to other minds, which also highlights the importance of reciprocal relations and their partially constitutive role in interpersonal understanding. Here, the various feedback from interaction partners and

bouts of interpersonal synchronization shape and structure the “interaction space” and the denouement of the social encounter.

In high-functioning autism several language-related abnormalities are present, which, we believe, can be best understood in terms of the “grounding” rather than the “message model” view of language processing: Individuals with high-functioning autism – in spite of their elaborate linguistic code, and the absence of developmental language delay in Asperger’s syndrome – have profound difficulties in understanding irony and insist on the use of the literal meaning of words, for which a more “objective,” rule-based, situation-independent and “correct” usage can be determined. Consequently, the language in high-functioning autism is characterized by pragmatic and semantic deficits with patients being less likely to integrate contextual information (Groen *et al.* 2010). Consistently, patients seem to have particular difficulties in adapting to the changes in linguistic labels in reference to an immediately given social context (Nadig *et al.* 2009). Whereas in normal controls language promotes interpersonal coordination by helping to coordinate attention even in the physical absence of an interlocutor (Richardson *et al.* 2007a; Tylén *et al.* 2010), the same does not appear to be true for individuals with high-functioning autism. Patients commonly describe difficulties in maintaining telephone conversations on account of the fact that they find it nearly impossible to know when to speak in the absence of visual cues. In summary, while the predominantly information-based functions of language (as described by the “message model” of language) seem to be intact in high-functioning autism, it is the socially constructed and interactionally coordinative functions of language, which operate on a more implicit and automatic level, that appear to be most impaired (Pexman *et al.* 2011).

**5.2.3. Meeting the interaction requirements of patients with high-functioning autism.** From a clinical perspective, individual reports of patients with HFA from our outpatient clinic are also noteworthy, in that patients describe not having any significant impairments of social interaction and communication when they interact with other persons diagnosed with HFA, which stands in striking opposition to the difficulties that systematically occur when they interact with persons without this diagnosis. While also raising issues about the normative aspects of psychiatric diagnoses, these anecdotal reports emphasize that successful interaction and communication are crucially a matter of interpersonal adjustments and (possibly) an awareness of the interactional requirements of another person. Investigating these issues in patients with autism, we suggest, might help to improve not only psychotherapeutic interventions, but could also help to substantially raise public awareness, thereby promoting flexibility and openness to diversity in styles of social interaction. This is especially crucial for the case of HFA: As we are normally not aware of our intuitive, nonverbal capacities that are automatic in nature, we do not even have the chance to take notice of the specific deficits in the communicative behavior of HFA patients. With respect to the focus of this article, namely, the scientific investigation of real-time social interactions, it is most interesting to contrast dyads of neurotypical persons with neurotypical-patient and patient-patient dyads.

Investigations of the latter type might help to shed light on the neural mechanisms that enable successful interactions between persons known for their social interaction impairments. Also, the study of differences in social interaction dynamics could prove to be a promising route and might be developed into a tool for helping differential diagnosis in psychiatric disorders.

## 6. Concluding remarks

In this article we have argued for the conception of a second-person approach to other minds, suggesting that interpersonal understanding is primarily a matter of social interaction and emotional engagement with others. We suggest that this account – well-grounded in current philosophical considerations – provides a different route to the investigation of intersubjectivity by emphasizing aspects of social cognition specifically related to the procedural nature and experiential aspects of social interactions. Furthermore, we have argued for the application of this approach to the neurobiological investigation of social cognition based on our analysis that “dark matter” in social neuroscience remains, due to difficulties in investigating and conceptualizing real-time social interactions. A second-person neuroscience will, therefore, make use of innovative experimental setups to investigate social interaction and its relationship to social cognitive abilities in more ecologically valid ways. Such developments will not only help neuroscience to really “go social,” but may also be relevant for our understanding of psychiatric disorders construed as disorders of social cognition.

Although preliminary neuroscientific evidence suggests that social cognition is, indeed, fundamentally different when we are engaged with others, embedded in social interaction, many questions remain unanswered. Studies are needed to directly compare social cognition from an interactor’s versus from an observer’s point of view. How do putative differences with respect to the reliance on underlying mechanisms relate to the large-scale neural networks that are known to be involved in social cognition? The use of ecologically valid paradigms to probe social cognition, we suggest, will help to elucidate their putatively complementary roles as a function of the pragmatic requirements of social interaction and may also help to understand how activity might be shaped by the dynamics and “history” of an ongoing interaction. Here, the interaction of gaze and other action-related cues will be of paramount importance. Also, studying cooperative and competitive interactions in an ecologically valid, emotionally engaged way will be important to spell out the functions of active participation and reciprocity in social interaction and how they relate to our perception of the human status of an agent. We do not know as yet, what the relative contributions and neuronal bases of implicit and explicit ways of understanding others in interaction as compared to observation are, nor how this may relate to cases of psychiatric disorders, which can be thought of as disorders of social cognition. Finally, the precise role of reward signals in social cognition needs to be investigated, since they could constitute an important driving force for participation in social interactions and could crucially influence other aspects of cognition and processes of self-regulation.

By taking social interaction and a second-person approach to knowing minds seriously, future investigations in and outside the field of social neuroscience are likely to provide radically new insights into the psychology and neurobiology of how we know other minds and will produce evidence for an interactive account of social cognition that emphasizes the constitutive role of participating in the social world.

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#### NOTES

1. Authors Leonhard Schilbach and Bert Timmermans have contributed equally to this article.

2. In sensu stricto, the term *dark matter* is used in physics and astronomy to describe matter, which is inferred to exist, but which has not been directly observed and may not even be observable. We use the term metaphorically to denote an important lacuna in current areas of research in social neuroscience, which have been more difficult to investigate and where, therefore, less is known, but which can at least in principle be explored empirically. To index this particular usage of the term, “dark matter” is consistently used in quotation marks throughout the paper.

3. Here, it is important to note that from a conceptual point of view we do not see the differences between the dimensions of “experience” and “participation” as being strictly categorical in nature. Also, it is important to emphasize that we are, here, referring to the characteristics of experimental paradigms, which do (or do not) elicit a sense of emotional engagement and which allow (or do not allow) a human subject to participate in social interaction.

4. From our perspective, making experimental paradigms more interactive and ecologically valid will allow the assessment of differences in the neural correlates of social cognition from an observer’s as compared to from an interactor’s point of view in an individual’s brain (see Fig. 1). In addition to that, however, another important question to investigate is whether more insights can be gleaned from quantifying inter-brain

effects of social interactions and to assess whether two interacting brains provide more information about the interaction than the sum of the individual brains (e.g., Hari & Kujala 2009, Hasson *et al.* 2012, Baess *et al.* 2012, Konvalinka & Roepstorff 2012; see also sect. 3.2.2 in our article).

5. While an in-depth analysis of this particular issue is clearly beyond the scope of this article, we would like to note that from our standpoint the suggestion of a second-person approach to other minds is consistent with an integrative account of psychopathology, which takes into account and weighs data gathered by means of various methods, including observation of and in interaction with the patient and those around her in an attempt to explore convergences of naturalist and normative reasoning.

6. This is a direct quote from one of the author’s patients, who was seen in the Adult Autism Outpatient Clinic at the Department of Psychiatry at the University Hospital of Cologne.

## Open Peer Commentary

### Parameterising ecological validity and integrating individual differences within second-person neuroscience

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**Abstract:** This commentary situates the second person account within a broader framework of ecological validity for experimental paradigms in social cognitive neuroscience. It then considers how individual differences at psychological and genetic levels can be integrated within the proposed framework.

Social interaction is more than the sum of its parts. The clarion call for a second person approach in neuroscience by Schilbach *et al.* provides an opportunity to define a parameter space for ecological validity in studies of social cognition (SoCog). The operative definition of SoCog studies for this commentary includes all such studies that use any stimuli that can reasonably be identified as belonging to a conspecific. This commentary then considers a fundamental question about the integration of individual differences within this framework of studying social interaction.

Stimuli generally used in SoCog experiments range from minimal/schematic representations (Bayliss & Tipper 2005; Fox 2000) to real-world social interactions (Chartrand & Bargh 1999). Paradigms that involve observing static stimuli without interacting (e.g., watching static photographs of facial expressions of emotion) have played pioneering roles in social cognitive neuroscience (Blair *et al.* 1999; Morris *et al.* 1996; Whalen *et al.* 1998). However, since ecologically valid signals of social interaction are dynamic in nature, a first parameter in this framework is that of *stimulus dynamics*. Accordingly, brain regions responding to static facial expressions show greater activity in response to dynamic expressions of emotion (LaBar *et al.* 2003). However, the nature of stimulus motion critically influences whether people perceive it as a *social/biological* stimulus, and how they respond to it (Kilner *et al.* 2007).

Chaminade and colleagues tested two dimensions of stimulus variation, by systematically manipulating anthropomorphism and

motion type (artificial vs. biological) in a range of stimuli characters (Chaminade et al. 2007). This demonstrated that the motion type was a strong predictor of whether participants found the stimuli to be “biological” or not, across all stimulus forms. In contrast, if the motion type was recognised as biological, there was little difference in biological/artificial ratings across a range of stimuli forms. This provides an important insight for designing dynamic stimuli for experiments suggested in the target article, since the nature of interaction changes considerably if the stimuli are perceived to be artificial/artificially controlled (Pfeiffer et al. 2011).

Form and dynamics thus constitute important stimulus dimensions for ecological validity of SoCog paradigms (as illustrated in my Figure 1, specifically in cases where P1 is a virtual character/avatar). Once the stimuli are perceived to be social/biological (either explicitly, or implicitly, e.g., by believing that a given dynamic stimulus is being controlled by another agent; Weibel et al. 2008), the stage is set for an ecologically valid social interaction – whose parameter space (comprising engagement and interaction) has been laid out in Figures 1 and 2 of the target article. Although social interactions have characteristics in addition to those of individual interactors, these are, nonetheless, influenced by individual differences. Interactions of a highly introverted person with a range of different strangers will have a certain common quality, which is possibly more due to individual differences than the interactions per se. It therefore is necessary to devise a set of experiments that parse out the influence of individual differences on the interactional parameters. Paradigms that use well-controlled (albeit, artificial) stimuli can address this to some extent. However, in more real-world social interactions (see my Fig. 1, where both P1 and P2 are humans), individual differences of both interactors can have a significant impact on social cognition (Zaki et al. 2008). The quantification of interactional parameters therefore needs to be sensitive to individual differences. Possible questions for such analyses include the extent to which the individual characteristics of P1 and P2 (in Fig. 1) and their mutual relationship (quantified as their discrepancy, or correlation) determine the magnitude of the interactional parameters.

At the psychological level, one such dimension of individual differences is autistic traits. The level of these traits can determine how sensitive an individual is to rewarding social stimuli (albeit, across a spectatorial gap), and thus, how s/he responds to these

(Kohls et al. 2009; Sims et al. 2012). By this account, individual differences in social motivation can have a considerable impact on at least one of the key interactional parameters (engagement). Similarly, at a genetic level, one such dimension of individual variability is sequence variants in genes involved in social-emotional behavior (Chakrabarti et al. 2009). In separate studies, we demonstrated that individuals carrying specific variants in the cannabinoid receptor (*CNRI*) gene were likely to show a greater ventral striatal response to happy faces, and look longer at them (Chakrabarti & Baron-Cohen 2011; Chakrabarti et al. 2006). The second person account raises key questions for the interpretation of these paradigms: Would these differences in social reward sensitivity be seen if the spectatorial gap is closed by making more ecologically valid, interactive paradigms? If yes, then it will be necessary to quantify how much of these observed differences are due to the interaction per se. If not, the utility of paradigms involving “inert stimuli” in SoCog studies will need to be systematically re-evaluated. The target paper raises these important testable possibilities.

In sum, this commentary situates the second-person account within a broader parameter space for evaluating SoCog paradigms (represented in Fig. 1), and raises the issue of integration of individual differences within the proposed framework.

### Social cognition is not a special case, and the dark matter is more extensive than recognized

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**Abstract:** The target article’s approach is applauded, but it is suggested that the “dark matter” may be much larger than even the current authors suspect. Cartesian and mechanistic assumptions infuse not only the discipline of cognitive psychology, but all societal accounts of the person. A switch to dynamical accounts in which lawfulness is observed within a given systemic context is suggested.

The basic idea underlying Schilbach et al.’s proposal to establish a second-person neuroscience is profound. People are incomprehensible without recognizing that experience arises, and behavior unfolds, in context. The context, for humans, is massively conditioned by our fellow humans – the physical environment having been reduced by-and-large to smooth, easily navigable, surfaces with essentially no danger of predation. The suggestion that nervous system activity might be likewise interpretable only with due recognition of the role of the social context in which it takes place, might even be considered revolutionary, if it were not that very many converging sources of evidence seem to be aligning to force the recognition that our best account of our lives, experiences, and actions are not provided by a solipsistic and mechanistic model of a hermetically sealed cognitive system, tragically isolated from its world, and implemented in the currency of nervous system activity (Gallagher & Zahavi 2008; Varela et al. 1991).

The considerable change in perspective of the scientist that is required to fully acknowledge this insight will not come easily, and it is clear in the present article that the authors too struggle to free themselves from a vocabulary that is built on a foundation of (methodological) Cartesian psychology, where causes lie hidden, the world is inferred, and others are a problem to be solved. For there is more to be overturned here than the excesses of individualistic and mechanistic cognitive psychology. The

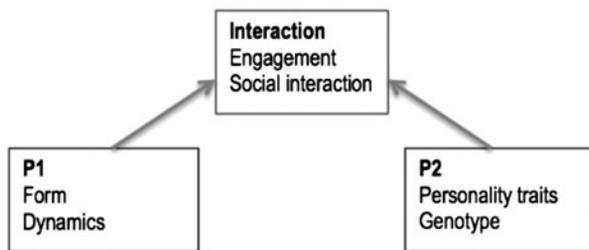


Figure 1 (Chakrabarti). A schematic parameter space for SoCog paradigms. Schilbach et al. propose two key parameters for quantifying social interaction (middle box). These are situated within a broader framework that includes the characteristics of the two interactors (P1 and P2). In cases where one of the interactors (e.g., P1) is a virtual character or an “avatar,” then characteristics such as form and dynamics are crucial in determining the nature of any interaction. In cases where both P1 and P2 are humans, the interaction parameters need to account for the variation explained by individual characteristics of P1 and P2. Individual characteristics of P1 and P2 could be explained at a psychological (e.g., psychological traits) or a genetic level.

sciences of the person that have developed in a post-Enlightenment, Occidental context have been constructed upon a pre-theoretical notion of an autonomous individual, bearing causal and moral responsibility for his or her own actions, with the brain/mind as the sole source of agency; this background is hard to shake. We will need to develop our concepts with care.

Old habits of thought die hard. For example, in considering the failure of high functioning autistic (HFA) individuals to engage in successful social coordination, the authors say (sect. 4.1, para. 2) “[the failure] might be related to their ability to activate ‘social brain’ areas when asked to make a conscious effort to do so.” This fails to step up to the mark and recognize that a felicitous social interaction is a coordinative process that cannot be disassembled into its components without losing its essence. The paean to computational models (sect. 4.3.1, para. 1) also suggests a clinging to a mechanistic, individualistic, understanding of the person. The authors are not hugely at fault here. It is virtually impossible to discuss experience and behavior without falling back on the problematic assumptions on which modern psychology is founded.

The language of dynamics is surely the way to make progress here. In dynamical modeling, the first and most important task is the identification of the system under consideration, and the differentiation of it from its domain-specific background. For the cognitive scientist, the system may be parts of the body, the whole body, the body plus tools, multiple bodies, and so on. In my own work (Cummins 2012), two speakers reading a text in synchrony are viewed as a single system, with no central locus of control. In modeling the behavior of sports fans in the Mexican wave, a simple model of the individual will suffice, if the interactions among those units are appropriately constrained (Farkas *et al.* 2002). This flexibility with respect to the domain in which lawfulness is recognized opens the door to a plurality of explanatory accounts of the structure of behavior and, equally, to a wealth of potential avenues for perturbing, influencing, and directing that behavior. Such an explanatory pluralism would not have been foreign to the pragmatic founders of the discipline of psychology, but it sits uneasily with naive scientism that expects a single truth to emerge in our study of the person.

One might contrast accounts of *control*, where the assumed causal origin of a behavior lies with a central executive, with the complementary notion of *coordination*, an emergent property that arises from the reciprocal interaction among complex systems with many redundant degrees of freedom (Cummins 2010; Kelso 1995). Where the control perspective will interpret skillful coping in a rich environment as a *predictive* (and representationally voracious) tour de force, a coordinative account will look rather for evidence of *coupling* and *entrainment* as hallmarks of the establishment of transient domains of relative autonomy across individuals. Within such domains, knowledge may, indeed, lie between persons, but this insight can only be properly shored up if the language of modular computationalism is replaced by a dynamical account, and the mentalistic vocabulary of psychology is quarantined and questioned.

Neuroscience *simpliciter* continues to make huge advances. Cognitive neuroscience must perforce build bridges between the physiology and the kind of concepts with which we describe ourselves. In leaning on the constructs of cognitive psychology, it risks failing to recognize the degree to which we collectively bring a human world into existence. Schilbach *et al.* have done us all a service by pointing to a large domain of our ignorance, what they call the “dark matter” of neuroscience. I suspect that the scale of the unknown territory may be much larger than currently appreciated. Even Descartes, in his presumed solipsistic introspection, expressed the thought “Cogito, ergo sum” in language—a means made possible only by recurrent practices of mutual coordination among individuals, and hence intersubjectively constituted in every way. Social cognition, so regarded, is not a special case, or a marginal sub-species; it is the fabric whereof human experience and behavior is woven.

## The second person in “I”-“you”-“it” triadic interactions

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**Abstract:** Second person social cognition cannot be restricted to dyadic interactions between two persons (the “I” and the “you”). Many instances of social communication are triadic, and involve a third person (the “him/her/it”), which is the object of the interaction. We discuss neuropsychological and brain imaging data showing that triadic interactions involve dedicated brain networks distinct from those of dyadic interactions.

Schilbach *et al.* defend the idea that social cognition research would benefit from studying “real-time social encounters in a truly interactive manner” (target article, Abstract). Endorsing “second-person” neuroscience would bridge the gap between the solipsist view of first person perspective, and third person social psychology. We agree with this idea, but we point out that second person studies cannot be restricted to *dyadic* relationships between two persons. Indeed, communicative or collaborative interactions always involve a third component: an object, a person, an event, or even the goal of the interaction itself. Therefore, many social interactions are intrinsically *triadic* (“I” talk to “you” about “him/her/it”).

Dyadic interactions are present very early in human infants as can be seen in the emotional domain (emotional contagion, attachment, etc.; see Hobson & Hobson 2012) and in the communicative domain (turn taking; see Kugiumutzakis 1998). They are also present in social animals in a variety of behaviors (feeding, grooming, courting, dominance/submission displays, etc.; de Waal 2005). Yet, they are distinct from triadic interactions (see our Figure 1), which emerge in humans only at the end of the first year and are considered to play a pivotal role in the development of human social cognition (Baron-Cohen 2005; Charman 2003). Impairment or delay in the acquisition of these triadic interactions has been observed in patients with autism whose social and communicative skills are severely affected (Baron-Cohen 1989). In nonhuman primates only some limited abilities for triadic interactions are observed—for example, instrumental pointing, in which the addressee is used to get an object of interest (Gómez 2005), or limited cooperation in hunting (de Waal & Malini 2010); but not communicative pointing, in which the addressee is invited to share the perceptual experience about an object (Tomasello & Carpenter 2005), or fully fledged cooperation (Rekers *et al.* 2011).

Neuropsychological studies enable the disentanglement of triadic from dyadic interactions. Heterotopagnosia is a puzzling acquired deficit which only arises in triadic situations where the target object is a human person: Patients cannot point at another person’s body parts, although they can grasp or touch them. They can also point correctly at dolls’ body parts, at videos of humans, at pieces of clothing, and at their own body, thus indicating a specific difficulty for communicative pointing directed to the physical body of another human (Cleret de Langavant *et al.* 2009; Degos *et al.* 1997; Felician *et al.* 2003). Interestingly, most of the errors consist of pointing at their own body parts, which they rationalize by stating that the body parts of

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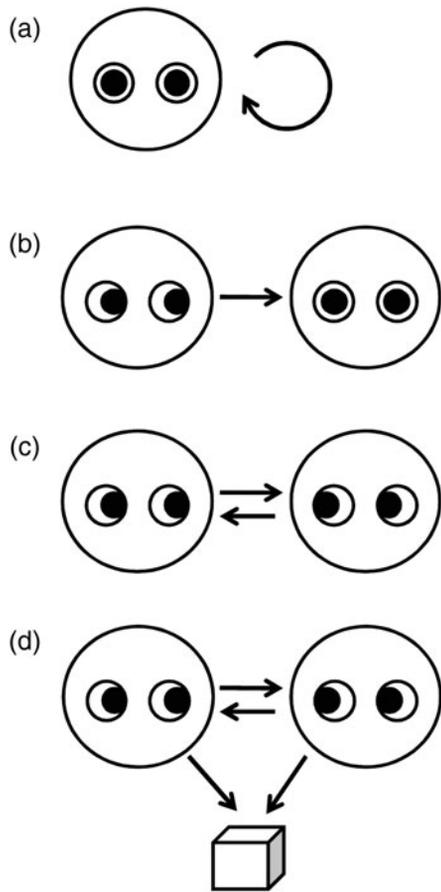


Figure 1 (Cleret de Langavant et al.). Four distinct perspectives in social cognition: (a) first person perspective, (b) third person perspective, (c) second person perspective: dyadic interaction, (d) second person perspective: triadic interaction.

the target individual occupy the same space as their own body parts.

Heterotopagnosia cannot be explained by a simple impairment of a human body representation or by other current theories in social cognition (Cleret de Langavant et al. 2009), but this syndrome reveals a crucial difference between dyadic and triadic interactions. Grasping and touching other's body parts involve a dyadic relationship between "I" and the target of the gesture. In contrast, pointing involves the triadic relationship of communication where "I" show to "you" the object "it" or the person "him/her." Comparing the kinematics of pointing at objects in both communicative and non-communicative situations in healthy participants, we showed a spatial reshaping of the pointing gesture according to the communicative interaction with a second person and to the position of the second person relative to the first person. This suggests that in communicative pointing, we use a *heterocentric* reference frame encoding the body and perspective of the second person who is addressed ("I" represent how "you" represent "this"). Such a reference is not used when pointing is dyadic or in grasping or touching. PET-scan imaging shows that this reference frame involves the right posterior superior temporal sulcus region and the right medial prefrontal cortex (Cleret de Langavant et al. 2011).

In addition, because performance in heterotopagnosia differs according to the object of the pointing (a real human or a figure of a human), we compared pointing at a living human's body, at a manikin's body, and at artifacts in healthy participants. Reaction times for pointing at artifacts or at a manikin's body parts were similar, whereas pointing at body parts of real persons was slower than pointing at artifacts. This demonstrated the specificity

of the body of other persons: Only a real person can be viewed both as a subject to communicate with ("you") or an object to communicate about ("him" or "her"). The left posterior intraparietal sulcus region was activated in healthy participants while they were pointing at another person's body (Cleret de Langavant et al. 2012). Presumably, damage in this area explains why patients with heterotopagnosia cannot consider the other person under both views ("you" and "him/her") simultaneously.

On the basis of our research on heterotopagnosia, we conclude that a *second-person* neuroscience should assess communicative/collaborative triadic interactions, as they offer a richer situation, including the switching of perspectives or frame of references between "you" and "him/her" perspectives. In a triadic interaction, the roles of the second and third persons are constantly dynamically redefined. This requirement should be taken into account in experimental designs using computerized avatars as opposed to real life participants.

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**Social affordances: Is the mirror neuron system involved?**

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**Abstract:** We question the idea that the mirror neuron system is the substrate of social affordances perception, and we suggest that most of the activity seen in the parietal and premotor cortex of the human brain is independent of mirroring activity as characterized in macaques, but rather reflects a process of one's own action specification in response to social signals.

We congratulate Schilbach et al. for raising these theoretical issues concerning the nature of social engagement. We are also enthusiastic about the re-emergence of the concept of "affordance" to characterize what is properly perceived by an engaged observer during a social interaction. We share the view that observing social *cues* (i.e., features of the environment whose function is not to affect a recipient) is qualitatively very different from processing social *signals*. Social signals are, in contrast to cues, features of the environment whose function is to *alter* a recipient's behavior and which are recognized and processed as such by the engaged observer. This theoretical shift is fundamental and we see the attempt to free social cognition from the "inferential detour" as salutary and promising. We also consider with great interest the various methodological improvements brought by Schilbach et al., and see their practical suggestions as highly relevant. However, we regret that the authors do not specify in more detail what they understand by "social affordances," and that they offer too few details about how they are perceived and processed by our cognitive apparatus. The clarification of these issues is crucial to considering the neural candidates, which might enable the perception of social affordances.

