



The Extended Body



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Abstract

In this paper we address some methodological and theoretical challenges faced by those wishing to go beyond current explanations of social cognition centered on 'theory' and/or 'simulation'. Methodologically, we integrate phenomenological and dynamical systems approaches in a mutually informing manner. We use this integrated methodology so as to explain some of the basic processes of embodied intersubjectivity. A dynamical systems analysis of recent modeling experiments of social interaction is shown to support an enactive and phenomenological conception of the inter-enaction of bodily resonance and embodied communication. The model also serves as a proof of concept for the possibility of an interactive maintenance of body memory. More generally, these results demonstrate how some vague phenomenological notions, such as Merleau-Ponty's 'intercorporeity', can be made compatible with modern scientific practices by analyzing them in terms of the mathematics of dynamical systems theory.

1. Embodied communication

Science has traditionally conceived of communication only in terms of abstract **information transfer**.

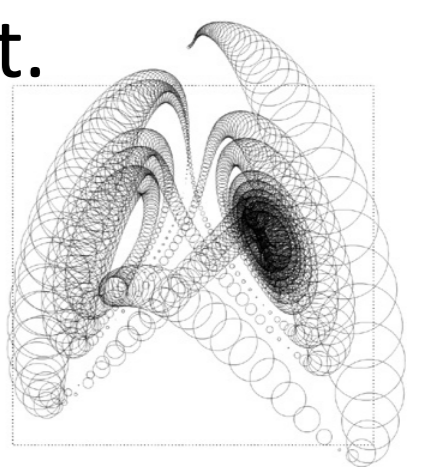
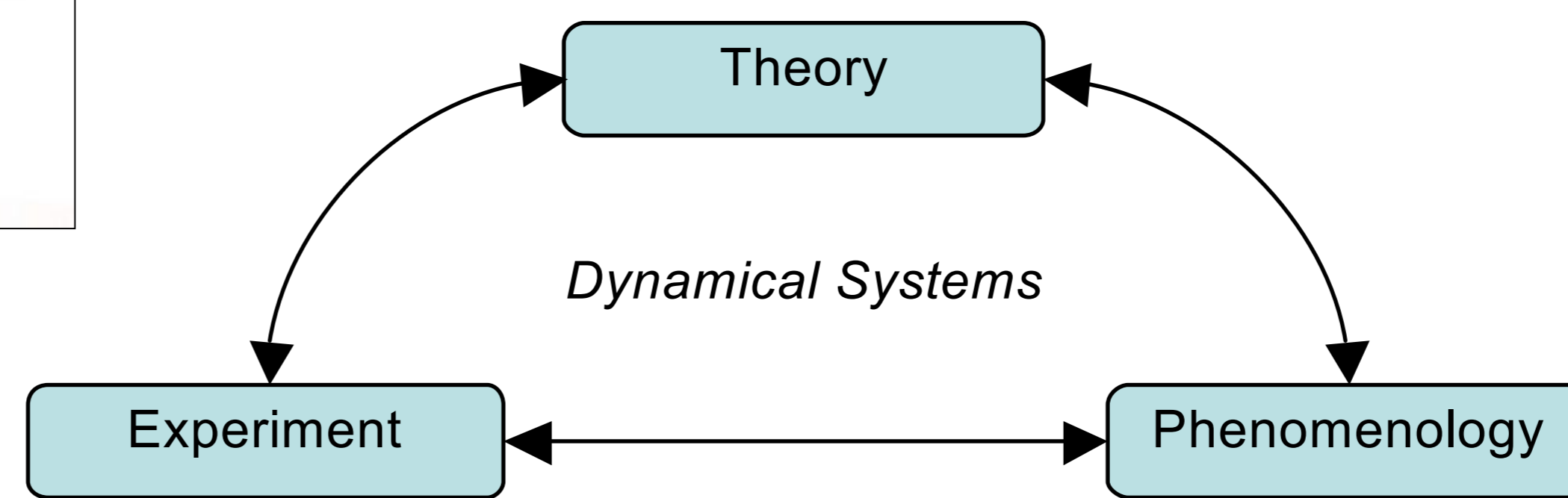


Phenomenology, on the other hand, has insisted that intersubjectivity is possible only in terms of **embodied interaction**.



