INTERACTIVE SENSE-MAKING IN THE BRAIN

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Abstract

One of the great challenges for the advancing field of 'social cognitive neuroscience' is to address issues concerning the neural underpinnings of human social interaction. Though some attempts have been made in this direction the conceptual frameworks underlying most existing paradigms are often unelaborated and ambiguous to the structure of human interaction. This presentation has two overall aims: first, to discuss which kinds of predictions logically follow from existing approaches to social cognition such as 'simulation theory' (ST) and 'theory of mind' (ToM), and why these might prove unproductive for the study of true social interaction. Following from this, we propose an alternative framework for neurocognitive studies of social interaction, rooted in enaction theory. A central distinction in our approach is the differentiation between observing and participating in social situations. This distinction has not been appreciated by ST and ToM advocates whom tend to treat interaction as continuous with the mentalistic act of 'figuring out the mind of the other'. We argue that contrary to observational social situations the nature of participatory interactions is not fully captured by reference to the autonomous, individual minds of the participants, but rather in their dynamic reciprocal couplings. These critically depend on material mediation. When engaging in interaction, participants enter into a shared referential space where bodies, acts and objects are perceived in a new functional perspective as mediators of social coordination and meaning. They become social symbols affording mutual responsiveness and co-action. A social enactive conceptual framing of participatory interaction thus calls for new types of experimental questions, hypotheses and paradigms geared to capture these cognitive and neurocognitive properties. We suggest three such testable predictions and bring these to a meta-analysis of a series of existing functional brain imaging studies of social cognition, joint action and non-verbal communication. When comparing brain activation patterns in studies of what we term observational social situations with studies featuring an element of enactive interaction these do not fully overlap. Interestingly, a consistent pattern of activations in studies of interaction cluster in an area of the inferior frontal gyrus (roughly comprising BA 44, 45, and 47) not normally considered part of the so-called 'social brain'. We suspect that this anatomical site might play a general role as an interface for socially interactive sense-making across expressive modalities of mediation (from bodies and objects to verbal language). Furthermore, the analysis supports our intuition that social observation and interaction should not be treated in direct continuation (as suggested by ST and ToM) but as differentially organized cognitive phenomena – not as one, but two social brains.

Keywords: participatory interaction, brain imaging, social enactment theory, material mediation, simulation theory, theory of mind

1 Social Cognition - Bridging the divide?

Two influential approaches pervade the majority of existing cognitive brain imaging studies on social cognition - theory of mind (ToM) and simulation theory (ST). No doubt,

these are successful in their account of a diverse range of social phenomena, from the feeling of empathy to the detection of deceit. But there are aspects of our social life that seem to work neither by theory-making nor simulation. We will argue that to capture the true cognitive profile of full-blown, cooperative social interaction other approaches are needed.

Common to theory of mind and simulation theory is that they take as their point of departure the autonomy of the individual mind. From this perspective a social situation has one person trying to figure out the fundamentally inaccessible mind of another by metarepresentation or simulation of internal cognitive states. This might be what is going on in some situations as when we 'passively' observe social phenomena from a distal third-person perspective (De Jaegher & Di Paolo, 2007; Gallagher & Hutto, 2008). As such ToM and ST can possibly account for some of the cognitive processes involved in the detection of false-beliefs or the comprehension of someone's intentional grasping. But these approaches seem unsuited to grasp the basic nature of participatory social interactions. Taking a ToM perspective on social interaction would entail something like two individual agents constantly working to 'bridge the gap' by figuring out the mind of the other. And in the simulation version the two interactants would understand each others' actions by something like an immediate pre-conceptual simulation, which is then attributed to the discrete other. In both cases the experience is taken primarily to be *about the other person* and his/her special mental dispositions toward the one self. From this perspective it is far from obvious how we manage in relatively effortless and efficient manners to achieve fine action coordination and joint sense-making. The emphasis on such 'person-centered' approaches as the grounds for participatory social interaction seems counterintuitive and unproductive. Rather than conceiving minds as individual representations that meta-represent one another, we suggest the human mind to be profoundly intersubjective in nature (Zahavi, 2008; Russel, 1998). Following the ideas of e.g. De Jaegher and Di Paolo (2007) and Zlatev et al. (2008), we will sketch out an enactive approach to the study of interaction structured along two related lines: 1) participatory interaction as an instance of dynamic, reciprocal coupling and coordination, and 2) attention to the special mediating role of the shared material environment in this process. Besides, we attempt to show how this conceptual approach can explain some of the recent findings in functional brain imaging studies of social cognition, revealed by a meta-analysis of a series of studies on non-verbal communication and joint action.

