



# From Mind Perception to Mental Connection: Synchrony as a Mechanism for Social Understanding

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## Abstract

Connecting deeply with another mind is as enigmatic as it is fulfilling. Why people “click” with some people but not others is one of the great unsolved mysteries of science. However, researchers from psychology and neuroscience are converging on a likely physiological basis for connection – neural synchrony (entrainment). Here, we review research on the necessary precursors for interpersonal synchrony: the ability to detect a mind and resonate with its outputs. Further, we describe potential mechanisms for the development of synchrony between two minds. We then consider recent neuroimaging and behavioral evidence for the adaptive benefits of synchrony, including neural efficiency and the release of a reward signal that promotes future social interaction. In nature, neural synchrony yields behavioral synchrony. Humans use behavioral synchrony to promote neural synchrony, and thus, social bonding. This reverse-engineering of social connection is an important innovation likely underlying this distinctively human capacity to create large-scale social coordination and cohesion.

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At different states in our lives, the signs of love may vary: dependence, attraction, contentment, worry, loyalty, grief, but at the heart, the source is always the same. Human beings have the rare capacity to connect with each other, against all odds.

Michael Dorris

People seek meaning in life through the company of others. Yet, as anyone who has ever felt lonely in a crowd can attest, company alone is not enough. What people really seek is connection, the pleasurable mutual engagement between oneself and another mind. However, despite its importance, the origin of mental connection is one of the greatest unsolved mysteries of science.

Here we review studies from a diverse literature that, collectively, converge on an origin of mental connection. First, we review evidence that the perceptual systems in the human brain are tuned to seek other minds and predict their behavior. Second, we suggest that the ability to dynamically predict behavior affords synchrony. We highlight the importance of synchrony as an adaptive neural mechanism by which people entrain to others; an adaptation that blurs the self–other boundary and promotes social bonds through the pleasurable feeling of connection. Finally, we speculate that the human brain, in contrast to the brains of other species, is uniquely able to reverse engineer connection-by-synchrony, thereby creating mass social coordination and cohesion.

## How the Brain Finds a Mind

As Piaget famously opined, cognitive development is about making models. As children develop, their models of the world become increasingly sophisticated via the shaping

processes of assimilation and accommodation (Piaget, 1954). Perhaps the earliest model the human brain develops is that of another being.

From birth, humans are predisposed to attend to animate beings. Newborns look more at faces than any other objects (Johnson, Dziurawiec, Ellis, & Morton, 1991), listen longer to human voices than other sounds (Vouloumanos & Werker, 2007), and gaze longer at upright versus upside-down displays of biological motion (Simion, Regolin, & Bulf, 2008). Since babies lack knowledge about the world, this initial interest is almost certainly driven by simple percepts. Indeed, two dots and a line are enough to capture an infant's attention, but only when presented in the configuration of a face: two dots for eyes, and a line for nose (Goren, Sarty, & Wu, 1975). This pattern-matching predisposition quickly develops into an increasingly sophisticated set of criteria for what qualifies as an animate being. The brain subjects faces, motion, and voices to a demanding array of tests designed to scrutinize input for evidence of a mind worthy of additional cognitive resources (e.g., action prediction, empathy).

### *The brain's Turing Tests*

Alan Turing, a mathematician and computer scientist, famously outlined a scenario that would define whether a computer could be said to "think." In this scenario, a person asks a series of spontaneous questions, and a second person or a computer responds to these questions via text. A computer passes the "Turing Test" if a human judge confuses its text responses with that of a real person. Today, computer programs can pass the Turing Test, albeit briefly. Indeed, Artificial Conversational Entities, or "chatterbots," initiate thousands of "chats" daily with unsuspecting Internet users who believe they are conversing with other human beings. By mimicking the behavioral characteristics of natural conversation, these chatterbots trigger the inference of another mind.

It is one thing to fool someone into believing that computer-generated text originated from a live source. The brain, after all, did not evolve to process the veracity of text message authorship. Fooling the brain's perceptual systems is a taller order. The human brain employs several perceptual Turing Tests devoted to scrutinizing faces, movements, and voices for evidence of minds worth modeling.

### *The facial Turing Test: it looks like it has a mind*

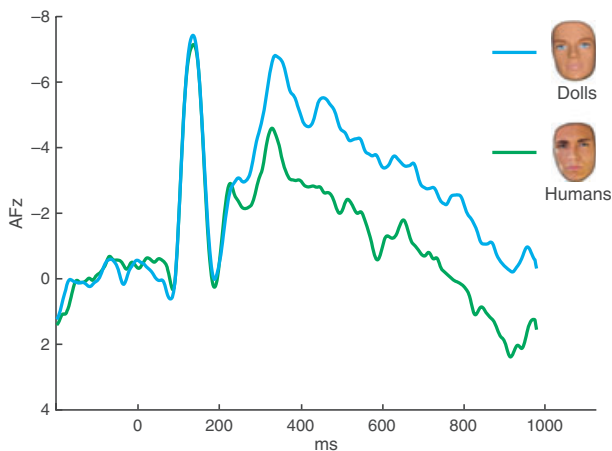
It is hard to overstate the importance of the face as a social stimulus. Faces identify people, display mental states, and are evaluated along a host of dimensions (e.g., attractiveness, maturity, trustworthiness). Faces are important for the very reason that their root word suggests: they serve as the *façades* of other minds. Commensurate with this importance, faces capture attention faster than other objects (Langton, Law, Burton, & Schweinberger, 2008) and evoke a specific and rapid electrocortical response (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Bentin et al., 2007; Watanabe, Kakigi, & Puce, 2003; Rossion & Jacques, 2008; cf. Gauthier, Curran, Curby, & Collins, 2003). This response is evoked by faces of all shapes and sizes, including schematic line drawings (Bentin et al., 1996; Gauthier et al., 2003; Rossion & Jacques, 2008; Watanabe et al., 2003). This broad response profile suggests that there is a rapid pattern-matching mechanism that flags input as a potential face (Jacques & Rossion, 2010; Sagiv & Bentin, 2001). This liberal detection mechanism is the reason people see faces in clouds, car grills, parking meters, and even the image of the Virgin Mary in a grilled cheese sandwich (Bloom, 2005).

Detecting a face is important for the inference of mind, but a quick jaunt to the local mall reveals that face detection alone cannot be the whole story. Mannequins have faces. Dolls, avatars, masks, sculptures and most paintings in the National Gallery have faces. How do we cope with these face-wearing imposters? How do we know that these faces are not worthy of our mental models? Part of the answer is obvious: mindless faces are typically motionless. However, people can tell whether a face has a mind just by looking at a photograph. Therefore, there must be cues available in a single image that affords the discrimination of mind.

This ability was recently investigated by Wheatley, Weinberg, Looser, Moran, and Hajcak (2011), who recorded electrocortical responses while participants viewed images of human faces and object faces (e.g., mannequins and dolls). The rapid, face-specific waveform described above was evoked by all faces regardless of whether they were animate or inanimate. However, only the human faces evoked a later sustained waveform with a latency of 400 ms (see Figure 1).

This suggests that a second level of scrutiny is applied to faces post-detection. While all faces capture attention; only faces with minds sustain attention. Further evidence of this claim was found using artificially created animacy continua. To create these stimuli, photographs of human faces were morphed in image space with well-matched inanimate object faces (e.g., statues, dolls).

Participants were asked to simply split an ordered row of faces (e.g., Figure 2) at the point where the face first appeared to “have a mind.” Across studies, people identified the same tipping point, an image around 65% human and 35% doll (Looser & Wheatley, 2010). It is at this point along the morph that faces first seem to have a mind attached.



**Figure 1** The time-course of mind perception. Doll faces and human faces evoke the same rapid electro-cortical response (see overlapping responses around 200ms). However, the later waveform illustrates a significantly larger response to human faces. Figure adapted from Wheatley et al. (2011) .



**Figure 2** Example of morphed stimuli used in animacy experiments (Looser & Wheatley, 2010).

One participant described this point as being the first moment that the face “appeared to look back at you.” This intuition is a good one, as a subsequent study revealed that the eyes are disproportionately important for conveying mind compared to other facial features (Looser & Wheatley, 2010). Passing the facial Turing Test requires perceiving not only the presence of a face, but that “the lights are on and someone is home.”

