

RUNNING HEAD: SYNC

Grounding Social Cognition: Synchronization, Entrainment, and Coordination

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Grounding Social Cognition: Synchronization, Entrainment, and Coordination

The tabula of human nature was never rasa. *W.D.Hamilton*

Introduction

Understanding the social in *social* cognition has presented a number of challenges that have been with us from the very beginnings of ‘modern’ psychology (cf. Semin, 1986). One of these is to come to terms with what the ‘social’ means. As Gallese has noted recently: “The hard problem in ‘social cognition’ is to understand how the epistemic gulf separating single individuals can be overcome” (Gallese, 2006, p. 16). The foundations of *Völkerpsychologie* in the 1850s (Lazarus, 1861; Lazarus & Steinhal, 1860, Wedewer, 1860; Waitz, 1859) constituted an attempt to overcome the then prevailing individual-centered psychology in German psychology by introducing a *social* level of analysis. The emerging modern social psychology in the early 20th Century grappled with this problem, fluctuating between notions of ‘group mind’ and ‘instinct’, with Durkheim, LeBon, Ross, Tarde, and Wundt arguing in different voices for collective representations, group mind, collective mind, collective consciousness, or *Völkerpsychologie*. Of these various influences, the prevailing view that emerged was driven by Floyd H. Allport’s vision of a social psychology that was individual-centered and regarded as a subdiscipline of psychology (Allport, 1924; cf. Post, 1980; Graumann, 1984, inter alia). This has very much remained the dominant view of mainstream social cognition and underlined with reference to the biological finitude of the individual.

The second challenge is to be found in the traditional perspective in social psychology that social cognition is best understood in terms of internal mental representations and it is social because its object is social, namely persons, groups or social events. Characteristically, traditional models of information processing are symbolic, and knowledge is

represented in an amodal fashion, namely dissociated from any sensory and motor bases. Consequently, there is dissociation between the symbolic representational system and the experienced event, with high-level symbolic processes driving cognition – a view that is modeled upon fundamental concepts and principles from computer science (e.g., Fodor, 1975; Newell & Simon, 1972; Marr, 1982; Vera & Simon, 1993).

Additionally, a representational or symbolic perspective on social cognition does not take into account the fact that cognition is for *action*, thus neglecting the link between cognition and action, and the dynamic and adaptive functions of social cognition (cf. Smith & Semin, 2004). Recent developments in cognitive sciences (e.g., A. Clark, 1997; Clancey, 1993, 1997a; Kirshner & Whitson, 1997; Barsalou, 1999; Yeh & Barsalou, 2000), neuroscience (e.g., Adolphs, 2006; Amodio & Firth, 2006; Rizzolatti & Craighero, 2004; Firth & Firth, 2006; Gallese, 2006; Sommerville & Decety, 2006), and primate cognition (e.g., Barrett & Henzi, 2005) have introduced different ways of looking at social cognition and have contributed to the social cognition model advanced in this chapter (see Semin & Cacioppo, 2007a,b).

Our representations of the social world are fundamentally connected with the actions that our bodies perform (e.g., Barsalou, this volume, Glenberg, this volume). An adaptive and dynamic view of social cognition suggests that a model of social cognition must address the fact that our nervous systems and the ways in which we represent the world must have evolved in close conjunction with our musculo-skeletal systems and their proper control, because we must adapt our behavior to meet bodily requirements in a continuously changing environment – thus neural systems have evolved to become tuned to particular embodiments. In this view, social cognition is best understood as grounded in bodily experience and intertwined with a wealth of interpersonal interaction and specialized for a distinctive class of stimuli. In the course of our lives, we are exposed to a vast range of stimuli, cars, buildings, trees, household objects, books, etc. However, other human beings and their bodily movements constitute a distinctive class of stimuli: the movements of other human beings can be mapped isomorphically onto our own bodies.

Finally, social cognition is not delineated by the ‘wetware between our ears’ and driven entirely by some inner processes and representations, but relies on resources that are distributed across neural, bodily and environmental features (e.g., Hutchins, 1995; Kirsch, 1995; Brooks, 1999; Agre, 1997) with the social and physical environment supporting social action and interaction (Smith & Semin, 2004).

In this chapter, we advance a model of social cognition which is driven by the above considerations and their implications, namely social cognition: (1) is embodied; (2) consists of affective, cognitive, behavioral and neurophysiological processes that are distributed between brains and bodies; (3) is manifested in coordination and entrainment of behaviors, and (4) constitutes a distinctive class or domain because of the isomorphism between human bodies and their movements.

The aim is to supplement individual centered developments in (affective, cognitive, neuroscientific) embodiment research with a social framework that allows to encompass the processes involved from joint perception to joint action and its temporally distributed regularities. To this end we present a *social cognition model* (SC-model), which conceptualizes social cognition as an *emergent* product of *jointly recruited* and *time-locked processes* rather than individual ones. Moreover, the model provides an *embodied grounding* of social cognition by anchoring these jointly recruited processes at the sensory motor level and constrained by the types of ‘tasks’ (e.g., dancing, playing tennis, a resource conflict, a dialogue).

In the first part to follow, we put forward the outline of our SC-model (cf. Semin & Cacioppo, 2007a,b). There is considerable empirical evidence from diverse research traditions, ranging from neurophysiology, to social, developmental, and ecological psychology that speak to different parts of the model. Admittedly, the relevant literatures are non-intersecting in a number of ways and leave considerable interpretive leeway. We shall selectively review this literature in the second part of this paper in relation to proposed SC-model, which, in our view, provides an integrated and integrating framework to these diverse strands of research. In the final section, we shall draw further conceptual and research implications of the proposed model.

The Social Cognition Model (SC-Model)

Social cognition is for the adaptive regulation of social interaction (Smith & Semin, 2004) and is the emergent outcome of a dynamic process of interaction between con-specifics. For action to be efficient and adaptive, it must be closely tuned to the immediate social environment. Such tuning must entail continuous monitoring of social settings in order to be flexibly responsive in such dynamic and continuously changing social niches.

Social cognition *emerges* from moment-by-moment interaction between con-specifics. It is an adaptive regulatory process that ultimately serves survival needs and is grounded on a dynamic, interactive and continuous monitoring process.

The organism, in order to adapt to a continuously changing environment has to have a finely tuned mechanism in place that is responsive to the multifaceted and dynamic features of the environment. Such a mechanism enables the organism to continuously monitor the environment by means of *discrete, recurrent* and *short-lived temporal intervals* (Andrews & Coppola, 1999; Andrews & Purves, 2005; vanRullen & Koch, 2003). This recurrent process maintains the sensitivity of the organism to changes in the environment. This is a process that cannot be switched off or voluntarily controlled and is therefore autonomous and automatic. While these features may apply generally to cognition and its functions, the unique feature of *social* cognition is that it is *distributed across brains* in a distinctive manner. The distinctive feature of *social* cognition is that it *relies* on a monitoring process that is unique because it is grounded on time-locked sensory-motor processes that give privileged and immediate mutual access by *coupling* two agents and thereby putting them on the same footing. It is *jointly recruited processes* with *overlapping* 'identities' that facilitates two agents to be put on the same page. In other words, such mechanisms facilitate reaching a state of correspondence between two parties. What counts for the one member must also count for the other. We refer to these jointly recruited processes by which this is achieved as '*synchronization*'. Specifically, we define synchronization as *jointly and simultaneously recruited sensory motor processes* that give simultaneous partial access between producer and

perceiver at a neural level¹. There are four distinctive features of these processes, namely they are: (a) *jointly recruited* by co-acting organisms; (b) *time locked*; (c) multimodal; and (d) occur without the presence of explicit communicative intent or communicative goals.