Contrary to what Schilbach and colleagues argue, we do not think that the mirror neuron system (MNS) is involved. First,

this might be the case for purely anatomical constraints: Neurons with mirror properties (MNs) only account for 17% (Gallese *et al.* 1996) of the macaque premotor (PM) and parietal neurons. Among these 17%, only 5.5% code for a strictly congruent action in the motor and the visual domain, whereas 8.6% code for two or more actions in the visual domain, and 1.3% for non-congruent actions. In humans, Mukamel *et al.* (2010) revealed that 14% of the recorded neurons in the supplementary cortex area responded to congruent observed actions, but 10% responded to non-congruent observed actions. We do not think the latter should be considered MNs. Rather, they may be categorized as “social” canonical neurons, that is, neurons that are active when foreseeing a possible social interaction (vs. interaction with an object as for canonical neurons) and preparing oneself accordingly.

There is a second reason – a functional one – why MNs would not be good candidates for the underpinning of the processing of social affordances: What is involved in the perception of social affordances is, cognitively speaking, very different from what MNs are known to do, that is, to simulate an observed motor pattern (Rizzolatti *et al.* 2001). Instead, we assume that the affordance perspective of social signals calls for the reexamination of previous findings to identify specific neural networks.

Let us first consider the notion of “social affordance.” Schilbach *et al.* define social affordance as “the possibilities for interaction provided by others” (sect. 3.1.1, para. 5). These possibilities, according to the authors, are characterized by “an activation of motor programs that could allow for interpersonal coordination of behavior” (sect. 3.1.1, para. 5). It must be clear that social signals can be considered affordances in the sense that they trigger a wide range of opportunities for actions in the observer. We, as animals, are continuously facing opportunities for action in our environment and are constantly collecting information in order to select the most relevant action from among numerous potential actions (Cisek 2007; Cisek & Kalaska 2010). This entails that brain activity during social interactions reflects this parallel processing of multiple representations of potential actions (social affordances) and their evaluation through the use of external as well as internal sensory information. Activity in the parietal cortex and connected motor regions might therefore reflect the representation of the various affordances (Cisek & Kalaska 2010).

In a recent study conducted by our team (Conty *et al.* 2012), participants faced dynamic stimuli depicting actors producing complex social signals involving gaze, a pointing gesture, and the expression of anger. We were able to show, using electroencephalography (EEG) coupled with functional magnetic resonance imaging (fMRI) that a binding of these social signals occurred in the PM as early as 200 msec after stimulus onset. Strict motor resonance (MNS) processing could not explain the activation in the PM, as anger expressions directed at an observer are perceived as a clear signals of non-affiliative intentions and are therefore less mimicked than averted anger expressions (Bourgeois & Hess 2008, Hess *et al.* 2007). We propose that activity in the PM is related to two complementary mechanisms: (1) the estimation of prior expectations about the perceived agent’s immediate intent, and (2) the specification of currently available actions for the observer to deal with in the immediate situation. Indeed, only the combination of the two could explain the highest level of activity in the PM for the highest degree of potential social interaction, that is, an angry person pointing, facing, and looking towards oneself. This activity in the PM may therefore reflect the competition between several representations of action opportunities, triggered by the ongoing social interaction, as well as the selection of an adaptive behavioral response.

In sum, we think that it is crucial to first ask whether the kind of cognitive activity that is involved in the processing of social affordances is compatible with what is conventionally thought of as the MNS, before considering all activities in the PM as mirroring processes. Second, it is important to consider regions that do not display mirroring properties – such as the amygdala (Sander

*et al.* 2003) – as fundamental in the evaluation of social signals and in the triggering of one’s own adaptive reaction. Consequently, it is reasonable to advance that the processing of social affordance involves a specific brain network, neuron populations, and mechanisms that differ (for the most part) from the MNS. Characterizing the neural specificities of the “social affordance network” beyond the MNS represents a challenging step in our understanding of the processing of social signals.

## Reciprocity between second-person neuroscience and cognitive robotics

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**Abstract:** As there is “dark matter” in the neuroscience of individuals engaged in dynamic interactions, similar dark matter is present in the domain of interaction between humans and cognitive robots. Progress in second-person neuroscience will contribute to the development of robotic cognitive systems, and such developed robotic systems will be used to test the validity of the underlying theories.

The second-person neuroscience framework presented by Schilbach *et al.* is of particular interest for researchers in the domain of cognitive robotics for two reasons that constitute a strong reciprocity between these domains. First, the “dark matter” in second-person neuroscience is also present in the domain of second-person robotics, and it is likely that advances in the neuroscience of second-person systems will contribute to robotic cognitive systems. Second, as these robot cognitive systems become increasingly advanced, they will become increasingly useful as tools in the pursuit of second-person neuroscience.

As second-person neuroscience matures, it will be able to characterize the human cognitive system so as to inform the implementation of artificial embodied systems capable of second-person cognition. Certain robot cognitive systems have primitive notions of “self” and “other” that can be revealed in mechanisms for shared planning (Dominey & Warneken 2011, Lallée *et al.* 2012). We have developed robot systems that can learn shared plans that specify the coordinated actions of self and other, and use these plans, including reversing roles. However, the underlying mechanisms are impoverished, as the robot cognitive system is somewhat spectatorial, and coupled to the other only through the succession of alternating actions in the shared plan. It is closer to the high functioning autistic who prefers to follow an explicit fixed plan, rather than adapt in real-time to open ended social interaction.

In their target article, Schilbach *et al.* outline a program for second-person neuroscience from which we can extract the following principals for second-person robot cognition:

1. The system should be motivated to socially engage. This is related to the intrinsic motivation to share intentions described in Tomasello (2009), cited in the target article.
2. This engagement is driven by the perception of social affordances.
3. Social affordances derive from the interaction dynamics of the system that is constituted by the two agents.
4. This requires that the system can perceive the other as a subject, which is more than recognizing the other as an agent. Instead, the other agent must be recognized as affording social interaction. Schilbach *et al.* stress that social interaction involves contingency between self and other. The detection of contingency is present in the earliest stages of infancy and plays a central role in

the infant's elaboration of its ecological self and its interpersonal or social self.

5. Once the system has perceived these affordances, it must engage. Crucially—what is the nature of the mechanism for engagement? Rochat (2010) importantly notes that in this context, Merleau-Ponty (1967) breaks with a “self/other” distinction, and suggests instead that one's own body perception and representation is fundamentally inseparable from, and melded with, the perception and representation of others in a process that he refers to as mutual alienation. “In the perception of others, my body and the body of others are coupled, as if performing and acting in concert” (Merleau-Ponty 1967, p. 24, translated from the French in Rochat 2010, p. 741).

6. Finally, the system must have a notion of what Schilbach et al. refer to as emotional engagement. We can consider that this is related to the intrinsic motivation to share experiences (Tomasello 2009), partially overlapping with point (1). Interestingly, the implementation of this motivation can be based on the lower-level detection of contingencies, and creating a form of internal reward for their detection. This would apply both for self-contingencies (motivating exploration) and mutual self-other contingencies, extending motivated exploration and engagement into the social domain.

As a first step toward a second-person robotics, responding to the 6 defined requirements, we can provide the cognitive system with mechanisms for contingency (correlation) detection. This can first be applied to self-contingencies that arise during development, for example, where limb motion leads to perfectly contingent vision and proprioception, allowing the system to begin to construct a self-model (Rochat & Striano 2001). This can then be gracefully extended to provide the basis for self-object, and self-other contingencies. Again, Schilbach et al. stress that social engagement and interaction relies crucially on contingent responses. Thus, as the system detects contingent responses in the other (e.g., gaze following, imitation of actions), it will construct the Merleau-Ponty mutual-relation, in which contingent relations and co-regulations form the basis for social games and norms in an extended self-other shared body schema. Such a robotic cognitive system could then be demonstrated to display child-like responses in the establishment of social interaction games, including negative emotional responses when the rules of the games are violated.

Such robotic systems will be used to validate second-person theories when tested with naïve subjects, and thereby contribute to shining light on the dark matter of second-person neuroscience. A principal advantage of robots in second-person neuroscience is that their behavior can be parametrically controlled within and between subjects. Although it is difficult to force experimental confederates to behave in controlled ways (e.g., “move your eyes but not your head”), robots can produce such behavior. In this context, we have recently studied human behavior in a second-person context during human-robot interaction (Boucher et al. 2012). The goal was to determine whether, during cooperative physical interaction, humans would exploit the gaze of their robot cooperator in order to reach more quickly to an object whose location was indeed indicated both by the robot's speech and gaze. We established that in ecological human-human interactions, naïve subjects indeed exploited gaze cues from their cooperation partner. We then implemented a human-based gaze heuristic for the oculomotor system of the robot, and demonstrated that naïve subjects benefit from robot gaze in the same way they do with human gaze (Boucher et al. 2012). Interestingly, the experiments also revealed that aspects of eye and head coordination in human gaze is less deterministic than we initially considered, and hence led to the potential refinement of the characterization of human gaze in cooperative physical interaction.

Thus, the development of second-person neuroscience as proposed by Schilbach et al. also helps to lay the groundwork for a reciprocal interaction between neuroscience and robotics, where

neuroscience helps to define the system, and robotics provides a novel tool for implementation and investigation of the emerging hypotheses.

## On projecting grammatical persons into social neurocognition: A view from linguistics

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**Abstract:** Though it draws on the grammatical metaphor of person (first, third, second) in terms of representations, Schilbach et al.'s target article does not consider an orthogonal line of evidence for the centrality of interaction to social cognition: the many grammatical phenomena, some widespread cross-linguistically and some only being discovered, which are geared to supporting real-time interaction. My commentary reviews these, and the contribution linguistic evidence can make to a fuller account of social cognition.

Schilbach et al.'s stimulating target article, proposing the centrality of real-time encounters to social cognition, tallies with work from the field of linguistics that exposes the intricacy of spoken interaction and assigns it a dominant role in shaping both social cognition and overall language structure (Enfield & Levinson 2006). In this commentary, I indicate some grammatical features of particular interest for social cognition in the hope of developing more subtle overall hypotheses about interactive social cognition as played out in verbal interaction.

Any comprehensive theory of social cognition, in neuroscience as in linguistics, obviously needs to draw on third-, first-, and second-person elements. With regard to the third-person, the episodic side of this concerns how languages characterize events: grammatical categories encoding who benefits from the event, how obligations are created, whether actions are volitional, and whether agents achieve their goals. Additionally, many languages grammatically encode more durable information about social relationships: kinship relations (Evans 2003) or different types of possession and group affiliations relevant to social reasoning.

With regard to first-person accounts, the empathetic representation of others' experiences, beliefs, and intentions—staple theory of mind—is enabled by many grammatical devices, including complement-taking attitude operators (*John believes that ...*), and constructions which represent beliefs and intentions as (fictitiously) quoted speech: “he plans/wants to go the river” becomes “he ‘I will go to the river’ saying-does” in many Papuan languages (Reesink 1993). Of particular interest here, given that the representation of others' psychological states is mediated and hypothetical, so hence never truly “first person,” are the many languages which have evolved means of representing the mental worlds of others in a way that simultaneously depicts them through two person-perspectives at once (Evans 2006), such as the “logophoric pronouns” in many West African languages, which present a third person's first-person perspective.

Though the grammar-derived metaphor of person categories employed by Schilbach et al. is useful and should generate fertile new research angles, as we pass to the second person we note one caveat where the European-grammar-derived categories might lead us astray. For many of the phenomena in Schilbach et al.'s article, we are really dealing here with the interaction between two participants—of a first and a second person—rather than simply of a second person per se, except in the special case covered in section 3.1.1 under the rubric of “Being addressed as you.”<sup>1</sup> Now many non-Indo-European languages have four person categories, not three, adding a “first-person

inclusive,” to denote the union of speaker and addressee. A more precise projection of grammatical metaphors would help draw our attention to possible differences between truly second-person and first-person inclusive phenomena in speaker-addressee interaction.

Languages are abundantly sensitive to the complexities of interpersonal interaction, which requires the simultaneous conjuring of: (a) alternating roles of two people as speaker and addressee, whereby “*I* becomes *you* in the address of the one who in turn designates himself as *I*” (Benveniste 1971, pp. 224–25); (b) footing between participants, such as intimacy or formality conditioning the choice between pronouns like *du* or *Sie*; (c) management of mutual attention; and (d) the dynamics that follow from asymmetries in who knows what. I focus below on just (c) and (d).

Regarding (c), a phenomenon only beginning to come to the attention of linguists, is the category of *engagement*, which encodes speaker’s assessments of how far the hearer’s attention is currently locked in with their own. This can apply to either events or entities. In the Colombian language Andoke (Landaburu 2007) the choice of grammatical auxiliary encodes whether or not the speaker judges that the addressee is attending to the event being described. In Turkish (Özyürek & Kita, n.d., unpublished manuscript) there is a three-term demonstrative set: *bu* versus *o*, like “this” versus “that,” encode close versus far from speaker in situations where joint attention is already established, but there is an extra term *şu* reserved for situations where joint attention is still being established.

Regarding (d), knowledge asymmetries between speaker and hearer – Heritage’s (2012) “epistemic gradient” – are a potent driver of interactive cognitive coordination, realized most centrally through what Karcevski (1941) called “ignorative-deictic” systems. This typically pairs a question word (*where?* *when?*) with a deictic response (*there!* *then!*) to adjust knowledge representations during interaction. As this English example demonstrates, many languages exhibit tight formal resemblances between the “ignorative” ( $\approx$  interrogative) and “deictic” forms. In English, the pairings are limited (there is no rhyming deictic counterpart of *who* or *which*). But there are other languages, such as Japanese and Tamil, where perfect formal proportions run through extensive systems organized around different epistemic domains (including many – like “in which manner,” “which side” – that are not obviously lexicalized in English). Japanese is particularly informative here, because its deictic series regularly opposes three values: near the speaker (*k*-initial, e.g., *kore* “this one”), near the addressee (*s*-initial: *sore* “that one near you”) and near neither (*a*-initial: *are* “that one [near neither of us]). We do not yet know if this shapes different attentional strategies in English and Japanese demonstrative use.

Some epistemic asymmetries reflect the difference between what is subjectively knowable (e.g., “feel lonely”) and what can be known by observation (e.g., give outward signs of feeling lonely). Many languages, for example, Japanese, employ different grammatical constructions for these two types. Interestingly, as interactants pass from statement (“I am lonely”) to question (“Are you lonely?”), the locus of “subjective authority” is passed to the addressee, sanctioning the use of the basic “private predicate” form in the second person (and now no longer applicable to the first).

Ultimately we must seek a model of social cognition that is equally informed by neuroscience and by linguistics. Studies of diverse grammatical systems and how they are used have the advantage of drawing on the variety of cognitively congenial systems evolved by different communities through time and – by hypothesis – potentially reconfiguring the brains of different language-speakers in subtly varying ways, which should form the subject matter for a second-generation of second-person neuroscience that includes interaction with language structure, as well as interaction with addressees.

#### NOTE

1. See Wechsler (2010) for a synthesis of linguistic observations regarding the issue of self-ascription (i.e., who is the “self” addressed by “you”).

## From synthetic modeling of social interaction to dynamic theories of brain–body–environment–body–brain systems

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**Abstract:** Synthetic approaches to social interaction support the development of a second-person neuroscience. Agent-based models and psychological experiments can be related in a mutually informing manner. Models have the advantage of making the nonlinear brain–body–environment–body–brain system as a whole accessible to analysis by dynamical systems theory. We highlight some general principles of how social interaction can partially constitute an individual’s behavior.

We agree with Schilbach *et al.* that the neuroscience of sociality should be enriched by a better understanding of the constitutive role of social interaction. An important challenge faced by the development of a second-person neuroscience is to devise new concepts and methods that can adequately capture and explain its complex dynamics.

From a dynamical perspective, an agent’s behavior is an emergent property of the brain–body–environment nonlinear system (Beer 2000). The parametric coupling between subsystems (i.e., its brain, body, and environment) constitutes one encompassing system, and it is only in this holistic context that the agent’s behavior can be distinguished as such. The same applies to social behavior among several agents. In the case when the current environment of an agent *A* includes another agent *B*, and vice versa, their mutual nonlinear coupling entails the temporary constitution of a multi-agent system (Froese & Di Paolo 2011a). On this view, social interaction is one kind of process in an irreducible “brain–body–environment–body–brain” system as a whole, as shown in Figure 1.

One insight that follows from this approach is that uni-directionally coupled agents (i.e., *A* is a detached observer of *B*) and mutually coupled agents (i.e., *A* and *B* interact with each other) are fundamentally different kinds of systems. In the former situation, common in the literature but hardly deserving to be called “social,” *B* is merely an independent parameter of *A*’s environment. In the latter situation, the nonlinear coupling between *A* and *B* results in emergent structures of the interaction process that provide top-down modulation of the two agents’ behavior. Therefore, the effective degrees of freedom of an agent involved in social interaction will continually be modified. This provides a basic dynamical account of the intuition expressed by Schilbach *et al.* that “social cognition is fundamentally different when we are in interaction with others rather than merely observing them” (target article, Abstract). Furthermore, we do not need to assume any specialized neural modules to explain such qualitative difference in brain activity, because it is the interaction process itself that constitutes the systemic difference.

As a case in point, this insight allows us to clearly distinguish between the two situations of “double TV monitor” experiments (Murray & Trevarthen 1985): When an infant is interacting with its mother via the live video transmission, there is one kind of

Agent A interacting with Agent B

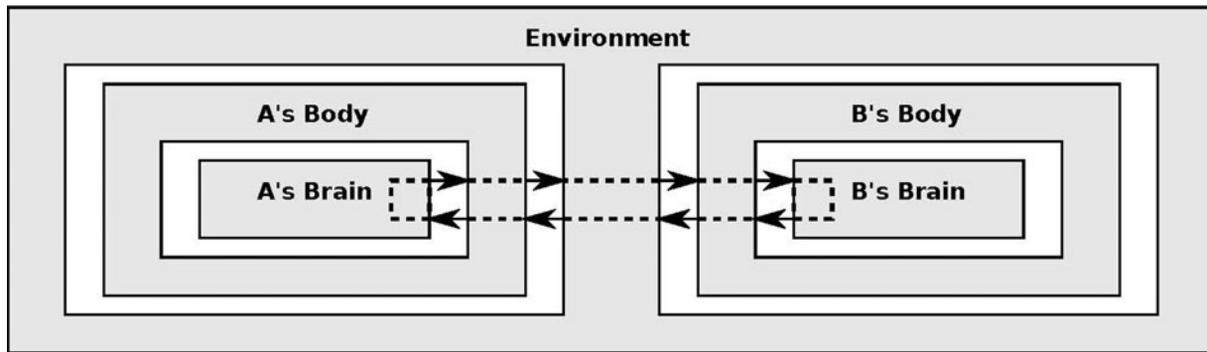


Figure 1 (Froese et al.). Illustration of a dynamical perspective on the interaction between two situated, embodied agents. Following the approach advocated by Beer (2000), an agent's nervous system (abbreviated as "brain"), body, and environment are each conceptualized as dynamical systems that are parametrically coupled. Here we extend this approach to show that when agent A is interacting with agent B their mutual coupling constitutes a brain–body–environment–body–brain system. Social interaction is partially constitutive of social cognition: An individual agent's social behavior depends on the coupling of all the subsystems and cannot properly be attributed to any one component in isolation from the others.

overall system; when it is watching the mother via video playback, there is a qualitatively different kind of system. This systemic difference between the two situations allows us to explain qualitative changes in the infant's behavior in a relational manner, since the behavior is either part of a social interaction or it is not. Various models of this experimental setup have repeatedly confirmed that the removal of mutual responsiveness, that is, social contingency, through playback will lead to qualitative changes in an agent's behavior, even without the presence of specialized neural modules inside of the agent's brain (Froese & Di Paolo 2008; Froese & Fuchs 2012; Iizuka & Di Paolo 2007; Ikegami & Iizuka 2007).

Moreover, only mutually coupled systems offer the possibility that the behaviors of the agents become entrained in such a way that the social interaction process is conditioned by its own self-sustaining organization. The implications of such autonomous interaction dynamics have been much discussed by the enactive approach to social cognition (De Jaegher et al. 2010). Various models have investigated the dynamical underpinnings of autonomous interaction processes, and illustrated how they enable and constrain individual behavior (De Jaegher & Froese 2009). It appears that one important explanatory factor is the increased stability of mutually responsive engagement (Di Paolo et al. 2008), which can in some cases make it easier for agents to jointly achieve tasks, but in other cases makes it more difficult for them to escape from the constraints of their mutual entrainment (Froese & Di Paolo 2010).

The systemic differences between detached social observation and mutual social interaction are even more pronounced when we consider that social interaction is normally not merely about mutual coupling, like the passive exchange of heat among commuters standing inside a packed metro. Social interaction is about coordinating to devise and realize shared goals (Froese & Di Paolo 2011a). One agent's behavior creates an opening for a joint action that can only be realized through the appropriate behavior of another agent. For instance, the act of giving a present to someone is constituted by one's giving as well as the other's receiving (without the other's corresponding act of acceptance the necessary conditions of one's giving cannot be satisfied).

A special property of social coordination is that it enables flexible renegotiation of an interaction process; robotic and modeling research has shown that such renegotiations can emerge spontaneously from the interaction dynamics (Froese & Di Paolo 2011b; Quinn et al. 2003). One reason for this flexibility is that agents are able to co-regulate their internal dynamics via the interaction process (Froese & Fuchs 2012; Froese et al. 2012). They

take advantage of the fact that they constitute one complex system, and that the organization of the state-space of each brain component is partially dependent on the organization of the state-space of the whole brain–body–environment–body–brain system.

Finally, we emphasize that this dynamical systems approach is suitable for taking the first-person perspective into account. These models can supplement traditional methods of phenomenology (Froese & Gallagher 2010), and they serve as a bridge between second-person neuroscience and phenomenological accounts of intersubjectivity (Froese & Fuchs 2012; Froese & Gallagher 2012).

### The brain as part of an enactive system

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**Abstract:** The notion of an enactive system requires thinking about the brain in a way that is different from the standard computational-representational models. In evolutionary terms, the brain does what it does and is the way that it is, across some scale of variations, because it is part of a living body with hands that can reach and grasp in certain limited ways, eyes structured to focus, an autonomic system, an upright posture, etc. coping with specific kinds of environments, and with other people. Changes to any of the bodily, environmental, or intersubjective conditions elicit responses from the system as a whole. On this view, rather than representing or computing information, the brain is better conceived as participating in the action.

We applaud Schilbach et al. on the long overdue venture to define a second-person neuroscience and to improve the neuroscientific study of social cognition. At the same time, we see an unresolved

tension in their account. Specifically, their questions about how the brain functions during interaction continue to reflect the conservative nature of “normal science” (in the Kuhnian sense), invoking classical computational models, representationalism, localization of function, and so forth. Yet, in proposing an enactive interpretation of the mirror neuron system (MNS), Schilbach *et al.* point beyond this orthodox framework to the possibility of rethinking not just the neural correlates of social cognition, but the very notion of neural correlate, and how the brain itself works.

The enactive interpretation is not simply a reinterpretation of what happens extra-neurally, out in the intersubjective world of action where we anticipate and respond to social affordances. More than this, it suggests a different way of conceiving brain function, specifically in nonrepresentational, integrative and dynamical terms (see, e.g., Hutto & Myin 2013). Although Schilbach *et al.* point clearly in the direction of ecologically valid enactive designs for investigating social interaction, they constantly fall back to the language of neural correlates, singling out measurable brain activation as the most relevant *explanans*. This vestige of neurocentrism is at odds with the path-breaking potential of a second-person neuroscience.

Functional magnetic resonance imaging (fMRI) technology goes hand in hand with orthodox computational models. Standard use of fMRI provides an excellent tool to answer precisely the kinds of questions that can be asked within this approach. Yet, at the limits of this science, a variety of studies challenge accepted views about anatomical and functional segregation (e.g., Shackman *et al.* 2011; Shuler & Bear 2006), the adequacy of short-term task-based fMRI experiments to provide an adequate conception of brain function (Gonzalez-Castillo *et al.* 2012), and individual differences in Blood-Oxygen-Level-Dependent (BOLD) contrasts in subjects performing the same cognitive task (Miller *et al.* 2012). Such studies point to embodied phenomena (e.g., pain, emotion, hedonic aspects) that are not appropriately characterized in representational terms but are dynamically integrated with their central elaboration.

Consider also recent challenges to the idea that so-called mentalizing areas (cortical midline structures) are dedicated to any one function. Are such areas activated for mindreading (Frith & Frith 2008; Vogeley *et al.* 2001), or folk psychological narrative (Perner *et al.* 2006; Saxe & Kanwisher 2003); a default mode (e.g., Raichle *et al.* 2001), or other functions such as autobiographical memory, navigation, and future planning (see Buckner & Carroll 2007; Spreng *et al.* 2008); or *self*-related tasks (Northoff & Bermpohl 2004); or, more general reflective problem-solving (Legrand & Ruby 2009)? Or are they trained up for joint attention in social interaction, as Schilbach *et al.* suggest; or all of the above and others yet to be discovered?

Neuroscience, like any other discipline, works with limited vocabularies and limited tools in a limited theoretical space. The technical limitations are, as Schilbach *et al.* make clear, even more obvious in the study of social cognition. In a scanner, two is already a crowd and three is impossible (also see Dumas 2011). In contrast to the computational/representational orthodoxy of fMRI, the enactive approach not only adds extra-neural externalities and interaction to the explanatory mix, but also redefines the role of the brain – the way the brain actually works in this mix – moving away from any idea of social cognition as a meeting of brains (Schilbach *et al.*'s Fig. 1).