*The motion Turing Test: it moves like it has a mind*

As Heider and Simmel (1944) famously demonstrated, facial cues are not necessary to evoke the perception of mind. Their classic stop-motion animation of three geometric shapes evoked rich attributions of agency and mental states. Since then, researchers have used similar stimuli to probe *how* motion evokes percepts of mind. Not surprisingly, perhaps, movement that is self-propelled (Premack, 1990) appears animate. But robots have self-propulsion. Do people mistake robots for sentient beings? Do people treat their Roombas as pets? The answer is almost always a flat “no.” Like the simple configuration of a face, self-propulsion appears to capture attention but not sustain it. Simple robots fail the Turing Test.

However, imagine that you own a Roomba that one day stops its predictable twisty amble across the kitchen floor. You assume a dead battery and go over to investigate. As you approach, it zooms down the hallway, dog-legs through the living room and out the front door where it stops, shaking, at the front steps. You would be forgiven for thinking that this is no ordinary Roomba. Indeed, you might find it impossible *not* to believe that the Roomba was attempting an escape. Perhaps you even feel a pang of guilt for your unwitting role in its dust-bound servitude. Seemingly unpredictable behavior by machines, such as computer malfunctions, evokes anthropomorphism (Waytz et al., 2010). As Waytz and colleagues suggest, people “make sense by making sentient”: objects that behave unpredictably evoke attributions of mind.

Other researchers have investigated the characteristics of movement that evoke the perception of a mind, including “non-Newtonian” velocity changes (Cicchino, Aslin, & Rakison, 2011; Tremoulet & Feldman, 2000), and movements that appear interactive and contingent (e.g., following, reacting – Blakemore et al., 2003; Scholl & Tremoulet, 2000; stalking – Gao, McCarthy, & Scholl, 2010). These findings have led some researchers to suggest that the detection of agency on the basis of these motion cues is a precursor of mental understanding (Blakemore et al., 2003). Indeed, viewing interactive geometric shapes activates the same cortices associated with understanding social information in human motion (Castelli, Frith, Happé, & Frith, 2002; Gobbin, Koralek, Bryan, Montgomery, & Haxby, 2007; Martin & Weisberg, 2003). In contrast, geometric shapes that move in random, Newtonian, or rigid ways are more likely to activate cortices associated with inanimate motion (Beauchamp, Lee, Haxby, & Martin, 2003; Martin & Weisberg, 2003). In short, Non-Newtonian motion patterns trigger attributions of animacy. As such, these patterns elicit additional monitoring and predictions of future behavior.

*The vocal Turing Test: it sounds like it has a mind*

The voice has been referred to as an “auditory face” (Belin, Fecteau, & Bédard, 2004). Similar to the importance of a face for the visual system, the ability to discriminate and recognize humans is among the most important functions of the auditory system (Beauchemin et al., 2006). More than simply the convoy for linguistic communication, the voice carries information about age, gender, approximate size, competence, and emotional expression (Driskell, Olmstead, & Salas, 1993; Latinus & Belin, 2011).

Consistent with other icons of mind, an early and liberal detector of voice-like cues is followed by a later, more stringent process that separates the hits from the false alarms. Levy, Granot, and Bentin (2001) conducted an EEG study investigating event-related potentials for non-phonetic human vocal sounds versus musical instrument sounds (brass, string, wind) that were matched to the fundamental frequency of the human voice. They asked participants to press a button each time they heard a piano tone (the target sound) while all other vocal and instrumental sounds acted as distractor tones. The authors found equivalent, rapid electrocortical responses elicited by every auditory stimulus category. However, human voices evoked a considerably larger, later positivity ( $\sim 320$  ms latency) compared to all other categories despite absence of a task that would necessitate this later activity. This two stage process – in which an initially indiscriminate response to any human-like sound is succeeded by a later, more discriminating process that privileges only human voices – mirrors the facial Turing Test. Together, these systems suggest that the human mind is efficiently organized to collect and then filter sensory input.

*Summary: mind detection*

Mind-imposters are easy to come by. Mannequins have faces and eyes, robots move, and automated messages speak. Yet we know that manufactured faces, mechanical motion, and programmed speech do not belong to another mind. These simple qualities are enough to catch our attention and initially fool our low-level detection processes. But the human mind has a more discerning model of what it means to have a mind, and these primitive copies are quickly discarded as non-minds. This allows us to study the clothes on a mannequin without engaging with it, to crash robotic toys together in mock-battle without remorse, and to hang up on the automated solicitor mid-sentence. Indeed, doing any of these things (conversing with a mannequin; apologizing to a toy; adhering to social niceties with a recording) would be considered aberrant behavior. The healthy human brain institutes multiple levels of perceptual scrutiny in order to discriminate true minds from mind imposters.

### **Simulating Other Minds**

Although finding a mind is a necessary first step for healthy social relations; it is only the first step. Actually *connecting* with another mind means the difference between surviving and thriving in a social world. Getting from mind detection to mental connection requires the ability to predict how another mind will behave. This ability draws upon explicit and implicit cognitive processes.

We simulate other minds explicitly by reasoning about, and actively imagining, others' perspectives (Davis, 1983). This seems to be evolutionarily recent, appearing only in great apes, and experiences a protracted development over the course of human childhood and adolescence (Preston & de Waal, 2002). Understanding others through cognitive perspective taking is closely linked with visual perspective taking, both behaviorally (Hamilton, Brindley, & Frith, 2009) and in terms of its neural correlates (Aichhorn, Perner, Kronbichler, Staffen, & Ladurner, 2006). This process can be cognitively taxing, as it involves the suppression of the perceiver's own viewpoint while imagining that of another agent (Decety & Jackson, 2004; Frith & Frith, 2003; Keysar, Lin, & Barr, 2003). As a result, it does not suit our everyday need to create and update models of other minds on the fly.

Emotion contagion – an implicit process – comprises an alternative, more primitive, means of forging immediate social connections that does not require us to simultaneously

hold online and distinguish between multiple perspectives (Preston & de Waal, 2002). Humans tend to experience emotion automatically in response to the affective displays of others (Niedenthal et al., 2005). This tendency appears to be hardwired, as one day old infants cry upon hearing others cry (Singer, 2006), and evolutionarily old, as mice display pain symptoms when viewing their cage mates experience pain (Langford et al., 2006). In its most basic form, the production of a response similar to one produced by a conspecific enables shared communication about aspects of the current environment relevant to survival, such as the approach of predators, the location of valuable resources or an infant in distress requiring a parent's attention (de Waal, 2007). In this way, the ability to synchronize with others enables emotion contagion.

On a larger scale, contagion seems closely linked to collective cultural rituals that engender cohesion and prosocial behavior (Durkheim, 1995; Sosis & Ruffle, 2004). Recent evidence suggests that these collective rituals achieve their prosocial benefits by evoking synchronized patterns of physiological arousal across participants, even in the absence of synchronized motor behavior (Konvalinka et al., 2011). Thus, synchronizing signals of arousal and emotion across individuals appears to be linked to the establishment of social cohesion on a grand scale.

Interestingly, this contagion may be most likely to 'infect' individuals who are familiar to us: in a collective ritual, only spectators and performers who are related to one another synchronize their patterns of physiological arousal states throughout a ceremony, and this cannot be explained by similarities in their motor patterns (Konvalinka et al., 2011). Similarly, mice behave as if in pain when observing their cage mate in pain, but not when observing strange mice in pain (Langford et al., 2006).

'Catching' the affective signals of familiar others appears to confer social benefits. Levenson and Ruef (1992) videotaped spouses interacting while wearing devices that recorded their level of physiological arousal (e.g., heart rate, pulse, skin conductance). Several days later, these spouses were most accurate at rating their partners' negative emotions at points during the recording when their level of physiological arousal matched that of their partner. Thus, the ability to synchronize allows us to spontaneously embody the affective experiences of familiar others, and this embodiment fosters better social understanding. Conversely, an impaired ability to synchronize with others, which often characterizes Autistic Spectrum Disorders, is associated with diminished social contagion (e.g., socially-triggered yawning – Helt, Eigsti, Snyder, & Fein, 2010). In short, the ability to embody the physical and social world may be a necessary condition of healthy sociality.