2. Methodology

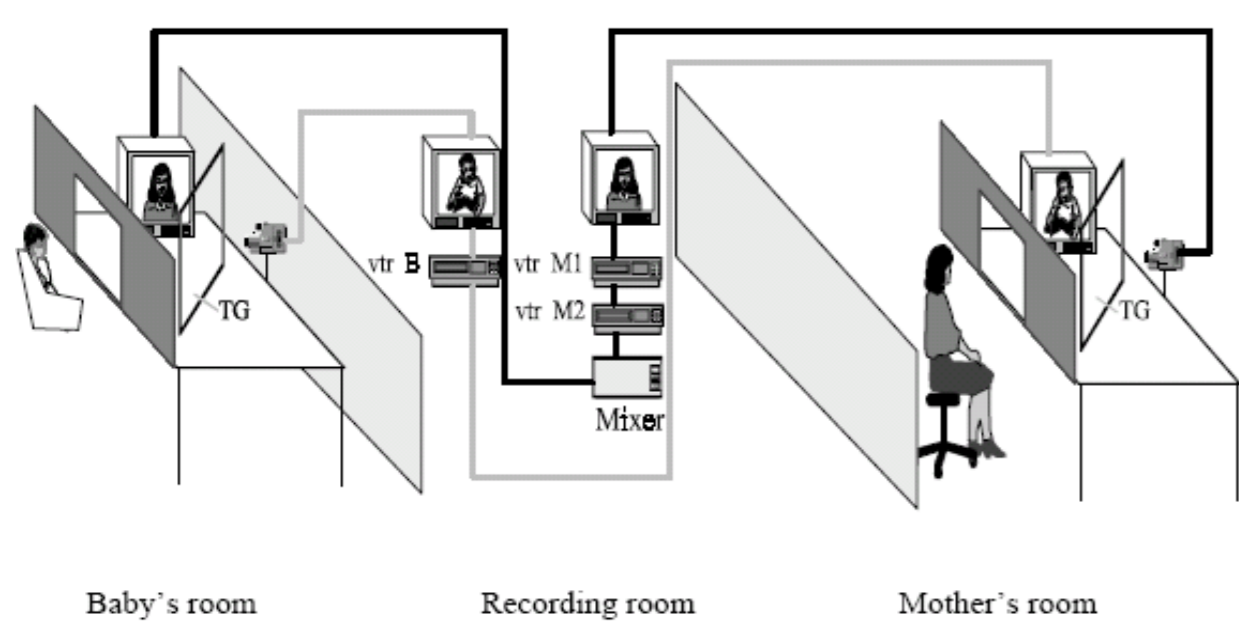
We propose an alternative framework for cognitive science by following the work of Varela and others: theory, experiment, and phenomenology are integrated into one coherent methodology by relations of **mutual enlightenment** and constraint.



In some cases the three areas can be brought together by means of **dynamical systems theory** and models (Froese & Gallagher 2010).

3. Experiments

In social and developmental psychology the notion of embodied social interaction has been most famously studied by Trevarthen and colleagues, who refer to it as **primary intersubjectivity**.