1.1 Interactive sense-making and material mediation

As indicated above, there might be good reasons for differentiating two distinct types of social encounters: 1) one in which we passively observe a social interaction from a third-person perspective, and 2) one in which we are first/second-person active participants in the social interaction (Tylén, 2007; De Jaegher and Di Paolo, 2007; Gallagher & Hutto, 2008). So far this important distinction has not been appreciated in ToM and ST approaches to social neurocognition that have almost exclusively favored the first type. As a consequence, findings related to the observational type of social experience have been suggested as general models for social cognition (cf. e.g. Gallese *et al.*, 2004). However, we will suggest that in social interactive encounters the structural dynamics of the whole situation is altered in fundamental ways, challenging these traditional models on several grounds.

In the enactive account, when two people engage in reciprocal social interactive activities they become part of an emergent coupled system making up the interaction. The interaction itself is thus the minimal object of study while the individual minds entering the interaction can only be considered constituent "subparts" as their complementary roles are defined and constrained in relation to the interactional whole (De Jaegher & Di Paolo, 2007). The object of mutual attention is thus not the participants' individual mental states, but the shared perceptual space of bodies, objects and action that scaffold joint sense-making. Interactive social meaning is thus a mutual creation *between* brains, minds, and the material mediations that form the interaction. From this approach it follows that the persons involved are neither preoccupied with theory-making nor simulation, but are continuously adjusting their actions in complementary ways by orientation of the dynamic matter of the interaction and mutual commitment to regulating social normative practices (Tylén et al, in review; Sinha & Rodríguez, 2008; Roepstorff & Frith, 2004). Such coordination dynamics include not only procedural practices of turn-taking and gaze-following and fine temporal motor coordination, but are likewise involved in scaffolding symbolic meaning construction. In both cases the driving force is found in aspects of our shared materiality.

The mediating impact of the material environment on human social cognition has been somewhat neglected in most approaches to human cognition that often pursue a more mentalistic or metarepresentational account. But several recent advances in intersubjectivity find our joint engagement with the *material* world to pave the way for new styles of symbolic thinking (Clark, 2006; Sinha & Rodríguez, 2008; Gallagher & Hutto, 2008; Roepstorff, 2008; Tylén et al, in review). Rather than being empty vehicles for encoded denotational meanings travelling *between* minds, social symbols primarily do their work in concrete local, contextualized settings by joint manipulation of their signifying materiality (Clark, 2006; Cowley, 2004; Kravchenko, 2007). Symbolic communication (e.g. in verbal languages, bodily gestures or material objects) is thus also a type of joint action (Clark, 1996) in which socially shared meanings are negotiated and grounded in specific social contexts by virtue of the social affordances of their materiality (Sinha & Rodríguez, 2008). Interaction is thus not about the participants involved, but about the subject matter. It is a collective 'making sense of the shared material space' between the participants.

1.2 Shared attention, social meaning and responsiveness

From the dynamic structural architecture of participatory interaction sketched out above it could be argued that participatory interaction is not even a cognitive enterprise and thus does not lend itself to traditional experimental cognitive studies of single subjects. This is not necessarily so. In the following we will consider three contrastive predictions characterizing the difference in cognitive profile between the observational and interactive social encounters: 1) differences in attention distribution of the interacting agents, 2) different semiotic profiles of the social meaning attributed to these situations, and 3) differences in the agents inclination to respond or co-act. Though the empirical evidence is still sparse some of these predictions already find support in recent behavioral studies.

Though the experimenters might not fully subscribe to our conceptual prospects the main ideas are supported in a series of recent studies of infant cognition (e.g. Gergely *et al.*, 2007; Senju & Csibra, 2008; Senju *et al.*, 2008). The experimental finding is that when

an infant observes an experimenter's behaviors from a third-person perspective, the infant seems to interpret the behaviors as expressing the preferences of this specific experimenter. In contrast, when the infant is directly addressed by the experimenter's ostensive cues (such as making eye-contact, nodding and vocalizing in 'motherese') the infant tends to interpret accompanying object-oriented behaviors as generalizable socially relevant information about the object world. In other words; in the first (observational) situation the infant learns about the specific preferences and dispositions of the other person (the experience is about *the person*) and in the interactive situation the infant learns something about the shared object world (the experience is about *the intersubjectively shared world of meaning*) (Gergely et al, 2007).

In support of our first predictions outlined above, the studies seem to suggest quite different attentional strategies for the two types of social encounters leading to different kinds of 'social meaning'. We speculate that this is due to differences in semiotic attitude to the scenes. Though quite compatible bodily actions or objects might be involved they become perceived in fundamental different ways. When we investigate another person in an observational fashion we might infer, explain or predict his/her behavior in terms of particular contents of mind and intentions towards the world. This style of 'private sense-making' is primarily dependent on indexical (causally explanatory) strategies (De Jaegher & Di Paolo, 2007; Tylén, 2007). In contrast, when we engage in interactive encounters aspects of the material world gain another semiotic status; bodily movements, facial expressions and material object manipulations are suddenly perceived and employed as intentional mediators of the ongoing dynamic coordination: they become shared social symbols (Tylén, 2007; Tylén et al, *in review*; Clark, 2005).