### **Connecting with Other Minds: The Importance of Synchrony**

The ability to read and embody the experiences of others as they unfold dynamically is a prerequisite for successful social interaction. Semin and Cacioppo use the term "monitoring synchrony" to refer to this time-locked neurophysiological and sensorimotor emulation of observed actions (Semin, 2007; Semin & Cacioppo, 2008, 2009). They posit that this monitoring synchronization allows individuals to "get on the same page" by granting "simultaneous partial mutual access to internal states" (Semin, 2007, p. 631). As Semin makes clear, synchrony is manifested in, but not reducible to, behavioral synchrony; synchronization can be established at neural, perceptual, affective, and behavioral levels (Semin, 2007). Emotional contagion, for example, (Hatfield, Cacioppo, & Rapson, 1992) appears to rely on synchronous couplings that may or may not be expressed overtly. Similar to Konvalinka et al.'s (2011) findings of physiological synchrony, Fadiga, Craighero, and Olivier (2005) demonstrated that an observer's motor cortex "resonates" in phase with

the actions of the person being observed (Fadiga et al., 2005; Gangitano, Mottaghy, & Pascual-Leone, 2001). While this resonance may lead to synchronous motor behavior at times, Baldissera and colleagues posit an inhibitory mechanism in the spinal cord that prevents this “underthreshold” neural synchrony from resulting in a constant stream of actions that replicate those observed (Baldissera, Cavallari, Craighero, & Fadiga, 2001).

Although synchrony is rooted in neural events that may or may not manifest in observable behavior, psychological research has focused on the times when it does (Chartrand & Bargh, 1999; Hove & Risen, 2009; LaFrance, 1982; Miles, Nind, & Macrae, 2009). As Hove and Risen (2009) have articulated, synchronized behavior comprises temporally coordinated movements, whether this involves the same actions (e.g., a marching band walking in stride) or different ones (e.g., members of an athletic team working in sync, players in an orchestra, conversational turn-taking – “effective complementary actions” – Semin & Cacioppo 2008, p. 114). In the former case, individuals represent mirrors of a single system. In the latter case, coordination of distinct roles benefits from an understanding of how the system moves as a whole.

Building upon the foundation of dynamical systems theory (Vallacher & Nowak, 1997), a resurgence of behavioral research has been investigating physical synchrony as a marker of affiliation and empathy. Concurrently, neuroscientists have been investigating synchrony as the neural basis for the binding of multi-sensory dynamic inputs. Together, these findings converge on a neural mechanism for connection.

Behavioral synchronies emerge naturally as rapport develops. It is not uncommon to suddenly discover that one has subconsciously picked up the mannerisms, expressions, or vocal cadence of a close friend, or vice versa: LaFrance (1982), for example, found that listeners tended to mirror the posture of an engaging conversational partner. At a very basic level, pure physical imitation has been found to increase liking and rapport between individuals (“the chameleon effect;” Chartrand & Bargh, 1999), which in turn cyclically results in greater levels of mimicry (Lakin & Chartrand, 2003). However, while mirroring occurs in synchronized behaviors, mimicry and synchrony are not strictly congruent. Mimicry entails the simple copying of perceived behaviors; the organic forging of synchrony requires *anticipation* of those behaviors. Synchrony requires knowing a person well enough to predict them (Keller, Knoblich, & Repp, 2007). Synchronous behaviors increase with the quality of the relationship (Julien, Brault, Chartrand, & Bégin, 2000), as well as similarity to oneself (e.g., synchronous duets with self- versus other-recordings; Keller et al., 2007). For this reason, synchronous behaviors are better indicators of similarity and better inducers of rapport than mimicry (Hove & Risen, 2009).

Behavioral synchrony has powerful effects on affiliation. Those who coordinate their actions have greater ties to community (McNeill, 1995), are perceived as and form social units (Lakens, 2010; Marsh, Johnston, Richardson, & Schmidt, 2009; Wiltermuth & Heath, 2009), and report greater “liking” (Bernieri, 1988; Ramseyer & Tschacher, 2011). In addition to rapport, synchrony also increases prosocial behaviors (Valdesolo & DeSteno, 2011). The connection between physical synchrony and social connection is also a proportional one: the greatest levels of rapport are found with the most stable forms of interpersonal synchrony (e.g., walking in-phase and anti-phase; Miles et al., 2009).

### *Synchrony as adaptation*

One could argue that the human brain seeks synchrony because synchrony is enjoyable. However, the deeper question is *why* did the human brain evolve to enjoy synchrony

with another mind? Pleasure, after all, is a mechanism by which evolution promotes adaptive behaviors: pleasurable sensations felt during an event ensure that an organism will try to replicate that event. Pleasure is evolution's great manipulation to promote the agendas of survival and reproduction. So, what are the adaptive benefits of synchrony that established its link to the brain's reward system? We speculate there to be at least two.

### *Neural efficiency*

A hallmark of mental connection is that it feels *effortless*. Not all pleasurable sensations arise from a lack of effort. Many pleasures require hard work, developing a skill, or otherwise stretching one's brain. Indeed, some pleasures can only be derived from the knowledge that a hard day's work was applied. This is not the case with connection. Connection and conscious effort seem to have an inverse relationship. Why does connection feel so easy? Once again, colloquial expressions may provide a clue. Connection is sometimes described as "sharing a mind" or being on the same "page" or "wavelength." Findings from neuroscience suggest that these expressions go beyond mere metaphor.

Perhaps because the human brain is such a metabolically expensive organ – comprising only 2% of the body's mass, yet requiring more than 20% of the body's energy – we seem to be "cognitive misers" by design (Fiske & Taylor, 1984). This is apparent in our everyday social functioning—unless motivated to do otherwise, we tend to rely on heuristics and stereotypes to guide much of our everyday behavior (Kahneman, Slovic, & Tversky, 1982). Although sometimes wrong (Judd & Park, 1993), these 'cognitive shortcuts' yield useful answers enough of the time to be rewarding and deployed by default in most situations. The brain's characteristic frugality is also apparent during normal cognitive development: unemphasized abilities decline over the course of infancy, such as the ability to discriminate other-race (Kelly et al., 2007) or other-species (Pascalis, de Haan, & Nelson, 2002) faces. The loss of behaviorally irrelevant abilities likely results from the brain pruning extraneous synaptic connections as it matures (Huttenlocher, de Courten, Garey, & Van der Loos, 1982). Efficiency appears to comprise a guiding principle of human brain structure and function. We suggest that being in 'sync' with others feels so effortless and enjoyable partly because it comprises a remarkably efficient mechanism for social understanding.

Neuronal synchrony appears to be a domain-general mechanism that supports efficient communication between brain regions, and binding independently perceived streams of information into a unified representation. Although its utility has been examined most extensively in studies of multi-modal perception (e.g., Maier, Chandrasekaran, & Ghazanfar, 2008), we suggest that social interactions that seem to share a 'beat' can also produce binding. Brain areas involved in the perception and production of dynamics literally entrain to the same oscillatory rhythm.

When the activity of two groups of neurons is synchronized, inter-area communication is made more efficient as the "rhythmic opening of their communication windows is coordinated between the groups," rendering neuronal membranes in both regions "sensitive for selected input and... deaf for deselected input" in tandem (Fries, 2005, p. 476 & 479). Similarly, signals from brain areas oscillating in synchrony engender larger activations in common downstream targets, enhancing further processing (Womelsdorf et al., 2007). For these reasons, inter-region neuronal synchrony has been posited to underlie the increased salience of congruent auditory and visual stimuli presented simultaneously over and above either stimulus presented in isolation (Bauer, 2008).