Thus, the neurophysiological sensorimotor processes involved in the execution of any real (or imagined) action give rise to synchronization at the neurophysiological sensorimotor level in the perceiver to that action (see Figure 1). The process of synchronization is time-locked to the observed stimulus. Obviously, synchronization means achieving a state of partial and not full correspondence between producer and perceiver. If synchronization *alone* were to lead to complete equivalence between the sensorimotor processes of a producer and a perceiver then there would be confusion between producer and perceiver, self and other (Adolphs & Spezio, in press). Moreover, complete identity would mean a never-ending loop of continuously performing the very same actions.

The complexity of the social environment and the adaptiveness required of social cognition is not only to continuously monitor but also *selectively respond to significant features of a dynamic social environment* by setting goals for action. It is important to address how adaptive action is induced in response to ‘significant’ stimuli. It is unlikely that processes by which adaptive action is achieved is an integral part of the monitoring processes. The monitoring process is a continuous one and any suspension of this process would reduce the adaptive potential of the organism since it would imply that further monitoring of potentially significant and continuous changes in the stimulus would cease and thus remain undetected. We therefore propose that the identification of significant stimuli entails goal-driven higher-level decision processes that run *parallel* to continuous monitoring processes. Higher order decision-making processes inducing

¹ *Notational Clarification:* The literature in this field is replete with diverse terms to represent processes that are induced in co-action, may these be jointly recruited neural processes (e.g., mirroring, resonance, imitation) or behavior (e.g. mimicking, imitation, empathy). In this paper we refer to jointly recruited neural processes in the observation and execution of an action as ‘*synchronization*’. Jointly executed *matching* behaviors, if not driven by any explicit goal is referred to as ‘*entrainment*’, and coordination of co-actions takes numerous forms as further specified in the last section of the main part of this chapter.

adaptive action are dissociated from the monitoring process that synchronization is responsible for. Thus, while the monitoring process involves the unconscious synchronization of neurophysiological sensorimotor activations, goal mediated processes give rise to the synchronization of complementary neurophysiological activations (e.g., table tennis, while monitoring the other's backhand –unconscious synchronization of neurophysiological activations–, a decision is made on how to counter the backhand with the goal of scoring a point – goal mediated synchronization of complimentary neurophysiological activations).

Goal mediated processes and synchronization jointly exercise differential inhibitory (e.g. Baldissera, Cavallari, Craighero, & Fadiga, 2001) and excitatory influences on the formation of action oriented mental representations, which then lead to a motor response by the perceiver.

Notably, if the perceiver detects a feature in the action of another (stimulus) that is significant, then higher order regulatory processes are recruited that ultimately serve adaptive purposes. A consequence of switching on of goal-driven higher order processes in response to significant stimuli is that goal activation weakens synchronization processes and thereby reduces the influence of synchronization on the motor behavior of the perceiver (action). In contrast, when *no competing or complementary goal* is activated then there will be less inhibitory influences on synchronization processes. One would therefore expect that in such situations a semi-stochastic transduction process will ensue that is likely to lead to and manifested in a certain amount of behavioral entrainment. Such entrainment will be considerably enhanced if the perceiver is given, for instance, an explicit goal to imitate the action of another.

Figure 1 provides a schematic overview of the SC-model. To summarize:

1. Any action, real or imagined, serves as a stimulus that –if significant– activates a goal in the perceiver *and*
2. Synchronization processes. These are *jointly and simultaneously recruited sensory motor processes* that give simultaneous partial access between producer and perceiver at a neural level.

The sensory–motor processes are *jointly recruited* by co–acting organisms,

These processes are *time locked*;

They are multimodal; and

They occur without the presence of explicit communicative intent or communicative goals.

They serve a continuous mutual monitoring function that serves dynamic adaptive purposes.

3. If the stimulus is significant then higher–level decision processes are recruited which entail goal mediated synchronization of neurophysiological activations. Notably,

4. Synchronization and higher level processes are dissociated, but jointly shape the mental representation of the stimulus and are both subject to inhibitory and excitatory influences before they shape these mental representations that is then translated to action in the form of a motor response.

5. The type of task environment requiring two or more persons, which can be socially shaped (e.g., dancing, playing tennis, conversation) or by the physical characteristics of a joint task (e.g., carrying a large and heavy object, etc.) presents distinctive affordances that shape the nature of the joint action (e.g., coordination).

6. If no goal is activated or the activated goal is weak, then synchronization, which is subject to inhibitory and excitatory influences, contributes to the shape of the cognitive, conative and affective mental representations that configure motor response of the perceiver. This is the result of a semi–stochastic transduction process.

7. In the absence of any goal activation or weak activation a degree of behavioral entrainment between two organisms is likely to ensue. The degree of entrainment will vary as a function of the excitatory and inhibitory influences upon the formation of cognitive, conative, and affective mental representations.

8. Motor responses are generally not time locked. External excitatory or inhibitory factors may contribute to this as in the case of turn–taking in

dialogue, nevertheless some degree of entrainment may still be manifested as has been shown as in the case of syntactic priming, namely a syntactic structure that has been used by one person to be used again by the other dialogical partner (e.g., Bock, 1986, 1989; Bock & Loebell, 1990) as we shall discuss in detail in the next section.

9. Behavior entrainment (entrainment of motor responses) is likely to occur when goal mediated neurophysiological activation is synchronized with the stimulus as a function of appropriate relevance and significance. Thus, specific goals, such as singing or dancing together give rise to entrained or complementary motor responses. A consequence of such entrainment involving such fusion of action is the emergence of considerable identity overlap resulting in the reduction of psychological distance, increased proximity and heightened rapport between co-actors.

10. Finally, the entire set of processes from the observation of the stimulus to the motor response consists of sensorimotor processes.

The model we have presented so far and depicted in Figure 1 is designed to capture the processes that ensue in an individual organism and represents only one half of the joint process that takes place between co-acting individuals.

11. Finally, and most importantly, for cognition to be social and an emergent product we have to interface two interdependent individuals in co-action. This yields the emergent social cognition case as represented in Figure 2, where the monitoring and decision-making pathways of both individuals, in a time locked and complementary fashion, give rise to interdependent motor responses. This joint action is what we refer to as emergent social cognition and is *distributed across two brains* (see Figure 2). Indeed, the model advanced here is not a single behavior exchange but a continuous process as depicted in the stylized representation of Figure 2 in Figure 3.

In the following section we shall examine the above noted steps in the light of the existing empirical evidence whereby the SC-model will serve us as an integrative frame. In referring to the empirical evidence we shall also contrast the SC-model with different models that have been developed for

specific phases (e.g., synchronization, entrainment, task driven joint action) of the general model we have outlined.

The SC-Model– The Evidence

There is an unusually rich literature and substantial empirical research across diverse areas that have a direct bearing to the SC-model that we have advanced here. The evidence comes from research at neural, emotional and behavioral levels. In the following, we refer this research as it pertains to the SC-model put forward here. In presenting the evidence for the different facets of the SC-model we shall also draw attention to theories that have been advanced and highlight the differences and overlaps between these theories and the model advanced here. Thus, two goals of this drive this section. One is to actually recast the empirical work to date into the framework advanced here. The second is to actually contrast the SC-model with other frameworks where necessary.

Synchronization

Action

The neural basis of synchronization processes derives from the rapidly accumulating neurophysiological evidence with human and non-human primates suggesting that intentional action, and the perception of such action, has a shared neural notation. This line of research started with the discovery of mirror neurons in area F5 of monkey premotor cortex (e.g., di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, Fogassi, 1996). Rizzolatti et al. (1996) demonstrated the existence of a particular class of visuomotor neurons (in the F5 area of the macaque monkey premotor cortex) that discharge when the monkey engages in a particular action (e.g., grasping a peanut) and when it observes another monkey engaging in the same action (for a review see Rizzolatti & Craighero, 2004).