The explanatory unit of social interaction is not the brain, or even two (or more) brains, but a dynamic relation between *organisms*, which include brains, but also their own structural features that enable specific perception-action loops involving social and physical environments, which in turn effect statistical regularities that shape the structure of the nervous system (Gallagher 2005). The question is, what do brains do in the complex and dynamic mix of interactions that involve moving, gesturing, expressive bodies, with eyes and faces and hands and voices; bodies that are gendered and raced, and dressed to attract, or to work or play; bodies that incorporate artifacts, tools, and technologies,

that are situated in various physical environments, and defined by diverse social roles and institutional practices?

The answer is that the brain participates in a system, along with eyes and face and hands and voice, and so on, that enactively anticipates and responds to its environment. How an agent responds will depend to some degree on the overall dynamical state of the brain and the various, specific and relevant neuronal processes that have been attuned by evolutionary pressures, but also by personal experiences (the historicity, as Schilbach *et al.* put it) of the agent (see Slaby *et al.* [in press] for evidence of this in depression). How an agent responds also depends on the worldly and intentional circumstances of the agent, the bodily skills and habits she has formed, her physical condition, a variety of so-called extraneous factors (see, e.g., Danziger *et al.* 2011), the person(s) with whom she is interacting, and what the other person may expect in terms of normative standards stemming from communal and institutional practices.

When a person turns her gaze towards you or reaches out to touch you, what happens is not just that her visual and motor cortices are activated; what happens also includes her eye movements and the movements of her arm that require peripheral (proprioceptive) and vestibular involvement. None of these things happen, however, if *you* are not there, and whatever happens next depends on your response, which involves your eye movements, facial expression, and what you do with your hands – which further involve peripheral and central processes that may be controlled more by *her* than by you, and perhaps by the fact that you are in a dance hall and dressed to the hilt. There is no denying that the brain has a role to play, but an explanation of what is going on here can never be cast solely in terms of neurons or mental states. If we are looking for an explanation of social cognition and interaction – the kind of things that happen *in the world* rather than in the brain, or scanner, or lab – then, as Schilbach *et al.* suggest, we need to employ a multiplicity of methods which includes neuroscience as one among many.

## Why not the first-person plural in social cognition?

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**Abstract:** Through the mental alignment that sustains social interactions, the minds of individuals are shared. One interpretation of shared intentionality involves the ability of individuals to perceive features of the action scene from the perspective of the group (the “*we*-mode”). This first-person plural approach in social cognition is distinct from and preferable to the second-person approach proposed in the target article.

Individualism is an entrenched and implicit assumption of a good number of mind and society studies. The role of the individual in guiding reflection about the nature of social cognition is traditionally presented under the view that interpersonal understanding can be achieved by passive, individual agents who process the relevant information about other agents “from the inside,” by simply observing them in action. It is the great merit of Schilbach *et al.*'s target article to have paved the way for a significant alternative to observational theories of social cognition based on modes of cognition other than the individual. Yet a central constituent of this alternative, the procedural dimension to social understanding, is construed along argumentative lines that raise several concerns. One line in particular, which is related to the way in which mental states are *shared* in relational dynamics, relies on

assumptions that might well turn out to be at odds with some aspects of the authors' proposal.

The target article discusses the concept of shared mental states mainly in the context of the empirical literature on joint attention, which in turn draws on philosophical work about collective intentionality (Tomasello 2009; Gallotti 2012). On one possible reading, a state of shared intentionality can be described as one in which individual agents think and act in the first person-plural (“we”), meaning in an irreducibly collective mode of cognition called the “we-mode” (Gallotti & Frith 2013). Hence, joint attention is, in the words of the target article, the experience of “attending to something together with someone and being aware that ‘we both’ are attending” (sect. 3.1.2, para. 2). This sense of “we-ness” evidently echoes the sort of directedness towards each other’s mind (“you-and-me”) that captures the gist of the second-person perspective. But the commonality is not merely conceptual. Both approaches direct philosophical and scientific attention to the sort of meeting of minds that is claimed to be characteristic of awareness of other minds. So the target article goes further in suggesting that the commonality is of substance and purpose: cognizing in the first-person plural (*we*) can be subsumed under the second-person label (*you*).

It is certainly the case that acting together produces a form of mental “attunement” that could not be attained if one’s action was conceived of in abstraction, or in isolation, from that of others. But the point is to specify the exact aspect of real-time interaction that individuates the relevant meeting of minds, and this is where the authors’ suggestion should be resisted on motivational and conceptual grounds. With regard to the motive, *we*-mode theorists traditionally postulate first-person plural representations (“*we*-representations”) to gain a better understanding of phenomena of sociality that could only be partially explained by representations which specify features of actions solely from the perspective of the first-person thinking and experiencing subject “*I*”. For example, research in group behavior shows that team-reasoners have a broader grasp of the action scene, which therefore narrows the range of possible interpretations of each player’s behavior, than a purely distributive, that is, individualistic, account of strategic interaction would achieve (Bacharach 2006). This is because individuals understand the action scene from a shared point of view, namely one that maps their own and the others’ action planning onto a group perspective (Tsai et al. 2011). Of course, people acting as a group see things differently from people acting as single agents. But the point of the *we*-mode is not that ongoing interaction plays a constitutive role for social knowing; it is that *individuals* are capable of thinking of themselves and the others as plural rather than single subjects of thought and agency. This move makes an important step forward from individualistic approaches to social cognition, but it certainly is not anti-individualistic enough to meet the standards of the second-person approach. Neither is it constrained by the anti-mechanistic spirit of the target article, because *we*-mode theorists aim to develop a causal-psychological account of the cognitive processes involved in group-thinking. It is this constraint that raises further conceptual doubts about the similarity of the *you*- and the *we*-mode approach.

In analyses of shared intentionality, the concept of *we*-ness has considerable explanatory power. The concept offers a vivid grasp of what it means to mutually understand each other and interact, precisely in terms of the individual agents’ perceiving themselves as a “*we*” doing things together. The current challenge for research in shared intentionality is to look down at low-level parts of the architecture of the brain that might instantiate the kind of functions identified as processes of *we*-thinking. Some of these processes are likely to be implicit: Although the experience of *we*-ness can rise to the level of consciousness, it need not do so (Frith 2012a). That is, people do not have to be in the mental state of attending to themselves as members of the same group for mutual understanding and interaction to occur. If this characterization of the *we*-mode turned out to be robust enough, then

this would be, at least partly, consistent with the claim of second-person theorists that no discrete form of psychological awareness needs to be internally generated and introspected upon as a prerequisite of social cognition. However, if *no* mechanism whatsoever is postulated for the idea that knowledge of other minds consists in directly perceiving *your* mind towards *me*, then something important seems to be left out of the picture. What is the exact process whereby experience of reciprocity alone secures full understanding of minds? Furthermore, if one succeeded in answering this question without reference to individual mechanisms, what would the advantage of this explanatory effort be after all? These are important questions for critically engaging the two literatures on the *we*- and the *you*-mode. They are especially important for generating the appropriate operationalization of the relevant theoretical constructs which will be so crucial for future experimental studies.

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### Talking to each other and talking together: Joint language tasks and degrees of interactivity

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**Abstract:** A second-person perspective in neuroscience is particularly appropriate for the study of communication. We describe how the investigation of joint language tasks can contribute to our understanding of the mechanisms underlying interaction.

Schilbach et al. make a powerful case that researchers should study social cognition and social neuroscience using interactive rather than observational paradigms. In this commentary, we claim that the most important basis for interaction is communication (where the interlocutors know that interaction is necessary for them to achieve their goal). As communication typically involves language, it is especially important that the language sciences assume a second-person perspective.

Perhaps surprisingly, the vast majority of work on language has considered isolated examples of production (e.g., naming pictures) or comprehension (e.g., reading texts), whether using behavioral or neuroscientific methods (e.g., Traxler 2012). But it is undeniable that dialogue is the basic site for language use, in both developmental and evolutionary terms (Clark 1996; Pickering & Garrod 2004). It is therefore the right time to conduct extensive “second-person” research in language use.

The little experimental work on dialogue has tended to involve two interlocutors jointly performing a task (e.g., Clark & Wilkes-Gibbs 1986) and indicates the importance of feedback on communicative success (e.g., Bavelas et al. 2000). There is clear evidence of entrainment, at levels from syntax (Branigan et al. 2000) to speech rate (Giles et al. 1991). Recent work has studied brain activation during speaking and listening (Menenti et al. 2011) and showed that communicative success correlates with the extent to which activity in the listener’s brain anticipates activity in corresponding areas of the speaker’s brain (Stephens et al. 2010).

But we believe that greater understanding is likely to result from studies of moment-by-moment processing in pairs of participants. Pickering and Garrod (2013) have argued that highly

interactive uses of language in dialogue are rendered possible by underlying (predictive) mechanisms common to language production and comprehension. To test accounts such as this, we propose the use of joint language tasks in a way that is analogous to testing whether co-actors form representations of each other's actions (i.e., of their own performed actions and of another's observed actions; Sebanz *et al.* 2006). Such tasks should of course involve two speakers "talking together"; however, we argue they need not necessarily involve fully-fledged interaction (i.e., "talking to each other").

One way of "talking together," for example, is talking at the same time. Albeit rare in natural conversations, it is theoretically interesting to investigate what happens when production and comprehension occur simultaneously. If the two share mechanisms, one would sometimes expect interference when they are engaged concurrently (Gambi & Pickering 2011). Another way of "talking together" is completing each other's utterances. Paradigms in which speakers are asked to jointly produce a sentence allow tests of the hypothesis that, given shared mechanisms between production and comprehension, coordinating with others is similar to coordinating with oneself. For example, timing in speech is affected by properties of upcoming linguistic elements (e.g., Griffin 2003). One could therefore ask whether it is also affected by the properties of an expected continuation by somebody other than the current speaker.

Although such tasks are unlike natural dialogue in many ways, they allow us to test the role of predictions about what another speaker is about to say. Thus, they can investigate questions like: How do beliefs about one's interlocutor influence anticipatory adaptation to their upcoming utterances? What is the minimum degree of interaction necessary for such beliefs to be taken into account in the first place? To what extent are beliefs modified as a result of the interaction? In addition, such tasks allow tight experimental control and therefore permit a meaningful comparison between "isolated talking" and "talking together," since in natural conversations it is much harder to disentangle the relative contribution of beliefs about one's partner from the direct influence of what they say or do during the interaction itself.

The latter point also relates to the interesting observation that there are various ways of entering a joint activity, with explicit commitments to shared goals and seamlessly automatic entrainment playing different roles at different times (Tollefsen & Dale 2012). Interestingly, the gaze coordination task proposed by Schilbach *et al.* could be used both in the investigation of how low-level entrainment influences the perception of being in a joint activity and in the study of how higher-level beliefs influence interactional dynamics (sect. 3.2.1). Similarly, with the joint sentence production task mentioned above, it would be possible to investigate how the degree of achieved coordination influences beliefs and feelings towards one's interlocutor, as well as the extent to which previous knowledge about one's interlocutor and their utterances affects the amount of coordination attained.

Finally, communication is best seen as existing on a continuum from monologue at one end to truly interactive dialogue at the other. In a casual conversation between intimates, the "flow" from one speaker to the other is likely to be seamless and the conversation is internally managed (i.e., the participants control the nature of the interaction). In a more formal situation such as an interview, a large-group discussion, or an audience attending to a story, the opportunities to interact are limited and are constrained by social rules.

Linguistic communication, therefore, represents an ideal case for the study of what it means to interact, because it allows researchers to compare behavior or neural activity in settings involving different degrees of interactivity. The study of communication is therefore likely to be very fruitful in the development of a second-person perspective in the cognitive sciences and neurosciences.

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## Brain games: Toward a neuroecology of social behavior

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**Abstract:** In the target article, Schilbach *et al.* defend a "second-person neuroscience" perspective that focuses on the neural basis of social cognition during live, ongoing interactions between individuals. We argue that a second-person neuroscience would benefit from formal approaches borrowed from economics and behavioral ecology and that it should be extended to social interactions in nonhuman animals.

The "second-person neuroscience" proposed by Schilbach *et al.* in the target article proffers the intriguing idea that social cognition during real-time interactions with another individual may be fundamentally different from passive observations of another's actions. Understanding the contribution of neural processes to ongoing interactions with complex beings is a fascinating research direction, with potential implications for the treatment of disorders attended by social deficits, as well as for ethics and public policy.

Several decades of neuroscientific research have sketched out the neural circuits that may translate perceptual information about other individuals into purposeful action. Specifically, regions of the human and nonhuman primate brain including the superior temporal sulcus and fusiform face area contribute to social identification (Tsao *et al.* 2008). The ventromedial prefrontal cortex, orbitofrontal cortex, and striatum appear to play a role in translating knowledge of others into motivational signals (Azzi *et al.* 2012; Burke *et al.* 2010; Cooper *et al.* 2010). The anterior cingulate cortex and fronto-insular cortex contribute to empathy and other-regarding cognition (Chang *et al.* 2013; Decety 2010; Gu *et al.* 2010). The so-called mentalizing and mirroring networks appear to participate in action and intention understanding (Becchio *et al.* 2012; Rizzolatti & Sinigaglia 2010). Circuits connecting these areas could translate social perceptual information into appropriate actions via decision-making mechanisms (Baumgartner *et al.* 2009, 2011; Knoch *et al.* 2009).

To better understand the neural mechanisms underlying social cognition, we propose that social neuroscience needs to ground its predictions and hypotheses in a formal framework such as that provided by behavioral game theory (Dorris & Glimcher 2004; Gintis 2009; Kosfeld *et al.* 2005; Lee 2008; Platt & Glimcher 1999; Tomlin *et al.* 2006). Schilbach *et al.* criticize game theoretical approaches for not recreating the dynamics of everyday real-life social encounters, but this common opposition has been rebutted before (Gintis 2009). Game theoretical frameworks are general and open, allowing formal delineation of specific hypotheses while not imposing restrictions on the behaviors that are being described. Formal approaches borrowed from economics, game theory, and behavioral ecology have been extremely useful in describing decisions in dynamic foraging or social environments (Chang *et al.* 2011; Hayden *et al.* 2011; Lee 2008; Sugrue *et al.* 2004).

These approaches can be extended to describe the dynamics of interacting individuals, with several advantages. First, they allow us to generate empirically testable and mathematically formalizable predictions about the neural mechanisms that could underlie decisions in complex social environments. Second, they allow for comparative analyses of decision processes in humans and other animals with respect to the demands placed on them in specific physical and social environments (Heilbronner *et al.* 2008; Kacelnik & Bateson 1996; Stephens *et al.* 2002).

Schilbach *et al.* also raise the concern that classical game theory paradigms involve mainly one-shot interactions or turn-taking. Although this structure is often used for simplicity, we contend that continuous interactions in interactive games can also be effectively described using a similar theoretical framework (Braun *et al.* 2009; Debreu 1952). Such mathematical tools would help translate some of the intuitive aspects of Schilbach *et al.*'s approach into concrete experimental predictions.

Second-person neuroscience would also benefit from broadening its inquiry to the interactions of nonhuman animals (Chang *et al.* 2011; Fujii *et al.* 2007; Washburn *et al.* 1990). Social complexity appears to have favored the evolution of higher social cognition in animals that have brains similar to ours, like macaques (Azzi *et al.* 2012; Barsalou, 2005; Chang *et al.* 2012; Rudebeck *et al.* 2006; Tsao *et al.* 2008) and in animals that have very different brains as well, like scrub jays and rooks (Bird & Emery 2010; Emery & Clayton 2001). We know from research in macaques, sheep, and mice that social cognition in mammals appears to rely on neural circuits that are similar, and perhaps homologous, to those in humans (Azzi *et al.* 2012; Barsalou, 2005; Jeon *et al.* 2010; Rudebeck *et al.* 2006; Sanchez-Andrade & Kendrick 2009; Tsao *et al.* 2008). One possible explanation is that we inherited those circuits from a common ancestor that possessed some level of social complexity. Alternatively, similar constraints applying to neural circuits could also have caused them to evolve in similar ways to support similar functions. How such functions are accomplished by neural circuits in animals with brains that are very different from our own—such as birds—remains an open question.

We agree with Schilbach *et al.* that studying the neural processes mediating live interaction between real agents is crucial for the maturation of social neuroscience as a discipline. What we propose is to supplement this approach with formal game theory and value-based analysis of preferences in humans and nonhuman animals. In our lab, for example, we study pairs of monkeys interacting both in economical and interactive games (Chang *et al.* 2011; Chang *et al.* 2013). Estimating preferences allows us to quantify how much monkeys value certain options (e.g., giving juice to another monkey). Game theory will allow us to generate predictions of the equilibriums that could develop over time between two interacting individuals (see Braun *et al.* 2009). Understanding the neural processes that underlie social cognition in such animals could powerfully inform our understanding of the evolutionary origins of our own social abilities.

## Second person neuroscience needs theories as well as methods

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**Abstract:** Advancing second-person neuroscience will need strong theories, as well as the new methods detailed by Schilbach *et al.* I assess

computational theories, enactive theories, and cognitive/information processing theories, and argue that information processing approaches have an important role to play in second-person neuroscience. They provide the closest link to brain imaging and can give important insights into social behaviour.

Schilbach *et al.* make a strong case that studying human social behaviour requires more than our traditional “isolation paradigms.” They detail a number of methods which will allow the neuroscientists of the future to study social interaction in a more meaningful way. They also suggest that new theoretical approaches are needed, going beyond traditional cognitive theories. However, they dedicate much less space to specifying what these new theories should be. In this commentary, I would like to reiterate the need for strong theories to drive forward the field of second-person neuroscience. Such theories must be clearly specified so that other researchers can test them, and must be falsifiable because theories that accept all data do not make strong predictions.

Here I consider three possible categories of theories drawn from different research traditions: computational models, dynamical systems, and cognitive models. I suggest that cognitive/information-processing models remain the most promising, but that all three approaches may be able to converge.

First, advances in the non-social domains of reinforcement learning and motor control have led to computational models of social interaction. Such models often use tasks or games derived from game-theory in which people interact within a set of rules. Impressive localisation of specific computational parameters in the brain has been possible with these models (Behrens *et al.* 2009; Hampton *et al.* 2008; Tomlin *et al.* 2006). Other related approaches include adapting motor control models to control not just physical objects (e.g., a tennis racket), but also social objects (e.g., another person) (Wolpert *et al.* 2003). These computational approaches are very powerful in the cases where the model can be specified. However, a current limitation is that these models are only applied to abstract, rule-bound contexts (e.g., iterated trust games). Such tasks are somewhat artificial and lack many of the behavioural cues (eye gaze, emotion, etc.) of real social interactions.

Second, research derived from ecological psychology and dynamical systems has led to an enactive approach to social neuroscience (Thompson 2007). This approach rejects traditional cognitive models, together with ideas of symbolic information processing and representation. Instead, it relies on dynamical systems (Port & van Gelder 1995; Thelen & Smith 1996). A key idea is that social cognition exists in the interactions between agents rather than in the information processing within the head of a single agent (De Jaegher *et al.* 2010). The target article endorses these approaches, and they seem particularly useful in thinking about infant development. However, there seems to be some tension between the claims of the strong enactivist models, and the neuroimaging method, which remains routed in studying activation within one brain at a time. This is clear in Figure 1 of the target article, which assumes localised information processing systems within each brain as the originators of the dynamic social interaction.

These diagrams of brain systems seem more compatible with a third approach, that of embodied information processing models. This type of model emphasises the overlap of motor, proprioceptive, linguistic and affective information processing streams (Prinz 2005). It thus rejects the strict modularisation of Fodor but retains the cognitive idea that the brain is an information processing device and that we can localise specific types of processing to specific areas of cortex. Such information processing models have in the past been used to describe performance on “spectatorial” tasks and in contexts without dynamics. However, this does not mean that they should always be used in this way.

An example of a more socially engaged information processing model is the STORM (social top-down response modulation) model (Wang & Hamilton 2012). This is based on the idea the

human brain contains a visuomotor processing stream (Cisek & Kalaska 2010) embedded within parietal and premotor cortex. This visuomotor stream is called the perception–behaviour expressway in social psychology (Dijksterhuis & Bargh 2001) and is also present in ideomotor theories of action (Prinz 2005). It is likely to incorporate the “human mirror neuron system” and its behaviour is almost certainly determined by associative learning over the lifetime (Heyes 2011). The central claim of the STORM theory is that information processing within the visuomotor stream is subtly and dynamically modulated by other social brain systems. For example, the tendency to spontaneously mimic other people is rapidly modulated by eye contact signals (Wang *et al.* 2010), and this modulation is implemented by processing in medial prefrontal cortex and enhanced connections from medial prefrontal cortex to superior temporal sulcus (STS) (Wang *et al.* 2011). Thus, key regions of the social brain (medial prefrontal cortex, mPFC) regulate information processing in the visuomotor stream (superior temporal sulcus, STS). In other contexts, other social brain systems such as those linked to reward and motivational processing are also likely to modulate the basic visuomotor stream. The key predictions of this model are that during dynamic interactions top-down influences on the visuomotor stream should be clearly visible. However, upward information flow from motor systems to mentalising systems (as suggested by simulation models; Gallese & Sinigaglia 2011) should be less prominent. Such predictions can be tested behaviourally or by means of neuroimaging combined with dynamic causal modelling (Friston *et al.* 2003).

It is not yet clear which of these three quite different categories of theory will provide the clearest answers to core questions about human social interaction and the functioning of the social brain. Here, I make the case for using information processing models in second-person neuroscience. Just because information processing approaches have sometimes been “spectatorial” or have lacked dynamics does not mean that they should always be this way. These models can be closely linked to brain activation, can be applied across a large number of contexts including psychiatric disorders, and are testable using methods like dynamic causal modelling.

Whichever type of theory ultimately prevails, having published theories will help to drive the field forward. In the new realm of interaction neuroscience, strong theories and clear models will help us choose which of the many possible experiments are worth pursuing, and will make our work more than just butterfly collecting.

## From the bottom up: The roots of social neuroscience at risk of running dry?

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**Abstract:** A second-person neuroscience, as an emerging area of neuroscience and the behavioral sciences, cannot afford to avoid a bottom-up, subcortical, and conative-affective perspective. An example with canid social play and a modern motivational behavioral neuroscience will illustrate our point.

We agree with Schilbach *et al.*’s suggestion that investigation of social cognition is too often restricted to passive observation, and social cognition is entirely different when one is interacting and emotionally engaged with others. We applaud their proposal for further investigation into second-person information but

suggest their outlook for future research is limited. We encourage investigation beyond the traditional parameters of social knowing. We suggest less emphasis on social “cognition” and more on a direct interaction between systems responsible for immediate social perception, affective processing and action. We propose a shift in focus, away from corticocentricity—a hierarchical interpretation of the brain with the cortex as the centre for “higher cognition,” responsible for top-down monitoring of subcortical structures (Parvizi 2009)—and toward social understanding as a dynamic system supported by bottom-up processes. Recent theories suggest that behavior is modulated by affective and conative processing of physical and social environmental stimuli (Berridge 2003; Panksepp 1998, Sivy & Panksepp 2011).

Due to the homology of affective systems among mammals, foundations of the human social mind can be investigated by studying subcortical systems, as done with other animals. In doing so, a biological component is added to social behavior without a restrictive emphasis on higher order processes. If adopting a functional and evolutionary framework, then canine social play is an ideal behavioral phenotype to consider for investigations into social knowing. Canine social play is a dynamic social interaction involving emotionally engaged conspecifics, modulated by subcortical processes.

Schilbach *et al.* identify three aspects of social interaction that are important for research in social neuroscience. Each aspect is evident in canine social play. *First*, a social encounter involves two players—an initiator and a responder. During the social play routine one dog elicits a response from another. The responder perceives and responds to socially relevant cues. The play bow is one cue that signals the invitation to play plus the intention to maintain play. The encounter requires frequent reappraisals; if one partner becomes too aggressive, play stops and that partner must modify their behavior in order for play to resume. The bow can signal reappraisal of a preceding action, and reinforce the intention to play (Bekoff 2008; Burghardt 2005). Consistent modification of approach and response relies on rapid recognition of the state of the other and flexibility in action output.

The playful interaction is dynamic, rich in anticipation, preparation, and revision, consisting of reciprocities based on perception of socially relevant information prompting a response. In keeping with Schilbach *et al.*’s description of a social interaction, reciprocities that occur during a play encounter may be sequential, but not predictable. Social play can be considered a system that evolves in response to the environment. It is a stable system as there may be a repertoire of behaviors, and unstable because the expression of the repertoire is nonlinear—it is responsive, and dynamic (Fentress & Gadbois 2001; Fentress & McLeod 1986; Smith & Thelen, 2003; Thelen & Smith 1994).

*Second*, the play interaction demands cooperation. Play is a voluntary encounter built on shared intentions and negotiations to initiate and maintain play at nonaggressive levels (Bekoff 2004; 2008). In a cooperative manner, threats of aggression are absent when large partners self-handicap and dominants exhibit role reversals (Bekoff 2004; Burghardt 2005). Critical to the interaction is the perception of sensory cues that indicate more than agency. It involves recognition of the state of the other, intentions, reconciliation, and consolation. We suggest social play is indicative of empathic responding between conspecifics. It may involve a same or similar mechanism that supports post-conflict affiliative (conciliatory) behavior (de Waal 2008; Palagi & Cordoni 2009).