To the extent that perceived and performed dynamics are similar during social interaction, neuronal activity in brain regions involved in their perception and action becomes



similar (Schippers, Roebroek, Renken, Nanetti, & Keysers, 2010). For this reason, Philips-Silver and colleagues suggest that the ability to entrain on shared sensory inputs also facilitates social coordination (Phillips-Trainor, et al., 2010). The resultant neuronal synchrony causes the ‘communicative windows’ of these areas to align, allowing for more mutually influential and effective communication (Fries, 2005; Patel, 2006). Further, inter-area neuronal synchrony results in enhanced output to common targets (Womelsdorf et al., 2007), such as associative regions involved in higher-level interpretations of the dynamics being perceived. Thus, in social situations where we ‘click’ with someone, neural representations of that person’s and our own dynamics seem to ‘click’ as well. The resultant enhanced communication between perception and action regions and their common targets may increase accuracy in predicting other minds (Sebanz & Knoblich, 2008; Zaki, Weber, Bolger, & Ochsner, 2009) and foster further behavioral synchrony all the while reducing the brain’s processing load to conserve energy. This neural efficiency may underlie the subjective experience of effortlessly “being one with” another person, or “marching to the same beat.”

Efficiency of any kind is rewarded by organisms seeking to conserve energy. However, data reduction via synchrony may have an additional pleasurable correlate: the loss of self, or perhaps more accurately, the loss of “other.” In essence, synchrony weakens the neural encoding of another person as a separate entity. A recent behavioral study corroborates this idea. Paladino, Mazzurega, Pavani, and Schubert (2010) brushed the cheek of participants while they watched a video of a stranger’s cheek being brushed in the same manner. The researchers manipulated whether the participant’s cheek was brushed synchronously or asynchronously with that of the stranger. Compared to asynchronous stimulation, synchronous stimulation resulted in confusion for whether sensations were felt (self-experienced) or seen (stranger-experienced) – a finding consistent with the rubber hand illusion (Botvinick & Cohen, 1998). More intriguingly, with synchronous stimulation, participants also felt more agency over the face in the video and believed that the face resembled them more. Even personality judgments of self and other blurred together. Participants judged the synchronously stimulated other, but not the asynchronously stimulated other, as having a more similar personality to themselves. Together, these findings suggest that synchrony yields a blurring of self and other and does so in a particular, self-oriented direction. The colloquial expression “being of one mind” may be more accurately stated as “being of *my* mind.”

### *Kinship signaling*

The feeling of connection is also described colloquially by a number of expressions with familial themes. Best friends consider themselves “kindred spirits,” “soul sisters,” “blood brothers”, even “brothers from another mother.” Why does the sharing of physiological rhythms evoke such a consistent and particular motif? One possibility, albeit a speculative one, is that shared rhythms suggest shared genes.

### *Recognizing kin is adaptive*

Animals that cannot recognize their mother or, more broadly, their social group (e.g., flock, pack, or herd) are at a considerable disadvantage for access to food and protection. Commensurate with its importance for evolutionary fitness, a number of animals including bees, tadpoles, birds, rodents, and monkeys detect genetic similarity (Rushton, 1989). Genetic similarity detection is sensitive and has sizeable behavioral consequences. Ground

squirrels, for example, produce litters that contain siblings and half-siblings. Despite sharing the same womb and nest, full siblings fight less often than half siblings (Fletcher & Michener, 1987). Several researchers have reported that primates will groom, form alliances with, defend, and share food more readily with kin than non-kin (see Walters, 1987 for a review). However, kinship is not the only genetic game in town.

As Dawkin's "selfish gene" hypothesis asserts, a gene can better ensure its own survival by promoting the reproduction of *any individuals* that share its copies (Dawkins, 1976). Rushton posited that an "individual may be genetically guided to learn its own phenotype, or those of its close kin, and then to match new, unfamiliar phenotypes to the template it has learned" (1989). Although Dawkins (1982) referred to this theory as the "armpit effect," he pointed out that it was not limited to finding similar smelling individuals but also individuals that look or *behave* like oneself. Indeed, the purpose of rhythmic sounds produced by many species (e.g., crickets, frogs) may be an adaptation selected under pressures for which social proximity was beneficial (e.g., mating, protection from predators: Allee et al., 1949; Phillips-Trainor et al., 2010).

Not limited to kinship, genetic similarity detection has been proposed as the mechanism behind friendship as well as "positive assortative mating:" the marrying of similar others (Epstein & Guttman, 1984). As Thiessen and Gregg (1980) put it, "The flow of altruistic behaviors, the ease of information transfer, and the genetic benefits of positive assortative mating are linked to the degree with which interacting individuals share homologous genes" (p. 111) adding that "friends of either sex, as well as mates, resemble each other in many ways, suggesting that genetic assortment operates at all levels of social affiliation" (p. 117).

Given its ubiquity across species, genetic similarity detection is likely to rely on a primitive neural loop: when similarity is detected, release reward. Such a reward signal should be distinct from other reward signals (e.g., sensory pleasure from food) and promote future social interaction. Oxytocin is one neurotransmitter that appears to fit this bill. Placental mammals, from rodents to humans, release and absorb oxytocin during bond-promoting activities such as maternal labor, intercourse, and nursing. In humans, intranasally administering this hormone increases empathy (Guastella, Mitchell, & Dadds, 2008; Singer et al., 2008), recognition accuracy of social cues (Domes, Heinrichs M., A. Berger, & Herpertz, 2010; Hurlemann et al., 2010; Marsh, Yu, Pine, & Blair, 2010), and trust (Kosfeld, Heinrichs, Zak, Fischbacher, & Fehr, 2005).

Markers of kinship are so powerful that human social systems routinely employ kinship labels. Consider fraternities and sororities as well as religious organizations that refer to their leaders as "fathers" and their congregation ("flock") as "brothers" and "sisters." Close family friends may get honorary titles of "aunt" or "uncle" or be chosen as godparents. These gestures are a way of indicating "you're one of us." Similarly, the desire to connect; to *belong* to a particular group may increase the likelihood of synchrony (Miles, Lumsden, Richardson, & Macrae, 2011). This suggestion may sound strange because until now we have focused on the detection of genetic similarity that proceeds organically, across species, without artificial manipulation. However, humans are able to exert top-down control of their own and others' experience top-down. This kind of reverse engineering is a powerful human innovation that allows us to manipulate pre-existing associations and biases in other humans' brains.

### *Engineering connection*

Artificially-created synchrony appears to yield the same effects as synchrony that occurs as a natural manifestation of mental connectedness, as long as people are naïve to the

artificiality (Lakens & Stel, 2011). Wiltermuth and Heath (2009) conducted several experiments investigating whether synchronous physical activity leads individuals to act more cohesively with their group. Importantly, the group members had no prior relationship or shared identity. Participants made to act synchronously (physically and vocally) performed more cooperatively, felt more connected with their counterparts, and trusted their counterparts more than those who acted asynchronously. Tapping paradigms have also been used to investigate the effects of an explicit external rhythm on synchrony. Hove and Risen (2009) found that participants who tapped a computer screen in synchrony with the experimenter rated her as more “likeable” at the end of the experiment. Conversely, inhibiting physical synchrony reduces feelings of connection. People rate interactions less positively when synchrony is inhibited (Marsh, Richardson, & Schmidt, 2009).

Synchrony may also engineer common ground when people desire reducing dissimilarity, such as in times of estrangement. If so, this may explain a seemingly counterintuitive finding in the literature. Miles et al. (2011) told participants that they would be discussing art with another person over a live video feed (in actuality, a pre-recorded video). Before the conversation began, two things happened: (1) participants were led to believe that the person either shared or did not share their art preferences and (2) participants were asked to do a series of arm curls as they watched the person on the video do the same thing. Participants synchronized more with the person that they believed held a different art preference. Miles explains the finding in terms of the need to belong (Baumeister & Leary, 1995) writing: “in the absence of any disincentive to affiliate with dissimilar others, interpersonal coordination may act as a medium to support the reduction in intergroup differences and lessen social distance (Miles et al., 2011, p. 501).” This conclusion was consistent with a follow-up study demonstrating that participants who believed they held a different art preference felt it was more important to agree about art than those who believed they held the same preference (Miles et al., 2011). This finding suggests that desiring common ground amplifies the likelihood of physical synchrony.