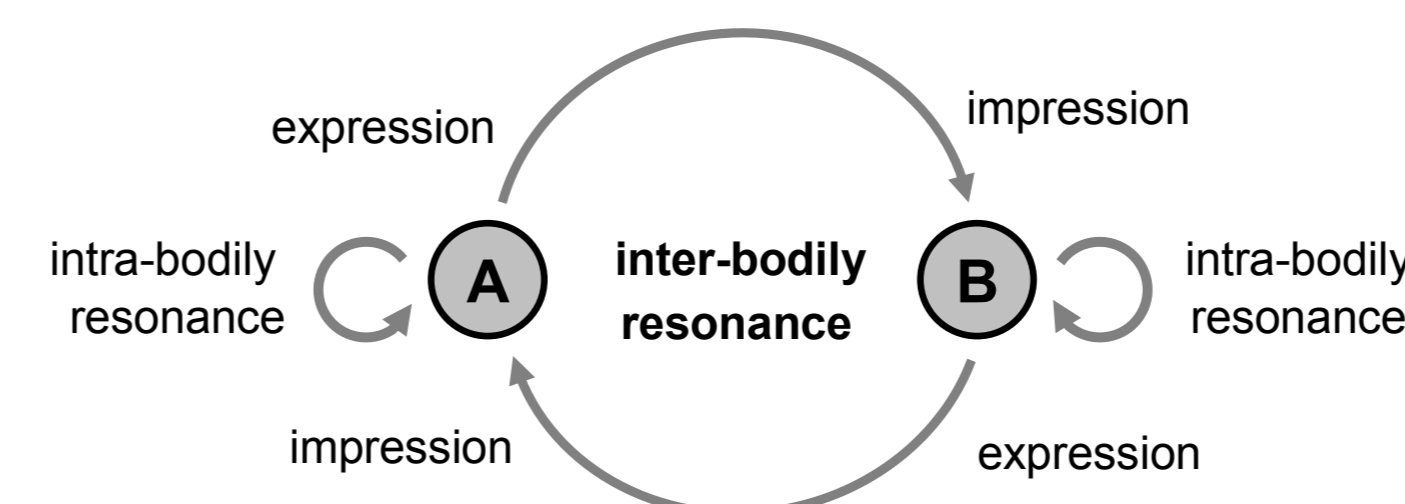


One famous study is the 'double TV monitor' experiment by Murray and Trevarthen (1985), which showed that interacting young infants have a sensitivity to social responsiveness.

Nadel et al.'s (1999) schematic of the 'double TV monitor' setup.

4. Phenomenology

Phenomenology rejects cognitivist explanations of primary intersubjectivity. Instead, it has developed the notion of an **extended body**, such as Merleau-Ponty's concept of intercorporeity, as well as recent accounts of inter-bodily resonance (Fuchs 1996) and mutual incorporation (Fuchs & De Jaegher 2009).



Each lived body is extended by the other. This is accompanied by a holistic impression of the interaction partner and a feeling for the overall atmosphere of the shared situation.

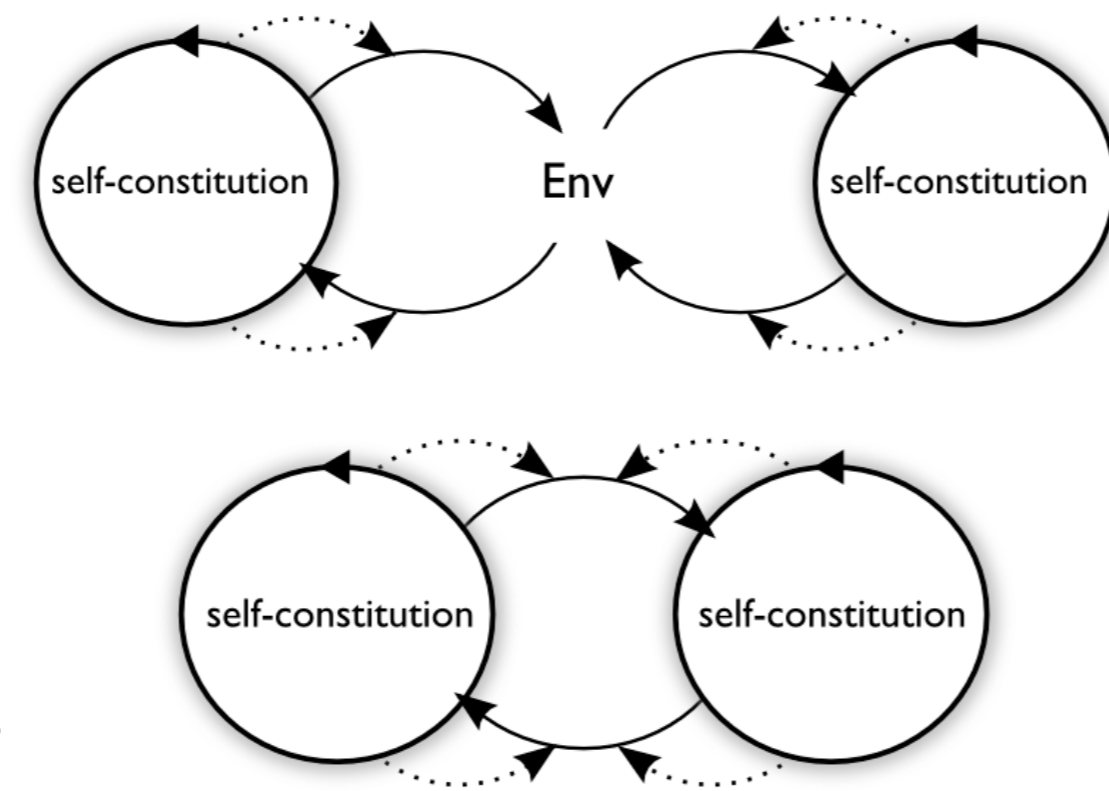
Schematic of the extended body (adapted from Fuchs 1996).