A subset of these neurons –termed ‘mirror’ neurons’ – also become active even when the final part of the action (e.g., grasping the peanut) is hidden (Umiltà, Kohler, Gallese, Fogassi, Fadiga, Keysers, & Rizzolatti, 2001). Critically, in the hidden condition the monkey must ‘know’ that an object (peanut) is behind the occluder and must observe the experimenter’s hand

going behind the occluder without seeing the completion of the action. More recently, Keysers and his colleagues (Keysers, Kohler, Umiltà, Nanetti, Fogassi, and Gallese (2003) have reported that specific populations of neurons ('audiovisual mirror neurons') in the ventral premotor cortex of the monkey discharge not only when a monkey performs a specific action but also when it sees or hears another monkey perform the same action. These neurons therefore represent actions independently of whether these actions are performed, heard or seen. Converging evidence about the adaptive nature of the mirror neuron system comes from Kohler, Keysers, Umiltà, Fogassi, Gallese, and Rizzolatti (2002) where monkeys were trained to rip a piece of paper. It was shown that once trained the mirror neurons involved in the execution of this action were recruited in response to only the sound of ripping. These studies suggest that single neurons in the premotor cortex synchronize not only to the actions that the other is executing, but also that the action along with the 'goal' is represented and inferred across different modalities. The correlation between mirror neuron activation in partially observed or merely heard conditions corresponds largely to the pattern of neurons recruited in the full performance of the actions, which result in a sound (peanut cracking) or complete action (grasping food). These studies suggest that single neurons in the premotor cortex synchronize not only to the actions that the other is executing, but also that the action 'goal' is represented and inferred in different modalities. The correlation between mirror neuron activation in partially observed or merely heard conditions corresponds largely to the pattern of neurons recruited in the full performance of the actions, which result in a sound (peanut cracking) or complete action (grasping food) suggesting that goal and action become functionally associated.

Admittedly, the evidence is correlational, based on the observation and execution of single discrete behaviors, that are either *transitive* (object related, as in the case of cracking a peanut) or *intransitive*, as in the case of mouth movements such as lip smacking, biting, licking ("communicative mirror neurons", Ferrari, Gallese, Rizzolatti, & Fogassi, 2003; Ferrari, Maiolini, Addessi, Fogassi, Visalberghi, 2005) suggesting that mirror neurons are multimodal (e.g., visual, auditory) – showing a *synchronization* between action execution and perception.

There is also an emerging body of evidence indicating the neural substrates of general action as well as emotional contagion effects in humans, raising the notion of a system of neurons that subserve an individual's capacity to recognize actions made by others and in so doing to mirror the observed actions. The human premotor cortex, which is involved in voluntary movements of the body, is organized somatotopically. Using functional magnetic resonance imaging (fMRI), Buccino, Binkofski, Fink, Fadiga, Fogassi, Gallese, Seitz, Zilles, Rizzolatti, Freund, (2001) localized areas of the brain that were active during the observation of movement by another individual. They found that regions of the premotor cortex were activated when individuals observed the actions of another and, more specifically, that the areas activated in the premotor cortex corresponded to the regions that would be active were the individual to have executed the observed actions. The findings of Buccino et al. (2001) are in accord with the hypothesis that there is a brain circuit that extracts and neurologically represents the motor commands of another individual's observed actions – the so-called “direct matching hypothesis”. The type of ‘mirroring’ noted by Buccino et al. (2001) does not require voluntary control. Evidence from other researchers indicates that imitative reactions are faster than simple visual reaction times, and that people's awareness of their own imitative reactions occurs significantly later than their imitative reactions. Indeed, there is considerable cumulative evidence revealing that movements of finger, hand, arm, mouth, or foot leads to the activation of motor-related areas of cortex (e.g., Grafton, Arbib, Fadiga, & Rizzolatti, 1996; Iacoboni et al., 1999; Manthey, Shubotz, & von Cramon, 2003; Stevens, Fonlupt, Shiffrar, & Decety, 2000). These findings hold in the case of movements that are biologically possible and not for impossible movements, as for instance an arm passing through a leg (Stevens et al., 2000).

Recent research has also revealed that listening to speech sounds activates premotor areas in the brain overlapping with areas that are responsible for the production of speech (Wilson, Saygin, Sereno, & Iacoboni, 2004). These research findings provide evidence for the existence of a *shared neural notation and how neural ‘parity’* (e.g., Liberman & Mattingly, 1985; Liberman & Whalen, 2000) *between a producer and receiver* is achieved in an automatic and pre-reflexive manner.

Emotion

Increasingly, the research on emotions suggests that afferent feedback generated by elementary motor entrainment with behavior expressive of emotions produces a matching emotional experience (e.g., Hatfield, Cacioppo, & Rapson, 1994; Dimberg, Thunberg, & Elmehed, 2000). Studies using functional neuroimaging techniques have shown that observing facial expressions of disgust and feelings of disgust activated very similar sites in the anterior insula and anterior cingulate cortex (e.g., Wicker, Keysers, Plailly, Royet, Gallese, Rizzolatti, 2003) and are involved in inducing what they term 'empathy' (Jabbi, Swart, Keysers, 2007). Indeed, single neuron recording experiments with humans show that the observation of pain and its experience activate the same neurons (Hutchison, Davis, Lozano, Tasker, Dostrovsky, 1999). The argument developed by a number of authors (e.g., Adolphs, 2006; Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Decety, & Grèzes, 2006) is akin to an insight offered by Lipps in the beginning of the 20th Century when he advanced the concept of 'Einfühlung'. "In the perception and comprehension of certain sensory objects, namely those which we represent afterwards as the body of another individual (or generally as the sensory appearance of such) is immediately grasped by us...This grasp happens immediately and simultaneously with the perception, and that does not mean that we see or apprehend it by means of the senses, We cannot do that, since anger, friendliness, or sadness cannot be perceived through the senses. We can only experience this kind of thing ourselves" (Lipps, 1903, p. 713, translation G. Jahoda, 2005). The emerging picture in the current research literature suggests that synchronization and or entrainment (depending on the dependent variables used in the diverse experiments) in the case of emotions leads to experiencing or feeling of the somatic state of the other, which does not necessarily mean conscious access. The cumulating evidence suggests that the neural perception – production synchronization observed for action is also applicable to emotion (cf. Adolphs, 2003; 2006). Indeed, research using electromyography techniques has shown that observers' facial expressions synchronize within a time window of 500 msec., even with subliminally presented facial expressions of emotion (e.g., Dimberg, et al., 2000).

Further evidence along these lines is provided by Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, (2003). Using functional magnetic resonance imaging (fMRI), Carr and colleagues (2003) found that the brain regions important for action representation and imitation, such as the superior temporal sulcus (STS), are connected to the insula and amygdala—regions in the limbic lobe that are involved in emotions. Indeed, recent research suggests that the observation of another person's emotional state recruits structures like the insula (Jackson, Meltzoff, Decety, 2005; Singer, Seymour, O'Doherty, Kaube, Dolan, Firth, 2004), a part of the cortex, which is also involved in the representation of our own somatic states. Additionally, there is evidence of an association of the insula with the conscious experience of one's own bodily state (Critchley, Wiens, Rotshtein, Oehman & Dolan, 2004). Indeed, observations of emotional states (e.g., a fearful body) not only induces increased activity in brain areas related to emotional processes but also areas that are responsible for the representation of action, suggesting that the synchronization process goes beyond establishing symmetry in experience, but puts the organism in a state of readiness for action (e.g., De Gelder, Snyder, Greve, Gerard & Hadjikhani, 2004)

Before closing this section, we should note that synchronization does not suggest complete equivalence or identity between producer and receiver but correspondence or 'parity'. Thus, in the research on mirror neurons with monkeys observing and performing an action approximately 20% of the neurons in the F5 are overlapping (Gallese et al., 1996). Similarly in behavioral research, which we shall review in the next section, it is obviously very specific behaviors out of a range of behaviors that synchronize. Moreover, Baldissera et al., (2001) examined whether the observation of action involves not only cortical motor areas but also low-level motor structures that resonate the observed actions as if they were performed by the observer. They had participants observe hand opening and closure and measured H-reflex size (to examine Spinal cord excitability) evoked in the flexor and extensor muscles. The findings reveal that observing participants H-reflex for flexors increased for hand opening and decreased for hand closing. The reverse was noted for extensors. These results suggest that there is an inhibitory mechanism *in the spinal cord* that stops the execution of the observed hand action. Thus, it is important to qualify that

synchronization does not produce *identity* between producer and perceiver but parity or correspondence. Obviously, if synchronization were to lead to equivalence between a producer's and perceiver's actions and emotions rather than an overlap then there would be complete confusion between producer and perceiver (Adolphs & Spezio, in press) and we would be performing the same actions all the time!