*Third*, play emerges in the young without training and continues throughout the life span, even after maturation of the motivational system for aggression and sexual maturation. Because play is observed in the wild among wolves and feral dogs, it is not considered an artifact of domestication (Bauer & Smuts 2007). Play may be an intrinsic function supported by a play-specific motivational system (Panksepp 1998). Social isolates show high levels of play-seeking behavior (Burghardt 2005), higher than controls (Panksepp 1998). Decorticates show normal levels of play solicitation (Pellis *et al.* 1992), however, if

damage extends to the limbic structures, then play declines (Panksepp et al. 1994). Lack of motivation to play has been associated with maladaptive forms of behavior such as depression (Burgdorf et al. 2011). The suggested benefits of play include recognition of social hierarchy, development of motor coordination, and the acquisition and refinement of social skills (Bekoff 2008; Miklosi 2008; Panksepp 2011). Moreover, play feels good and is associated with a release of endorphins. We concur with the authors' suggestion to consider the influence of reward-related processes on action control due to the hedonic experience of social stimuli.

Play is a source of fundamental pleasure and play as reward is a strong incentive. Research supports the idea of a subcortical locus of control for play, with stimuli predicting play activating the mesolimbic dopaminergic pathway (Panksepp 1998; Siviy 1998). Neurotransmitter release in a proposed PLAY circuit may modulate the playful interaction with noradrenergic and opioid pathways influencing attention and pleasure respectively (Panksepp 1998; Siviy 1998; Siviy & Panksepp 2011). Rats emit ultrasonic vocalizations (50–55 kHz range) during play and when anticipating play, and the mesolimbic dopaminergic system controls production of these vocalizations (Burgdorf et al. 2007).

Fundamental pleasure may be supported by a three-part subcortical reward system based on sensory pleasure (*liking*), incentive motivation in response to cues (*wanting*) and associations between cues and pleasure to follow (*learning*) (Kringelbach & Berridge 2009). Berridge and colleagues identified distinct neural representations of each component of this system for a common reward. Opioid stimulation in the nucleus accumbens increased both liking and wanting signals represented by firing in the ventral pallidum. Dopamine stimulation increased wanting signals and behaviors, but not liking and wanting. Neither affected neurochemical modulation of Pavlovian signals (Smith et al. 2011). Separate neural firing may indicate that motivation and liking components of the system can be modulated independent of learning supported by cognitive representation. Fundamental pleasure experienced during social interaction with conspecifics and supported by subcortical structures may not require cortical interfacing for higher order processing. As Kringelbach and Berridge (2009) suggest, wanting matched with liking may “facilitate engagement with the world.”

Schilbach et al. suggest the need for a *naturalistic social interaction* for investigation of the neural mechanisms supporting social understanding, yet their examples involve laboratory-controlled interaction with virtual characters and an emphasis on higher order cognitions. A study of second-person neuroscience could benefit from an examination of bottom-up mechanisms (i.e., affective and conative processes) that have been well demonstrated in other species and contexts (e.g., canine play behavior).

## Advancing the neuroscience of social emotions with social immersion

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**Abstract:** Second-person neuroscience offers a framework for the study of social emotions, such as embarrassment and pride. However, we propose that an enduring mental representation of oneself in relation to others

without a continuous direct social interaction is possible. We call this state “social immersion” and will explain its impact on the neuroscience of social emotions.

The so-called dark matter in social neuroscience contains the experience of social emotions such as embarrassment, guilt, or pride. Thus, second-person neuroscience is an ideal framework to shed light upon the neural foundations of social emotions. Schilbach et al. do not emphasize in their review the great potential second-person neuroscience could have on social emotion research. This aspect is important, where broadening our understanding of social emotions as an integral part of the human emotional repertoire is overdue.

Social emotions require the representation of oneself in relation to others and primarily emerge through reciprocal interaction between two or more individuals (Tangney et al. 2007). Despite the constraints of the laboratory setting, social neuroscience studies have investigated social emotions such as embarrassment (Krach et al. 2011; Takahashi et al. 2004), pride (Takahashi et al. 2008), shame, and guilt (Wagner et al. 2011). Commonly used in this research is some form of written or pictorial vignette that asks participants to judge, simulate or re-enact a briefly described situation. In doing so, the integral part of social emotions – the reciprocal interaction with others and also the representation of oneself in relation to others – remains “dark matter.” It is unlikely that paradigms using vignettes have been able to fully capture the neural foundations of the actual *experience* of social emotion. Given the relevance of social emotions regarding developmental psychology and mental disorders, the lack of knowledge is intriguing.

In order to induce and assess social emotions in a social neuroscience laboratory, strong emotional engagement and reciprocal interaction are necessary in the experimental setting. However, we question whether *direct*, continuous reciprocal interactions are necessary. Rather, it is the mental representation of oneself in relation to others that is essential. This representation has to be implemented in the participant's mind, resulting in *social immersion*. We understand social immersion to be a state that makes the participant perceive others as active, salient, and significant during the experiment. In order to implement this state, not only the content of the experiment (e.g., emotional vignettes) has to be carefully manipulated, but also the context of the experiment has to be actively designed (e.g., compelling cover story). The latter enables participants to immerse in a constructed social reality that is highly controllable by the experimenter. Instead of treating social emotions as a mere side-effect within social interactions, the control of the experimental context allows selective priming of specific social emotions.

In a state of social immersion, the mental representation of oneself in relation to others (i.e., the social representation) and the actual social interaction might not be corresponding during the entire experiment (see our Figure 1). In the pre-recording phase, initial face-to-face interaction establishes a social representation of others as active, salient, and significant. When the data recording starts (e.g., participant enters scanner room), the trajectories of the social representation and the social interaction bifurcate. Now, *without* direct, continuous interaction it is possible to elicit ecologically valid social emotions. Referring to the target article, this means that a class B interaction contingency is perceived as class D interaction contingency (cf. schematic depictions 1B and 1D of the target article's Fig. 1).

This approach implies several benefits for social emotion neuroscience. First, person–group interactions are possible (e.g., audience effects) with moderate technical effort. Second, repetitive induction of genuine social emotions is feasible in the controlled environment (e.g., manipulated negative feedback by confederates). Third, reduced cognitive costs (e.g., no need for recollection of autobiographic episodes) facilitate the investigation of social emotions in clinical samples such as people with autism or schizophrenia. Fourth, the experiments

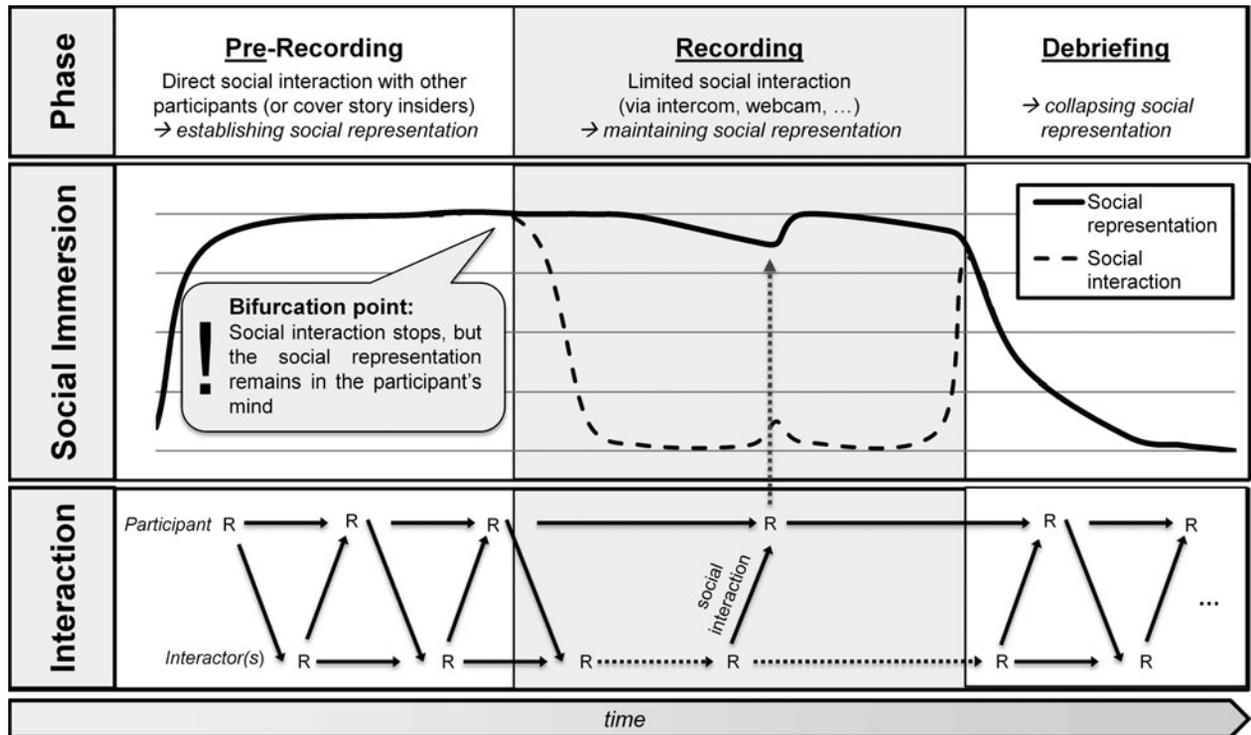


Figure 1 (Krach et al.). Schematic depiction of experimental phase (top), level of social immersion (middle), and interaction contingencies (bottom) over time. In the Pre-Recording phase, the participant acquires a social representation of herself in relation to others by direct social interaction and emotional engagement (left side). In the Recording phase, the direct social interactions stops at the bifurcation point (e.g., participants enters MRI scanner room), but the social representation persists. Intermittent direct social interactions assure the maintenance of the social representation (e.g., short intercom exchange). At debriefing, a correspondence between the social representation and social interaction is re-established.

will be more attractive for participants, which is especially relevant for studies that involve children and adolescents. However, one drawback might be the higher costs in terms of price and time to induce social immersion (e.g., paying multiple participants or confederates).

To conclude, we expect that the neuroscience of social emotions will be stimulated by the flexibility, ecological validity, and feasibility of social immersion paradigms.

### A mature second-person neuroscience needs a first-person (plural) developmental foundation

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**Abstract:** Schilbach et al.'s model assumes that the ability to "experience" minds is already present in human infants and therefore falls foul of the very intellectualist problems it attempts to avoid. We propose an alternative relational, action-based account, which attempts to grasp how the individual's construction of knowledge develops within interactions.

We applaud Schilbach et al.'s target article for its critique of the assumptions of contemporary neuroscience. We largely agree with their attack on the "spectator" view inherent in current

research and theory. The second-person perspective and its constituent parts, emotional engagement and social interaction, fill many of the gaps in these approaches to the origins of human skills. However, the authors fail to adequately account for the processes in which second-person understanding of others emerges within development, particularly in establishing social understanding in infancy. A crucial issue concerns how infants and children come to be able to overcome the *spectatorial gap* which is described so well in the paper (sect. 2.1).

The article's developmental perspective (sect. 2.2) assumes repeatedly that within interactions infants experience "minds" that are directed towards them. As a result the authors do not avoid the very problem of foundationalism (Allen & Bickhard 2013) that they are attempting to critique. Simply changing the terminology from, for example, "mindreading" to "experience" or "engagement" does not help them avoid falling into one of two traps: merely describing the fact that infants get involved in interactions, on one hand, or assuming that words like "engagement" actually explain how an understanding of such interactions emerges, on the other. The authors appear to suggest that there is a starting point at which infants do not possess sophisticated skills. Yet, without explaining how these skills emerge, this second-person account is incomplete. To compound the problem there is occasional slippage into the very approach (theory theory: e.g., sect. 4.2.1, final paragraph), which they are earlier at pains to distance themselves from.

We suggest that the central importance of interactions in human social neuroscience can only be understood from a relational action-based perspective. Rather than framing interactions in terms of their second-person components, we need to grapple with the means by which understanding is developed by an individual within such interaction. Knowledge of "you" must

emerge from somewhere. It cannot simply be attributed to me experiencing your “mind.” As Hurlley (2008) recently argued, a lower level, non-Cartesian developmental model of social neuroscience would initially be based upon first-person plural experience. In our view, human infants become involved in interactions and get into the behavioural flow of shared activities, even though they are largely stage-managed by the adult. As a result, infants become naturally attentive to gestures that are intentional because they are repeated and become predictable. For example, they attend to a purposeful grasp but not a reach with the back of the hand (e.g., Woodward 1999). Such competence, which is evident before the child’s first birthday, does not mean that human infants grasp “minds.”

How can we explain the emergence of social skills and knowledge within this first-person plural experience? We feel that Schilbach et al. misinterpret our account (Carpendale & Lewis 2004; Stack & Lewis 2008) as supporting a second-person approach when really this and related ones (e.g., Barresi & Moore 1996) stress the infant’s perspective on shared experience with others. From this perspective, early forms of awareness are sensorimotor and take place within practical activities like toy manipulation or social second-person interactions. Such actions make the infant able to attend to and then follow simple gestures expressing emotion, gaze, or bodily orientation. According to this approach, infants build gradually upon these actions to construct increasingly complex forms of knowledge. These provide the basis for reflective forms of social understanding and communication. The activity-based approach would never automatically assume that infants read or experience minds, as this is too rich an interpretation of their attention to human actions.

Evidence for our perspective comes from the errors of older children. We agree with the authors that some form of representational redescription may explain the process of transfer from simple to more complex understanding (sect. 4.2.1), but the target article is particularly vague about how this might take place, or what actually gets redescribed, and how. This might simply be an omission due to the ambitious scope of the article. However, such claims and the observation that individuals with autism have difficulties in social interactions (sect. 2.2.1, para. 4), make their second-person perspective yet more under-specified. According to an action-based approach, shared interactions enable the infant to *re-present* the world, anticipating the outcome of various intentional actions. Development is a protracted process because the inferences that transform actions into representations are dependent on hard won, small-scale achievements. Although infants seem to follow purposeful reaches (Onishi & Baillargeon 2005), they also make simple perceptual errors in such tasks, with inferences being based on the mere presence of others at set points within an event (Sodian & Thoermer 2008). This lack of an objective appreciation of another’s perspective has been demonstrated across the third year (Moll et al. 2011; O’Neill 1996), extending into early childhood (Flavell et al. 1980; McGuigan & Doherty 2006). Such findings suggest that knowledge of what others have (and have not) experienced continues to be framed in terms of engagement with, and dis-engagement from, others. Even preschoolers do not simply “experience” the mind, as assumed in the target article.

In short, we feel that Schilbach et al.’s claim that we need to make social neuroscience truly social is well placed but the second-person perspective does not specify how humans acquire such skills. It is not sufficient to present simple diagrams showing that interactants’ neural processes act in synchrony (Fig. 1D of the target article) or to state that early affective exchanges “pave the way” to later understanding without specifying how the paving is laid. An action-based theory originating within *first-person plural* interactions provides a more detailed, and more plausible, account of these developmental processes.

## Merging second-person and first-person neuroscience

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**Abstract:** Schilbach et al. contrast second-person and third-person approaches to social neuroscience. We discuss relations between second-person and *first-person* approaches, arguing that they cannot be studied in isolation. *Contingency* is central for converging first- and second-person approaches. Studies of embodiment show how contingencies scaffold first-person perspective and how the transition from a third- to a second-person perspective fundamentally involves first-person contributions.

In developing their framework for second-person neuroscience, Schilbach and colleagues contrast their approach with what they consider third-person approaches, widespread in cognition and social neuroscience, in which participants simply observe (but do not interact with) others. Surprisingly, Schilbach et al. have less to say about the converse relation, between their second-person neuroscience and *first-person* approaches. Recent research has provided rich descriptions of the first-person experience of embodiment, the role of sensory and motor signals in forming such experiences, and their subsequent effects on cognition and behaviour. Here, we will discuss points of potential convergence between first- and second-person approaches and argue that the two cannot be approached in isolation from each other.

First, the key factor differentiating second-person from third-person approaches on Schilbach et al.’s view is *contingency*. Second-person others respond contingently to an observer’s actions, whereas third-person others do not. Intriguingly, this idea of contingency is also central to recent approaches to studying first-person experiences of embodiment (for reviews see Longo & Haggard 2012; Tsakiris 2010). In the case of first-person experience, this plays out at both the perceptual and motoric levels. In terms of perception, our somatic experiences (e.g., of touch, pain, or position sense) are contingently related to our experiences in other sensory modalities (e.g., visual, auditory, or vestibular sensations). For example, my tactile experiences as I reach to pick up my coffee mug are exactly temporally and spatially congruent with my visual experience of seeing my hand grip the mug. This visual-tactile match is a strong cue that the hand I see is *my* hand, and can be manipulated to produce perceptual illusions of embodiments such as the rubber hand illusion (Botvinick & Cohen 1998), full-body illusions (Lenggenhager et al. 2007), or the body-swap illusion (Petkova & Ehrsson 2008). In the rubber hand illusion, for example, vision of touch applied to a prosthetic hand in temporal and spatial synchrony with felt touch on one’s own hand creates the compelling illusion that the rubber hand actually is one’s hand (the sense of *body ownership*) and corresponding proprioceptive biases (Botvinick & Cohen 1998; Longo et al. 2008; Tsakiris & Haggard 2005).

Contingency in first-person approaches also plays out in terms of action. The actions of our body are contingently related to our intentions. When I form an intention to lift my arm, it is *my* arm that lifts. The contingent relation between efferent motor commands and visual and proprioceptive feedback strongly influences our first-person experience of our body, over and above matches between vision and proprioception alone. This is another strong cue for body ownership, and creates an additional sense of *agency* over one’s body (i.e., the feeling that I am in control of my body). Recent results have demonstrated that ownership and agency are distinct and separable components of the experience of embodiment (Longo et al. 2008) and have distinct functional consequences on behaviour (Kammers et al. 2009; Longo & Haggard 2009; Tsakiris

*et al.* 2006) and separable neural correlates (Tsakiris *et al.* 2010). Thus, contingency, both of perception and action, plays a critical role in structuring first-person experiences of our own body.

As Schilbach and colleagues point out, however, contingency also plays a fundamental role in differentiating our second-person experiences of immediate others from third-person experiences of more distant others. This raises a critical question: What differentiates contingent relations specifying first-person experiences from those specifying second-person experiences? This is an important question for future research, about which we can only speculate here. We wish to propose, however, that first-person experiences may be primary and possibly even necessary prerequisites for second-person experiences. For example, first- and second-person contingency differ in terms of their immediacy, both temporally and logically. When I form an intention to act, my own action follows immediately, whereas your response comes later. Any instance of contingency specifying second-person relations thus follows the sequence: *Intention* → *My Action* → *Your Action*, where the first arrow indicates the contingent relation specifying a first-person experience and the second arrow indicates the contingent relation specifying a second-person experience. The second-person contingency cannot exist without the first-person contingency, because the sequence: *Intention* → *Your Action* would not indicate that I am *interacting* with you (a second-person relationship), but would rather indicate that I *am* you (a first-person relationship).

Related to the preceding argument is the possibility that embodied interactions may alter self-other boundaries, which suggests that the transition from a third- to a second-person perspective may fundamentally involve, but also affect, first-person representations. This possibility has been explored by extending the known role of multisensory integration from body-awareness to self-other boundaries. In the “enfacement illusion” (Sforza *et al.* 2010; Tsakiris 2008), participants see someone else’s face being touched at the same time as their own face, creating a situation that resembles the experience of looking at oneself into the mirror, albeit the “mirror reflection” of one’s face is replaced by another individual. Synchronous interpersonal multisensory stimulation (IMS) between the two faces changes self-face recognition, as the other’s face is perceived to be more similar to one’s own face (Tajadura-Jimenez *et al.* 2012). Interestingly, and of particular relevance for our understanding of the second-person perspective, IMS also influences social cognition processes of inference and conformity (Paladino *et al.* 2010). Such findings support a model of first-person perspective according to which our sense of self is plastically affected by multisensory information as it becomes available during self-other interactions. Shared multisensory experiences might explain how the “I” comes to be identified with “me,” allowing this “me” to be represented as an object for others, as well as for one’s self.

Together, these considerations suggest that there are important points of connection between the first- and second-person perspectives, meaning that neither can be investigated in isolation from the other. In particular, it will be critical for future research to investigate how contingency alters both the relation of the self to its “self” or body (first-person neuroscience), and the relation of the self to the other (second-person neuroscience).

## A second-person approach cannot explain intentionality in social understanding

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**Abstract:** A second-person approach that prioritizes dyadic emotional interaction is not well equipped to explain the origins of the

understanding of mind conceived as intentionality. Instead, the critical elements that will deliver the understanding of self and other as persons with intentionality are shared object-centered interactions that include not only emotional engagement, but also joint attention and joint goal-directed action.

The second-person approach advocated by Schilbach and colleagues may be seen as one of a group of theoretical approaches that avoid the “simulation theory” and “theory theory” horns of the dilemma of understanding other minds. Like other relational approaches (e.g., Barresi & Moore 1996; Carpendale & Lewis 2004; Hobson 2002; Moore 2006; Zlatev *et al.* 2008), Schilbach *et al.* argue that minds are known within and through interaction with others. As a viable theory, however, their second-person approach has a number of significant drawbacks. Here we focus on two – its over-reliance on emotional engagement and its over-emphasis of dyadic, rather than triadic, interaction. We believe that a significant reason for these shortcomings is that Schilbach *et al.* appear not to have a coherent account of what it means to understand mind; certainly they never actually define what that means. Obviously they want to avoid the standard representational theory of mind account of mental understanding. But instead of a structured analysis, they seem to assume that the understanding of mind is immanent in a variety of different social phenomena, including contingent social interaction and emotional reactivity to others.

Our position, consistent with a long intellectual tradition in philosophy of mind (e.g., Brentano 1874/1973), is that understanding mind entails understanding intentionality. We take intentionality to cover all of its myriad forms, ranging in complexity from simple object-directed action to complex embedded mental states (see Barresi & Moore 1996), and ranging across a variety of psychological qualities, including not only emotional, but also epistemic, and conative forms.

For Schilbach *et al.*, there are two key features to the second-person approach: emotional engagement and social interaction. We address the limitations of these two features of their account in reverse order.

All relational approaches to social understanding place social interaction at the core. Knowledge of minds happens through interaction with others. For some authors, social interaction is seen primarily as the solution to the problem of other minds (e.g., Carpendale & Lewis 2004; Hobson 2002). For others, it is the solution not only to that problem, but also necessarily to the problem of how the self’s own intentionality comes to be known (Barresi & Moore 1996). Schilbach *et al.* argue for the primacy of a particular form of social interaction – face-to-face or what is often termed in the developmental psychology literature, “dyadic.” For them, second-person appears to mean primarily the kind of social stimulation available within dyadic interaction. Certainly dyadic interactions can have special dynamic properties, such as contingency of the actions of self and other, and particular characteristics, such as full-face gaze. Yet, although it is true that these properties and characteristics are key attractants to young infants, the processing of this information does not necessitate any awareness of the other *as being another* – or being a person of the same kind as the self. Indeed, empirical evidence has suggested that these phenomena could be subserved by “subpersonal” attentional and sensorimotor mechanisms (Moore & Barresi 2009; Paulus 2011).

The same problem holds for their view on motor resonance in the Mirror Neuron System when observing others’ actions. While we agree that these motor processes may support social interaction either by predicting the future effect of the other’s action or by directly preparing a timely response, the activation of a motor program alone need not lead to an awareness of another’s mind in any conceptual sense (Paulus 2012). There is a conceptual gap between the activation of one’s own motor system through the perception of another person’s action and the ascription of an intention to this person or to the self (Jacob 2009).

The problem with purely dyadic interactions is that there is no obvious way for the intentionality of action – its object-

directedness – to be manifest. That is, it is unclear how the properties of dyadic interactions alone, such as contingency and second person characteristics, could reveal intentionality at all. Intentionality is tied inextricably to actions on objects, whether real or represented, and therefore to triadic interaction. Triadic interaction involves participation in joint or coordinated actions over shared objects, often directed at particular effects (Paulus et al. 2012) and it is through participation in these interactions that the activity of both self and other becomes interpretable as intentional (Moore 2006; Tomasello et al. 2005). Therefore, while we agree with Schilbach et al. that dyadic interaction is a necessary context for intentional understanding, we argue that it cannot be sufficient.

Schilbach et al. reserve a place of particular importance in their theory for emotional engagement. We agree that emotional engagement is of critical importance, particularly during early development, for bringing people into the kinds of interactive situations that will ultimately enable intentional understanding. However, intentionality involves much more than emotion. Interactive partners engage in other forms of coordinated activity where emotion may play a relatively minimal role. Two broad forms of coordinated activity involve shared epistemic relations to objects and shared conative relations to objects or goals. By epistemic relations, we mean psychological activity that is directed at the acquisition, elaboration, and negotiation of knowledge. Shared epistemic activity, such as joint attention, can deliver an understanding of epistemic mental activity that will elude purely emotional engagement, such as the understanding of perspective and belief. By conative activity, we mean activity that is willed, purposeful, and goal-directed. Shared conative activity, such as imitation and cooperation involving joint goals, provides an entry into the understanding of goal-directed actions and desires. Emotional interaction on its own is not well-suited to the acquisition of an understanding of either epistemic or conative types of intentional relations.

In short, although we applaud Schilbach et al.'s attempt to set the neuroscience of social understanding in a context that places social interaction as the foundation, we believe that their account must be elaborated to show how interaction beyond emotional engagement can yield the key understanding of mind as intentional.