The last prediction that seems to follow from the proposed enactive approach to social cognition is related to the social normative practices of interaction. In most cases when we are addressed ostensively by someone to take part in a joint action we will feel an almost automatic inclination to respond. Such addressing gestures are part of a distributed normative structure that is only realized by the complementary turn-taking effort of both parties. One act calls for the other in a dialogical structure across participants. If a participant fails to respond, i.e. fulfill her role in this shared normative structure, the interaction is likely to break down (cf. e.g. Garfinkel's breaching experiments, Garfinkel 2002).

The motivated predictions concerning differences in attention, semiotic attitude and responsiveness in relation to observational and interactive styles of social encounters are likely to be reflected in functional brain activity of social agents engaged in these situations. Though so far this has not been systematically investigated, a series of existing functional brain imaging studies might throw some light on the biological underpinnings of participatory interaction.

2 The Social Brain

In recent years, a still growing number of brain imaging studies address the neural underpinnings of social cognition. As mentioned above two well-established and influential approaches, ToM and ST (closely allied to the mirror neuron literature) have dominated this field. The findings are summarized under appealing titles like 'The meeting of minds' (Amodio & Frith, 2006), 'Understanding intentions in social interactions' (Walter et al, 2004), and 'A unifying view of the basis of social cognition' (Gallese et al, 2004). A

common trait in these studies is – again - an 'observational approach' to social phenomena. While a full review of this large literature is beyond the scope of this presentation, we will attempt a brief overview of the basic functional anatomical findings. These will be compared with a number of studies on joint action and non-verbal communication that can be argued to conceptually imply an element of interaction. Interestingly, the findings do not fully overlap. Rather, the two clusters of studies involve a number of dissociate functional activations which could suggest (contrary to the expectancies of ST and ToM) that observational and interactive social situations are in fact subserved by partly dissociate systems due to their fundamental structural cognitive differences.

2.1 Theory of Mind in the brain

One of the well-established paradigms in cognitive neuroscience is sometimes treated under the somewhat presumptuous headline "the social brain" (cf. e.g. Gobbini et al, 2007). It more or less implicitly defines 'social' in term of our abilities to 'mentalize', that is, to make inferences about the mental states of others. In an extensive series of studies of 'theory of mind' and 'mentalizing' (cf. e.g. Castelli at al, 2000; Walter *et al.*. 2004; Gallagher *et al.*, 2000, 2002; Gallagher & Frith, 2003, 2004; Amodio & Frith, 2006; Fletcher *et al.*, 1995; Kampe *et al.*, 2003; Saxe, 2006; Schilbach *et al.*, 2006, etc.) it has been suggested that a distinct pattern of brain areas including (among others) the temporal poles bilaterally, the right temporo-parietal junction (TPJ), the right superior temporal sulcus (STS) and the medial prefrontal cortex (MPFC) are involved in explaining and predicting the behavior of other people regardless of the sensory modality or task involved.

A couple of these studies could potentially be of great relevance for the present conceptual purposes as they seem to entail an element of cooperative interaction. In Kampe *et al.* (2003) and Schilbach *et al.* (2007) the experimenters investigated functional brain activations related to subject-directed ostensive cues (Sperber and Wilson, 1986). Like in the behavioral studies of Gergely, Senju, Csibra and colleagues such cues could arguably be said to facilitate the initiation of social interaction. Still, when the activation patterns in MPFC largely replicate the findings from other ToM studies it is likely due to the fact that no real interaction follows from these cues. They are thus merely expressing the intention to initiate a not yet realized interaction and in that sense they are still perceived as being about the particular mental dispositions of the depicted person.

2.2 Simulation in the brain

Another cluster of studies on social neurocognition are founded on simulation theory (ST). Though we acknowledge that ST has a long history preceding Gallese and colleagues' groundbreaking finding of mirror neurons in the F5 motor cortex of monkeys (Gallese *et al.*, 1996), we will in the following brief overview primarily focus on the human mirror-neuron literature (e.g. Gallese *et al.*, 1996, 1998, 2004; Gallese, 2007; Buccino *et al.*, 2001, 2004; Decety & Grèzes, 2006; Rizzolatti & Craighero, 2004, Newman-Norlund *et al.*, 2008, etc.). The central idea is that the basic mechanism for understanding other people is not conceptual reflection but a very direct and immediate mental simulation (mirroring) of the other's emotions and actions. When we thus for instance recognize someone's motor actions as intentional and meaningful it is because special populations of mirror

neurons related to our own motor system simulate the action and thereby impose on us a similar imagined first-person experience of intentional action.

Since single cell recordings in the human brain are not possible the existence of mirror neurons in humans cannot be directly validated as in the case of monkeys. Still, when investigating action perception using functional brain imaging 'mirror activation patterns' are consistently found in compatible sites of the human brain including the rostal part of the inferior parietal lobule (IPL) and in the pars opercularis of the inferior frontal gyrus (IFG) and adjacent areas of the premotor cortex homologue to the F5 areas of the monkey brain (Rizzolatti & Craighero, 2004). Furthermore, some brain areas involved in emotional affect (e.g. the insula) show the same mirroring behaviors (Gallese *et al.*, 2004). Although it is likely that the mirror neuron system is involved in direct access to the emotions and actions of others it is not entirely clear how these simulations are 'fed into our own decision making system' to explain the actions of others and navigate social terrain (Gallagher, 2007).