5. Theory

This phenomenological notion of the extended body is complemented by the **enactive approach to social interaction** (De Jaegher & Di Paolo 2007).

The manner in which one agent's movements affect the environment can result in changes to sensory stimulation for the other agent, and vice versa, thus creating a multi-agent recursive interaction.

Their activities become entwined in such a manner that their mutual interaction results in an interaction process, which is itself characterized by an autonomous organization, i.e. an emergent structure in its own right.



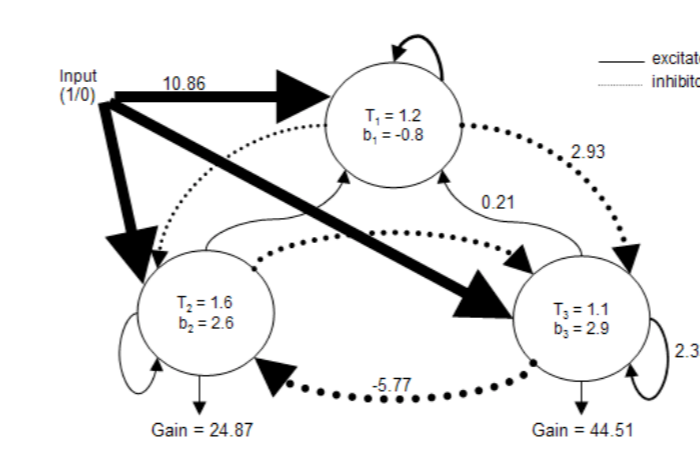
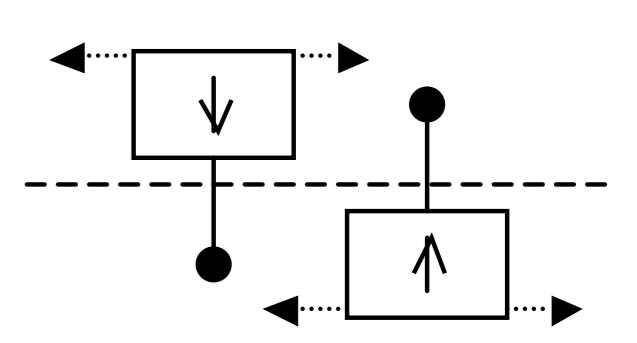
Schematics of the autonomous dynamics of social interaction (Froese & Di Paolo, in press).

6. Agent-based computer model

This enactive notion of the extended body is further supported by agent-based **computer models** of the dynamics of social interaction.