The pleasure associated with “oneness” is well known to anyone that has gathered in a large group with a shared purpose. According to the hive hypothesis, “People need to lose themselves occasionally by becoming part of an emergent social organism in order to reach the highest levels of human flourishing” (Haidt, Seder, & Kesebir, 2008, p. 133). That is, dyadic synchrony may be scaled up. Group dynamics may serve to overcome individual rhythms, thereby providing a more compelling beat to which to entrain. Rock concerts, sports matches, and religious congregations may also utilize common global rhythms to evoke mass (hive) sentiment (Phillips-Silver, Aktipis, & Bryant, 2010). Neda, Ravasz, Brechet, Vicsek, and Barabási (2000) demonstrated, for example, that synchronous clapping rhythms emerge when large audiences applaud. It is possible that other simultaneous reactions to an observed event such as directed cheering (e.g., screens that instruct one to “MAKE SOME NOISE!” after a home run), the synchronized bowing of heads in prayer, and joint singing also evoke entrainment to a shared social beat. This may explain why military cadences and marching in formation work to strength soldiers’ camaraderie and boost morale, or why dance is used to become “absorbed in the unified community” (Freeman, 2000; Olaveson, 2004; Phillips-Silver et al., 2010; Radcliffe-Brown, 1922, p. 252, as cited in Wiltermuth & Heath, 2009). In comparison to research on other animal species (see Strogatz, 2003), evidence for large-scale human synchrony is limited primarily to anecdotes (but see Neda et al., 2000). It remains unclear, for example, whether humans manipulate synchrony to create large-scale coordination and cohesion: a scaled-up version of Hove and Risen’s tapping paradigm (2009).

*Engineering disconnection*

In the same way that humans engineer connection, they can break it. Disconnection has its own advantages as there are times when the message we wish to send is that we are assuredly *not* on the same page. Faster nodding than the cadence of someone's speech can convey "you need to speed up", while slower movements can convey "slow down;" in either case decoupling is meant to communicate the desired speed to ensure connection. More often, perhaps, disconnection is engineered to stop a connection from forming in the first place. In an oft-cited study in social psychology, Bargh, Chen, and Burrows (1996) found that priming elderly words such as "gray", "wrinkle", and "Florida" resulted in participants walking more slowly. However, Cesario, Plaks, and Higgins (2006) found that this is only true for people who hold relatively positive implicit attitudes about the elderly. People who hold negative implicit attitudes toward the elderly actually *speed up* when primed with elderly words. Cesario and colleagues suggest that people who dislike the elderly speed up to hinder potential interaction.

Engineering disconnection can also have loftier goals. For instance, when the situation calls for a reflection on differences, disabling synchrony may afford a more critical assessment of differing goals. For example, an employee may be better served by recognizing when the boss is displeased and expressing respectful (i.e., uncoupled) posture rather than attempting to emulate the boss's movements or intonations. Uncoupling may also aid (and indicate) better encoding of individuating information, such as the sentiments of a significant other that differ subtly from one's own. Reflecting upon differences requires a network of neural activity that can be dissociated from the network supporting synchrony (Frith & Frith, 2012). Some degree of uncoupling may also keep interactions from becoming too predictable to sustain interest. Indeed, maximally enjoyable social interaction may be best sustained under conditions of moderate synchrony with intermittent idiosyncratic input (e.g., personal anecdotes, reactions). As yet, the literature lacks a complete picture of how and when these different neural systems, and their associated implicit and explicit cognitive strategies, combine and compete to optimize social understanding (Zaki, Hennigan, Weber, & Ochsner, 2010). What is clear, however, is that humans are the only known species able to direct these mechanisms themselves to make and break connection at will.

*Shared experience*

This paper highlights the role that connecting bodies plays in connecting minds. However, overt behavioral synchrony is not necessary to engender shared experience. People may experience the feeling of connection in a theater, for example; just knowing that the person next to them is seeing the same thing. Furthermore, most of us have had the experience of meeting a stranger that happened to have attended the same high school, watched the same children's television show, or experienced the same major life event. In such instances, a social bond appears almost instantaneously; based merely on the knowledge of shared past experience. Thus, synchrony does not appear to be a necessary precondition of feeling connected. However, synchrony may strengthen these sorts of connections. In the movie example, laughing at the "right" times likely increases perceived connection. Likewise, learning about a shared history is presumably amplified by a synchronous display of delighted recognition. It is our hope that future research will lead to a more comprehensive understanding of the implicit and explicit process that function both separately and in tandem to support the human capacity for mental connection.

## Conclusion

“Man is by nature a social animal” (Aristotle, 1986 trans.), and as such, we are surrounded by other social animals. This fact requires that our brains efficiently locate and continuously predict others’ thoughts and actions. Often, prediction is effortful; interactions with strangers can be disjointed and discomfiting, even when marked by moments of understanding. Yet sometimes, people just “click.” As though tuned to the same internal frequency, they fall into effortless conversation, experience the same rise and fall of emotions, and feel as though the other can finish their thoughts. Why people “click” has yet to be fully elucidated, but scientists are converging upon neural and behavioral synchrony as playing a pivotal role. Synchrony may serve as an adaptive marker of genetic similarity; we synchronize most with similar others. Synchrony also reduces the brain’s processing load with a likely consequence of reducing perceived self-other differences. These benefits are neither mutually exclusive nor exhaustive. The critical point is that synchrony appears to ensure those benefits through the activation of a reward signal experienced as pleasurable mental connection. In turn, the feeling of being “on the same wavelength” promotes further social bonding.

Naturally-arising synchrony affords resonant dyadic connections across multiple species. However, the human brain is rarely content to simply let nature take its course. By discovering ways of artificially creating synchrony, the human brain succeeded in reverse-engineering connection. Once the province of Nature alone, dyadic and social group bonds can be manipulated through simple, synchronous action. Stepping out of Nature means stepping out of Nature’s constraints of scale. This uniquely human innovation made large-scale social coordination not only possible but pleasurable. Nonhuman animals can bond with their mates and social groups. Only a human being can experience connection with a thousand people at once.

## Short Biographies

Thalia Wheatley has published widely on the topics of animacy, intention, emotion, and morality using behavioral, neuroimaging, and crosscultural methods. Her current research focuses on how the brain perceives a mind from visual and auditory cues (e.g., faces, music, movement). Before coming to Dartmouth College where she presently teaches, she held a postdoctoral research fellowship in the Laboratory of Brain and Cognition at the National Institutes of Health. She holds a BA in Psychology from the University of Texas at Austin and a PhD from the University of Virginia.

Olivia Kang is a graduate student in the Psychological and Brain Sciences department at Dartmouth College. Her research, currently supported by a fellowship from the National Science Foundation, combines social psychology, cognitive neuroscience, and music. She has co-authored papers in these areas for *Music Perception* and *Social Psychological and Personality Science* (in press). Olivia obtained her BA from Princeton University.

Carolyn Parkinson is a graduate student at Dartmouth College, where her work investigating the neural underpinnings of social cognition and other domains of abstract thought is supported by a fellowship from the Natural Sciences and Engineering Research Council of Canada. She has published on these topics in the *Journal of Cognitive Neuroscience*, the *Encyclopedia of Human Behavior*, *Behavioral Brain Research*, and the *Journal of Clinical Child and Adolescent Psychology*. Previously, she obtained her Hon. BSc from McGill University where she studied Psychology and Neuroscience. Her current work involves behavioral, neuroimaging and crosscultural research on interactions

between information presented to our different sensory modalities, and how this information structures representations of abstract concepts.

Christine Looser's research interests lie at the intersection of social cognition and visual perception. She has published on the perception of faces, minds, and animacy. Christine is currently a PhD candidate in Cognitive Neuroscience in the Department of Psychological and Brain Sciences at Dartmouth College. She received a BA from the College of the Holy Cross where she pursued interests in philosophy, psychology, and biology.