The converging research evidence we have reviewed selectively reviewed suggests that the architecture of the human perceptual and neural system is specifically designed for the recognition of movements of conspecifics in a privileged way. Indeed if mapping human beings and their bodily movements does constitute a special or distinctive case then it should be species specific. Buccino, Lui, Canessa, Patteri, Lagravinese, Benuzzi, Porro, and Rizzolatti, (2004) examined human observers who were exposed to mouth movements performed by humans, monkeys, and dogs. The movements were either transitive (e.g., biting a piece of food) or intransitive (e.g., barking, silent speech, lip smacking). Interestingly, while the observation of biting reactions recruited the mirror circuit, intransitive mouth actions gave rise to the activation of different cortical foci as a function of the observed species, showing that actions within the motor repertoire of the human subjects were mapped on their motor system, whereas non-human movements were mapped as a function of their visual properties.

The body of research reviewed above underlines the fact that bodily movements constitute a distinctive class of stimuli as we argued in the introduction to this chapter. The movements of other human beings can be mapped isomorphically onto our own bodies. These findings speak to species-specific mapping process and underline the view that synchronization leads to the formation of a type of sensory neural representation that has an entirely different ontological status than knowledge about the world in general. One can therefore regard synchronization as a *heritable foundation of communication and the embodied building block of social cognition*.

Two questions are relevant in the context of the research we reviewed so far. The first question is about the function of synchronization processes preceded with a general caveat about the research reviewed above. The function question also invites an evaluation of theoretical accounts that have

been advanced to come to terms with the explosively accumulating and increasingly sophisticated data on mirroring processes. The second question is: do synchronization processes have an innate basis? This has been predominantly addressed with behavioral research with non-human and human infants as well as children.

Neural Mirroring: Alternative Accounts and the SC-Model

There are a variety of accounts addressing the meaning and function of the findings reviewed above (e.g., Firth & Firth, 2006; Grèzes and Decety, 2001; Decety & Grèzes, 2006; Iacoboni, 2005; Jeannerod, 1999; Goldman, 2002, 2005; Keysers & Gazzola, 2006). For space reasons, we shall deal with only one prominent account namely the one advanced by Gallese (see however, Semin & Cacioppo, 2007b). Central to Gallese's conceptualization is the notion of "shared manifold" (e.g., Gallese, 2001, Gallese, 2003 and Gallese, 2005a), namely a shared meaningful interpersonal space (e.g., Gallese, 2001). 'Shared manifold' is regarded by Gallese as grounding the understanding of action or emotion. The shared manifold is achieved in a process in which the perception of an action or emotion induces a motor 'simulation'. This embodied simulation process is direct, automatic and escapes conscious access, and leads the observer to achieve a neural coupling with an agent thereby reconstituting the other's emotion or intentional action and creating a shared bodily state. This 'experienced state' constitutes the basis of mutual or direct understanding. "By means of embodied simulation, we do not just "see" an action, an emotion, or a sensation. Side by side with the sensory description of the observed social stimuli, internal representations of the body states associated with these actions, emotions, and sensations are evoked in the observer, 'as if' he/she would be doing a similar action or experiencing a similar emotion or sensation" (Gallese, 2006, p.xxxx). The neural correlate of such embodied simulation mechanism is to be found in mirror neuron systems and – as the above quote implies – the shared neural state the bodies of the agent and observer follow the same functional rules in which the other becomes another 'self'. Mutual understanding in this view is non-propositional. The shared bodily state achieved through embodied simulation is at a basic level of understanding and does not entail declarative representation. Most importantly, in this view the function of mutual understanding is not merely

modeling agents, their actions and emotions, but also the successful *prediction* of upcoming events.

Admittedly, social cognition does not consist of merely passive experiences of observing another perform an action or express a particular affective state. Moreover, social cognition does not consist of internal or intraindividual processes alone, even if these processes constitute a genuinely social state, as in the case of a ‘shared manifold’ that Gallese refers to. Social cognition consists of a dynamic, unfolding processes that takes place between two or more agents, who are engaged in action and reaction, and the shape of this interaction takes a multitude of forms ranging from a wide range of different non-verbal to verbal exchanges. What does the embodied simulation model represent in the context of a broader conception of social cognition as a distributed processes taking place between two or more individuals? In the context of the SC-model advanced here embodied simulation processes correspond to what we refer to *synchronization* processes, namely jointly and simultaneously recruited sensory motor processes that give simultaneous partial access between producer and perceiver at a neural level. However, in the context of the SC-model, although serving identical functions to embodied simulation (obtaining a shared neural state and prediction of the other’s actions) we regard it primarily as a *monitoring* mechanism. The simulation model is more adapted to account for social cognition as a still photo rather than a *continuously unfolding dynamic* monitoring process. Synchronization is a mechanism that facilitates two agents to be put on the same sensory motor page and serves the anticipation of what is to follow next. Moreover, monitoring processes alone do not shape unfolding interaction. Unfolding action is shaped as a function of the significance of the incoming stimuli and the type of ‘countermeasures’ these may necessitate influencing the type of re-actions one may be likely recruit and execute.

While in agreement with Gallese’s account of the process inducing a ‘shared bodily state’, which we refer to here as synchronization, the SC-model by taking a broader framework for the definition of social cognition, in our view, situates ‘embodied simulation’ mechanisms within a different functional context. While understanding how two or more agents achieve ‘being on the same somatic state page’ is important in identifying

mechanisms by which the epistemic gulf separating single individuals is bridged at a biological level, it does not address or incorporate the general process of what social cognition covers and the multitude of bridging layers that exist as a behavioral and linguistic level (Semin, 2007).

Moreover, the SC-model regards social cognition as *distributed between two brains* rather than a representation (non-declarative) in one person. Further, the model specifies the interaction between goal driven processes and autonomous and automatic synchronization processes as they shape ideomotor representations and contribute to the formation of motor responses. Indeed, social cognition as locked within a brain or between two brains falls into the classic representational fallacy that underestimates, or worse ignores the fact that cognition is for action and that social cognition is for the adaptive regulation of social interaction. Thus, while there has been a considerable influence of Gallese's conceptualization upon our view of the synchronization process, Gallese's claim about social cognition falls short of coming to terms with higher order goal driven processes, the distributed nature of the experiential knowledge induced by synchronization, the fact that synchronization is a continuous process and how this process contributes to the formation of motor representations for action as well as the emergent nature of social cognition.

Developmental Evidence

If synchronization is a jointly recruited process then the question arises as to whether this is an innate capacity or not. The neurophysiological evidence from adult human and non-human primates does not permit us to answer this question. Obviously, diverse actions (e.g. cracking peanuts, ripping paper, using chopsticks) used in human and non-human primate studies are acquired skills. If, however, synchronization is an innate social process then such jointly recruited processes should be evidenced at a behavioral level (entrainment) early on in development particularly during a period where goal driven higher decision processes are not yet in place.