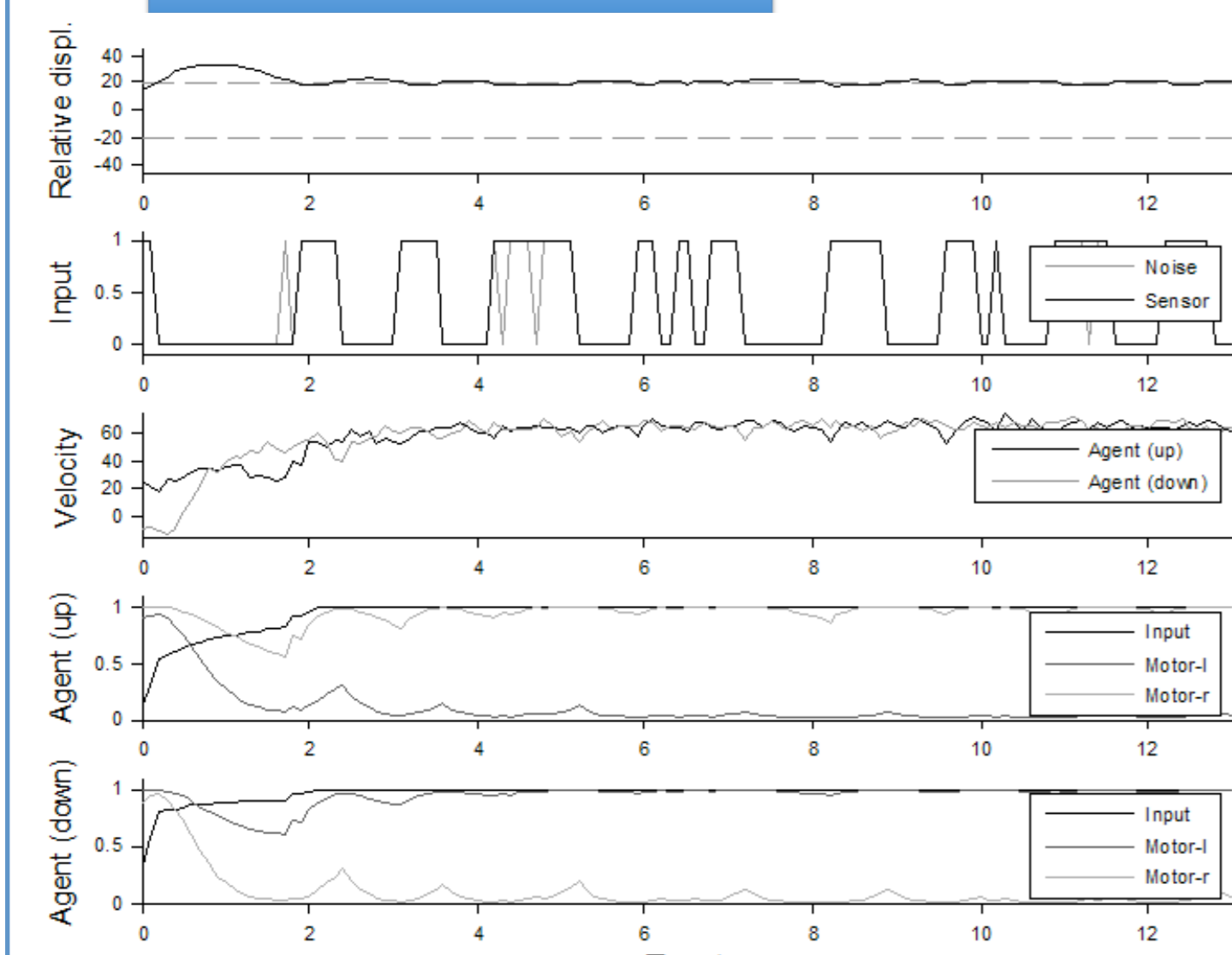
Schematic view of the simulation model by Froese and Di Paolo (2008).

The two model 'agents' have an equally wide body, are only able to move in a horizontal direction, and are equipped with a single 'on/off' contact sensor at the center of their body. They face each other in an unlimited continuous 1D space