## Endnote

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## References

- Allee, W. C., Emerson, A. E., Park, O., Park, T., & Schmidt, K. P. (1949). *Principles of Animal Ecology*. Philadelphia: W.B. Saunders.
- Aichhorn, M., Perner, J., Kronbichler, M., Staffen, W., & Ladurner, G. (2006). Do visual perspective tasks need theory of mind? *NeuroImage*, **30**, 1059–1068. doi: 10.1016/j.neuroimage.2005.10.026.
- Aristotle (1986). In W. D. Ross (Ed.), *Politica* (p. 1253) Oxford: Oxford University Press.
- Baldissera, F., Cavallari, P., Craighero, L., & Fadiga, L. (2001). Modulation of spinal excitability during observation of hand actions in humans. *European Journal of Neuroscience*, **13**, 190–194. doi: 10.1046/j.0953-816x.2000.01368.x.
- Bargh, J. A., Chen, M., & Burrows, L. (1996). Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. *Journal of Personality and Social Psychology*, **71**, 230–244. doi: 10.1037/0022-3514.71.2.230.
- Bauer, M. (2008). Multisensory integration: A functional role for inter-area synchronization? *Current Biology*, **18**, R709–R710. doi: 10.1016/j.cub.2008.06.051.
- Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, **117**, 497–529. doi: 10.1037/0033-2909.117.3.497.
- Beauchamp, M. S., Lee, K. E., Haxby, J. V., & Martin, A. (2003). fMRI responses to video and point-light displays of moving humans and manipulable objects. *Journal of Cognitive Neuroscience*, **15**, 991–1001. doi: 10.1162/089892903770007380.
- Beauchemin, M., De Beaumont, L., Vannasing, P., Turcotte, A., Arcand, C., Belin, P. et al. (2006). Electrophysiological markers of voice familiarity. *European Journal of Neuroscience*, **23**, 3081–3086. doi: 10.1111/j.1460-9568.2006.04856.x.
- Belin, P., Fecteau, S., & Bédard, C. (2004). Thinking the voice: Neural correlates of voice perception. *Trends in Cognitive Sciences*, **8**, 129–135. doi: 10.1016/j.tics.2004.01.008.
- Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience*, **8**, 551–565. doi: 10.1162/jocn.1996.8.6.551.
- Bentin, S., Taylor, M. J., Rousselet, G. A., Itier, R. J., Caldara, R., Schyns, P. G. et al. (2007). Controlling inter-stimulus perceptual variance does not abolish N170 face sensitivity. *Nature Neuroscience*, **10**, 801–802. doi: 10.1038/nn0707-801.
- Bernieri, F. J. (1988). Coordinated movement and rapport in teacher–student interactions. *Journal of Nonverbal Behavior*, **12**, 120–138. doi: 10.1007/BF00986930.
- Blakemore, S.-J., Boyer, P., Pachot-Clouard, M., Meltzoff, A., Segebarth, C., & Decety, J. (2003). The detection of contingency and animacy from simple animations in the human brain. *Cerebral Cortex*, **13**, 837–844. doi: 10.1093/cercor/13.8.837.
- Bloom, P. (2005). Is God an accident? *Atlantic Monthly*, **296**, 105–112.
- Botvinick, M., & Cohen, J. D. (1998). Rubber hand 'feels' what eyes see. *Nature*, **391**, 756. doi: 10.1038/35784.
- Castelli, F., Frith, C., Happé, F., & Frith, U. (2002). Autism, Asperger syndrome and brain mechanisms for the attribution of mental states to animated shapes. *Brain*, **125**, 1839–1849. doi: 10.1093/brain/awf189.
- Cesario, J., Plaks, J. E., & Higgins, E. T. (2006). Automatic social behavior as motivated preparation to interact. *Journal of Personality and Social Psychology*, **90**, 893–910. doi: 10.1037/0022-3514.90.6.893.
- Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: The perception–behavior and social interaction. *Journal of Personality and Social Psychology*, **76**, 893–910. doi: 10.1037/0022-3514.76.6.893.
- Cicchino, J. B., Aslin, R. N., & Rakison, D. H. (2011). Correspondences between what infants see and know about causal and self-propelled motion. *Cognition*, **118**, 171–192. doi: 10.1016/j.cognition.2010.11.005.
- Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, **44**, 113–126. doi: 10.1037/0022-3514.44.1.113.

- Dawkins, R. (1976). *The Selfish Gene*. New York: Oxford University Press.
- Dawkins, R. (1982). *The Extended Phenotype: The Gene as the Unit of Selection*. New York: Freeman.
- Decety, J., & Jackson, P. L. (2004). The functional anatomy of human empathy. *Behavioral and Cognitive Neuroscience Reviews*, **3**, 71–100. doi: 10.1177/1534582304267187.
- Domes, G., Heinrichs M., Michel, A. Berger, C., & Herpertz, S.C. (2010). Oxytocin improves “mind-reading” in humans. *Biological Psychiatry*, **61**, 731–733. doi: 10.1016/j.biopsych.2006.07.015.
- Driskell, J. E., Olmstead, B., & Salas, E. (1993). Task cues, dominance cues, and influence in task groups. *Journal of Applied Psychology*, **78**, 51–60. doi: 10.1037/0021-9010.78.1.51.
- Durkheim, E. (1995). *The Elementary Forms of Religious Life*. New York, NY: Free Press.
- Epstein, E., & Guttman, R. (1984). Mate selection in man: Evidence, theory, and outcome. *Social Biology*, **31**, 243–278. doi: 10.1080/19485565.1984.9988579.
- Fadiga, L., Craighero, L., & Olivier, E. (2005). Human motor cortex excitability during the perception of others' action. *Current Opinion in Neurobiology*, **15**, 213–218. doi: 10.1016/j.conb.2005.03.013.
- Fiske, S. T., & Taylor, S. E. (1984). *Social Cognition*. Reading, MA: Addison-Wesley.
- Fletcher, D. J. C., & Michener, C. D. (1987). *Kin Recognition in Animals*. New York: Wiley.
- Freeman, W. (2000). A neurological role of music in social bonding. In N.L. Wallon, B. Merker & S. Brown (Eds.), *The origins of music* (pp. 411–424). Cambridge: The MIT Press.
- Fries, P. (2005). A mechanism for cognitive dynamics: Neuronal communication through neuronal coherence. *Trends in cognitive sciences*, **9**, 474–480. doi: 10.1016/j.tics.2005.08.011.
- Frith, U., & Frith, C. D. (2003). Development and neurophysiology of mentalizing. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **358**, 459–473. doi: 10.1098/rstb.2002.1218.
- Frith, C. D., & Frith, U. (2012). Mechanism of social cognition. *Annual Review of Psychology*, **63**, 287–313.
- Gangitano, M., Mottaghy, F. M., & Pascual-Leone, A. (2001). Phase-specific modulation of cortical motor output during movement observation. *Cognitive Neuroscience and Neuropsychology*, **12**, 1489–1492. doi: 10.1097/00001756-200105250-00038.
- Gao, T., McCarthy, G., & Scholl, B. J. (2010). The wolfpack effect: Perception of animacy irresistibly influences interactive behavior. *Psychological Science*, **21**, 1845–1853. doi: 10.1177/0956797610388814.
- Gauthier, I., Curran, T., Curby, K. M., & Collins, D. (2003). Perceptual interference supports a non-modular account of face processing. *Nature Neuroscience*, **6**, 428–432. doi: 10.1038/nn1029.
- 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. doi: 10.1162/jocn.2007.19.11.1803.
- Goren, C. C., Sarty, M., & Wu, P. Y. K. (1975). Visual following and pattern discrimination of face-like stimuli by newborn infants. *Pediatrics*, **56**, 544–549.
- Guastella, A.J., Mitchell, P.B., & Dadds, M.R. (2008). Oxytocin increases gaze to the eye region of human faces. *Biological Psychiatry*, **63**, 3–5. doi: 10.1016/j.biopsych.2007.06.026.
- Haidt, J., Seder, J. P., & Kesebir, S. (2008). Hive psychology, happiness, and public policy. In E. A. Posner & C. R. Sunstein (Eds.), *Law and Happiness* (pp. 133–156). Chicago: The University of Chicago Press.
- Hamilton, A., Brindley, R., & Frith, U. (2009). Visual perspective taking impairment in children with autistic spectrum disorder. *Cognition*, **113**, 37–44. doi: 10.1016/j.cognition.2009.07.007.
- Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1992). Primitiv emotional contagion. In M. S. Clark (Ed.), *Emotion and Social Behavior. Review of Personality and Social Psychology*, Vol. 14, (pp. 151–177). Thousand Oaks, CA: Sage Publications.
- Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *American Journal of Psychology*, **57**, 243–259. doi: 10.2307/1416950.
- Helt, M. S., Eigsti, I-M., Snyder, P. J., & Fein, D. A. (2010). Contagious yawning in autistic and typical development. *Child Development*, **81**, 1620–1631. doi: 10.1111/j.1467-8624.2010.01495.x.
- Hove, M. J., & Risen, J. L. (2009). It's all in the timing: Interpersonal synchrony increases affiliation. *Social Cognition*, **27**, 949–961. doi: 10.1521/soco.2009.27.6.949.
- Hurlemann, R., Patin, A., Onur, O.A., Cohen, M. X., Baumgartner, T., Metzler, S. et al. (2010). Oxytocin enhances amygdala-dependent, socially reinforced learning and emotional empathy in humans. *Journal of Neuroscience*, **30**, 4999–5007. doi:10.1523/JNEUROSCI.2847-10.2010.
- Huttenlocher, P. R., de Courten, C., Garey, L. J., & Van der Loos, H. (1982). Synaptogenesis in human visual cortex—Evidence for synapse elimination during normal development. *Neurogenesis*, **33**, 247–252. doi: 10.1016/0304-3940(82)90379-2.
- Jacques, C., & Rossion, B. (2010). Misaligning face halves increases and delays the N170 specifically for upright faces: Implications for the nature of early face representations. *Brain Research*, **1318**, 96–109. doi: 10.1016/j.brainres.2009.12.070.
- Johnson, M. H., Dziurawiec, S., Ellis, H., & Morton, J. (1991). Newborns' preferential tracking of face-like stimuli and its subsequent decline. *Cognition*, **40**, 1–19. doi: 10.1016/0010-0277(91)90045-6.

