a novel view that is able to stimulate research that improves our understanding about the ability of humans to interact, communicate, and socialize with others.

A mass assembly of associative mechanisms: A dynamical systems account of natural social interaction

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Abstract: The target article offers a *negative, eliminativist* thesis, dissolving the specialness of mirroring processes into a solution of associative mechanisms. We support the authors' project enthusiastically. What they are currently missing, we argue, is a *positive, generative* thesis about associative learning mechanisms and how they might give way to the complex, multimodal coordination that naturally arises in social interaction.

A central challenge to social cognition is in understanding how the divide between individual minds becomes bridged during social interaction. It is not surprising then that the mirror neuron system (MNS) engenders the sort of fascination it does, as it provides cortical evidence that the way we relate to others is inextricably linked to the actions of our own bodies. Importantly, as Cook et al.'s associative learning hypothesis posits, these interpersonal connections are highly attuned to changes in our social environment that mitigate (or abolish altogether) appeals to innate processes. Given the domain-general characteristics of associative learning, such a mechanism is thus well situated to account for a wide range of sensorimotor possibilities in a variety of interactional contexts. Yet, in most of the studies reviewed in the target article, movements are confined to relatively simple interactions involving repetitive and overlearned behaviors such as grasping, clasping, lifting, or flexing movements of the hands, fingers, and feet. When more naturalistic interactions are considered, such as those of professional dancers and musicians, coordination of movement is extensively structured around explicit training. These phenomena do provide valuable cases to test the associative hypotheses. But they do not yet resemble the complex, coordinated behavior of social interaction.

When two people interact, complex patterns of behavior emerge quite spontaneously. These patterns are organized across multiple types of movement that simultaneously co-occur with little to no conscious awareness. Nevertheless, they form a stable network of associations that guide how people converge on meaning and respond to higher-level communicative goals. The mechanisms proposed by Cook and colleagues surely hold great promise in better understanding how social cognition is distributed and grounded in interpersonal motor behavior. But these associative mechanisms must figure into the complex array of overt and covert processes that are present when two people interact. At present, there is no good theory of how this interleaving takes place. We have recently termed this problem the "centipede's dilemma" of interaction research (Dale et al. 2013).

One approach that seems to have promise comes from the methodological and theoretical toolbox of dynamical systems theory. Like the target article, this approach sees even human interaction as emergent from domain-general processes acting in concert – viewing human interaction as a self-organizing system. At the core of this approach is a focus on how the components of a system interact over time. Components are drawn in part from processes underlying social cognition, such as visual attention, executive control, motor priming, and many others (see Dale et al. [2013] for a more comprehensive list). These processes span a range of complexity, too, from basic biomechanical constraints of conversants, to higher-level ones such as inferences regarding knowledge and beliefs. Based on these many potential interactions, it is unlikely that any single component alone will explain the collective behavior that emerges. Instead, interaction gains its structure through a process of self-organization in which the various components mutually influence and constrain each other.

There is growing evidence that this interdependence holds across diverse processes during interaction. For example, individual frequencies of oscillatory movements, such as those generated in the way people naturally sway their bodies, spontaneously converge as stable in-phase and anti-phase rhythms (Schmidt et al. 1990), and even hold across more irregular fluctuations of movement (Shockley et al. 2003). Similar forms of coordination, albeit expressed as more subtle, global patterns of recurrence, are also evident in how people gesture, laugh and smile, touch their faces, nod their heads, and even scan a visual scene (Louwerse et al. 2012; D. C. Richardson et al. 2008). Moreover, for each behavior being coordinated, people respond to one other across unique timescales, where the near overlap of postural synchrony stands in contrast to the longer delays between head nods.

The findings just described involve interdependence, between two people, of one behavior, sometimes called "synchrony" or "alignment" (Pickering & Garrod 2004). Yet there is also interconnectivity cutting across *different* behaviors. Each behavior mutually constrains the other within and across conversational partners. Even more remarkable is that this multimodal coordination is also simultaneously modulated by social and task demands that arise in conversation. The strength of coordination increases, for example, when there is a greater possibility for misunderstanding (Louwerse et al. 2012), when people believe that they might not share common ground (D. C. Richardson et al. 2007), when two people develop a shared vocabulary (Dale et al. 2011), and even when one person is deceiving another (Duran et al., in preparation). Thus, the communicative context itself integrates those involved into a more coherent and stable two-person unit. Put differently, the associations are *doing more* than just bridging their respective behaviors. They are supporting the integration of each individual's cognitive processes and behavioral patterns into a coupled system.

We have argued that the associative approach must be supplemented with an understanding of the naturalistic dynamics of social interaction. Whatever core capacities human beings have to engage in rich social interaction, they must *act together* in order to bring it about. This is a *positive explanatory* thesis about domain-general processes and how they function to support human joint performance. Our ambitious hypothesis is that movement coordination – a mass assembly of associative mechanisms – performs the function of facilitating information transmission. Such hypotheses cannot be tested if single sparse behaviors are studied in isolation. We can't reach these phenomena by studying finger lifts and grasping. Instead, we need to measure complex spontaneous interactions between people, and capture the coordination using new integrative frameworks, such as dynamical systems theory (see M. J. Richardson et al. 2014). The methods and concepts in this framework permit the study of language, social cognition, and social interaction – the phenomena that excite supporters of the mirror neuron system – yet might also explain them with the simple mechanisms laid out in this target article.