Since the whole idea of a simulative understanding of other people is about 'bridging first-person and third-person experiences' no elaborate predictions concerning the first-person/second-person social encounter have yet come from this approach. However it has been suggested that the mirror-system might facilitate communication. The proposed anatomical sites' partial overlap with Broca's area (BA 44 and 45) of the left inferior frontal gyrus (IFG), a structure consistently found in studies of verbal language production and comprehension (cf. e.g. Price, 2000; Wallentin *et al.*, 2005, 2006, among many others) has motivated some speculations concerning simulation being the basic underlying mechanism of human language (see Rizzolatti & Craighero, 2004 or Gallese, 2007 for reviews). However, this is still the subject of ongoing debate (cf. e.g. Toni *et al.*, 2008). A couple of recent investigations however do attempt (at least indirectly) to suggest how the mirror system might relate to first/second-person participatory interaction. In two studies on the neural underpinnings of cooperative joint action Newman-Norlund and colleagues found activations of the human mirror system when two subjects had to continuously coordinate their actions in a complementary fashion to solve cooperative tasks (Newman-Norlund *et al.* 2007, 2008). Interestingly, a general finding across these studies is that activation in some regions of the mirror system (e.g. the right IFG) is more enhanced in conditions of non-imitative, complementary actions than in imitative conditions. This could seem counterintuitive since the mirror system has mostly been thought to involve imitative simulations, but Newman-Norlund and colleagues hypothesize certain populations of mirror-neurons to be 'broadly congruent', context sensitive neurons rather than strictly imitative, context independent neurons. The first ones are thus supposedly involved in the planning of non-imitative, complementary actions (Newman-Norlund *et al.*, 2007a). Though these findings are highly relevant and promising for our stated objective concerning the neural underpinnings for participatory interaction there are a couple of central issues that are not considered in these studies. These are related to joint sense-making and its proposed material mediation, possibly related to other structures of the IFG.

2.3 Non-verbal communication in the brain

While ToM and ST pose ambitions towards a general theory of social cognition ironically this is not where we find the most studies on participatory interaction. Rather these are

often reported as instances of (non-verbal) communication. A series of studies on various kinds of non-verbal communicative mediation thus allow for meta-interpretations with regard to the proposed enactive framework of participatory interaction. These are studies that in their experimental design contrast communicative and non-communicative conditions (cf. e.g. Lotze *et al.*, 2006; Dietrich *et al.*, 2007; Lawrence *et al.*, 2006; Tylén *et al.*, in press). Like in the studies on ostensive cues treated above they feature the experimental subject as the intended addressee of the communicative activity. Though it can be argued that this form of interaction is less strong than the case of joint motor action, conceptually they do involve an element of interaction in their framing of the subject as aa addressee and cooperative interpreter of social communicative meaning (Tylén, 2007; Tylén *et al.*, in review). Interestingly, the brain areas involved in the studies of non-verbal communication do not consistently overlap with the areas found in studies of ST and ToM as might have been expected if these cognitive strategies had been subserving social interaction. Rather, activations gather in a cluster of areas of the IFG traditionally associated with verbal language and semantics.

In an fMRI experiment, Lotze *et al.* (2006) contrasted the neural responses to three different kinds of right hand movements: isolated hand movements (e.g. twisting a lid), body-referred movements (brushing teeth) and expressive gestures (e.g. holding up the index finger to threat someone). While the first two are not intended as communicative signals the third mediates social communicative meaning. In the body-referred and the expressive movement conditions the experimenters found activity in the STS of the social brain network. This area has previously been associated with the perception of another person's action (Gallagher & Frith, 2004). But, when the expressive gesture condition was contrasted with the body-referred movement condition only the left ventro-lateral prefrontal cortex (VLPRC)/Brodmann Area (BA) 47, was active. Interestingly, this area has previously been associated with semantic processing in verbal language (cf. e.g. Dapretto & Bookheimer, 1999; Fiez, 1997).

In another imaging study of brain regions associated with the perception of non-verbal vocalizations Dietrich *et al.* (2007) found a similar pattern. They were interested in the fact that in addition to words in a natural language people make use of other types of vocalizations to express social meaning. For instance, affective bursts like laughter or cries have an intrinsic (indexical) social communicative function in signaling other individuals' affective states, but in addition vegetative sounds such as belches and yawns are sometimes produced deliberately to signal arbitrary (symbolic) communicative meanings. This fact was manipulated in Dietrich *et al.*'s experiment. While being scanned subjects were instructed to classify different types of vocalizations including affective bursts (e.g. laughter) and vegetative sounds (e.g. snoring or belching) in terms of their presumed function: communicative signals vs. non-signals. As in the previous study, we could have expected the task in this study to involve mentalizing or simulation as it targets the recognition of communicative intentions. But when the experimenters contrasted vocal signals with non-signals an interesting additional pattern of areas normally not considered part of mentalizing or simulation were elicited. The hemodynamic responses resided in areas of the left hemisphere temporo-parietal junction, proposed to be an verbal 'auditory-to-meaning interface' in previous studies (cf. e.g. Hickok & Poeppel, 2000), together with some structures of the inferior frontal gyrus (left BA 47 and right BA 44 and 45). Again these are all areas consistently found in studies of verbal language and semantics.