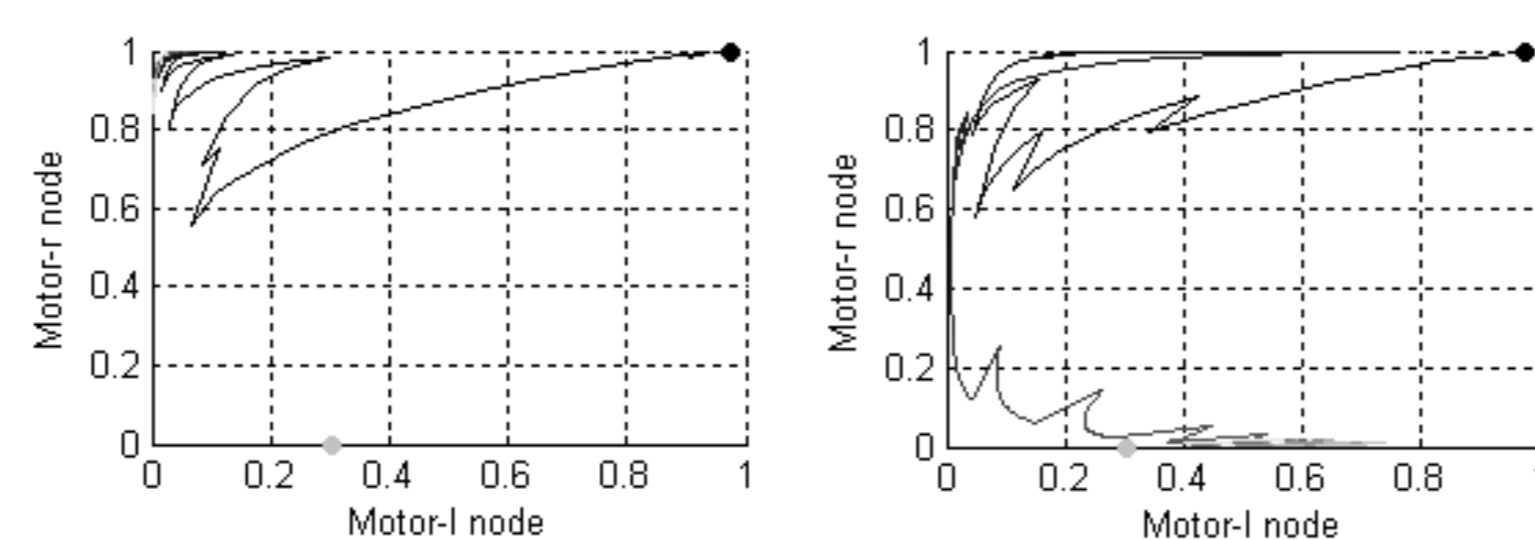


The movement of each agent depends on the activity of an artificial neural network, which has been evolutionarily optimized for the task of producing coordinated left- or right-ward sideways movement with the other agent.

5. Dynamical analysis



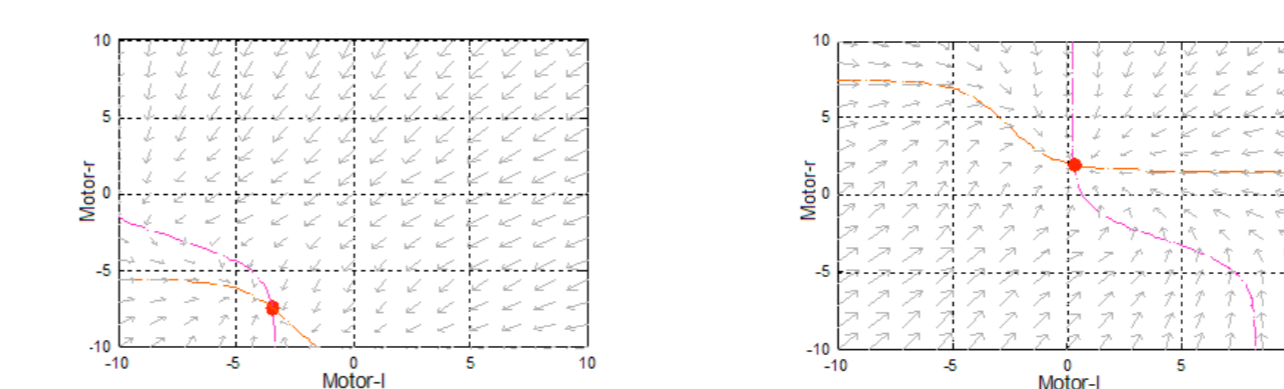
Trace of the behavioral and neural dynamics of the establishment of **coordinated interaction**.



Illustrations of one agent's behavior as a state trajectory of its motors. During mutual interaction with the other agent (left), the agent is producing oscillatory motion. Note that it is situated in a region of **transient behavioral dynamics** between two fixed-point attractors (black and grey dots). This region of dynamics is inaccessible when the movements of the other agent are substituted by a non-responsive playback of previously recorded movements (right).

Result: the agent is sensitive to the responsiveness of the other agent, because its coordination behavior depends on the overall dynamics of the interaction process.

In addition, the analysis reveals that the dynamics of the interaction process are not absolutely external to the internal dynamics of the agent's body.



The reason for this **co-dependency of internal and external dynamics** is that the contact sensor has evolved to be a parameter of the agent's motor schema. Thus, the motor state space is organized differently depending on whether sensory input is off (left) or on (right). For more details of this dynamical analysis, see Froese (2009).

Result: the bodies of the agents are dynamically extended during the interaction process.

5. Conclusion

The notion of the **extended body** provides a more suitable basis for the study of sociality than the cognitivist-internalist mechanisms of traditional cognitive science.

- It better accords with the results of social and developmental psychology.
- It better accords with the insights of the phenomenology of intersubjectivity.
- It better accords with the theory of the enactive approach to cognitive science.
- It better accords with dynamical systems analysis of social interaction.

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