## Second-person neuroscience: Implications for Wittgensteinian and Vygotskian approaches to psychology

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**Abstract:** Interactive approaches to development and social psychology may particularly benefit from the non-dualist features of a second-person neuroscience. In that context, I discuss the compatibility of a second-person neuroscience with a Wittgensteinian analysis of psychological concepts and its connections to a Vygotskian approach to psychological development.

A “second-person neuroscience” avoids elements of dualism in psychological theories. For interactionist approaches in social and developmental psychology this is particularly welcome. It also makes possible a Wittgensteinian neuroscience. Here, I focus on its compatibility with Wittgenstein's philosophy and Vygotsky's (1978) developmental psychology.

Wittgenstein's thought (Wittgenstein 1953; 1969) has influenced several interactionist approaches in psychology, including social

constructionist and discursive theories (e.g., Edwards & Potter 1992). Like Schilbach et al.'s focus on emotional engagement and social interaction, these approaches also emphasize interest-based, emotionally (and morally) loaded social interaction.

Few would argue that an aim of Wittgenstein's philosophy was to show that a dualist interpretation of psychological terms was mistaken and confused. Echoing a similar aim, Schilbach et al. correctly identify the continuing “methodological dualism of behavior and mind” (sect. 1.1, para. 4, their emphasis) in psychology and how a second-person neuroscience can avoid it.

More fully, Wittgenstein (1953) argued that psychological concepts gain meaning by how they are used in the “forms of life” and “language-games” that characterize meaningful action (“meaning as use”). Their meaning is not reliant on ontologically private states and events occurring in a world of individual experience.

In this light, Wittgenstein's so-called private language argument is an argument for the conceptual priority of the activities and interactions that ground language, and therefore thought, over supposedly private phenomena. Further, and analogous to Schilbach et al.'s focus on real time, ecologically valid social interactions, Wittgenstein leaned heavily upon considerations of ordinary, everyday uses of language for his analysis.

Conceptual compatibility goes further than a shared focus on everyday interactions. Wittgenstein (1969), for example, stated that human action is grounded not on an “ungrounded presupposition” but on an “ungrounded way of acting” (p. 17e, O.C. 110). From a Wittgensteinian perspective, first-person (e.g., simulationist) and third-person (e.g., Theory Theory) approaches in social neuroscience—as characterized by Schilbach et al.—incorrectly assume that social cognition is grounded on “ungrounded presuppositions” (i.e., various spectatorial representations of, or inferences about, others' minds). By contrast, a second-person approach highlights processes of emotional engagement and interaction. These ground action in the immediacy of action itself. In Wittgenstein's terms, social cognition occurs within, and is motivated by, “ungrounded ways of acting.” By implication, a “Wittgensteinian” second-person neuroscience then must explain how first- and third-person perspectives arise out of ontogenetically and conceptually prior second-person engagement. This is presumably one reason why Schilbach et al. (sect. 4.2) are interested in how implicit social cognition is transformed into explicit cognition (sect. 4.2).

On this last question, Vygotskian developmental psychology can provide insights for ontogenetic neuroscientific research. For Vygotsky (1978), development involves organizing maturing functions into “higher” processes, largely through social interaction. Maturing functions are co-opted and restructured to subserve the higher psychological processes specified by the cultural environment.

Using a simple example, Vygotsky (1978) explained how an adult might complete an infant's unsuccessful grasping movement. This completion psychologically reconstructs the infant's grasping movement as a pointing gesture, once perceptual and attentional processes have matured. As Vygotsky (1978, p. 56) put it, there is “a change in that movement's function: from an object-oriented movement it becomes a movement aimed at another person, a means of establishing relations.”

Schilbach et al. (sect. 2.2.1, para. 2) note how the emotional power of attention directed towards newborns grounds second-person engagement. They later hypothesize that “the second-person approach suggests that acts of mentality should be meaningful to infants depending on the infant's ability to respond to them when they receive them, *regardless of whether the infants can do the actions themselves*” (sect. 4.2.1, para. 4, emphasis added). This suggestion aligns well with a Vygotskian account of the origins of how infants participate in socially meaningful activity and is supported by Tomasello and colleagues' work on the early development of joint attention, shared intentionality, and cooperative activity (see Tomasello 2009).

In Vygotsky's view this fundamental interaction involves a tension between psychological development (“maturing” functions)

and learning and instruction. Given this tension, the process could neither begin nor be maintained without the natural responsiveness of infants to “acts of mentality” (target article, sect. 4.2.1, para. 4). Emotional engagement and circuits delivering reward signals draw infants into the process by which learning and development are coordinated. A second-person neuroscience could investigate the neural correlates supporting this integration of learning and development and, along the way, test and refine Vygotsky’s developmental theory. Reciprocally, Vygotsky’s framework could guide that neuroscientific investigation.

As mentioned, Schilbach *et al.* also highlight the question of how *implicit* processes become available for *explicit* social cognition. They mention Anderson’s (2010) theory of the reuse of brain areas during ontogeny and suggest that cognitive circuitry developed in early interactions may be reused, and re-described, to develop explicit social cognition. Neural reuse of this type is straightforwardly translatable into a Vygotskian framework based on the social reconstruction of maturing functions. Further, reuse of implicit processes for explicit social cognition corresponds with a central process in Vygotsky’s approach—internalization.

For Vygotsky (1978) all functions appear twice: “first *between* people (*interpsychological*), and then *inside* the child (*intrapsychological*)” (p. 57, emphasis in original). The incorporation of speech into practical action mediates this shift, as Schilbach *et al.* also argue. Initially, speech is provoked and determined by activity. It is descriptive, emotionally expressive, and communicative (e.g., to describe a situation or ask for help). Through social interaction—and via egocentric speech—it develops a “planning function” that precedes and dominates activity. From a role in controlling the external world it turns inward and exerts control over the self, setting the scene for the emergence of first- and third-person social orientations.

Wittgenstein (1953, p. 232e) wrote of the “confusion and barrenness of psychology,” stating that “in psychology there are experimental methods and *conceptual confusion*.” Schilbach *et al.*’s proposal in the target article helps avoid the dualist confusion Wittgenstein identified. It therefore could harness experimental and other methods to solve “the problems which trouble us” in social psychology.

## The use of non-interactive scenarios in social neuroscience

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**Abstract:** Although we fundamentally agree with Schilbach *et al.*, we argue here that there is still some residual utility for non-interactive scenarios in social neuroscience. They may be useful to quantify individual differences in prosocial inclination that are not influenced by concerns about reputation or social pressure.

Schilbach *et al.* argue that economic scenarios may not recreate the interaction dynamics of everyday-life social encounters, on account of their implicit view of the subject as a simple recipient of information. Indeed, economic scenarios are poor stand-ins for natural interactions. A mature social neuroscience inevitably requires dynamic, “second-person” paradigms. However, some aspects of social cognition are best studied in controlled, restricted

scenarios, where the subject is anonymous and unobserved, as the presence of another human presents as many interpretational problems as the absence of one. We propose that in some cases, controlled, *first-person* economic scenarios are still useful for a mature study of social interaction. These scenarios enable measures of individual differences and provide a window into basic brain-behavior relationships which can serve as a rudimentary “glossary” for decoding the complex datasets posed by second-person paradigms.

Experimental paradigms in social studies exist somewhere between two extremes: On one, we have controlled, observer-based protocols to study phenomena like empathy for pain or emotional reactivity. Individual subjects are exposed to stimuli which are ordered and controlled in order to group features of interest. These are then assigned to contrasts in order to isolate correlates of those features within our dataset of dependent variables. This allows us to abstract across conditions, making it possible to extrapolate and generalize. On the other extreme, we have observational studies of social phenomena *in vivo*, which assume that we cannot examine components of social scenarios in isolation without altering them beyond recognition. The first extreme is unrealistic, by assuming that there is such a thing as context-independent behavior. The second lacks the ability to say anything about anything other than its subject, if we cannot abstract and extrapolate beyond its context. In short, the first lacks validity, while the second lacks generalizability.

A second-person neuroscience may, in avoiding the problems inherent to the first extreme, stray too close to the faults of the latter: Namely, if we are to study interactions, how do we categorize them without somehow restricting them, and, most importantly here, how do we interpret data derived from interactions? Beyond inter-subject correlations such as those observed in hyper-scanning, what can we say about the neural mechanisms of interaction? To give an example by analogy, if we are studying a pair of linked oscillators, we are aware that their behavior in isolation may say little about their behavior in interaction. However, when in interaction, we can say nothing more than “they are in sync; they are decoupled, etc.” We can still say very little about how their internal architecture produces the observed behavior. But what if we could group varieties of oscillators according to their internal properties? Then, we might observe that, for example, AB, BB, and AA dyads tend to coalesce into significantly different stable states. Bringing the analogy back to social neuroscience, we propose that a study of individual differences rooted in internal structure and function can best link interaction-level data with the internal properties of the interactive agents.

The study of individual differences in empathy and prosocial behavior generally falls into two camps: Neurobiological studies have proposed “low-level” neural mechanisms for empathy based on mirroring and simulation (Carr *et al.* 2003; Singer *et al.* 2004). On the other hand, studies of prosocial behavior have focused on the role of empathy in our decision-making, primarily through observational studies of prosocial behavior, and economic studies of sharing and fairness using games (Fehr & Camerer 2007). Each of these fields has historically measured individual differences using questionnaires. However, a handful of studies in the last few years have at last attempted to bridge the gap, foregoing questionnaires to directly relate differences in brain activity to differences in behavior. This sort of study, in our view, best exemplifies the utility of controlled economic scenarios. Our research, for example, attempts to correlate individual differences in neural correlates of mirroring with behavior in the Dictator game. Rather than attempting to mimic natural social interactions, we attempt to isolate neural biomarkers of noncompliant prosocial behavior. Subjects are asked to share a portion of a sum of money with virtual profiles which represent real people in the community who will actually receive the money. By assuring subjects that they are anonymous and unobserved, we can isolate neural correlates of *prosocial inclination* or *empathic*

concern, as we are not confounding their behavior or cognition with the presence of another in interaction. Because, in point of fact, it is in those very scenarios where we are unobserved, and anonymous, yet still aid others, that we can be said to act without concerns for our reputation or due to social pressure. Thus, to best measure differences in brain activity, connectivity, and structure which map onto variability in controlled, noncomplacent altruistic behavior, subjects should not interact. We believe that the results of this sort of study can allow for neural biomarkers of prosocial behavior which can aid in the interpretation of behavior patterns within interaction.

We agree that interactions between multiple subjects may not be reducible to the characteristics of their participants. Dyads, triads, and other group configurations may one day be the basic unit of social neuroscience. We may one day refer to “group states” in social neuroscience, as a unit of information separate from and incommensurable with the states of the individuals within them. This parallels the study of quantum mechanics and complexity theory, which require us to consider the behavior of systems holistically, defying the reductionist notion that group states are reducible to the sum of their parts. However, the volume of data that we can expect from studies of social interaction, and the intricate complexity of relating this data back to mechanistic models of brain function, suggests that it may be useful to parameterize the interactive agents. This can be done by measuring individual differences based on internal functions, even if the paradigms we use to do this sometimes bear little resemblance to natural scenarios.

## What we can learn from second animal neuroscience

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**Abstract:** There are several facets of second-person neuroscience which can benefit from comparisons with animal behavioral neuroscience studies. This commentary addresses the challenges involved in obtaining quantitative data from second-person techniques, the role of stress in inducing robust responses, the use of interactive functional magnetic resonance imaging (fMRI), and the value of applying interactive methods to studies of aggression and depression.

A comparison of second-person neuroscience with animal behavioral neuroscience reveals several common facets between these fields. Discussion of these similarities may lead to improvements in second-person neuroscience techniques. One facet is the experimental challenges involved in obtaining quantitative data from second-person techniques. Quantitative data is necessary in the study of disorders that involve disrupted social behavior. The use of virtual interactors will be valuable in this regard, but there is also a need for interpersonal interactions. Screening of interactors will reduce some of the variability, but there is more inherent variability in quantitative second-person techniques compared to current social neuroscience methods. However, observational studies in animals or humans may not be able to identify relevant differences between experimental groups because of the confounds imposed by the observational process or the fact that observation does not trigger the responses necessary to identify significant differences.

Although Schilbach *et al.* compare adult second-person neuroscience with studies of infants as an example of a successful application of second-person neuroscience, the personal psychological

history of two adults will generate greater variability than interactions between an adult and an infant. In animal studies, more ethologically and ecologically relevant social interactions have been used in stress studies for many years (Tamashiro *et al.* 2005). With investigations where social defeat is the objective, the use of larger and/or more dominant animals is key to inducing social defeat and generating consistent and reliable data, but effects are gender specific (Haller *et al.* 1998). If social conflict, but not defeat, is the objective, then similarly sized or smaller animals with a consistent social ranking may be more effective (Nephew & Bridges 2011). Another key benefit to socially interactive animal studies is the role of stress in inducing robust and relevant responses, especially in the study of depression. Exposure to chronic social stress is a strong predictor of the development of depressive disorders (Hammen 2005), and emphasis on the second-person neuroscience approach in humans could be a powerful tool in exploring the etiology of affective disorders through the investigation of changes in social interaction over time during exposure to chronic social stress. The use of stressful stimuli has been valuable in rodent fMRI.

A third facet of second-person neuroscience addressed in animal studies is interactive fMRI. Functional MRI work in conscious rodents has illustrated the necessity of using robust stimuli. Rodent fMRI work from the labs of Marcelo Febo and Craig Ferris have used ethologically relevant interactions between rat dams and their pups (Febo *et al.* 2005; Ferris *et al.* 2005), and also rat dams and threatening male intruder rats (Nephew *et al.* 2009). These studies have provided a wealth of information on the real time neuroanatomy of maternal care and aggression, and highlight some of the challenges to interactive imaging studies. Stimuli such as direct suckling by pups and the presence of a male intruder rat elicit robust blood oxygen level dependent (BOLD) responses. Although consistent data has been collected from rat dams actively nursing their pups, this interaction is extremely complex and simultaneously activates brain areas involved in reward, sensation, and lactation. Efforts to tease apart the motivational brain regions involved in BOLD responses have been challenging, as presenting novel objects or pups without contact between the dam and pup does not produce substantial changes in BOLD activity. In contrast, novel objects and the presence of pups produce reliable behavioral responses in the home cage. The lack of BOLD responses to these stimuli is hypothesized to be a result of the strength of the stimulus relative to the basal level of response to the imaging procedures, despite acclimatization. In human imaging, it is likely that there is a certain degree of basal BOLD response to the imaging procedure, and the use of robust, ethologically relevant stimuli will produce significant and consistent data. While virtual imaging paradigms provide control and consistency, are the limitations of this technology any less than the limitations involved in observational or hyperscanning studies? A necessary component with the use of fMRI work in both animals and humans is supporting data from other experimental paradigms. In animals, interactive BOLD data can be supported by electrophysiology, neuroendocrine, and behavioral studies (Caffrey *et al.* 2010; Febo & Ferris 2007), and similar combinations can be used in human neuroscience. The challenge of collecting consistent data from two interacting humans can be attenuated by the use of large sample sizes and/or carefully chosen research groups and experimental paradigms. For studies using interpersonal interactions, it will be advantageous to use interaction paradigms that create responses greater than the noise introduced by variations in psychological background.

Two fields of social neuroscience in addition to autism where interactive methods would be valuable are aggression and depression. While second-person neuroscience studies of high-functioning autism (HFA) patients certainly have merit, the lack of specificity in autism diagnoses may be limiting to this area of research, and studies of aggression or depression may not involve as many confounds. For both human and animal studies

of aggression, observational studies are limited in what they can address. Interactive animal studies on the neurocircuitry of aggressive behavior have generated a wealth of data which are translationally relevant for disorders involving altered aggressive responses, such as post-traumatic stress disorder (PTSD) (Ferris *et al.* 2008). The comments by Schilbach *et al.* on the importance of reward circuits and social interaction suggest that second-person neuroscience is a valuable addition to the study of depression as well. Anhedonia and attenuated social interaction are common features of depression, and the second-person neuroscience method can address both features in studies of depression in males and females. In humans, Lane Strathearn and others have shown that it is possible to record differences in fMRI responses to stimuli such as infant cry or infant pictures in healthy mothers (Strathearn *et al.* 2009), but the most relevant BOLD differences are from studies comparing healthy and depressed mothers (Laurent & Ablow 2012). Strong collaborations between animal and human researchers focused on developing ecologically and ethologically relevant second-person neuroscience experimental paradigms will advance the development of social neuroscience.

## Social perception and “spectator theories” of other minds

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**Abstract:** We resist Schilbach *et al.*'s characterization of the “social perception” approach to social cognition as a “spectator theory” of other minds. We show how the social perception view acknowledges the crucial role interaction plays in enabling social understanding. We also highlight a dilemma Schilbach *et al.* face in attempting to distinguish their second-person approach from the social perception view.

Schilbach *et al.* argue that their “second-person” approach to social cognition—which emphasizes the centrality of interaction and emotional engagement in facilitating social understanding—differs fundamentally from what they term “spectator theories.” Under the latter heading they include not just “Theory Theory” (TT) and “Simulation Theory” (ST), but also what they aptly term the “social perception” approach. Although we suspect similar questions could be raised with respect to TT and ST, we focus on the question of whether it is true that the social perception approach is “committed to an observer epistemology” (sect 1.2, para. 2) and thus is a “spectator theory.”

The social perception approach comes in different forms (see, e.g., Duddington 1918; Gallagher 2008; Hobson 2008; Scheler 1954; Stout 2012; Wittgenstein 1980). Common to all is the idea that we can sometimes perceive (and thus need not infer) the mental states of others (Krueger 2012; Krueger & Overgaard 2012; Overgaard 2012). But *contra* Schilbach *et al.*, it is not clear that this commits the social perception approach to a “spectator theory of how we relate to other people” (sect 1.2, para. 2). For, first of all, there is no reason to construe the social perception theory as a general theory of “how we relate to other people.” Not only is the theory fully consistent with the idea that social life is more a matter of interacting with, than merely observing others. Additionally, it can also maintain that when we perceive others' emotions and goals, say, we typically do so in order to facilitate or enable interacting with them. For example, I may perceive anger in another person's facial expressions and gestures; the

former expresses specific features of the anger whereas the latter articulates its intensity and level of arousal (Ekman 1965). But this need not involve a static observational stance. Rather, I see this anger as affording (or perhaps constraining) further interactive possibilities. My social perception is thus typically part of an ongoing process in which I use what I see in others to further negotiate my engagement with them.

More importantly, the social perception account can maintain that the ability to perceive others' mental states may be a capacity that is developed and/or refined within interaction, for example, the face-to-face interaction characterizing early infant-caregiver exchanges (see, e.g., Hobson 2002; Legerstee 2005). Moreover, even in adult perceivers, our exercise of the ability may be greatly facilitated by current interaction with others—and may in some cases be hindered in the absence of interaction (see, e.g., Gallagher 2008). For example, certain socially-salient details—gestures, intonation, posture, shifts of spatial proximity, and so forth—may only become available for perception as an interaction unfolds over time. And when we perceive facial gestures (e.g., a smile or frown), we automatically attune to these gestures by involuntarily mimicking them (Dimberg & Thunberg 1998). As one of the target article authors notes in another paper, this mimetic response seems to indicate that “the process of perceiving faces always includes an ‘enactive’ element through which we engage with and respond to stimuli instead of a mere ‘passive’ perception of face-based cues” (Schilbach *et al.* 2008a, p. 45). The social perception approach is fully compatible with this observation.

But Schilbach *et al.* are right that at least standard versions of the social perception approach suggest that social cognition is “something that could in principle occur in the presence of a one-way mirror, where a detached observer reads out the mental states of another person” (sect. 2.1, para. 2). However, it seems highly plausible that “detached” social perception of the “one-way mirror” sort could *in principle* occur; indeed, it might be something that happens fairly frequently—as, for example, when we perceive the emotions expressed by people on TV, while watching one's fellow diners in a restaurant, or when viewing others from a distance.

So Schilbach *et al.* are faced with the following dilemma. Either they maintain that social perception is in principle impossible in the absence of current social interaction, as, for example, in the case of the one-way mirror. This is a very strong claim: A single instance of social perception without interaction (e.g., successfully perceiving a diner's expression of happiness *as such* across a crowded restaurant) would suffice to falsify it. Or else they acknowledge that the latter is a possibility. But then they are wrong to suggest that their “second-person” approach is distinguished from the social perception approach by the “spectatorial” nature of the latter. For, the sort of purely “spectatorial” social cognition that the social perception approach as such makes room for (e.g., recognizing emotional expressions at a distance or in the absence of interaction) is one that Schilbach *et al.* themselves want to accommodate.

In our view, it is crucial to recognize the broad scope of our social competence, encompassing situations in which we are active participants, as well as situations in which we are passive bystanders. Despite their justified emphasis on the primacy of interaction, Schilbach *et al.* recognize this complexity and attempt to develop their view accordingly. However, in doing so, they fail to show that the social perception approach to social cognition is genuinely committed to the sort of “observer epistemology” they see their own view as opposing.

Although we have here focused on the social perception approach, our commentary also raises the more general question of whether the theoretical commitments of existing approaches really are so opposed to the “second-person” approach championed by Schilbach *et al.* Defenders of TT, for example, have long emphasized the importance of social interaction for the development of desire and belief understanding (e.g., Repacholi

& Gopnik 1997; Ruffman et al. 1998). “Development in social cognition depends on two-way traffic between self and other,” as Meltzoff et al. (1999, p. 19) put it more than a decade ago. So perhaps it is not just the social perception approach that in reality is less “spectatorial” than Schilbach et al. make it appear to be.

## Interaction versus observation: A finer look at this distinction and its importance to autism

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**Abstract:** Although a second-person neuroscience has high ecological validity, the extent to which a second- versus third-person neuroscience approach fundamentally alters neural patterns of activation requires more careful investigation. Nonetheless, we are hopeful that this new avenue will prove fruitful in significantly advancing our understanding of typical and atypical social cognition.

We enthusiastically applaud the call for a second-person neuroscience as described in the target article by Schilbach et al., and are excited for the new insights this avenue of research will bring. In this commentary, we expand on the target article in two ways. First, we suggest increased emphasis on characterizing the differences in neural processing during an interaction as compared to observation. Second, we elaborate on the potential importance of this research to our understanding of autism.

Schilbach et al. argue that engagement in interpersonal interaction fundamentally changes cognitive and neural processing as compared to such processing during observation alone. For example, interpersonal interaction may recruit additional neural regions or systems that are not present during third-person observation. The authors present compelling preliminary pieces of evidence to support their theory, as well as many suggestions for future directions. Here we discuss several notable differences between observing a person and engaging with a person, which can make isolating the interaction component difficult. First, engagement with another involves a contingency (or back and forth) between participants rather than passive perception and as such includes an element of action. Second, and related to the first, when a response is required (as is common in an interaction as compared to observation) attentional demands may be higher. Third, the stimuli used to elicit the feeling of being in an interaction have different low-level characteristics than those that signal no interaction. A final possibility is that there is something special about being engaged with another that goes beyond the simple differences described above.

Controlling for these differences is important, and although Schilbach et al. devote attention to this problem, they do not address whether stimulus characteristics secondary to the interaction could drive differences in neural processing. For example, in one study participants are presented with a face either facing towards or away from them that makes either communicative or arbitrary facial movements (Schilbach et al. 2006). Ventral medial prefrontal cortex (vmPFC) and amygdala regions are recruited to a greater extent for the communicative facial expressions directed towards the participant but these regions may be sensitive to direct gaze and facial movement independent of social engagement. While these expressions are typically

encountered in the context of an interaction, they are also seen in movies, TV, and pictures when the viewer is (presumably) detached. Although interaction is often a more ecologically valid social situation, it is an open question of how, once other factors are controlled for, this interaction fundamentally changes the neural correlates of social processing.

We have begun to address this question (Redcay et al. 2010) by borrowing a method from developmental psychology (e.g., Kuhl et al. 2003; Murray & Trevarthen 1985) in which participants are engaged in a simple, highly scripted interaction that is either conducted via live video feed (“face-to-face”) or via video recording. The recorded conditions included one in which the same video from the live interaction was repeated and one in which a video of the experimenter from a different interaction was played. Crucially participants were told to continue to play along in the recorded condition even though the experimenter would not be able to see or hear them. These controls allowed for an examination of brain regions that were recruited during an interaction that could not be accounted for by differences in stimulus properties. Comparison of live and recorded conditions revealed that largely the same set of brain regions were engaged in both conditions. For example, robust recruitment was seen in the posterior superior temporal sulcus (STS) during both live and recorded conditions, which is not surprising given the STS’s role in human action perception (e.g., Pelphrey et al. 2004; Saxe et al. 2004). Interestingly, the live condition showed increased activation of the posterior STS, and this extended more posteriorly into the temporo-parietal junction (TPJ), a region associated with theory of mind processing. Thus, this study offers support for differences in the magnitude of activation in brain systems between live, contingent interaction, and non-contingent interaction when stimulus characteristics are constant and some support for fundamental differences in the brain systems recruited. Future studies which control for action, attention, and stimulus characteristics (in addition to those proposed by Schilbach et al.) will be critical to disentangle where the “bookends” (sect. 4) begin and end; in other words, what are the differential effects of second- versus third-person approaches to social cognition on neural patterns of activation?