Besides, note that one of the prefrontal components (left BA 47) overlaps with the findings of Lotze *et al.* (2006).

A third study of interest in this connection addressed aspects of 'body language'; ways we direct motor acts at other people as signals recruiting "shared representations" (Lawrence *et al.*., 2006). The experimenters used an adapted version of the Profile of Non-Verbal Sensitivity or PONS test (Rosenthal *et al.*, 1979) in a fMRI experiment assessing subjects' understanding of non-verbal communication. In the scanner subjects saw a series of short video clips showing an actor conveying various types of facial and bodily expressions and gestures, and were asked to rate them on either a non-social (face or body?) or a social (angry or happy?) decision task. The experimenters interpreted subjects' behavioral responses (button presses) to the social condition in terms of their ability to empathize. Empathy is also normally considered part of our 'theory of mind' (Lawrence *et al.*, 2006), yet in the main contrast between *social perception* and *non-social perception,* none of the regions supposed to be part of the 'social brain' were activated. Rather, similar to the previous examples the primary main effects are found in the dorso-lateral prefrontal cortex (DLPFC/BA 46) and inferior frontal gyrus (BA 44) including Broca's area bilaterally (among a couple of other sites). The authors interpreted these patterns of activation in terms of an orientation to 'shared representations'. The same areas are however part of a common network involved in various aspects of language processing (cf. e.g. Hagoort, 2005).

Finally, in an event-related fMRI study on object mediated communication Tylén and colleagues presented two contrastive types of images to subjects (Tylén *et al.,* in press). In the test condition images depicted static scenes with configurations of everyday material objects that were manipulated in striking ways that seemed to call for a symbolic interpretation (e.g. chairs put out in the street to reserve a parking place or a bunch of flowers left on the doorstep of a private home to express a declaration of love, etc.). The control condition had the same objects in their canonical instrumental (or accidental) non-communicative contexts. Again, the main conditions thus contrasted communication and non-communication though in an externalized material mediation. The experimenters found that when subjects made communicative interpretations and explored the object configurations as sources of intentional social meaning they had enhanced activity in part of the fusiform gyrus and the pars triangularis of the IFG (BA 45).

The studies on non-verbal communication introduced above (Lotze *et al.*, 2006; Dietrich *et al.*, 2007, Lawrence *et al.*, 2006 and Tylén *et al.,* in press) are all concerned with a special type of social encounter; situations where bodily movements, facial expressions, vocal sounds, hand gestures and material objects are recognized as intentional signals addressing the subject to mediate social meaning. And as such they call for a cooperative, interpretative attitude in the addressee. While from the point of view of the well-established approaches in social cognition, we could have expected 'conceptual reflection' or 'immediate simulation' to be central components in such interactions related to for instance the recognition of communicative intent (Walter *et al.*, 2004; Kampe *et al.*, 2003; Schilbach *et al.*, 2006; Gallese, 2007; Buccino *et al.,* 2004), areas of these brain networks seem to play a somewhat marginal role in the studies. Instead, we consistently find activation in closely adjacent regions of the IFG.

It might be noted that some of the findings in these studies (e.g. in Dietrich *et al.* 2007 and Lawrence *et al.*, 2006) tap into areas of BA 44 of the IFG that are also considered part of the mirror system and thus potentially could be interpreted in terms of mental simulation. Still, since the contrastive control conditions feature very similar vocalizations and gestures it is not obvious why the mirror system should be activated in the test and not the control conditions. Rather, the activations found in various neighboring sites of the IFG (BA 44, 45 and 47) could be seen as expressing a common trend; the same areas have thus been proposed as comprising the "unification area" by Paul Hagoort (cf. e.g. Hagoort, 2005; see also Müller & Basho, 2004, for an interesting discussion). Rather than assigning very subtle differentiated functions to each of these Brodmann areas, Hagoort finds them to be closely functionally related as an interface for the integration of various aspects of semantic and pragmatic meaning in verbal language.

Since the same cluster of areas consistently show up in studies on the diverse range of expressive mediations from gesture to objects (e.g. also including 'musical semantics', Vuust *et al.* 2006; 2005) we suggest to ascribe this 'unification site' a more general function across expressive modalities as responsible for human interactive sense-making and meaning construction. This idea is consistent with the often posed proposition that verbal language both ontogenetically and phylogenetically evolves from non-verbal modes of interactive communication (Arbib, 2005; Donald, 2001; Tomasello, 1999; Zlatev, 2008).