There is considerable research with neonates that has examined entrainment, namely whether matching others' motor responses is an innate faculty or not. This research has the same paradigmatic features as the neurophysiological studies reviewed earlier. It relies on the minimal co-

presence social paradigm. Here, the dependent variables are behavioral and therefore: Does an observer *entrain* with the bodily movement executed by a 'model' and is it an innate capacity?

It is informative to have a brief look at the evidence with non-human primates before proceeding with the work on neonates and children. The research with non-human primates appears to be equivocal. Some suggest that chimpanzees can imitate (Preston & de Waal, 2002) while other studies suggest that extensive training (e.g., Custance et al., 1995) or experience and contact with humans (e.g., Tomasello, 1998, 2003; Whiten, 1998; Whiten et al., 1996) is necessary for imitation. For instance, Myowa-Yamakoshi, Tomonaga, Tanaka and Matsuzawa (2004) examined a nursery-reared infant chimpanzee (*Pan troglodytes*) between 5 to 15 weeks of age demonstrating that the infant imitated tongue protrusion (during 5 – 10 weeks) and mouth opening (5 – 11 weeks). Both types of entrainment ceased after 12 weeks. In another study with two chimpanzees reared from birth by their biological mothers, Myowa and colleagues (2004) observed discrimination between and entrainment of tongue protrusion and mouth opening at less than 7 days of age. This differential neonatal imitative behavior ceased after 2 months of age and was replaced by indiscriminate mouth opening responses. What these results suggest is that the disappearance of neonatal entrainment also marks the onset of social communicative behavior such as a decrease in neonatal spontaneous smiling and an increase in social smiling (e.g., Tomonaga, et al., 2004), etc. They also reveal evidence for a very early but limited and short-lived repertoire (tongue protrusion and mouth opening) of entrainment in primates.

Whether human infants have an innate ability to entrain (imitate) specific facial gestures was stimulated by two experiments reported by Meltzoff and Moore (1977) suggesting that 2 to 3 week old infants do entrain to specific facial gestures (e.g., tongue protrusion, mouth opening). The research was followed up by Meltzoff and colleagues (e.g., Meltzoff & Moore, 1983, 1992; see Meltzoff & Moore, 1997 for a review) as well as by other research groups (e.g., Heimann, Nelson, & Schaller, 1989; Legerstee, 1991). While a number of studies were able to replicate these findings (e.g., Field, Woodson, Greenberg, & Cohen, 1982; Vinter, 1986; Reissland, 1988) others were unable to do so (Hayes & Watson, 1981; McKenzie & Over, 1983) and a

Careful analysis of infant entrainment across a range of gestures in the literature by Anisfield (1991, 1996) suggests that there is conclusive and reliable evidence for entrainment of *tongue protrusion* – the most widely studied gesture (see also Heyes, 2001). The likelihood of neonates performing a tongue protrusion gesture increases significantly if they have observed the gesture being performed.

The restriction of the range of behaviors that infants entrain with, namely tongue protrusion may in fact be indicative for the constitutive function of mouth movements for communication. If it is the case that the supportive evidence is only reliable in the case of movements of the mouth and face regions then this may not be surprising, given that this is the part of the human body has the highest overall communicative significance in general. Thus, ironically, the critical assessment of the reliability of human neonate entrainment may not be due to a coincidental resemblance as Heyes (2001) has suggested, but may be regarded as constituting indirect evidence for the innateness of *synchronization processes* that ground communication. Recently, research by Chen, Striano, and Rakoczy, (2004) has revealed that when neonates hear the spoken phonemes /a/ and /m/ then they produce lip movements that correspond to these movements. This is obtained irrespective of whether the baby's eyes are open or closed. Thus, differential mouth movements are produced even when no visual signal is available. This research appears to speak to a hard-wired connection between the motor processes involved in the production and perception of speech. While the evidence with neonates suggests entrainment, a more differentiated picture emerges with older children in the context of research on 'imitation'. It has been shown that by the age of six months infants are able to selectively distinguish between human action and object motion and encode a goal of a reaching movement that they observe, which is comparable to more advanced understandings of goal-directed action (Woodward, 1998) and that infants who are 12 months old relate single actions to overarching goals (Woodward & Summerville, 2000). The research with neonates does not allow one to differentiate between the goal of a movement and the movement. Thus, if the observed behavior is picking up a toy with your left hand, then do children entrain (i.e. picking up the toy with their left hand) or do they reproduce the goal (i.e., picking up the toy with their right hand)? The

question in terms of the SC-model we have advanced here is whether the emergence of goals as significant stimuli constitutes an inhibitory influence upon entrainment.

A considerable amount of the research speaking to this issue relies on a experimental paradigm involving an *explicit imitation instruction* of touching a body part or an object on the child's left or right side with a left or right hand movement (e.g., Swanson & Benton, 1955; Wapner & Cirillo, 1968). Two features of this paradigm are relevant for the examination of "entrainment", namely the goal of the movement (i.e., the object or body part to be touched) and the hand movement (i.e. right or left hand movement). The research reveals that if there is a *goal* to the executed movement, for instance, one of two adjacent dots are stuck on a table and the model covers one of the dots with a hand movement, then the child (average age 4.4 years) always covers the right dot. However, if the model executed a contra-lateral hand movement to cover the dot, then the child uses an ipsi-lateral hand movement (Bekkering, Wohlschläger, & Gattis 2000, Experiment 3; Schofield, 1976). If however, the goal (dot) is removed and the same hand movements are executed, then 'entrainment' is observed. Ipsi-lateral movements produce ipsi-lateral performance and contra-lateral model movements lead to the production of contra-lateral hand movements. Thus, in terms of the SC-model one finds that the presence of a goal (significant stimulus, e.g., a dot) inhibits entrainment under these experimental conditions. Obviously, the important caveat in the context of 'imitation' experiments is that they provide explicit instructions to 'imitate' the model. Thus, the experimental conditions induce an explicit motor response goal that is further specified by the body part or object that defines the motor responses' designation (See for an overview, Wohlschläger, Gattis, & Bekkering, 2003). Consequently, entrainment in such conditions is not automatically driven but explicitly instructed.

There are diverse theoretical approaches developed to capture the processes responsible for the entrainment observed with neonates, and the 'imitation' findings briefly reviewed above. A prominent one is the Active Intermodal Matching (AIM) model developed by Meltzoff and Moore (1977) which proposes that when a body movement is observed the visual representation of the movement is converted to a supramodal

representational system (Figure 4). This system contains information that allows matching visual with proprioceptive information leading to a pattern of motor activation that can lead to performing the same action.

In terms of the SC-model, neonate evidence can be regarded as the consequence of a stimulus (face with tongue protrusion) driven activation of the synchronization pathway with no inhibitory influences or for that matter higher order processes such as goals exercising an influence on the emerging mental representations that shape the motor response. The precise neural underpinning of this process would appear to require further research. Proponents of direct-matching models (e.g., Meltzoff & Decety, 2003) have drawn parallels between the research on mirror neurons and the research with neonates. However, this account of 'imitation' does not appear to be completely unproblematic as can be seen with the research on older children to which AIM is also supposed to apply.

As Bekkering et al. (2003) have pointed out; direct-mapping theories (including mirror neuron simulation models) are unable to account for systematic and consistent deviations from model movements, namely the repeatedly observed *mirror image* 'imitation' of adult model movements. Furthermore, AIM and direct matching models can also not deal with differences between goal vs. movement driven 'imitation' described earlier.