Characterizing these “bookends” is especially important for understanding autism, a developmental disorder characterized by impairments in social interaction, particularly in the intentional coordination of attention with others, or joint attention (e.g., Charman 2003; Mundy & Newell 2007). However, offline laboratory-based tasks often fail to find deficits in joint attention behaviors (Nation & Penny 2008; Redcay et al. 2012). Similarly, tasks tapping into belief representations demonstrate fairly typical performance (e.g., Senju et al. 2009) and even typical neural patterns of activation (e.g., Dufour et al. 2012). One possibility is that these third-person studies may be failing to capture the challenges of a real-time social interaction for a person with autism. A recent study of ours (Redcay et al., in press) compared patterns of activation during a real-time joint attention game between high-functioning adults with autism and typical adults. Whereas typical adults demonstrated selective recruitment of the left posterior STS and dorsal medial prefrontal cortex (dMPFC) during joint, as compared to solo, attention, the participants with autism revealed a pattern of reduced selectivity due to both hypoactivity during the joint conditions and hyperactivity in the solo condition. These data suggest a failure to modulate these brain regions according to whether the task required a social interaction. Importantly, the differential effects of second- versus third-person interaction might vary between typical and atypical populations, or change throughout development. This presents a major challenge to our understanding of the neurobiology of social processing in autism, but we are optimistic that a continued second-person neuroscience approach will reveal the mechanisms underlying real-world social difficulties in autism.

## Social affordances in context: What is it that we are bodily responsive to?

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**Abstract:** We propose to understand social affordances in the broader context of responsiveness to a field of relevant affordances in general. This perspective clarifies our everyday ability to unreflectively switch between social and other affordances. Moreover, based on our experience with Deep Brain Stimulation for treating obsessive-compulsive disorder (OCD) patients, we suggest that psychiatric disorders may affect skilled intentionality, including responsiveness to social affordances.

We suggest that the two constituents of a second-person approach proposed by Schilbach et al. – emotional engagement and social interaction – are best seen as aspects of bodily or *skilled intentionality*. Skilled intentionality can be understood as adequate responsiveness to a *field* of relevant affordances (Rietveld, in press) enabled by embodied know-how or abilities. From phenomenology (e.g., Merleau-Ponty 1945/2002) and ecological psychology (e.g., Gibson 1979; Reed 1996) we learn that normally we engage skillfully with our environments (Ingold 2000/2011). This skillful engagement is a form of unreflective action that is “solicited” or “motivated” by the situation. It is characterized by responsiveness to “affordances” (Gibson 1979; Rietveld 2008); to possibilities for action offered by the environment. Affordances are relations between aspects of the environment and abilities (Chemero 2003). Crucially, we are selectively responsive to one affordance rather than another: In the context of the particular situation and depending on the person’s concerns, some affordances are more relevant than others. Social affordances are a subcategory of affordances, namely possibilities for social interaction offered by the environment. For example, a friend’s sad face invites comforting behavior, a person waiting for a coffee machine can afford a conversation, and an extended hand affords a handshake. The field of relevant affordances integrates social affordances and other affordances such as object affordances, epistemic affordances, place affordances, and even possibilities for reflection.

Although social interactions are extremely important for understanding both our everyday life and possible disorders of it, it is important to take into account that they take place within a broader context: Any relevant possibility for social interaction is embedded in a field of other soliciting possibilities for action. While engaged in a conversation with a friend, the cup of coffee on the table affords drinking from it, and my iPhone affords checking my email. Every now and then I unreflectively switch from interacting with my friend to drinking and back to the conversation afforded by my friend. Thus “the context” is not a static pre-given: What is at the foreground and what is at the background for us shifts – depending both on what happens in the environment and on our current needs. It is important to understand how we switch spontaneously from responsiveness to a social affordance to responsiveness to another affordance, and back, because this is what happens in real life all the time.

Are we just “responsive to the socially relevant, expressive behavior of others” (target article, sect. 3.1.1, para. 3) or are we

responsive to something broader? Our work on skillful unreflective action suggests that it is the *whole* field of relevant affordances (social and other) that we are responsive to. This also explains why we switch so easily between interacting with a person and interacting with an object: We are immersed in an integrated field of relevant affordances, each of which can solicit activity. Affordances in the background can solicit activity because they are bodily *potentiating*. A relevant affordance can generate bodily “action readiness” (Frijda 1986; 2007), that is, the readiness of the affordance-related ability (Rietveld, 2008). In this way, starting from bodily or skilled intentionality, our perspective avoids an artificial separation between social cognition and nonsocial engagements with the environment.

All this amounts to putting social affordances in context, which is in line with our findings in psychiatry, where we investigate the phenomenology of patients suffering from treatment-refractory obsessive-compulsive disorder (OCD) who are treated with Deep Brain Stimulation (DBS). DBS treatment consists of permanently implanted electrodes that deliver electrical pulses to a target brain region. DBS of the nucleus accumbens shows encouraging results as treatment for therapy-resistant OCD (Denys et al. 2010). OCD is characterized by the presence of recurrent and anxiety-provoking thoughts, images, or impulses (obsessions), typically followed by repetitive ritualistic behaviors (compulsions) to relieve anxiety. One could interpret compulsions as a disturbance in affordance-responsiveness, the perpetuation of a meaningless act that is an ongoing but inappropriate response to the field of affordances. Interestingly, some patients respond rapidly to DBS and many report profound changes (Denys et al. 2010). Important changes do indeed concern the social dimension: Patients report increased social interests and communicative interactions. However, patients also report a different interaction with the world in general; feeling more open and less anxious. Some even report a renewed sense of their own body, and more intense perception of the world. This suggests that at least certain kinds of psychiatric disorders may be described by changes or dysfunction in affordance-responsiveness, including responsiveness to social affordances.

There is something right in Schilbach et al.’s suggestion of understanding psychiatric disorders as “disorders of social cognition” (sect. 5.1). However, they are not disorders of *just* social cognition. From the OCD patients treated with DBS, it becomes very clear that many aspects of engagement with the world change all together: perception, reflection, mood, interests, and social interaction. These phenomenological changes can be understood as changes in their responsiveness to the field of affordances as a whole, not just to the social affordances encountered. This general capability of affordance-responsiveness may correspond to brain activities that heavily interact and need to be understood in rapidly communicating neuro-circuitries (Freeman 2000; Friston 2011; Friston et al. 2012; Thelen & Smith 1994) rather than separate brain areas, which in turn explains the integrated responsiveness to the field of affordances. This general capability of affordance-responsiveness may be directly influenced by brain manipulation such as with DBS.

To conclude, Schilbach and colleagues make an interesting call for a second-person methodology for neuroscience. We also support their broader understanding of social cognition as fundamentally encompassing the implicit, bodily, affective, and contextual aspects of our social interactions. We suggest that a fruitful way to integrate these aspects is to understand social interactions as a form of skilled intentionality. We are bodily responsive to a field of relevant affordances, including social and other affordances. Such a broader account sheds light on how we unreflectively switch between these affordances. Finally, based on our experience with DBS for treating OCD patients, we suggest that psychiatric disorders may affect affordance-responsiveness in general.

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## Further steps toward a second-person neuroscience

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**Abstract:** Schilbach et al. contribute to neuroscience methodology through drawing on insights from the second-person approach. We suggest that they could further contribute to social neuroscience by more fully spelling out the ways in which a second-person approach to the nature and origin of thinking could transform neuroscience.

By integrating social neuroscience with a second-person approach, Schilbach et al. make a significant contribution, at least to neuroscience methodology. A further contribution, we suggest, would be to more fully spell out the implications of a second-person approach for neuroscience. We take it that the second-person approach is a form of a relational, action-based, or developmental systems approach (e.g., Carpendale & Lewis 2010; Overton 2006) because Schilbach et al. state that their second-person approach to knowing minds is based on an “interactive account of social cognition that emphasizes the constitutive role of participating in the social world” (sect. 6, para. 3). From this sort of a perspective, knowledge is interactive rather than representational, and this should lead to a different way of thinking about what the brain does. Neuroscience can only explain cognition as well as the psychological theory it is assimilated to, so there is a second and deeper level at which a relational metatheoretical approach to the nature and origin of thinking could transform neuroscience. Schilbach et al., however, are somewhat silent on these implications. We encourage them to be more explicit in order to avoid the problematic assumptions presupposed in the computational view of the mind.

A relational, action-based, approach would re-conceptualize cognitive and social cognitive development in an embodied and situated context of mutual engagement. According to such an account, children construct knowledge by learning the interactive potential of aspects of the world as experienced, which enables them to anticipate the results of their actions and thereby engage in viable interactions with the world. Cognition, then, does not consist of computations performed on internal symbols, but is a process of anticipatory and adaptive action, and develops through the mastery of physical and social interactions. Importantly, if an agent’s knowledge depends on its history of situated actions and interactions in its environment, it simply cannot be characterized in terms of internal representations of an outside world (Marshall 2009).

If meaning, communication, language, and thinking cannot emerge independently of social-emotional interaction, then the brain cannot be viewed in the classical computationalist sense as a detached information-processor, which, in any event, is a vacuous claim because it assumes a homunculus (e.g., Heil 1981; Tallis 2004). Rather, neural activation and interconnectivity formed through social experience must enable persons to anticipate increasingly complex interactions within a given environment based on their interaction histories, and to elicit more complex social, emotional engagement. Furthermore, the brain must do this *without* being described as a thinking or social entity in and of itself, or else a second-person neuroscience would ascribe to the parts of an organism cognitive functions that can only properly be ascribed to the whole, thus succumbing to the *mereological fallacy* that plagues contemporary neuroscience (Bennett & Hacker 2003).

Despite the fact that in the target article Schilbach et al. have pioneered new experimental paradigms, admirably critiqued “spectatorial” theories of social cognition (Hutto 2004), and promoted the neuroscientific study of ongoing social interaction dynamics and social synchronies, the danger remains that even in trying to situate brain activity in a sociocultural context, social engagements will once again be reduced to computational manipulations of purely internal representations in an individual, isolated mind, as has generally been the case in classical cognitivist approaches to social cognition (Frith & Frith 2006; Goldman 2006). Indeed, many of the methods advocated by the authors may be applauded by traditional cognitive neuroscientists who have retained the information-processing assumptions of classical cognitive science. For such theorists, the only shift in thinking required by this target article may be that emotional engagement and ongoing interaction must be included in the experimental design in order to isolate the peculiar social cognitive functions that characterize social encounters. Such theorists might even suggest that social cognitive functions could be better localized in the brain by employing two functional magnetic resonance imaging (fMRI) machines to study both individuals in a dyadic interaction, rather than just one. We suggest that Schilbach et al., in crafting experimental methods to be employed in service of a new, second-person framework for neuroscience, have not clarified the framework governing the *interpretation* of subsequent experimental results, and have inadvertently improved the methods of a traditional neuroscience that continues to operate on a notion of a detached, information-processing individual mind. This leaves open the possibility that these same second-person methods could just as easily be used by traditional neuroscientists to locate specific brain structures in which social cognition supposedly resides, and to interpret those brain structures as sites of the internal symbol manipulation that supposedly *constitutes* social cognitive functioning. The innovative methods of second-person neuroscience, therefore, do not protect theorists from the mereological fallacy (Bennett & Hacker 2003).

A challenge for a second-person neuroscience is getting from the subpersonal level of neural activity to the personal level of meaning, rationality, and normativity. This distinction is generally neglected in neuroscience, perhaps because it seems difficult to bridge this gap from the perspective of a computational approach. From an action-based approach, however, neural activity makes action possible, and meaning emerges as infants learn the interactive potential of their world. Within infants’ interpersonal social and emotional engagement human forms of communication emerge, making self-awareness and thinking possible. Neural pathways are structured through experience in social-emotional interaction and play a causal role in interactivity. Although neurons are necessary, we cannot locate rationality and normativity at that level, nor indeed the interpersonal experience of engagement with others that is so important in the second-person approach. Rather, psychological phenomena at the personal level are emergent, and, as Schilbach et al. state, are constituted through participation in the social world. This needs to be made explicit in a second-person neuroscience.

We encourage Schilbach et al. to further integrate the second-person approach with neuroscience. If the traditional, computational view of the individual mind cannot account for the emergence of meaningful communication, and ignores important aspects of embodied and situated social cognition, then it is necessary to adopt a second-person approach informed by an embodied relational metatheory in interpreting the neuroscientific data on social cognition.

### NOTE

1. Deceased.

## Mirror neurons are central for a second-person neuroscience: Insights from developmental studies

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**Abstract:** Based on mirror neurons' properties, viewers are emotionally engaged when observing others—even when not actively interacting; therefore, characterizing non-participatory action-viewing as isolated may be misleading. Instead, we propose a continuum of socio-emotional engagement. We also highlight recent developmental work that uses a second-person perspective, investigating behavioral, physiological, and neural activity during caregiver–infant interactions.

We comment on two points: one conceptual, relating to the implications of the discovery of mirror neurons, and the second methodological, relating to the application of a second-person perspective in developmental psychology. Schilbach *et al.* wish to distinguish two types of social interactions—active participation among individuals (e.g., face-to-face), and passive social viewing (e.g., watching a movie of someone)—claiming there may be key differences in the neurophysiology underlying these different types of interactions. However, we think this is in part a false dichotomy; rather, there is a continuum of social-emotional engagement, influenced by a variety of factors. The level of (current or future) active interaction is one such factor, but others include the relationship between individuals, the perceiver's goals, and the types of actions viewed (e.g., Breithaupt 2012). We are in agreement with Rizzolatti and colleagues that mirror neurons allow viewers to go beyond cold, detached, third-person, mere spectator perspectives, even if viewers make no active interaction attempts (Rizzolatti & Sinigaglia 2010; Sinigaglia 2010). Therefore, the characterization of non-participatory action viewing as isolated (an “isolation paradigm”) may be misleading.

Instead, viewers can be emotionally engaged by simply viewing others. Anyone who has felt the emotional pain of a favorite actor or actress while watching a movie can testify to this. The importance of phenomenology in theorizing—that viewers are not pure spectators, but that social perception involves emotional engagement—has been arguably the greatest implication of the discovery of mirror neurons. Several scholars, including Husserl, who is considered the father of phenomenology, and Merleau-Ponty, previously reasoned and theorized that our perception of the world activates sensorimotor programs and thus allows our bodies to have first-person knowledge about the object of our perception. Work on the mirror neurons system for facial expressions (Ferrari *et al.* 2003) and emotions—by Iacoboni, Aglioti, Wickler, Singer, and others from our group in Parma—demonstrate that when we see emotions, there is a brain mirroring in the traditional mirror areas (premotor-parietal), as well as in deep areas of the brain involved in first-person perception of emotion, such as the cingulate cortex and the anterior insula. In other words, it is *as if* viewers experience the same emotion as that displayed by the other. The simulation account (Gallese & Goldman 1998) is tightly linked to the empirical work on mirror neurons, and the simulation account is indeed an empirical bridge between the mirror neuron work and the phenomenological grounding previously mentioned. Moreover, nearly all work on single cell recordings of mirror neurons involves second-person interactions; thus, the simulation paradigm and the mirror neuron discovery are of utmost importance for theorizing about a neuroscience of social interaction.

We agree with the authors that there is a need to look more at interactions involving brain networks for coordinating actions and

second-person engagements. The dynamics occurring during a social interaction have different requirements when the observer is passively viewing a scene, compared to actively engaging with another individual. For example, in an active engagement there is concurrent activation of executive function networks, which plan and coordinate online movements with the interacting agent, during potential intersubjective exchanges.

Developmental psychological studies have utilized this second-person perspective, and in doing so have been useful in describing the complexity of social interaction from early in the postnatal period. In particular, emotional responses between caregivers and infants are of utmost importance in tracking the developmental emergence of social understanding. Early interactions between caregivers and infants are formative in a number of ways, giving infants opportunities for learning and also strengthening bonds between infants and caregivers. Studying caregiver–infant interactions is particularly important, as those early interactions can have lasting impacts on later social and emotional development. Interactions with real social partners—not simply avatars—can provide more ecologically valid measures of social engagement and perception. Moreover, caregiver–infant interactions can be used as a guide for the creation of ecologically valid adult studies (e.g., Dumas 2011).

A number of developmental studies (not mentioned by Schilbach *et al.*) have successfully utilized a second-person perspective, investigating behavioral, physiological, and neural synchrony during caregiver–infant interactions, which may serve as models for second-person developmental research. For example, in work with humans, Feldman and colleagues found heart rate synchrony between mothers and infants during face-to-face interactions (Feldman *et al.* 2011), Messinger and colleagues discovered stable individual differences in infants' attention to mothers' faces, controlling for maternal behaviors, such as smiling (Messinger *et al.* 2012), and Musser and colleagues found neural correlates of maternal sensitivity during face-to-face interactions (Musser *et al.* 2012). Recent work in our lab examined newborn infant monkeys' live face-to-face interactions with human caregivers. Electroencephalogram (EEG) recordings revealed a 5–6 Hz activity suppression when the infants produced facial gestures and when infants observed facial gestures, but not when they observed non-biological stimuli (Ferrari *et al.* 2012). This EEG suppression, named mu-rhythm, is considered a signature of the mirror neuron system. This finding suggests that the basic elements of the mirror neuron system are operational in the first week of life and might be central for early face-to-face interactions.

## Toward a neuroscience of interactive parent–infant dyad empathy

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**Abstract:** In accord with social neuroscience's progression to include interactive experimental paradigms, parents' brains have been activated by emotionally charged infant stimuli—especially of their own infant—including baby cry and picture. More recent research includes the use of brief video clips and opportunities for maternal response. Among brain systems important to parenting are those involved in empathy.

This research may inform recent studies of decreased societal empathy, offer mechanisms and solutions.

Within the field of social neuroscience, investigators are now studying the brain basis of human parenting, using paradigms in accord with the ideas of Schilbach *et al.* in the target article. Recent neuroimaging studies, in which mothers respond to infant stimuli, have demonstrated the functional significance of many parental care-giving-related brain regions—building on rodent neuroscience. In summary, a broad array of brain regions activate to baby-cries (Swain, Mayes, & Leckman 2004) and pictures (Swain & Ho 2010) and according to measures of parent–infant interaction, thoughts, and behaviors—highlighted by parts of the amygdala (alarm), striatum/nucleus accumbens (NA; motivation and reward). In humans, cortical response circuits are added, including the anterior cingulate for decision-making, inferior frontal gyrus for theory of mind, as well as orbitofrontal cortex, insula, periaqueductal grey, and dorsomedial prefrontal cortex that regulate complex social-cognitive functions currently under study. (For reviews, see Barrett & Fleming 2011; Mayes *et al.* 2005, Swain 2011a; 2011b; Swain *et al.* 2011.)

One of the key conceptualizations in the neuroscience of parenting has been that of empathy, which has been a central topic in social neuroscience highlighting the insula (Decety & Jackson 2004, Lamm *et al.* 2007). Among parents, the insula was activated while reacting to own baby cry (Kim *et al.* 2010) and more among breast-feeding versus formula-feeding mothers (Kim *et al.* 2011). Furthermore, observing and actually imitating faces of their own child activated in the insula and other cortical motor imitation and mirror neuron systems (Lenzi *et al.* 2009), which correlated positively with levels of maternal empathy assessed with independent validated interviews. Support for the insula being part of a general system of empathy includes responses of non-parents to baby-pictures (Schechter *et al.* 2012)—which also involves premotor cortex activation in preparation for appropriate behavioral responses (Caria *et al.* 2012).

Direct studies of reciprocal baby brain function in response to their parents are yet to be done; however, a recent neuroimaging study of mothers showed how perceived maternal care (a proxy for animal models' licking and grooming behaviors) affects both brain structures and functional response to own-baby cries in adult mothers (Kim *et al.* 2010). In this study, mothers who reported higher maternal care in their own childhood showed higher gray matter density, proportional to the number of neurons, in a range of higher cortical areas and executive function areas, including the insula, superior and middle frontal gyri, orbital gyrus, superior temporal gyrus, and fusiform gyrus. There were also increased functional responses in a number of frontal brain regions and the insula in response to own-baby cries. This may reflect long-term effects in humans of early-life mother–child interactions affecting adult maternal mother–infant interactions.

Three recent studies of maternal interactions with brief video clips come closest to second-person neuroscience. (Atzil, Hendler, & Feldman 2011, Atzil, Hendler, Zagoory-Sharon, Winetraub, & Feldman 2012, Schechter *et al.* 2012). In Atzil *et al.* (2011; 2012), mothers were scanned while observing several own and standard infant-related vignettes. Beyond basic motivation/reward nucleus accumbens (NA) responses, functional NA and amygdala were functionally correlated with emotion modulation, theory-of-mind, and empathy networks including the insula. In studies by Schechter *et al.* (2012) mothers with post-traumatic stress disorder (PTSD) and controls, epochs of play and separation from their own and unfamiliar children were processed by regions including the insula. Extensions of this work might be to ask mothers to respond to the visual stimuli as if they were actually there with a push-button device to attempt parenting responses. Other experimental approaches on the horizon include direct electroencephalography (EEG) or functional near-infrared spectroscopy (fNIRS) studies of simultaneous interacting mother–infant dyads.

The neuroscience of maternal–infant dyadic interaction and empathy leads to a concern regarding apparent societal declines in

other-orientation in the United States. For example, Americans are less likely than ever to participate in many types of social experiences, from sharing dinner to attending religious services (Putnam 1995; 2000). Moreover, dispositional empathy has declined among American college students from the 1980s onward (Konrath *et al.* 2011), suggesting that young people today find it difficult to experience others' emotional worlds (O'Brien *et al.* 2013). Finally, there has been a recent change in attachment style. Today's college students increasingly report having a predominantly avoidant attachment style (Chopik *et al.* 2011; Konrath *et al.*, under review), which is characterized by having positive views of the self but negative views of others (Bartholomew & Horowitz 1991). It has been suggested that these trends may be related to modern electronic “social” interactions, many of which are at the level of mere observation (e.g., email, social networking sites) instead of dynamic interaction (discussed in the target article), and many of them are also lower in emotional engagement. Even tools that are more socially interactive (like Skype) do not currently allow eye contact. In fact, the “virtual” characters described in the target article have more properties of actual social interaction (i.e., eye contact, real-time responsiveness) than many social interactions commonly experienced today.

These considerations beg many broad social policy questions regarding the effects of different media environments on mother–child interactions. Parents may be continually distracted by their social media from caring for their infant—effectively simulating a still-face paradigm to their own infant (Tronick *et al.* 1978), which encourages infants to first try harder to engage their parent, and then to withdraw and become distressed (Mesman *et al.* 2009). Could some of the social changes described above be partially explained by an increase in still-face-like parent–infant interactions? Moreover, it is not just parents who are increasing their screen time in recent years. Children are now watching more television than ever and it is now common for toddlers to be proficient iPhone users (Konrath 2013). Does this affect the development of fundamental social cognitive capacities?

We recommend that future research take into account parental and child media use when examining neural signatures of attachment and bonding. Excessive media use may be a relatively unexplored risk factor, or a marker, for poor parent–infant attachment, with concerning implications for social-cognitive development. Second-person neuroscience used to optimize dyadic interventions may offer a solution (Swain *et al.* 2012).

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## It takes two to talk: A second-person neuroscience approach to language learning

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**Abstract:** Language is a social act. We have previously argued that language remains embedded in sociality because the motivation to communicate exists only within a social context. Schilbach *et al.*

underscore the importance of studying linguistic behavior from within the motivated, socially interactive frame in which it is learnt and used, as well as provide testable hypotheses for a participatory, second-person neuroscience approach to language learning.

Language is a strikingly social behavior. While it is possible to have social behavior that is not linguistic, the converse is not true. Language is learned, perceived, and produced within the fabric of social interaction. Using developmental and comparative literature, we have previously contended that the presence of structural and functional linkages between subcortical motivation systems, and conventional language and social circuits in the brain, are critical determinants of the evolution and development of language in a given species (Syal & Finlay 2011). A research program that aims to study language-learning needs to attend to language as embedded in its ecological context, acquired in the early development of an obligatorily social, gregarious, and often-altruistic species, where the motivation to learn to communicate with conspecifics drives both its ontogeny and phylogeny. To that end, researchers have thus far focused on the role of socially derived motivation in language learning through studying infant-caregiver interactions in the development of vocal communication (Goldstein & Schwade 2008; Kuhl 2007b). However, this corpus of knowledge has been constrained by the inability to study brain-behavior linkages through the acquisition of functional neuroimaging data that model ecologically valid social interactions. The novel methodologies discussed by Schilbach *et al.* in the target article use eye-tracking in conjunction with functional magnetic resonance imaging (fMRI) to create interactive paradigms that allow human participants to experience the effects of their gaze on that of a social counterpart, simulating a naturalistic social interaction, while allowing researchers to gather MRI data that elucidates underlying neural networks. This approach provides an immensely pliable platform on which social motivation in vocal learning can now be placed and probed, in both adult and infant language learners. For instance, the role of joint attention in guiding the learning of artificial object-labels in (a) adults, using both eye-tracking and fMRI, or (b) infants, using interactive eye-tracking setups, are immediate examples of experimental questions that can be addressed using these paradigms.