3 The Tale of Two Social Brains

Based on the socially enactive framework outlined in the initial parts of this paper we might hypothesize not one common mechanism and brain network for social understanding but several depending on the type of social task at hand. For the matter of the current argument we will propose a rude and simplistic model comprising two such 'social brains', that is, two dissociate neural networks underpinning various types of social understanding. One system is thus concerned with an observational style person-oriented approach and another - a interactive style object-oriented approach. The first system is thus concerned with various strategies for extracting social information from the perceived behavior of the other. It may work by mentalizing or simulation (or both) but essentially serves the same goal; to 'privately' understand the other. The reviewed empirical literature suggests that the system anatomically comprises a distributed set of regions such as the MPFC, TPJ, STS and the temporal poles bilaterally plus the IPL, the pars opercularis of IFG and possibly the insula.

The second system facilitates our engagement with other people in dynamic participatory interactions for purposes of joint sense-making. In these situations, participants' alignment of pragmatic implicatures, fine attentional attunement and complementary coordination entail mutual commitment to highly schematic social norms and practices in which roles are assigned and enacted. This socio-normative process is a triadic endeavor heavily scaffolded by material mediation in the form of mimetic and symbolic acts, objects and places affording mutual responsiveness.

Far too few brain imaging studies have explicitly addressed the issue of participatory interaction in proper contrastive experimental manipulations. However, the few existing studies that can be argued to feature an element of interaction point to the

'unification area' of IFG (BA 44, 45, 47) as one of the possible anatomical candidates for this interactive style of social cognition.

3.1 Toward an Enactive Framework for the Study of Social Neurocognition

By first sight, a social enactive framework for interactive sense-making would seem somewhat unfeasible to operationalize into concrete testable neurocognitive hypotheses. The idea that the cognitive profile of participatory interaction is not fully represented and thus cannot be captured in the individual minds and brains of the participants but only in their complex dynamical couplings seems to call for something like hyper-scanning paradigms where two persons are scanned simultaneously while interacting. Such paradigms are not beyond reach but until they are up and running other testable hypotheses more suited for state-of-the-art functional brain imaging seem to follow from the conceptual elaborations posed above. In the preceding, we have suggested three such hypotheses. One of these is that participatory interactions involve a special kind of joint attention to the mediating role of bodies, actions and objects. Another is that these interactions are structured by mutual orientation to socio-normative implicatures that assign complementary roles to the interactants. And a third hypothesis is that these normative structures and their material mediations afford for social engagement and thus evoke mutual responsiveness.

Until further investigations are carried out along the lines proposed in this paper we suspect that at least some of the aspects of participatory interaction are subserved by brain regions of the IFG which consistently shows up in existing studies involving elements of interaction.

References

Amodio, D.M., Frith, C.D. (2006). Meeting of Minds: the medial frontal cortex and social cognition. *Nature Reviews, Neuroscience, 7*, 268-277

Arbib, M.A. (2005). From monkey-like action to recognition to human language: an evolutionary framework for neurolinguistics. *Behavioral and Brain Sciences, 28*, 105-167

Buccino, G. Binkofski, F., Fink, G.R., et al. (2001). Action observation activates premotor and parietal areas in a somatotopic manner: an fMRI study. *European Journal of Neuroscience*, *13*, 400–404

Buccino, G. Lui, F., Canessa, N., Patteri, I., et al. (2004). Neural Circuits involved in the recognition of actions performed by nonconspecifics: an fMRI study. *Journal of Cognitive Neuroscience, 16*, 114-126

Castelli, F., Happé, F., Frith, U., Frith, C.D. (2000). Movement and mind: a functional imaging study of perception and interpretation of complex intentional movement patterns. *NeuroImage, 12(3)*, 314–325

Clark, A. (2006). Material Symbols. *Philosophical Psychology, 19(3)*, 291-307

Clark, H.H. (1996). *Using Language.* Cambridge University Press, UK

Clark, H.H. (2005). Coordinating with each other in a material world. *Discourse Studies, 7*, 507-525

Cowley, S. (2004). Contextualizing bodies: human infants and distributed cognition. *Language Sciences*, *26*, 565–591

Dapretto, M., Bookheimer, S.Y. (1999). Form and content: Dissociating syntax and semantics in sentence comprehension. *Neuron, 24*, 427–432

De Jaegher, H. & Di Paolo; E. (2007). Participatory Sence-Making: an enactive approach to social cognition. *Phenomenology and the Cognitive Sciences, 6(4)*, 485-507

Decety, J., Grèzes, J., (2006). The Power of Simulation: imagining one's own and other's behavior. *Brain Research, 1079(1)*, 4-14

Dietrich, S., Hertrich, I., Alter, K., Ischebeck, A., Ackermann, H., (2007). Semiotic aspects of nonverbal vocalizations: a functional imaging study. *NeuroReport, 18(18),* 1891-1894