- Judd, C. M., & Park, B. (1993). Definition and assessment of accuracy in social stereotypes. *Psychological Review*, **100**, 109–128. doi: 10.1037/0033-295X.100.1.109.
- Julien, D., Brault, M., Chartrand, É., & Bégin, J. (2000). Immediacy behaviors and synchrony in satisfied and dissatisfied couples. *Canadian Journal of Behavioral Science*, **32**, 84–90. doi: 10.1037/h0087103.
- Kahneman, D., Slovic, P., & Tversky, A. (1982). *Judgment Under Uncertainty: Heuristics and Biases*. New York: Cambridge University Press.
- Keller, P. E., Knoblich, G., & Repp, B. H. (2007). Pianists duet better when they play with themselves: On the possible role of action stimulation in synchronization. *Consciousness and Cognition*, **16**, 102–111. doi: 10.1016/j.concog.2005.12.004.
- Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L., & Pascalis, O. (2007). The other-race effect develops during infancy: Evidence of perceptual narrowing. *Psychological Science*, **18**, 1084–1089. doi: 10.1111/j.1467-9280.2007.02029.x.
- Keysar, B., Lin, S., & Barr, D. J. (2003). Limits on the theory of mind use in adults. *Cognition*, **89**, 25–41. doi: 10.1016/S0010-0277(03)00064-7.
- Konvalinka, I., Xygalatas, D., Bulbulia, J., Schjodt, U., Jegindo, E.-M., Wallot, S. et al. (2011). Synchronized arousal between performers and related spectators in a fire-walking ritual. *Proceedings of the National Academy of Sciences*, **108**, 8514–8519. doi: 10.1073/pnas.1016955108.
- Kosfeld, M., Heinrichs, M., Zak, P. J., Fischbacher, U., & Fehr, E. (2005). Oxytocin increases trust in humans. *Nature*, **435**, 673–676. doi:10.1038/nature03701.
- LaFrance, M. (1982). Posture mirroring and rapport. In M. Davis (Ed.), *Interaction Rhythms: Periodicity in Communicative Behavior* (pp. 279–298). New York: Human Science Press.
- Lakens, D. (2010). Movement synchrony and perceived entitativity. *Journal of Experimental Social Psychology*, **46**, 701–708. doi: 10.1016/j.jesp.2010.03.015.
- Lakens, D., & Stel, M. (2011). If they move in sync, they must feel in sync: Movement synchrony leads to attributions of rapport and entitativity. *Social Cognition*, **29**, 1–14. doi: 10.1521/soco.2011.29.1.1.
- Lakin, J. L., & Chartrand, T. L. (2003). Using nonconscious behavioral mimicry to create affiliation and rapport. *Psychological Science*, **14**, 334–339. doi: 10.1111/1467-9280.14481.
- Langford, D. J., Crager, S. E., Shehzad, Z., Smith, S. B., Sotocinal, S. G., Levenstadt, J. S. et al. (2006). Social modulation of pain as evidence for empathy in mice. *Science*, **312**, 1967–1970. doi: 10.1126/science.1128322.
- Langton, S. R. H., Law, A. S., Burton, A. M., & Schweinberger, S. R. (2008). Attention capture by faces. *Cognition*, **107**, 330–342. doi: 10.1016/j.cognition.2007.07.012.
- Latinus, M., & Belin, P. (2011). Human voice perception. *Current Biology*, **21**, R143–R145. doi: 10.1016/j.cub.2010.12.033.
- Levenson, R. W., & Ruef, A. M. (1992). Empathy: A physiological substrate. *Journal of Personality and Social Psychology*, **63**, 234–246. doi: 10.1037/0022-3514.63.2.234.
- Levy, D. A., Granot, R., & Bentin, S. (2001). Processing specificity for human voice stimuli: Electrophysiological evidence. *NeuroReport*, **12**, 2653–2657.
- Looser, C. E., & Wheatley, T. (2010). The tipping point of animacy: How, when, and where we perceive life in a face. *Psychological Science*, **21**, 1854–1862. doi: 10.1177/0956797610388044.
- Maier, J. X., Chandrasekaran, C., & Ghazanfar, A. A. (2008). Integration of bimodal looming signals through neuronal coherence in the temporal lobe. *Current Biology*, **18**, 963–968. doi: 10.1016/j.cub.2008.05.043.
- Marsh, A. A., Yu, H. H., Pine, D. S., & Blair, R. J. (2010). Oxytocin improves specific recognition of positive facial expressions. *Psychopharmacology (Berl)*, **209**, 225–232. doi: 10.1007/s00213-010-1780-4.
- Marsh, K. L., Johnston, L., Richardson, M. J., & Schmidt, R. C. (2009). Toward a radically embodied, embedded social psychology. *European Journal of Social Psychology*, **29**, 1217–1225. doi: 10.1002/ejsp.666.
- Marsh, K. L., Richardson, M. J., & Schmidt, R. C. (2009). Social connection through joint action and interpersonal coordination. *Topics in Cognitive Science*, **1**, 320–339. doi: 10.1111/j.1756-8765.2009.01022.x.
- Martin, A., & Weisberg, J. (2003). Neural foundations for understanding social and mechanical concepts. *Cognitive Neuropsychology*, **20**, 575–587. doi: 10.1080/02643290342000005.
- McNeill, W. H. (1995). *Keeping Together in Time: Dance and Drill in Human History*. Cambridge, MA: Harvard University Press.
- Miles, L. K., Lumsden, J., Richardson, M. J., & Macrae, C. N. (2011). Do birds of a feather move together? Group membership and behavioral synchrony. *Experimental Brain Research*, **211**(3), 495–503. doi: 10.1007/s00221-011-2641-z.
- Miles, L. K., Nind, L. K., & Macrae, C. N. (2009). The rhythm of rapport: Interpersonal synchrony and social perception. *Journal of Experimental Social Psychology*, **45**, 585. doi: 10.1016/j.jesp.2009.02.002.
- Neda, Z., Ravasz, E., Brechet, Y., Vicsek, T., & Barabási, A.-L. (2000). The sound of many hands clapping. *Nature*, **403**, 849–850.
- Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Personality and Social Psychology Bulletin*, **9**, 184–211.
- Olaveson, T. (2004). ‘Connectedness’ and the rave experience: Rave as the new religious movement? In G. St John (Ed.), *Rave Culture and Religion* (pp. 85–106). London: Routledge.