From early life, human children attend to social cues, share information, join games, and generally cooperate, serving a form of social learning limited largely to humans (Moll & Tomasello 2007). These prosocial tendencies also sustain vocal learning behavior during development, wherein numerous structural aids to language learning are presented to the infant in a characteristically social environment replete with positive feedback. For example, mothers reliably use predictable prosodic contours to modulate infant affect and attention (Fernald 1992; Fernald & Simon 1984). They engage in contingent turn-taking vocal interactions with their infants that facilitate vocal development (Goldstein & Schwade 2008). They use variation sets – sentences with partially overlapping syntactical structure – to aid word learning (Onnis *et al.* 2008). Recent work has shown how learning of the structural regularities of language can emerge from the richness of social interactivity embedded in the human ecological niche. Specific forms of contingently delivered vocal reinforcement from a social counterpart cause infants to change correspondingly specific features of their own vocalizations towards developmental advancement (Goldstein & Schwade 2008). Contingency of social interaction remains a core requirement in these learning processes – infants do not display vocal learning when the same amount of stimulation is provided in a non-contingent social interaction (Goldstein & Schwade 2008; Goldstein *et al.* 2003; Goldstein *et al.* 2010a), or through audio-visual media (Kuhl *et al.* 2003). Indeed, the extent of learning is in fact determined by the amount of social engagement – greater shared visual attention between infants and interactive social agents facilitates greater language learning (Conboy *et al.* 2008).

An idea essential to this approach is that social contingency in dyadic or triadic interactions is inherently rewarding, and promotes

learning through the recruitment of motivational neurocircuitry, and the facilitation of shared attention. In support of this, initial data using the experimental paradigm outlined in the target article suggest a role for reward-related circuitry in initiating joint attention on both neural and behavioral levels (Schilbach *et al.* 2010b). Numerous studies have highlighted the role of contingency in specific forms of reward-based learning. In adults, the caudate nucleus within the dorsal striatum is sensitive to reinforcement of action and shows a robust response when subjects perceive a contingency between their actions and task-outcomes (Tricomi *et al.* 2004). The caudate is also involved in encoding stimulus salience (Zink *et al.* 2006) and, in language learning, reward-related caudate activation in response to contingent feedback facilitates the learning of non-native phonetic contrasts in adults (Tricomi *et al.* 2006). This social hypothesis of language learning suggests that reward-based instrumental learning and positive affect systems may be critical to language development, not only in terms of acquisition, but also in the flexible integration of newly learned information within the existing lexicon. Positive affect embedded in social interaction could facilitate language-learning through salience-tagging information and/or shifting focus towards a broader information encoding context. Data from adults indicates that positive affect can lead to fundamental shifts in information processing through the facilitation of flexible modes of cognition (Isen 2002), which increase the breadth of attentional allocation in both perceptual and conceptual domains (Rowe *et al.* 2007; Schmitz *et al.* 2009). Additionally, as a social act, language learning and use involves not only the ability to make narrow associations between words and their referents, but also the broader capacity of reading another's mental states, possibly invoking a network of shared activation between minds. The affiliative role of positive emotions is likely critical to this interpersonal network resonance.

Past work on language learning has accorded limited significance to emergent properties of social interactions. The second-person approach to neuroscience posits social interaction and emotional engagement with social counterparts as fundamental features of social living that enable us to understand and learn from the minds of others, highlighting the importance of studying real-time interaction dynamics between individuals in an ecologically valid manner. Within the ecological framework of vocal learning, the parent-infant dyad constitutes a socially distributed system of learning, best viewed as a consolidated network that incorporates the learner, the social interactor, the interaction between the two, and the effect of each actor on its own and the other's nervous system.

## Second-person social neuroscience: Connections to past and future theories, methods, and findings

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**Abstract:** We argue that Schilbach *et al.* have neglected an important part of the social neuroscience literature involving participants in social interactions. We also clarify some part of the models the authors discussed superficially. We finally propose that social neuroscience

should take into consideration the effect of being observed and the complexity of the task as potentially influencing factors.

Our first point is that Schilbach et al. have neglected a relatively important part of the social neuroscience literature in which participants are actually involved in social interaction or exclusion/rejection with others. This major part of the literature shows that an overlap in neural activation exists between physical pain and social pain (following rejection). Studies that illustrate this point most commonly use the Cyberball paradigm, a computerized ball-tossing game eliciting feelings of social rejection and distress, which has previously been used in functional magnetic resonance imaging (fMRI) studies (e.g., Eisenberger & Lieberman 2004; Eisenberger et al. 2003). In this paradigm, participants who were first involved in a simulated ball-tossing game with two other players were then *implicitly* excluded from the game by the other two players who only passed the ball to each other, thereby socially *rejecting* the participant. Interestingly, the fMRI results showed that rejection produced brain activity in areas that are also activated when people experience physical pain.

We agree with Schilbach et al.'s claim that a second-person neuroscience would be particularly relevant to understanding mental or behavioral disorders. We have, in fact, recently examined social rejection (using Cyberball) in alcohol-dependent inpatients (Maurage et al. 2012). In this study, 22 abstinent alcohol-dependent participants and 22 paired controls played Cyberball during fMRI recording. Participants were first included by other players, then excluded and finally re-included (when the other two players resumed passing the ball to the participant). We found increased activation in brain areas typically associated with social-rejection feelings and with impaired ability to inhibit these feelings (as indexed by a reduction in frontal activation) in alcohol-dependent participants compared to matched controls. Reduced frontal regulation was suggested to be responsible for the interpersonal alterations observed in alcohol-dependence, which seems to be reinforced by impaired fronto-cingulate connectivity. As suggested by Schilbach et al., this very recent publication confirms the importance of second-person neuroscience studies as a dynamic tool for helping differential diagnosis in psychiatric disorders and also shows neglected studies related to second-person neuroscience.

Some other examples from this important field of literature may be found in studies investigating obedience to authority (such as the Milgram experiment). In a recent fMRI study, Cheetham et al. (2009) investigated the neural basis of obedience and empathy in participants who were instructed to punish a victim with electric shocks for every incorrect answer the victim gave. Other important examples of second-person social neuroscience come from studies on racism (Olsson et al. 2005), out-group dehumanization (Hein et al. 2010), and even cognitive dissonance (Kitayama et al. 2004). These studies represent only a few examples among many others of second-person social neuroscience effects that deserve to be reported in the current article.

The second point we argue is that Schilbach et al. have neglected an important aspect of the Simulation of Smiles (SIMS) model. The SIMS model recently proposed by Niedenthal et al. (2010) does not only constitute a model of *how* involuntary mimicry occurs during social interactions (as discussed by Schilbach et al.), but also specifies the involvement of different neural areas (e.g., amygdala, somatosensory cortex) in the psychological understanding of others' feelings during second-person interactions. This model constitutes a theoretical model of second-person understanding of emotional states, which was applied to smiling only because this emotional expression constitutes one of the more complex and ambiguous expressions involved during social interaction. For instance, the SIMS model specifies the influence of different social contexts (e.g., cultural, affiliative) on the use of functional triggers (mainly eye contact) inducing subsequent embodied or grounded processes. As far as we understand, this SIMS model clearly fits with what Schilbach and colleagues have coined as second-person

neuroscience "going social" and represents a direct and detailed second-person theoretical model of social interactions.

Finally, based on the findings from social psychology, we would like to stress the importance of taking into consideration, in future social neuroscience studies, the *effect* of being observed as well as the *complexity* of the task. Researchers have shown that performance may be impacted by the mere (or even imagined) presence of other people. More specifically, it has been claimed that in simple (well-learned) tasks, the presence of others leads to performance increments, whereas in complex (not well-learned) tasks performance is negatively influenced by the presence of others. This effect has been named the "activation theory model" by Zajonc (1965; see Strauss [2001] for a review of this phenomenon). As well, many studies in nonhuman primates have also shown that these effects are not limited to humans but have been observed in other social species, such as Capuchin primates (Dindo et al. 2009). We believe it is important to consider this phenomenon in future social (e.g., second-person neuroscience) experimental situations because it implies that performance – in fMRI, for instance – does not rely solely on participants' abilities but also depends on the internal awareness of the presence (or envisaged presence) of others. In our opinion, this highlights the importance of better understanding whether (and how) activity in the neural network may be modulated by the feeling of being observed and/or evaluated. Moreover, such social neuroscience fMRI investigations may confirm (or disconfirm) the involvement of specific cognitive processes during social interactions (attention, short-term memory, etc.) (Muller et al. 2004). This could be particularly important in psychopathology such as (social) anxiety disorders or alexithymia, as most of those disorders are known to be related to impaired attentional processes (Rossignol et al. 2007; Vermeulen et al. 2008) or memory processes (Vermeulen & Luminet 2009; Vermeulen et al. 2010).

## Authors' Response

### A second-person neuroscience in interaction<sup>1</sup>

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**Abstract:** In this response we address additions to as well as criticisms and possible misinterpretations of our proposal for a second-person neuroscience. We map out the most crucial aspects of our approach by (1) acknowledging that second-person engaged interaction is not the only way to understand others, although we claim that it is ontogenetically prior; (2)

claiming that spectatorial paradigms need to be complemented in order to enable a full understanding of social interactions; and (3) restating that our theoretical proposal not only questions the mechanism by which a cognitive process comes into being, but asks whether it is at all meaningful to speak of a mechanism and a cognitive process when it is confined to intra-agent space. We address theoretical criticisms of our approach by pointing out that while a second-person social understanding may not be the only mechanism, alternative approaches cannot hold their ground without resorting to second-person concepts, if not in the expression, certainly in the development of social understanding. In this context, we also address issues of agency and intentionality, theoretical alternatives, and clinical implications of our approach.

We are pleased and surprised to find that the second-person approach described in the target article resonates so positively with most commentators. An important number of those endorsements also suggest ways in which this account could conceptually be expanded further (e.g., **Cummins; Rietveld, de Haan, & Denys [Rietveld et al.]**), or into other domains such as language and communication (**Evans; Gambi & Pickering; Syal & Anderson**), animal research (**Hamon-Hill & Gadbois; Nephew; Simpson & Ferrari**), and robotics (**Dominey; Froese, Lizuka, & Ikegami [Froese et al.]**). In our response, we touch upon these suggested extensions (sect. R2). Afterwards we focus on comments that suggest providing further details in describing the theoretical specifics of the second-person approach (e.g., **Gariépi, Chang, & Platt [Gariépi et al.]**; **Hamilton**) (sect. R3). Also, we noticed that some commentaries take issue with the fact that we seem to push the second-person issue too far (e.g., **Moore & Iacoboni; Overgaard & Krueger; Simpson & Ferrari**), while on the other hand others suggest that we do not apply it consistently (e.g., **Gallagher, Hutto, Slaby, & Cole [Gallagher et al.]**; **Hamilton; Sameen, Thompson, & Carpendale [Sameen et al.]**) (sect. R5). Lastly, another group of commentaries exists – focusing on issues of intentionality and agency (**Gallotti; Krach, Müller-Pinzler, Westermann, & Paulus [Krache et al.]**; **Cleret de Langavant, Jacquemot, Bachoud-Lévi, & Dupoux [Cleret de Langavant et al.]**; **Lewis & Stack; Longo & Tsakiris; Moore & Paulus**) – which seems to read assumptions into our article that we do not make (sect. R4). Therefore, we think it is necessary to start off by briefly re-stating what our proposal for a second-person neuroscience is and what it is not, what it hopes to add, and what its limitations are before we tackle the other questions (sect. R1). As in the target article, we end by discussing clinically relevant aspects of our proposal, which have been referred to in different commentaries (**Chakrabarti; Nephew; Redcay, Rice, & Saxe [Redcay et al.]**; **Rietveld et al.**) (sect. R6).

## R1. Rebooting a second-person neuroscience

What may have irritated a number of commentators is that our proposal is simultaneously *less* and *more* extreme than some assume or deduce from our target article, as in the following three respects: First, we are less extreme, in the sense that we do not claim that second-person engaged interaction is the only way to understand others, although we defend our claim that it is ontogenetically prior. Second, we are more extreme in a methodological sense,

in that we claim that crucial aspects of social understanding remain under-studied as long as we assume that spectatorial paradigms are the only approach that can tell us meaningful things about how we go about in the social world. Third, and most importantly, we are extreme in our theoretical proposal to start looking in a different way at concepts like “minds” or “intentionality,” in that these are not just “properties” to be read into behavior. The neurobiological substrates that can be found in such instances may be real, but it is unclear what their fine-grained functional role might be in the field of social cognition. To us this seems comparable to earlier stages of the search for human psychology, in which logical operators and symbolic processing proved to be fruitful in computing aspects of conscious human thinking and decision-making, but not in describing the basic nature of human cognition, in that it failed to capture the subsymbolic processes that underlie logic and symbols. However, in the case of social understanding, our approach is more radical in that it not only questions the mechanism by which a cognitive process comes into being, but it also questions whether it is at all meaningful to speak of a mechanism and a cognitive process when it is confined to intra-agent space.

Before advancing to the discussion of more specific points raised by the commentaries, we will briefly touch upon two general concerns: First, as stated in the previous paragraph, we do not, at any point, exclude the possible existence of an *observation* mode of social cognition, a way of theorizing about people from a third-person stance, in terms of a “*we-mode*” (**Gallotti**) or by means of “simulations” of what others feel: We can certainly infer things about others when we are observing them through a one-way mirror. Rather than denying first- and third-person social cognition, we want to emphasize the status of second-person engagement and direct interaction. While we acknowledge that within interaction there is a continuum (**Simpson & Ferrari**), we also hold that there is something fundamentally different about direct interactions with the world or with others. Specifically, we do not think that approaches that give priority to first- and third-person modes can satisfactorily describe how these interaction-related faculties come into existence. Importantly, we do not think that they are necessary prerequisites for successful social interaction, whereas we propose that a second-person mode is a prerequisite for coming to know others. From a developmental point of view – rather than assuming the existence of a gap between self and other – we understand the subjective experience of such a “gap” as a result of development through interaction and engagement with others, a process in which, for instance, contingencies related to my own volition and that of others may play an important role (see target article sect. 4). In other words, it seems to us that it is the emergence of the capacity for reasoning about people for inference and simulation that needs to be investigated and understood as resulting from our prior ability to interact with them, and not how social actions and interactions emerge from our capacity to represent knowledge about other people.

Second, the focus of our article falls on neuroscientific methods, and more precisely, on possible solutions for the problems or potential incompatibilities that seem to exist between a neuroscientific approach that focuses on an individual’s brain, and a social and cultural world in which “information processing” does not seem to be at all

limited to the confines and characteristics of particular individuals. One of the core insights here is that neuroscience should not content itself with a spectatorial view of social cognition. This is why we advocate the adoption of paradigms that allow a person to engage or interact with someone in a meaningful manner. Indeed, some commentaries (e.g., **Vermeulen, Pleyers, & Mermillod** [Vermeulen *et al.*]) identify paradigms which they assume could be considered as belonging to the category of “second-person” studies such as Olsson *et al.* (2005), Hein *et al.* (2010), or Kitayama *et al.* (2004), whereas in fact these studies are purely observational. So is the concept of social immersion (**Krach *et al.***), whereby interaction is merely used to prime a different way of reasoning. According to our proposal, these paradigms are insufficient to approach, explore, and explain the core processes that go on and constitute everyday-life social interactions.

On the other hand, the need for a second-person neuroscience that looks beyond the individual brain as an explanans does not imply that looking at an individual brain is incompatible or meaningless in a second-person context (as suggested by **Gallagher *et al.*** and **Sameen *et al.***), or that specific brain activations cannot be an adequate explanans for a well-defined explanandum. The core message of a second-person neuroscience is that in social cognition studies, the part that is often left out, in an attempt to isolate an explanandum, a scientific phenomenon, or a system (which has, in psychology, been confused with isolating a person), might not just be part of the explanandum, but might well be the crucial explanans. In other words, we should not simply abandon any specific way of probing parts of the system, but we should be aware that we are only dealing with parts of a causally complex dynamic framework out of which we lifted a specific and perhaps non-essential part. Consequently, we should not draw conclusions on how people interact or what parts of the brain are responsible for a function in interaction, if we have never taken such measurements during interaction. Otherwise, the functional role we ascribe to specific brain areas is confined to a spectatorial account, which sits comfortably behind the one-way mirror.

## R2. Contextualizing and extending the second-person account

The fact that we do not seek to replace all other alternative theoretical accounts, but instead advocate the primary role of second-person engagement and interaction for social cognition and describe its sufficient empirical characterization as a key target for the future of social neuroscience, does not make the implications of our approach less wide-ranging. As **Cummins** suggests in his commentary “the ‘dark matter’ may be much larger.” In fact, as Cummins points out, the overarching problem lies in the occidental tradition of focusing on the individual, rather than on the context. Indeed, this is also reflected in the issue of free will in western philosophy, and the controversy surrounding experiments questioning free will (e.g., **Haggard 2008; Libet 1985; Soon *et al.* 2008**), which revolve around the question of whether our actions are determined by our own volition or are instead decisions caused by “something else.” In this context we can also mention studies on unconscious determinants of behavior

and unconscious behavioral priming or goal activation (**Bargh & Earp 2009; Custers & Aarts 2010; Doyen *et al.* 2012**). In all of the above described cases, the fact that we perceive as exotic the idea that individuals might be mere pawns in an environment that “controls us” outside of awareness, only stems from an artificial split between individual agents and their environment, and between individuals. On the contrary (as suggested by **Dominey**), one could argue for a starting point, which holds that individual agents are intertwined with and part of their environment. Consequently, the question should be how we come to perceive ourselves as intentional agents that are separate from others and how this develops and results from our innate capacity for (inter-) action and engagement. What is the minimal requirement, not only of the individual brain, but of the dynamic system, that can account for the fact that I am able to perceive other people as different from myself, without taking this “gap” between self and other as epistemologically given?

Both **Cummins** and **Froese *et al.*** point towards the importance of focusing on dynamic systems, an idea that **Dominey** extends to robotics. Crucially, this includes an interaction between “A’s brain” and “A’s body,” as well as “B’s brain” and “B’s body” (see **Froese *et al.***, but also **Longo & Tsakiris**), with the important point being that these cannot be isolated from their shared environment. This harks back to what we mentioned earlier, namely that taking into account the dynamic system does not imply that one cannot assume sub-systems. It just means that these cannot be studied in isolation. As **Longo & Tsakiris** suggest for agency, **Cummins** points towards outcome prediction as an important mechanism. For instance, predictive coding mechanisms might constitute one of the brain’s primary functions, which could be related to subcortical bottom-up processes and reward mechanisms (**Hamon-Hill & Gadbois; Swain, Konrath, Dayton, Finegood, & Ho [Swain *et al.*]**). One interesting question is whether, at the system level, there is something like “shared predictive coding”—how the coupled system anticipates its own future states as well as those of the emergent, overt system behavior as co-constructed by the agents meeting each other in a social encounter. This ties in with **Cummins’** suggestion to go a step further, not only investigating brain activities in interactive settings and relating brain activities of different agents, but also to relate these to emergent phenomena in the interaction process. Approaches to study dynamic patterns of interpersonal gaze adjustment by making use of virtual characters in interactive settings have been introduced by **Bente *et al.*** (2007b; 2008b). These studies, however, have been restricted to the behavioral aspect of gaze coordination and have neglected the social cognitive dimension and its neural correlates. Our ongoing efforts are targeting the integration of both behavioral and neural data captured during human interactions, and utilize newly established dual eye-tracking methodology to connect experimental variations to participants’ responses (**Barisic *et al.* 2013**).

As highlighted in the target article, another important field in which interpersonal dynamics come into play is language research. This is also emphasized by the insightful comments provided by **Evans, Gambi & Pickering**, and **Syal & Anderson**, who suggest that a second-person neuroscience can learn from language research as well as it should itself “assume a second-person perspective”

(Gambi & Pickering) because – historically – the majority of work in this field has considered isolated examples of language production or comprehension without focusing on pairs of participants engaged in dialogue. We are thankful to these authors for pointing towards this interesting parallel in research development and are in full agreement with their view that investigations of real-time dialogue are likely to advance our knowledge of processes of interpersonal prediction and adaptation in joint activities. We are also intrigued by the comment provided by Evans, who draws attention to the person category of “first-person inclusive” to denote the union of speaker and addressee in non-Indo-European languages and thereby reminds us to also raise questions about cultural differences, as well as the intricate relationship of culture and social interaction.

Furthermore, the issue of language-based communication also ties in with the insightful commentary provided by Kevin Moore who discusses similarities between the second-person approach and a Wittgensteinian analysis of psychological concepts. According to Moore both approaches converge in their argument for a priority of interaction in grounding language and providing meaning that is not reliant on “ontologically private” states. Moore is also right in suggesting that our interest in the transformation of implicit to explicit social cognition stems from the idea that first- and third-person perspective arise from ontogenetically prior second-person experiences. We are also most sympathetic to Moore’s suggestion that on a Vygotskian view social interactions serve as the motor, that drives developmental processes (“maturing functions”) and may lead to their “internalization,” thereby allowing for the emergence of explicit forms of social cognition.

### R3. How far and wide: Situating the second-person account within current theories of social cognition

Some commentaries (Hamilton; Gallagher et al.; Sameen et al.) seem to suggest that we do not take the second-person idea far enough, whereas others seem to suggest that we take it too far (Moore & Iacoboni; Overgaard & Krueger). We take this disparity in judgment as an opportunity to spell out further where we situate our account.

Hamilton argues that the target article lacks a sufficiently detailed theoretical model of how social cognition works in order to lead empirical investigation of the neural mechanisms enabling it. We agree that – although the underlying philosophical ideas are only sketched in broad strokes – Hamilton is right to place the authors beside proponents of the enactive approach like de Jaegher et al. (2010), who emphasize interaction dynamics as an important feature and – in part – constitutive aspect of social understanding. Hamilton goes on to discuss (i) computational models derived from game theory, (ii) enactive approaches based on dynamical systems theory, and (iii) information processing models, which emphasize the idea of the brain being involved in generating predictions about future events. Hamilton clearly favors the latter kind of approach. She also hints at the possibility that these theories might not be mutually exclusive, but may converge.

Traditionally, enactive approaches have been formulated as being massively anti-representational, thus engendering

a paradigm shift in the cognitive sciences (Chemero 2009; Hutto 2008; Thompson 2007; Varela et al. 1991). Yet, it should be emphasized that the main idea of enactive cognition is not incompatible with the traditional idea that the brain is in the business of processing information by way of representations. This should already be clear when we trace back the use of the term “enactive” to its origins in the work of Jerome Bruner (1964). Apparently unbeknownst to Varela et al. (1991), Bruner introduced the notion in the context of his distinction of three ways of storing the knowledge that is acquired consecutively during the cognitive growth of the infant: enactive, imagistic, and linguistic representations.

The first kind of representation is, according to Bruner, essentially connected to and inseparable from the execution of certain actions. While the latter idea is compatible with Varela’s later usage of the term, the idea that it is fundamentally a kind of representation is not. Yet, even though we cannot elaborate this thought further here, it demonstrates that simply placing a theory alongside enactive approaches does not yet determine the details of the theory. Enactive theories range from providing very modest to very strong claims, and some of the basic ideas are actually deemed compatible with the idea of predictive coding (cf. Clark 2013). So we agree with Hamilton’s assessment that the theoretical options discussed are not mutually exclusive; and as mentioned above, the goal was not to replace the existing theories altogether. As in the development of new experimental paradigms, further work needs to be done in order to support empirical research with an appropriate theoretical background.

Overgaard & Krueger defend the social perception view (as proposed, e.g., by Gallagher 2008) against our criticism that it remains committed to a spectator theory. They present us with a dilemma between the (implausible) claim that social perception is impossible and acknowledgment of its possibility, which would show that our approach and the social perception view cannot be distinguished. But this appears as a dilemma only if we had proposed that there is merely one means of coming to understand others, namely, by way of interacting with them. However, this is not what we claimed. We claim that paradigmatically social situations are characterized by interaction and engagement and that in such situations, social cognition is fundamentally different from situations where we are mere observers. This, of course, implies that the latter situations are also possible. The problem for the social perception approach, in our view, is of a conceptual nature, because it is typically cashed out in terms of direct perception. Yet, it is just not clear whether direct social perception is possible without involvement or interaction. As recent debates have shown, the notion of “direct perception” is not unproblematic. This is acknowledged by Gallagher (2001) and Hutto (2008) who supplement their view with a further “narrative” hypothesis, according to which young children are exposed to stories in which people act for reasons based on their beliefs and desires. Such narratives are supposed to provide the necessary scaffolding for the acquisition of the concepts of belief and desire. So, even in these terms, the social perception view on its own is not enough to explain the full range of social cognitive abilities. Second, the notion of perception at play here must be a rich one. Gallagher (2008) calls it “smart perception,” which is conceptual (epistemic

seeing) and includes a wide range of background assumptions and world knowledge when, for example, it is claimed that even young children directly perceive affordances. This appears problematic, because this notion of perception lines up with a weak notion of “theory” as in the “theory theory” approach. Thirdly, not only in light of philosophical debates about the epistemology of perception, but also in light of recent developments in the neuroscience of perception, it is questionable whether there is such a capacity or process as direct perception. According to the predictive coding hypothesis, brains are in the business of predicting future sensory events. In turn, these hypotheses are tested by sensory feedback and by action (Friston 2010; Frith 2007; Hohwy 2012). Clark (2013) has recently given an overview of the explanatory strength of this general approach to brain functions while leaving no room for direct perception. On this, we agree with Rietveld *et al.*, who adopt this view with regard to human beings’ responsiveness to affordances. So, the defender of the social perception approach faces the dilemma of enriching her notion of perception so much that it is in danger of collapsing into a version of “theory theory.”