Donald, M. (2001). *A Mind So Rare: The evolution of Human Consciousness*. New York: Norton

Fiez, J. A. (1997). Phonology, semantics, and the role of the left inferior prefrontal cortex. *Human Brain Mapping*, *5*, 79–83

Fletcher, P.C., Happé, F., Frith, U., Baker, S.C., Dolan, R.J., Frackowiak, R.S., Frith C.D. (1995). Other Minds in The Brain: a functional imaging study of "theory of mind" in story comprehension. *Cognition, 57(2)*, 109-128

Gallagher, H.L., Happa, F., Brunswick, N., Fletcher, P.C., Frith, U. Frith, C.D. (2000). Reading the Mind in Cartoons and Stories: an fMRI study of 'theory of mind' in verbal and nonverbal tasks. *Neuropsychologia, 38(1),* 11-21

Gallagher, H.L., Jack, A.I., Roepstorff, A., Frith, C.D. (2002). Imaging the Intentional Stance in a Competitive Game. *NeuroImage, 16,* 814-21

Gallagher, H.L., Frith, C.D. (2003). Functional Imaging of 'Theory of Mind'. *TRENDS in Cognitive Science, 7(2)*, 77-83

Gallagher, H.L., Frith, C.D. (2004). Dissociable neural pathways for the perception and recognition of expressive and instrumental gestures. *Neuropsychologia, 42(13)*, 1725-36

Gallagher, S. (2007). Simulation trouble. *Social Neuroscience, 2 (3-4)*, 353-65

Gallagher, S. and Hutto, D. (2008). Understanding others through primary interaction and narrative practice. In J. Zlatev, T. Racine, C. Sinha and E. Itkonen (eds), *The Shared Mind: Perspectives on Intersubjectivity*. Amsterdam: John Benjamins

Gallese, V., Fadiga, L., Fogassi, L., et al. (1996). Action recognition in the premotor cortex. *Brain*, *119,* 593–609.

Gallese, V., Goldman, A. (1998). Mirror neurons and the simulation theory of mind-reading. *TRENDS in Cognitive Sciences*, *2(12)*, 493-501

Gallese, V., Keysers, C., Rizzolatti, G., (2004). A unifying view of the basis of social cognition. *TRENDS in Cognitive Sciences, 8(9)*, 396-403

Gallese, V., (2007). Before and below 'theory of mind': embodied simulation and the neural correlates of social cognition. *Philosophical Transactions of the Royal Society B, 362*, 659-669

Garfinkel, H. (2002). *Ethnomethodology's Program*. New York: Rowman and Littlefield

Gergely, G., Egyed, K., Király, I. (2007). On Pedagogy. *Developmental Science, 10(1)*, 139-146

Gobbini, M.I, Koralek, A.C., Bryan, R.E., Montgomery, K.J., Haxby, J.V. (2007). Two takes on the social brain: A comparison of theory of mind tasks. *Journal of Cognitive Neuroscience, 19*, 1803-1814

Hagoort, P. (2005). On Broca, brain, and binding: a new framework. *Trends in Cognitive Sciences*, *9(9)*, 416-423

Hickok, G., Poeppel, D. (2000). Towards a functional neuroanatomy of speech perception. *Trends in Cognitive Sciences*, *4*, 131–138

Senju, A. Csibra, G. & Johnson, M.H. (2008). Understanding the referential nature of looking: Infants' preference for object-directed gaze. *Cognition, 108*, 303-319

Kampe, K.K., Frith, C.D., Frith, U. (2003). "Hey John": signals conveying communicative intention toward the self activate brain regions associated with "mentalizing," regardless of modality. *Journal of Neuroscience*, *23(12)*, 5258-5263

Kravchenko, A.V. (2007). Essential Properties of Language, or, why language is not a code. *Language Sciences, 29*, 650-671

Lawrence, E.J., Shaw, P., Giampietro, V.P., Surguladze, S., Brammer, M.J., Davis, A.S. (2006). The role of 'shared representations' in social perception and empathy: An fMRI study. *NeuroImage, 29(4)*, 1173-1184

Lotze, M., Heymans, U., Birbaumer, N., Veit, R., Erb, M. Flor, H., Halsband, U. (2006). Differential cerebral activation during observation of expressive gestures and motor acts. *Neuropsychologia, 44*, 1787-1795

Müller, R-A., Basho, S. (2004). Are non-linguistic functions in "Broca's area" prerequisites for language acquisition? FMRI findings from an ontogenetic viewpoint. *Brain and Language, 89*, 329-336

Newman-Norlund, R.D., van Schie, H.T., van Zuijlen, A.M.J., Bekkering, H. (2007a). The Mirror Neuron System is more active during complementary compared with imitative action. *Nature Neuroscience, 10(7)*, 817-818

Newman-Norlund, R.D., Noordzij, M.L., Meulenbroek, R.G.J., Bekkering, H. (2007b). Exploring the Brain Basis, of Joint Action: Co-ordination of actions, goals and intentions. *Social Neuroscience, 2(1)*, 48-65