These problems are circumvented in Bekkering et al.'s (e.g., 2004) theory of goal-directed imitation (GOADI), which – as the authors state – does not make an explicit differentiation between goal directed movements, and movements that do not have a goal (Figure 5). The argument is that once a goal is selected then it elicits the motor program with which it is most strongly associated (ideomotor principle). Furthermore, the model suggests that observed model behavior (motor act) is decomposed into separate parts from which a few hierarchically organized goal aspects are selected. This hierarchy follows functionality 'principle'. If goals are present (e.g., such as a dot) then they are selected over means (e.g., effectors or movement paths). Furthermore, it is claimed that imitation behavior is driven by the same mechanisms for children, adults and animals (Bekkering et al., 2003, p.503).

GOADI is a model of explicitly induced "imitation". The driving force according to the model is goal-driven higher order decision process. Although the focus is upon what and why people engage in 'imitation', it

could also be a model for *any* instructionally induced movement execution (e.g., do precisely the opposite movement to the one performed by the model, etc.). There are two important provisions missing in the model. The first is that by definition it is an individual centered model and it differs from the SC-model in that respect. Second, it is exclusively about goal-mediated processes that are not automatic. In that sense, it is not in conflict with the goal-mediated pathway proposed by SC. However, the model misses out on the automatic pathway mediated by synchronization processes and would appear to dismiss any potential role this pathway may play (Bekkering et al., 2003, p. 503). Thus, the model's explanatory range is restricted and consequently has no conceptual provision for automatic processes such as synchronization.

Admittedly neonate imitation is likely to be automatic and driven by synchronization (a jointly recruited process). In contrast, research, which falls under explicitly induced imitation, is entrainment and coordination (in our terminology) driven primarily by goal-mediated mental representation inducing motor behavior. Examples of such behavior are choral singing, dancing, etc. Moreover, the model by focusing on intraindividual processes also ignores the emergent properties that result as an interaction between coordinated movements that are driven by properties external to the organism (such as the dot as an environmental stimulus outside of the interaction between the model and imitator). Thus, in our view, the SC-model we advanced not only subsumes both direct-matching process models, AIM, GOADI, but provides a functionally operational model that has an integrative breadth and can accommodate for specific phenomena that neither of the models can address (the signature of what is social, namely jointly recruited processes) or decide explicitly not to address (e.g., GOADI, automatic processes).

Entrainment and Coordination

The SC-model we have advanced configures the steps from perception to production, incorporating its expression in joint action. For methodological reasons, there is, to our knowledge, no research that has integrally investigated the entire pathway. There is however considerable evidence that can contribute to our understanding of how coordination and entrainment contribute to 'joint action' and provide illustrations for the

types of outcomes specified by the SC-model. Notably, the relevant literatures on behavior or action are non-intersecting in a number of ways, which leave considerable interpretive leeway – as is the case with the research presented in the preceding section on synchronization.

In social psychology, there has been a wealth of research relevant to coordination and entrainment. The earliest reference to entrainment was by McDougall (1908), who noted that spectators assume the postural manner of athletes they were observing. The research interest seems to have gone in ebbs and tides since the 1960ies (e.g., Bernieri, 1988; Bernieri, Reznick, & Rosenthal, 1988; Bernieri, Davis, Rosenthal, & Knee, 1994; Condon & Ogston, 1966, 1967; Kendon, 1970; Tickle-Degnen and Rosenthal, 1987; Bavelas, Black, Chovil, Lemery, & Mullett, 1988; Bavelas, Black, Lemery, & Mullett, 1986a, b). Notably, the focus in this early research is with reference to ‘social interaction’ as the unit of analysis rather than the individual (e.g., Schefflen, 1982). Among these, a line of research is to be found running under the labels of *mirroring* or *mimicry* (e.g., Bavelas, Black, Lemery, & Mullett, 1986; Dabbs, 1969; O'Toole & Dubin, 1968), namely a focus on an individual's imitations or mimicking of the limb movements performed by another. This focus was reintroduced in the late 1990ies (e.g., Chartrand & Bargh, 1999; van Baaren, Maddux, Chartrand, de Bouter, & van Knippenberg, 2003; van Baaren, Horgan, Chartrand, & Dijkmans, 2004). The research covers a wide range of behaviors from emotion contagion (Hatfield, Cacioppo, & Rapson, 1994), postural sway (e.g., Shockley, Santana, & Fowler, 2003), playing piano (Keller, Knoblich, & Repp, 2007), paralinguistic behaviors (see Giles & Coupland, 1991), the use of syntactic structure by dialogical partners (e.g., Bock, 1986, 1989; Bock & Loebell, 1990), to arbitrary behaviors (e.g., Chartrand & Bargh, 1999) just to name a few. Not surprisingly, there are also differing conceptual frameworks as well as substantial variations in methodological sophistication or lack thereof. The theoretical frameworks range from individual centered direct, unmediated action-perception models (Dijksterhuis & Bargh, 2001), to non-reductive ecological approaches (Marsh, Richardson, Baron & Schmidt, 2006), to cognitive models of joint action (e.g., Sebanz, Bekkering, & Knoblich, 2006).

Before discussing the relevant research within the SC-model, a note on what is understood here with coordination of action and entrainment of

action is necessary. Action coordination can take a great variety of manifest forms ranging from, for instance, a dialogue, talking and walking, a soccer game, the performance of open-heart surgery, two people moving a very heavy object, to implementing a war strategy. Two features of coordination stand out. One is that the participants in a joint action have to be on the same page regarding the ‘task’ at hand, namely share a ‘common ground’ and engage in joint action abiding by the rules pertinent to the ‘task’ (dialogue, tennis, surgery operation, pushing a large object, etc.) which are quintessential to grounding the task. The second feature is that joint action is an open system (whatever the task) and can lead to the same result (goal or end state) despite differences in the initial conditions. In other words, coordination is not a determinate path, but is characterized by equifinality. Moreover, coordination can take place over behavioral cycles that can vary from milliseconds to hours or longer. The temporal nature of these cycles is a function of the type of ‘task’ that is being performed. This can be illustrated with any type of social interaction, which consists of situated linguistic and/or behavioral exchanges, such as a dialogue or a tennis game. Obviously, coordination in social interaction is multimodal (e.g., verbal, motor movement).

With entrainment, we refer to the *alignment of behaviors or rhythms* during social interaction borrowing the term from earlier work (e.g., Condon & Ogston, 1966, 1967)². As is the case with coordination, entrainment is also multimodal. Entrainment refers to a state between two persons that results when the cyclical behavioral movements of one person influence the cyclical movements of another person and *they oscillate in rhythm*. A typical example is provided in the spontaneous transition of an applauding audience from disordered clapping to entrained clapping (Neda, Ravasz, Brechet, Vicsek, & Barabasi, 2000) and then back again to disordered clapping only for entrained clapping to reemerge again a little later. This remarkable phenomenon is evidenced despite considerable individual differences in clapping tempos. It would appear that the transition to entrained clapping enhances noise intensity and requires less effort, whereby each clapper

² Subsequently used as synchrony specifically referring to the *judged* “gestaltlike harmoniousness or meshing of interpersonal behaviors” (Bernieri et al., 1988).

affects the other both locally and globally. Entrained behavior occurs rhythmically and one way of capturing their regularities is to model its cycles, periods, frequencies, and amplitudes. Depending on the particular behavior and interaction in question, behavioral cycles of entrainment in interpersonal behavior can range from milliseconds to hours. Indeed, entrainment as we refer to it here is a pervasive phenomenon not specific to human social behavior alone (cf. Strogatz, 2003). Entrainment can be captured in terms of characteristic cycles, periods, frequencies, and amplitudes and its investigation can focus on the degree to which behavioral cycles of a couple are in phase or not (e.g., early developmental work Brazelton, Koslowski, & Main, 1974; Bullowa, 1975; Davis, 1982; Rosenfeld, 1981; Stern, 1974).