This discussion leads naturally to the comments put forward by Gallagher *et al.* and Sameen *et al.* who criticize our account of containing an unresolved tension by maintaining that social neuroscience is supposed to be in the business of locating neural correlates of social cognition, which they suggest is at odds with the main thrust of the enactive approach to cognition that we seem to endorse. More specifically, these authors point out that our approach is still dealing in representations, whereas the enactive approach rejects this notion altogether. First, we have already elaborated above that only extreme versions of the enactive approach (e.g., Hutto & Myin, *in press*), are really at odds with the idea that neural/mental representations play a special role in the explanation of cognition. In fact, representations can be a fruitful conceptual instrument if they are understood as eliciting the functional role of neural processes in a three-place concept of representation as opposed to a simple causal-correlative understanding of representation (e.g., Vogeley & Bartels 2011). Second, and this point specifically addresses Sameen *et al.*, if the task of cognitive neuroscience is not supposed to be the investigation of the neural mechanisms that enable cognitive activities, then the critics must determine an alternative task for cognitive neuroscience. Surely, the idea of a neural correlate is coherent enough if it is not understood as a neo-phrenological attempt to isolate brain regions, which are responsible for specific cognitive functions. Instead, the relevant neural mechanisms must be conceived in terms of the context of dynamics that include body and (physical as well as social) environment. Since the main thrust of our target article is to provide new ideas for research in the neurosciences that deals with the nature of social cognition, emphasis was placed on what neuroscientists could do to investigate social cognition in an ecologically valid way. While this will continue to include measuring brain activity, we are in full agreement with Gallagher *et al.* that “the question is, what brains do in the complex and dynamic mix of interactions.” Finally, whether (some or all) embodied phenomena relevant to social cognition can (or should) be characterized in representational terms is an open and important question.

Simply assuming that they cannot (or should not), like the authors do, is surely inappropriate (Vogeley & Bartels 2011). Here, it is important to distinguish different claims associated with embodied, embedded, enactive, and extended cognition. While it is not clear whether Gallagher *et al.* and Sameen *et al.* would subscribe to all of these different theses, the role played by the various cultural, evolutionary, and personal factors in shaping not only cognition, but also the cognition-enabling brain circuitry, has to be investigated in the context of the more general debate about the so-called extended mind. That is, the background question of this debate is whether these factors can be said to be constitutive elements of cognitive processes or merely important scaffolding or shaping factors. Only if one were to hold a strong extended mind thesis (Clark & Chalmers 1998), would the role of brain circuitry for cognition be diminished. But whether such a strong claim can be vindicated against the more modest scaffolding-claim (Adams & Aizawa 2008) is also an open question (Menary 2010). In sum, the important role that body and environment play in the dynamics of social cognition has been already sufficiently emphasized in the target article (e.g., see sect. 2). Moreover, the general idea of the enactive approach, namely that cognition is an activity of the whole organism, is compatible with an explanatory framework that makes use of mental representations, even if these have to be understood in a more action-oriented sense (Clark 2001; Wheeler 2005). Whether a radical enactivism or the extended mind thesis can be vindicated is an open question.

#### R4. Agency, intentionality, and development

Another focus of commentaries dealt with how our second-person account may be seen to fall short with respect to explaining the experience of agency and intentionality. Specifically, several authors suggest a role of perspectives and triadic interaction in the development of ascriptions of agency and intentions, which partially stems from a misinterpretation of our proposal.

Longo & Tsakiris suggest that second-person experiences presuppose first-person (singular) experiences and that the former cannot be investigated independently of the latter. Their main point is that contingencies also play an important role in the first-person experience of embodiment, ownership, and agency, which can all be experimentally manipulated. Of course, our proposal does not imply that investigations of first-person experience (e.g., by means of the famous rubber hand illusion) cannot inform the investigation of social cognition in interesting ways. In their argument for the claim that first-person experiences are necessary for second-person experiences, Longo & Tsakiris focus on the case where I form an intention, which leads first to my own action and only then elicits the action of another. But one of the main points of the target article was to emphasize cases where “being addressed as you” (sect. 3.1.1) in social interaction may elicit a reaction on my part that can lead to reciprocal intentional relations. It is not clear how Longo & Tsakiris’s discussion of body ownership and bodily agency bears on the issue, unless they want to argue that first-person agency experiences are ontogenetically prior to second-person agency experiences (in addition to the question whether they are logically prior): We think that this is not

the case. In fact, as suggested by, for instance, **Dominey** and **Froese et al.**, the gap between self and other may be largely artificial and may only develop at a later ontogenetic stage. One can, for example, imagine that differences in contingencies, with respect to my own intentions and action outcomes as compared to my intentions and others' action outcomes, can lead to a differentiation between self- and other-agency. As **Lewis & Stack** write, "infants become naturally attentive to gestures that are intentional because they are repeated and become predictable." Importantly however, in our proposal, contingencies as described by Longo & Tsakiris are only a part of what it means to be in a second-person interaction with someone.

Another example of reading our proposal as more radical than it is, are the commentaries of **Gallotti, Krach et al.**, and **Lewis & Stack**. Gallotti argues—in line with ideas developed by Chris Frith (see Frith 2012b)—that the emphasis on the second-person perspective should be replaced by a first-person plural perspective or "*we-mode*." Similarly, Lewis & Stack suggest that second-person understanding may emerge from a more foundational "first-person plural experience." Here, too, it seems important to repeat that we never argued that it is impossible to represent ourselves as being in a "*we-mode*." Persuasively, Gallotti emphasizes that the *we-mode* may constitute an irreducible mode of cognition vis-à-vis cognitive states in the *I-mode*. As Searle (1990) and others have shown, *we-intentions* (e.g., "we are playing this game together") cannot be analyzed in terms of or reduced to a sum of the individual intentions of the agents and that the *we-mode* has considerable explanatory power. We can completely agree with this claim and have actually said nothing to undermine it. In addition to Gallotti's claim, our account can actually tell a persuasive story about the origin of our *we-intentions*. Surely, *we-intentions* cannot simply precede social interaction. Neither should we take *we-intentions* as brute, inexplicable facts. The only viable explanation seems to be that joint engagement and activities may lead to intentions in the *we-mode*. That is, the *we-mode* presupposes the features emphasized in our approach and is thus no replacement for it. Even if the *we-mode* was irreducible to two *I-modes*, it would still assume that within an interaction, the actions of an agent can be causally explained in terms of representations that reside in that agent alone. In this sense, it would be clearly spectatorial and would downplay sensorimotor accounts (see, e.g., Lewis & Stack). Rather than downgrading ideas of collective intentionality, our approach can lead towards an answer to the question of how collective intentions arise from interaction dynamics and emotional engagement.

In the same vein as **Gallotti**, commentators **Lewis & Stack** suggest that "knowledge of 'you'" emerges from a previously shared context in which infant and adult form a (proto-) conversational unit that can be described as a very early first-person plural experience. As mentioned before, we suggest that it may be the other way around. Implicitly, Lewis & Stack acknowledge this when they contend that these shared activities are "largely stage-managed by the adult." Without needing to discuss whether it is actually genuinely participatory and jointly "managed," it is clear that this implies that someone takes the initiative by emotionally engaging with the other in a communication loop that is characterized by reciprocity, and is supported by social affordances. Furthermore, they

ask what may fill the "spectatorial gap." Even from a spectatorial perspective, one valid suggestion might be that it is essentially a form of embodied sensorimotor know-how (McGeer 2001; Schlicht, forthcoming). This is actually what Lewis & Stack themselves seem to suggest. The earliest forms of awareness are arguably "sensorimotor and take place within practical activities." One important characteristic of know-how (with respect to some ability) is that its development goes hand in hand with the ability to recognize the execution of this ability in someone else's actions. Knowing how to swim enables one to recognize when someone else executes her swimming ability successfully (McGeer 2001). Similarly, the suggestion would be that we develop social know-how in the context of scenes of mutual engagement and interaction. But, as mentioned before, the crucial difference in our approach is that this development of social know-how is not a faculty we develop to "bridge a gap." Rather, it constitutes our primary way of experiencing others. This is in line with Bruner's (1964) suggestion that the developmentally primary form of representation is "enactive" in the sense that it is embodied and inextricably tied to (inter-) action. It provides the "basis for reflective forms of social understanding," as Lewis & Stack emphasize. As argued above, the first-person plural perspective does not emerge from nowhere, but instead may be seen to arise from second-person experiences. Our point is not that all infant attentiveness already and necessarily involves complex awareness of other's minds. Our point is that it could. Lewis & Stack are very clearly ruling out any reference to awareness of mind in early infancy on the grounds that this is too rich an interpretation. But this is precisely the point. Why should mentality be assumed to be too rich? Because it is non-perceivable and needs inference is the usual answer in cognitive developmental psychology. It is not clear whether this is Lewis & Stack's answer, too, but if so, they fall prey to the very same methodological behaviorism that according to our argumentation neuroscience and psychology should try to avoid.

**Krach et al.** present a methodological equivalent of **Gallotti's** argument, in that they suggest that having direct interactions is not necessary, but that instead priming interactions by social immersion might suffice to put people in some social state of mind. In our view this proposal runs into the same trap as the *we-mode* proposal by suggesting that our brain may simply switch to an "interaction mode," which represents ourselves in some interactive context. But from a methodological point of view, putting people in such a state does not seem like an acceptable substitute for actually having them interact. One might observe differences with non-social immersion situations, but these would still bear no relationship to the experience of being engaged in ongoing interaction.

An interesting issue put forward by **Moore & Paulus** and **Cleret de Langavant et al.** is related to differences between dyadic and triadic interactions. Even though we focus on dyadic interactions in our article, we, of course, do not claim that social cognition stops there. Triadic intentional relations clearly are complex interactions, and we are happy to agree upon the view that joint attention enriches the kind of social encounters that go on in the first few months of life. In fact, we specifically refer to the importance of looking at how triadic interactions develop out of dyadic ones and make suggestions about how to investigate

their neural bases in the target article (sect. 3). For instance, it might be that triadic interactions hold the key in the development of a distinction between how my own and someone else's actions are coupled to an effect in the outside world, something that the dyad may not provide. Unfortunately, Moore & Paulus do not substantiate or present evidence for their strong claim that the third element is a necessary component for social cognition. They are claiming that "it is unclear how the properties of dyadic interactions alone [...] could reveal intentionality at all" simply because, as they state, "intentionality is tied inextricably to actions on objects." Based on this premise, they hold that "the problem with purely dyadic interactions is that there is no obvious way for the intentionality of action – its object directedness – to be manifest." Hereby, the authors neglect the possibility that an action performed by another may be directed at oneself (as is often the case in the first 7–8 months of life, viewed from the perspective of the infant) and that this may itself reveal intentionality and elicit a basic form of intentional understanding. Furthermore, Moore & Paulus do not demonstrate that their stronger claim is true. Indeed, the quote above seems to reveal a relatively narrow conception of intentionality, which appears to be confined to intentional actions towards objects, excluding many other manifestations of intentionality, as in love (emphasized by Brentano [1874/1973]) or attention, which are both dyadic intentional relations. This is surprising in light of their contention that intentionality comes in many different flavors. Recent philosophical debates have demonstrated that a more viable notion of intentionality also includes – in addition to propositional attitudes like belief and desire – more basic manifestations of intentionality like sensorimotor or bodily intentionality (cf. Merleau-Ponty 1958; Schlicht, forthcoming; Sinigaglia 2008). This basic form of intentionality is crucial in the early stages of cognitive development and reveals itself in dyadic intentional relations. The same line of argument holds for their criticism of our emphasis on emotional engagement. The point, again, was not to downgrade other features of social cognition, but to emphasize the role of emotional engagement in contrast to traditional approaches.

Furthermore, **Moore & Paulus** charge the authors of the target article for a lack of a positive account of "what it means to understand mind." Possibly, the philosophical approach behind this was underemphasized in the target article. Yet, we tried to make clear that an approach in line with enactive and embodied approaches, based on the notion of embodied sensorimotor know-how might be one way to go (McGeer 2001; Schlicht, forthcoming). This approach emphasizes that there is a form of social understanding that is more basic, different in nature and below (propositional) mentalizing as traditionally understood. We are thankful to **Rietveld et al.** for elaborating the relevant kind of "skilled intentionality" that is important for such engagement and the pick-up of social affordances in context. Rietveld et al. attempt to align social cognition with "nonsocial engagements with the environment" by embedding social affordances in a richer context of affordances in general, based on the plausible claim that any affordance has to be conceived of in a whole field of quite different affordances. However, although this is true, social affordances are still quite different from "object affordances" because they are much more

complex and transient elusive during an ongoing social interaction. This is due to the fact that objects of the environment are indifferent to our attempts to understand them, while other people immediately react to such attempts and thereby modulate the field of social and other affordances.

**Cleret de Langavant et al.** argue that a second-person neuroscience should be able to explain communicative triadic intentional relations. In order to emphasize the difference between dyadic and triadic intentional relations, they point to the pathological condition of heterotopagnosia, which suggests that brain networks for dyadic and triadic relations may be different. We agree that this is an important issue that deserves further investigation and in our target article we have discussed studies of joint attention, which use virtual characters (Schilbach et al. 2010b) and which have the potential of directly comparing the neural correlates of dyadic and triadic relations. We are thankful for the pointer provided by Cleret de Langavant et al. that in cases such as heterotopagnosia, the use of anthropomorphic virtual characters may be of limited use.

## R5. Theoretical accounts of the second-person and the role of the "mirror neuron system" (MNS)

Some commentaries emphasize the need for strong theoretical accounts that could promote the development of a second-person neuroscience. We have already mentioned **Hamilton** in this respect, who compares the applicability of computational models such as game theory (see also **Gariépy et al.**), dynamic models (see also **Froese et al.**), and cognitive models. Furthermore, Hamilton advances her proposal of the so-called STORM (social top-down response modulation) model, which she describes as a "socially engaged information processing model" based upon the idea of the brain's visuo-motor stream being modulated by other "social brain systems." As mentioned earlier, all these models describe only part of the social reality; for instance, computational models and cognitive models are very useful at a non-dynamic level (see the target article's Fig. 2). However, these models necessarily assume a causality reducible to one agent, which may be the case in observational situations, but not in interaction. This said, we acknowledge that there is a component within a single individual that can tell us something about how non-interactive social cognition works. The "modulation" that Hamilton describes in STORM assumes that there is some sort of "generator" that generates social behavior, which is then streamlined according to context. Again, this falls into the trap of assuming agent-internal drives that somehow must compete with the context that has to be integrated in a unified account. We suggest the reverse, namely that, despite some intrinsic reward-related motivational component, the social context is the initial drive in this process, making use of brain areas that have developed sensitivities to contexts over prolonged social learning. We are not denying such "modulation," in as much as it is simply the recruitment of stored information on ongoing information processing. But the core is that, in interaction, such modulations may only make sense in the context of the other.

**Gariépy et al.** suggest game theoretical conceptions as a suitable theoretical framework. We found it surprising that

the authors call on Gintis (2009) to overcome critiques on game theory, as Gintis (2009) himself states that game theory alone is not a satisfactory account for a couple of things, such as belief sharing. Specifically, Gintis (2009, p. 243) writes:

The reason for this contrast between the natural and the behavioral sciences is that living systems are generally complex, dynamic adaptive systems with emergent properties that cannot be fully captured in analytical models that attend only to local interactions. The hypothetico-deductive methods of game theory, the Beliefs-Preferences-Constraints (BPC) model, and even gene-culture co-evolutionary theory must therefore be complemented by the work of behavioral scientists, who adhere to more historical and interpretive traditions, as well as that of researchers who use agent-based programming techniques to explore the dynamic behavior of approximations to real-world complex adaptive systems.

This sounds very much like a proposal that is in favor of an expansion of game theory, rather than a justification of its use in all contexts. Gintis (2009) goes on:

A complex system consists of a large population of similar entities (in our case, human individuals) who interact through regularized channels (e.g., networks, markets, social institutions) with significant stochastic elements, without a system of centralized organization and control (i.e., if there is a state, it controls only a fraction of all social interactions and is itself a complex system). A complex system is adaptive if it undergoes an evolutionary (genetic, cultural, agent-based, or other) process of reproduction, mutation, and selection. To characterize a system as complex adaptive does not explain its operation and does not solve any problems. However, it suggests that certain modeling tools are likely to be effective that have little use in a noncomplex system. In particular, the traditional mathematical methods of physics and chemistry must be supplemented by other modeling tools such as agent-based simulation and network theory.

This, in fact, is exactly where we want to be heading (cf. **Froese et al.**), although we acknowledge that at this point a formal model including dynamics is lacking. Furthermore, game theory is essentially about decision-making, preferably in a “game” context—that is, in a context in which cooperation and/or competition play a central role. Many human interactions are not about decision making. In fact, they often do not contain a cooperative or competitive context (Pfeiffer et al. 2011). It is important to look at what motivates people outside of external reward or otherwise “optimal decisions” (Engemann et al. 2012).

**Dezecache, Conty, & Grèzes (Dezecache et al.)** question whether “mirror neurons” are involved in the processing of social affordances, understood as action possibilities in the context of social interactions. Yet, they simply assume a canonical interpretation of the function of mirror neurons, namely, as facilitating simulation. This is clear when they write that the affordance interpretation is in conflict with “what MNs are known to do, that is, to simulate an observed motor pattern.” In the light of recent controversies about the “correct” interpretation of the mirror mechanism (de Bruin & Gallagher 2012; Gallagher 2007; Gallese & Sinigaglia 2011), that is, whether they facilitate simulation or direct social perception, it is surprising—at least at this stage—that Dezecache et al. presume that anything is supposedly “known” about the function of mirror neurons. One may, however, suggest an

alternative interpretation of the “mirror neuron” activation that has less to do with the understanding of another person’s mental states. Several studies suggest that “mirror neurons” may encode one’s own action possibilities in the light of an observed action. Buccino et al. (2004) showed that such neurons do not fire upon observation of a dog barking, presumably because barking is not in one’s human motor repertoire. More to the point, Gazzola et al. (2007) investigated aplanic patients, born without either arms or hands, while they observed healthy subjects perform hand actions. In addition, they recorded neural activity correlated with the performance of actions with mouth or feet. They found that the patients’ “mirror neurons” fired upon their observation of hand actions, yet it was the set of neurons that was typically activated when the patients themselves performed actions with their mouth or feet. That suggests that they encode or transform perceptual information about an intentional action in terms of what they themselves can do. This interpretation is also not in conflict with other existing studies. In contrast to canonical neurons, “mirror neurons” are social in the sense that they require observation or execution of an action, they are not activated merely upon perception of an object without an action being performed on it (Schlicht, forthcoming).

**Simpson & Ferrari** similarly seem to conflate the empirical discovery of the “mirror neuron” network with ways of interpreting it when they suggest that the simulation interpretation of the “mirror neuron” discovery is “tightly linked” to the discovery. Against this way of seeing things, it should be emphasized that the “simulation theory” is not part of the discovery of “mirror neurons” even though this may still be a widespread view. Moreover, taken as a theoretical option in the explanation of social cognition, simulation theory is patently circular because it presupposes what it aims to explain, namely, an understanding of another person’s mental states (Newen & Schlicht 2009). At the core of the “simulation theory” are pretend mental states that are thought to be used as input for a decision mechanism in order to attribute its output to the other person. But in order to produce such pretend mental states in oneself that bear a sufficient resemblance with the other person’s mental states, one already needs to know what the other person feels or thinks. This objection led Goldman (2006) to defend a hybrid account containing elements of theory-theory. **Simpson & Ferrari** claim that “nearly all work on single cell recordings of mirror neurons involves second-person interactions,” but they do not demonstrate that this is actually so. The example of perceiving someone else’s emotional facial expression is clearly not an example characterized by reciprocity and interaction dynamics. But it suggests that the activation of “mirror neurons” is first and foremost tied to perception and the selection of adaptive behavioral responses, not to simulation, which is in line with **Dezecache et al.**’s interpretation of data from a recent study by Conty et al. (2012). This is in accordance with studies of our group that suggest that the human mirror neuron system is involved in early detection of potentially socially salient signals, whereas the evaluation of actually socially salient signals is then handed over to the medial prefrontal cortex as part of the mentalizing system (Kuzmanovic et al. 2009; Santos et al. 2010). It is also in accordance with the interpretation of “mirror neuron” activation as underlying

the execution and observation of embodied skills. Whether, in light of all this, one would like to continue calling these sets of neurons, mirror neurons, is an entirely different question.

In the context of accounts of “embodied simulation” often closely associated with the discussion of “mirror neurons,” **Vermeulen et al.** draw attention to the recently described Simulation of Smiles (SIMS) model by Niedenthal *et al.* (2010) and argue that we fail to discuss this proposal in spite of it being “a direct and detailed second-person theoretical model.” While we are sympathetic to the ambitious SIMS account and the emphasis it puts on personal involvement, for example, by means of eye-contact, we also note important differences in comparison to our account. As discussed at great length in the target article, we, again, do not subscribe to the notion of “simulation” both on conceptual as well as empirical grounds. With regard to the putative “mirror neuron system” (MNS) – often thought to underlie the respective “simulations” – it seems plausible to us to assume that neural activity in the relevant brain regions is modulated by sensorimotor experience, which is often obtained through interactions with others. Rather than providing “simulations,” activity changes in these brain regions might, therefore, be more closely related to perceiving possibilities for (inter-) action (cf. **Rietveld et al.**). Furthermore, we believe that the use of ecologically valid experimental paradigms will help to further elucidate the contributions of both the MNS and the mentalizing network of the brain during social interaction (Becchio *et al.* 2012; Schilbach 2010; Wang *et al.* 2011).

## R6. Clinical applications and individual differences

Finally, we address the set of commentaries which focuses on the individual in terms of disorders (**Nephew; Redcay et al.; Rietveld et al.**), in terms of the importance of individual differences (**Chakrabarti; Moore & Iacoboni**), and in terms of the investigation of motivational, reward-related components of cognition (**Hamon-Hill & Gadbois; Swain et al.**).

**Moore & Iacoboni** argue for a residual utility of non-interactive experimental scenarios, in the context of establishing individual differences, whereby one needs to be able to separate one agent’s characteristics from the other’s. While we acknowledge the importance of individual differences (see sect. 6 of the target article), we think that looking at individual differences does not require abandoning interaction. As suggested by **Chakrabarti**, it is plausible to assume that social interactions, which have characteristics in addition to those of the individual interactors, are influenced by individual differences; for example, the degree to which interactors may exhibit autistic traits or carry genetic polymorphisms that can modulate cerebral responses to different reward stimuli (e.g., Chakrabarti & Baron-Cohen 2011). We are thankful to Chakrabarti for raising this important point and his confirmation that interactive paradigms might be particularly well suited for the investigation of social reward sensitivities, both in healthy controls, as well as cases of pathology.

Similarly, **Nephew** and **Vermeulen et al.** point out that standardized investigations of social interaction could be a

useful “tool” for the identification and differential diagnosis of psychiatric disorders (cf. Vogeley & Newen 2009). We use the example of high-functioning autism as a case in point, but it is certainly true that disorders such as schizophrenia, and possibly also chronic depression and personality disorders, can be construed as disorders of social interaction, rather than social observation. With regard to autism and the question of reward-related neurocircuitry contributing to an intrinsic motivation during social interaction, it is also noteworthy that prominent accounts of autism suggest specific “social motivation” deficits without resorting – to the best of our knowledge – to interaction-based paradigms to test these and their underlying neural bases. Importantly, neural networks that do not involve reward-related neurocircuitry, but have been implicated in social cognition, appear to be relatively intact in autism (Marsh & Hamilton 2011). In this line of thought, we are grateful for the commentary provided by **Redcay et al.**, who carefully describe relevant differences between interaction and observation and the challenges associated with isolating the interaction component. Redcay *et al.* also present their own experimental approach of using a live face-to-face video feed in conjunction with neuroimaging methodology, which resonates well with our proposal of truly interactive paradigms. Also, the authors are in agreement with our suggestion that the investigation of differences between interaction and observation could be particularly relevant to the advancement of our understanding of autism, as spectatorial tests often fail to find differences between patients and controls (e.g., Nation & Penny 2008). Also, Redcay *et al.* refer to exciting recent neuroimaging evidence in autism, which capitalizes on this distinction and demonstrates hypoactivity in patients’ brains for a real-time joint attention task and hyperactivity during a control condition, which suggests a failure to modulate brain responses according to whether the task required a social interaction or not (Redcay *et al.* 2012). This is completely in line with our suggestion of the translational potential of the second-person neuroscience approach.

## R7. Concluding remarks

In writing the target article our goal has been to highlight that in spite of the remarkable progress made in the young and emerging field of social neuroscience, the neural mechanisms that underlie real-time social encounters – which should be a the very heart of the field’s research interests – are only beginning to be studied. In order to take on this challenge, social neuroscience may be helped by drawing upon a second-person approach to knowing other minds, which is based on interaction and emotional engagements between people, rather than mere observation. The commentaries we have received in response to this proposal have provided important and fruitful new aspects for the critical discussion and the possible conceptual improvement of the account, most of which we have hopefully been able to engage with, more or less directly. None of the challenges raised appear to be fatal to our proposal, but, instead, may have helped to enrich the sketched “landscape” of a second-person neuroscience both in terms of relevant theoretical and empirical questions.

## NOTE

I. Authors Leonhard Schilbach and Bert Timmermans have contributed equally to this Response article.

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[The letters “a” and “r” before author’s initials stand for target article and response references, respectively]

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