Newman-Norlund, R.D., Bosga, J., Meulenbroek, R.G.J., Bekkering, H. (2008). Anatomical Substrates of Cooperative Joint-Action in a Continuous Motor Task: Virtual lifting and balancing. *NeuroImage, 41*, 169-177

Rizzolatti, G., Craighero, L., (2004). The Mirror-Neuron System. *Annual Review of Neuroscience*, *27*, 169-92

Roepstorff, A. (2008). Things to think with: words and objects as material symbols. *Philosophical Transactions of the Royal Society B, 363*, 2049-2054

Roepstorff, A., Frith, C.D. (2004). What's at the top in the top-down control of action? Script-sharing and 'top-top' control of action in cognitive experiments. *Psychological Research, 68*, 189198

Rosenthal, H., Hall, J.A., DiMatteo, M.R., Rogers, P.L., Archer, D., (1979). *Sensitivity to Nonverbal Communication: The PONS Test*. Baltimore: The Johns Hopkins University Press

Russell, J. (1987) Rule-following, mental models, and the development view. In M. Chapman & R. A. Dixon (eds.), *Meaning and the growth of understanding: Wittgenstein's significance for developmental psychology*. New York: Springer

Saxe, R. (2006). Uniquely Human Social Cognition. *Current Opinion in Neurobiology, 16*, 235-239

Schilbach, L., Wohlschlaeger, A.M., Kraemer, N.C., Newen, A., Jon Shah, N., Fink, G.R.,

Vogeley, K., (2006). Being With Virtual Others: Neural correlates of social interaction. *Neurophychologia, 44*, 718-730

Senju, A. & Csibra, G. (2008). Gaze following in human infants depends on communicative signals. *Current Biology, 18*, 668-671

Senju, A., Csibra, G. & Johnson, M.H. (2008). Understanding the referential nature of looking: Infants' preference for object-directed gaze. *Cognition, 108*, 303-319

Sinha, C. & Rodríguez, C. (2008). Language and the signifying object: From convention to imagination. In J. Zlatev, T. Racine, C. Sinha and E. Itkonen (eds), *The Shared Mind: Perspectives on Intersubjectivity*. Amsterdam: John Benjamins

Skipper, J.I., Goldin-Meadow, S., Nusbaum, H.C., Small, S.L. (2007). Speech-associated gestures, Broca's area, and the human mirror system. *Brain and Language, 101*, 260-277

Sperber, D. & Wilson, D. (1986). *Relevance: Communication and Cognition*. Oxford: Blackwell

Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge: Havard University Press

Toni, I., de Lange, F.P., Noordzij, M.L., Hagoort, P. (2008). Language beyond action. *Journal of Physiology – Paris, 102*, 71-79

Tylén, K. (2007). When agents Get Expressive: A theory of semiotic agency. *Cognitive Semiotics, 0*, Aarhus: special promotional issue

Tylén, K., Weed, E., Philipsen, J.S. (in review). Taking the language stance in a material world: a comprehension study

Tylén, K., Wallentin, M., Roepstorff, A. (In Press). Say It With Flowers! A fMRI study of object mediated communication. *Brain and Language,* doi:10.1016/j.bandl. 2008.07.002

Vigneau, M., Beaucousin, V., Hervé, P.Y., Duffau, H., Crivello, F., Houdé, O., Mazoyer, B., Tzourio-Mazoyer, N. (2006). Meta-analyzing left hemisphere language areas: Phonology, semantics, and sentence processing. *NeuroImage, 30*, 1414-1432

Vuust, P., Roepstorff, A., Wallentin, M., Mouridsen, K., Østergaard, L. (2006). It don't mean a thing… Keeping the rhythm during polyrhythmic tension, activates language areas (BA 47). *NeuroImage*, *31(2)*, 832-841

Vuust, P., Pallesen, K.J., Bailey, C., van Zuijen, T.L., Gjedde, A., Roepstorff, A., Østergaard, L. (2005). To musicians, the message is in the meter: pre-attentive neuronal responses to incongruent rhythm are left-lateralized in musicians. *NeuroImage*, *24(2)*, 560-564

Walter, H., Adenzato, M. Ciaramidaro, A., Enrici, I., Pia, L., Bara, G.B., (2004). Understanding Intentions in Social Interaction: the role of the anterior paracingulate cortex. *Journal of Cognitive Neuroscience, 16(10)*, 1854-1863

Zahavi, D. (2008). Simulation, projection and empathy. *Consciousness and Cognition, 17*, 514-522

Zlatev, J. (2008). From proto-mimesis to language: Evidence from primatology and social neuroscience. *Journal of Physiology - Paris, 102*, 137-151

Zlatev, J., Racine, T.P., Sinha, C., Itkonen, E. (eds.). (2008). *The Shared Mind: Perspectives on Intersubjectivity*, Converging evidence in language and communication research 12, Amsterdam/Philadelphia: John Benjamin's Publishing Company