More recent work from an ecological approach also treats interaction as the unit of analysis and draws on human movement science and coupled oscillator theory (see Marsh et al., 2006 for an overview). This research focuses on behavioral data arguing that an *embodied* approach to uncovering perception action systems resulting in entrainment has to rely on the examination of dynamic properties of actual behavior taking place between individuals, rather than mentalistic, representational constructs. Thus, while convergent with the perspective adopted in the SC-model, that the object of social cognition is an emergent interaction unit, – an outcome of joint action – this approach differs in that the primary focus is the analysis of behavior.

Coordination and entrainment are simultaneously occurring processes during social interaction. Take for instance a dialogue. Any dialogue features a variety of instances of multimodal coordination as well as multimodal entrainment. A dialogue can simultaneously manifest *coordination* as in the case of turn taking in a conversation (e.g., Sachs, Schegloff, & Jefferson, 1974), or introducing a new topic, as well as *entrainment*, for instance at a syntactic level (e.g., syntactic priming, Bock, 1986, 1989; Bock & Loebell, 1990), affective level (e.g., mood contagion, Neumann and Strack, 2000), movement level (e.g., Chartrand & Bargh, 1999), affective facial expressions (e.g., Dimberg, et al., 2000), and breathing movements (e.g., Furuyama, Hayashi, & Mishima, 2005). Coordination and entrainment can converge when joint behavior is goal driven (e.g., playing tennis versus choral singing)

be consciously accessible or escape conscious access (two people moving a heavy object versus emotional contagion) or a combination of both.

In the following we refer selectively to the literature relevant to the entrainment and coordination propositions advanced by the SC-model and where relevant highlight the different conceptual frameworks that have been advanced to account for different types of co-action that have been investigated.

In presenting the SC-model we argued that the goal of joint action along with the type of task environment (social or physical features of the task) contributes to the shape and nature of the joint action.

The nature of coordination and of entrainment in joint action will obviously vary depending on whether two people are attempting to move a heavy stone, a large table, play table-tennis or having a conversation. There is of course a well established tradition on how language is used to coordinate joint action and establish what is termed 'common ground' (H. Clark, 1996). A significant portion of this work has relied on the transmission of 'representations' in interpersonal communication (cf. Krauss & Chiu, 1998; Krauss & Fussell, 1996). A recurrent theme in this field is what one may be referred to as 'coordination in communication, namely the different ways in which 'representational correspondence' can be established in joint action by for instance, 'audience design' (e.g., Krauss & Fussell, 1996), 'referential communication' (Clark & Brennan, 1991; Fussell & Krauss, 1989a; b), and 'grounding' (e.g., H. Clark, 1996; Keysar, 1997).

It is more recent that research has focused on coordination and entrainment occurs at a non-verbal behavioral level. Oftentimes, this research focuses on a specific feature of joint behavior or action, for instance conversations, and is not interested in other features of joint behavior that accompany such behavior. However, there are numerous exceptions. For instance, Shockley and his colleagues (2003; Shockley, Baker, Richardson, & Fowler, 2007) examined whether conversation fosters interpersonal postural entrainment (postural sway) and revealed that convergent speaking patterns mediate interpersonal postural entrainment (see also Condon & Ogston, 1966; Kendon, 1970; LaFrance, 1982). Postural sway is not the only behavior that entrains outside of conscious access, but also dialect (Giles, 1973), and speech rate (Street, 1984). Natale (1975) found across 20 interviews that

interviewees entrained their voice intensity to that of interviewers, a finding that appears to be stable across different studies (see Cappella, 1981). Similarly, pausing frequency (Cappella & Planalp, 1981) has been shown to entrain. Entrainment has also been shown to hold for gestural (see Furuyama, Hayashi, & Mishima, 2005) movements of interacting individuals without the individuals intending to entrain. Spontaneous entrainment occurs when interactants have full visual access to each other (cf. joint attention – Sebanz et al., 2006), but the above studies suggest that visual information is not the only medium recruited by participants to entrain.

A further line of research that has emerged non-cumulatively although sharing even terminology is the recent developments on mimicry (e.g., Bavelas, et al, 1986; Bernieri et al., 1988; Dabbs, 1969; O'Toole & Dubin, 1968) is a series of studies revealing that perceiving another's mannerisms leads to unconscious mimicry of the behavior (Bargh, Chen, & Burrows, 1996; Chartrand & Bargh, 1999; Dijksterhuis & Bargh, 2001; Johnston, 2002). For instance, Chartrand and Bargh (1999) had a trained experimenter rubbing her nose or shaking her foot while interacting with a participant. Their results revealed that when the experimenter rubbed her nose, then participants were more likely to do so as well rather than shake their foot, and in the experimental condition when the experimenter shook her foot, then the likelihood of participants shaking their foot was higher than rubbing their nose.

Earlier research by Bavelas and her colleagues (e.g., Bavelas, Black, Chovil, Lemery, & Mullett, 1988; Bavelas, Black, Lemery, & Mullett, 1986) examined what they refer to also as 'motor mimicry' defined as behavior by an observer appropriate to the situation of another (e.g., wincing at the other's injury or ducking when the other does). They argue that the function of such motor mimicking is primarily communicative (Bavelas et al., 1988). They created a situation with a victim of an apparently painful injury and controlled the amount of eye contact that the victim had with a participant observing the victim. They were able to reveal that motor mimicry displayed by the observing participant was significantly shaped by the visual availability of the victim, suggesting that mimicry may serve a communicative function.

The research evidence to date suggests that mimicry occurs outside of conscious awareness, and without any intent to mimic or imitate. Numerous

studies have investigated the diverse moderating conditions and consequences ‘mimicry’ such as self-monitoring (Cheng & Chartrand, 2003) and type of self-construal (van Baaren, Maddux, Chartrand, de Bouter, & van Knippenberg, 2003; van Baaren, Horgan, Chartrand, & Dijkmans, 2004). One of the interesting consequences of mimicry or entrainment is that it leads to increased liking of an interaction partner (Chartrand & Jefferis, 2003; Dijksterhuis & Bargh, 2001). Indeed, there appears to be reliable evidence for the relationship between entrainment of different types of movements and liking (Bernieri & Rosenthal, 1991; Chartrand & Bargh, 1999; Julien, Brault, Chartrand, & Begin, 2000; LaFrance, 1982; LaFrance & Broadbent, 1976; Lakin & Chartrand, 2003).

Entrainment: SC-Model, Priming, Coupled Oscillatory Modeling

The different accounts for entrainment all focus on behavioral outcomes and in some cases focus on intrapsychological consequences. From the ecological perspective, which takes a coupled oscillator theory approach to explain periodically recurring regularities in the movements of two persons. Here the unit of analysis is the behavioral interaction and the objective is to model the temporal organization of the movements of two (or more) people. While modeling the temporal organization of movement provides an insight into the regularities, their cycles, the breakdown of regularities, and relies on very sophisticated technology to record joint movements, it makes no attempt to understand the neural and psychological forces driving such behavior. Thus, specific phenomena such as the affective and motivational precursors as well as consequences of entrainment, the contribution of entrainment and coordination to socially distributed knowledge and more complex multimodal processes such as conversation, dialogue do not currently seem to feature as relevant phenomena in this approach.