- Paladino, M.-P., Mazzurega, M., Pavani, F., & Schubert, T. W. (2010). Synchronous multisensory stimulation blurs self-other boundaries. *Psychological Science*, **21**, 1202–1207. doi: 10.1177/0956797610379234.
- Pascalis, O., de Haan, M., & Nelson, C.A. (2002). Is face processing species-specific during the first year of life? *Science*, **296**, 1321–1323. doi: 10.1126/science.1070223.
- Patel, A. D. (2006). Musical rhythm, linguistic rhythm, and human evolution. *Music Perception*, **24**, 99–104.
- Phillips-Silver, J., Aktipis, C. A., & Bryant, G. A. (2010). The ecology of entrainment: Foundations of coordinated rhythmic movement. *Music Percept*, **28**, 3–14. doi: 10.1525/mp.2010.28.1.3.
- Piaget, J. (1954). *The Construction of Reality in the Child*. (M. Cook Trans.). New York: Basic Books.
- Premack, D. (1990). The infant's theory of self-propelled objects. *Cognition*, **36**, 1–16. doi: 10.1016/0010-0277(90)90051-K.
- Preston, S. D., & de Waal, F. B. M. (2002). Empathy: Its ultimate and proximate bases. *Behavioral and Brain Sciences*, **25**, 1–72. doi: 10.1017/S0140525X02000018.
- Radcliffe-Brown, A. R. (1922). *The Andaman Islanders*. New York: Free Press.
- Ramseyer, F., & Tschacher, W. (2011). Nonverbal synchrony in psychotherapy: Coordinated body movement reflects relationship quality and outcome. *Journal of Consulting and Clinical Psychology*, **79**, 284–295. doi: 10.1037/a0023419.
- Rossion, B., & Jacques, C. (2008). Does physical interstimulus variance account for early electrophysiological face sensitive responses in the human brain? Ten lessons on the N170. *Neuroimage*, **39**, 1959–1979. doi: 10.1016/j.neuroimage.2007.10.011.
- Rushton, J. P. (1989). Genetic similarity, human altruism, and group. *Behavioral and Brain Sciences*, **12**, 503–559. doi: 10.1007/BF01065540.
- Sagiv, N., & Bentin, S. (2001). Structural encoding of human and schematic faces: Holistic and part-based processes. *Journal of Cognitive Neuroscience*, **13**, 937–951. doi: 10.1162/089892901753165854.
- Schippers, M. B., Roebroek, A., Renken, R. J., Nanetti, L., & Keysers, C. (2010). Mapping the information flow from one brain to another during gestural communication. *Proceedings of the National Academy of Sciences*, **107**, 9388–9393. doi: 10.1073/pnas.1001791107.
- Scholl, B. J., & Tremoulet, P. (2000). Perceptual causality and animacy. *Trends in Cognitive Sciences*, **4**, 299–309. doi: 10.1016/S1364-6613(00)01506-0.
- Sebanz, N., & Knoblich, G. (2008). From mirroring to joint action. In I. Wachsmuth, M. Lenzen & G. Knoblich (Eds.), *Embodied Communication*, (pp. 129–150). Oxford, UK: Oxford University Press.
- Semin, G. R. (2007). Grounding communication: Synchrony. In A. W. Kruglanski & E. T. Higgins (Eds.), *Social Psychology: Handbook of Basic Principles* (2nd edn), pp. 630–649. New York, NY: The Guilford Press.
- Semin, G. R., & Cacioppo, J. T. (2008). Grounding social cognition: Synchronization, coordination, and co-regulation. In G. R. Semin & E. R. Smith (Eds.), *Embodied Grounding: Social, Cognitive, Affective, and Neuroscientific Approaches*, pp. 119–147. New York: Cambridge University Press.
- Semin, G. R., & Cacioppo, J. T. (2009). From embodied representation to co-regulation. In J. A. Pineda (Ed.), *Mirror Neuron Systems*, pp. 107–120. New York, NY: Humana Press. doi: 10.1007/978-1-59745-579-7\_5.
- Simion, F., Regolin, L., & Bulf, H. (2008). A predisposition for biological motion in the newborn baby. *Proceedings of the National Academy of Sciences USA*, **105**, 809–813. doi: 10.1073/pnas.0707021105.
- Singer, T. (2006). The neuronal basis and ontogeny of empathy and mind reading: Review of literature and implications for future research. *Neuroscience and Biobehavioral reviews*, **30**, 855–863. doi: 10.1016/j.neubiorev.2006.06.011.
- Singer, T., Snozzi, R., Bird, G., Petrovic, P., Silani, G., Heinrichs, M. et al. (2008). Effects of oxytocin and prosocial behavior on brain responses to direct and vicariously experienced pain. *Emotion*, **8**, 781–791. doi: 10.1037/a0014195.
- Sosis, R., & Ruffle, B. J. (2004). Ideology, religion and the evolution of cooperation: Field experiments on Israeli Kibbutzim. *Research in Economic Anthropology*, **23**, 89–117. doi: 10.1016/S0190-1281(04)23004-9.
- Strogatz, S. (2003). *Sync: The Emerging Science of Spontaneous Order*. Hyperion: New York.
- Thiessen, D., & Gregg, B. (1980). Human assortative mating and genetic equilibrium: An evolutionary perspective. *Ethology and Sociobiology*, **1**, 111–140. doi: 10.1016/0162-3095(80)90003-5.
- Tremoulet, P. D., & Feldman, J. (2000). Perception of animacy from the motion of a single object. *Perception*, **29**, 943–951. doi: 10.1068/p3101.
- Valdesolo, P., & DeSteno, D. (2011). Synchrony and the social tuning of compassion. *Emotion*, **11**, 262–266. doi: 10.1037/a0021302.
- Vallacher, R. R., & Nowak, A. (1997). The emergence of dynamical social psychology. *Psychological Inquiry*, **8**, 73–99. doi: 10.1207/s15327965pli0802\_1.
- Vouloumanos, A., & Werker, J. F. (2007). Listening to language at birth: Evidence for a bias for speech in neonates. *Developmental Science*, **10**, 159–164. doi: 10.1111/j.1467-7687.2007.00549.x.
- de Waal, F. B. M. (2007). The 'Russian doll' model of empathy and imitation. In S. Braten (Ed.), *On Being Moved: From Mirror Neurons to Empathy* (pp. 49–69). Amsterdam: John Benjamins Publishing Company.
- Walters, J. R. (1987). Kin recognition in non-human primates. In D. J. C. Fletcher & C. D. Michener (Eds.). *Kin Recognition in Animals*, pp. 359–393. New York: John Wiley.

- Watanabe, S., Kakigi, R., & Puce, A. (2003). The spatiotemporal dynamics of the face inversion effect: A magneto- and electro-encephalographic study. *Neuroscience*, **116**, 879–895. doi: 10.1016/S0306-4522(02)00752-2.
- Waytz, A., Morewedge, C. K., Epley, N., Monteleone, G., Gao, J-H, & Cacioppo, J. T. (2010). Making sense by making sentient: Effectance motivation increases anthropomorphism. *Journal of Personality and Social Psychology*, **99**, 410–435. doi: 10.1037/a0020240.
- Wheatley, T., Weinberg, A., Looser, C., Moran, T., & Hajcak, G. (2011). Mind perception: Real but not artificial faces sustain neural activity beyond the N170/VPP. *PLoS ONE*, **6**, e17960. doi: 10.1371/journal.pone.0017960.
- Wiltermuth, S. S., & Heath, C. (2009). Synchrony and cooperation. *Psychological Science*, **20**, 1–5. doi: 10.1111/j.1467-9280.2008.02253.x.
- Womelsdorf, T., Schoffelen, J-M., Oostenveld, R., Singer, W., Desimone, R., Engel, A. K. et al. (2007). Modulation of neuronal interactions through neuronal synchronization. *Science*, **316**, 1609–1612. doi: 10.1126/science.1139597.
- Zaki, J., Hennigan, K., Weber, J., & Ochsner, K. N. (2010). Social cognitive conflict resolution: Contributions of domain-general and domain-specific neural systems. *Journal of Neuroscience*, **30**, 8481–8488. doi: 10.1523/JNEUROSCI.0382-10.2010.
- Zaki, J., Weber, J., Bolger, N., & Ochsner, K. (2009). The neural bases of empathic accuracy. *Proceedings of the National Academy of Sciences*, **106**, 11382–11387. doi: 10.1073/pnas.0902666106.