Contrastively, the current version of the mimicry research, which relies on the individual as the unit of analysis, relies on a priming account. The assumption is that “perceiving an action activates the mental representation of this action, which in turn leads to the performance of the action” (Dijksterhuis & Bargh, 2001, p. 8). Indeed, this account of entrainment shows no theoretical interest in the temporally distributed regularities in joint movement – a central focus in ecological work, nor does it show an interest

in jointly recruited mediating processes as advanced by the SC-model. Indeed, the so-called “perception-action expressway” (Dijksterhuis & Bargh, 2001) has an uncomplicated approach to explaining how an individual's behavior affects the behavior of another individual. Thus, in this view the temporal dynamics of interpersonal entrainment do not feature. There is no distinction between coordination and entrainment, though the data on which the mimicry research relies consists of the frequency with which a target displays the *same* behavior as a stooge.

The approaches to co-action (e.g., Sebanz et al., 2007; Marsh et al., 2006) do not speak to how the different pathways activated by significant goals and synchronization processes contribute to the shape of entrainment and coordination. The SC-model specifies these conditions. In the absence of goal activation that recruits coordination (e.g., playing table tennis) synchronization processes (subject to inhibitory and excitatory influences) contributes to the shape of the cognitive, conative and affective mental representations that configure the motor responses of the perceiver. Arguably, this is what is noted in the mimicry research. This is argued to be the result of a semi-stochastic transduction process leading to some periodic entrainment. Unfortunately, the mimicry research has to our knowledge not examined the temporal dynamics of ‘mimicry’. In more specifically defined behavioral studies as is the case with research conducted within the ecological framework often the behaviors of individuals are instructionally induced (but not always, e.g., Shockley et al., 2007), thus supplying a goal and showing systematic temporal dynamics of behavior, though the mechanisms by which the pick-up of information about how the other phases its movements, and how these mechanisms lead to temporal co-organization of movement or entrainment are not of any theoretical interest in this approach (cf. Marsh et al., 2006). From an ecological perspective the suggestion is that movement is ‘lawfully’ constrained by other people's movements (Marsh et al., 2006) and best modeled in terms of coupled oscillator theory without any recourse to any jointly recruited intra-personal processes may these be neural or psychological.

Obviously, there are numerous naturally occurring instances where the behavioral goals of co-actors are explicitly prescribed as in the case of gospel singing and dancing, inter alia. These are instances where behavior

entrainment (entrainment of motor responses) is likely to occur when goal mediated neurophysiological activation is synchronized with the stimulus as a function of appropriate relevance and significance. A consequence of entrainment involving such fusion of action is the emergence of considerable identity overlap resulting in the reduction of psychological distance, increased proximity and heightened rapport between co-actors, as the early and recent research on mimicry has demonstrated. These are situations where the boundaries between self and other are reduced or on extreme occasions even dissolve, such as religious rituals.

Conclusions

We began this chapter by arguing that social cognition constitutes a distinctive class or domain because of the isomorphism between human bodies and their movements. Our environment consists of a boundless array of variegated sources of stimulation ranging from diverse inanimate artifacts to the cosmos of nature. Within this boundless diversity, human beings and their bodily movements constitute a distinctive class of stimuli (e.g., Buccino, et al., 2004), since their movements can be mapped isomorphically onto our own bodies. "... (T) he architecture of the human perceptual and neural system is specifically designed for the recognition of species-specific movements in a privileged way thereby establishing a type of knowledge that has an entirely different ontological status than knowledge about the world in general (Semin 2007, p. xxx). The SC-model we advanced in this chapter builds upon this and advances a framework that acknowledges the fact that cognition cannot be *social* without mechanisms that facilitate achieving some common or symmetrical base between two organisms. Consequently, the model relies on an analytic unit that is different from the traditional Western focus – evident in the writings of Plato and Aristotle – of the isolated, thinking individual. For historical and cultural reasons, the individual constitutes a prominent analytic focus and is the prevalent analytic unit in psychology and related disciplines. The individual is also a prominent unit for practical methodological reasons. Such an analytic incision offers itself readily given the biological finitude of the individual. However, it does not necessarily lend itself as readily for conceptualizing what it means to be a '*social* species' and the analysis of social cognition in general. Consequently, the proper understanding of social cognition requires an analytic unit that

consists of a coupled unit and jointly recruited processes. This is also one of the contributions of the SC-model to the emerging to the emerging embodiment literature. Social, cognitive, affective, and neuroscientific approaches to embodiment rely predominantly on individual centered analyses and generally do not attend to the distributed and emergent nature of the phenomena under examination. The social dimension of our lives plays a crucial role in the way we are shaped; the way we form images of our world; how we interact with and within it.

A further implication of the model advanced here is its significance for grounding communication – an aspect that none of the theorizing or research reviewed here has addressed (see however, Semin, 2007).

A surprising facet of the research we have reviewed is that its foundational significance for *communication* has not been fully realized. It is likely that this is in part due to an implicit or even explicit commitment to the individual as the analytic unit that may have detracted attention from a critical function of synchronization processes, namely grounding communication. This concern may be articulated for broad research fields driven with direct-matching constructs such as the mirroring, simulating, and resonance upon perceiving another's action (e.g., Rizzolatti, Fadiga, Gallese, & Fogassi, 1996; Rizzolatti & Craighero, 2004); the extensive social psychological work on *mimicking*, *matching* another's behavior (e.g., Bernieri, 1988; Bernieri, Reznick, & Rosenthal, 1988; Bavelas, et al., 1988; Chartrand & Bargh, 1999); the voluminous work on *imitation*, *empathy*, *sympathy* (e.g., Wohlschläger, Gattis, & Bekkering, 2003; Preston & De Waal, 2002; Heyes, 2001; Meltzoff & Moore, 1997; Tomasello, 1998; Iacobini, in press) or on emotion contagion (Hatfield, Cacioppo, & Rapson, 1994). As the central constructs in these converging fields all indicate, the analytic anchor is located at the level the *individual*, who is imitating somebody else, or being emotionally taken over by the feelings of the other, simulating, mirroring, mimicking, or putting him or herself in the shoes of the other, emphatically or otherwise.

The fact that human beings and their bodily movements constitute a distinctive class of stimuli also means that they have evolved mechanisms that permit them to be coupled by being put on the same footing, namely synchronization processes. It is important for any social species to have such

mechanisms that facilitate obtaining a state of equivalence – what counts for one member must count for the other and such mechanisms – by giving privileged access to each other – ground mutual recognition and intelligibility. Mutual recognition is by definition a collaborative process and it takes two to collaborate. In other words, ‘sameness recognition’ cannot come about without interacting, or without exchanging information while navigating in a joint environment. While the particular ways in which mutual recognition and intelligibility is achieved varies between species, the general characteristics of the mechanism or process by which two parties communicate and by which mutual recognition and intelligibility is achieved remains the same. Thus, while synchronization processes have a very important function by putting two or more agents on the same page and allowing the predictability of the other and consequently adapting our behavior to meet bodily requirements in a continuously changing environment, it is also the a scaffolding that carries communication which cannot take place unless two parties are on the same page, or in the terminology used in a different context, have established ‘common ground’ (H. Clark, 1972). The point being that ‘common ground’ which is established in dialogue is a symbolic process that is not grounded. Notably, Human communication is not merely speech (e.g., Bavelas & Chovil, 2000).

Language-based communication is about meanings and implications conveyed by articulatory gestures that are very important for coordination, but this is the tip of a *multimodal* communication iceberg which would not be possible without the co-operation of a range of *neural and motor* processes outside of conscious control that provide inter alia a continuous monitoring process by means of which agents are put on the same page. Face-to-face communication is composed of a simultaneously integrated set of audible and visible acts and any act of communication is a unified process resulting from the integration of information from multiple sensory modalities. All finely integrated motor expressions along with communicative gestures and are not loosely or randomly occurring features of communication (e.g., Condon, 1982; Davies, 1982). This list is merely to draw attention to the fact that human communication does not consist of only *what is said*, but that what is said (speech) is just a part of a multimodal expressive ‘whole’ and its emergence constitutes social cognition.

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