Are you interacting with me?
The embodied dynamics of minimal agency detection

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Social interactions may lead to coordinated behaviours when mutual anticipations are formed dynamically. This mutuality of influences is a key property of the interaction process but its dynamical characteristics have not been sufficiently investigated from a theoretical perspective. In contrast, important empirical evidence points to the central role of dynamic mutuality in sustaining and forming several aspects of an ongoing interaction. This is clearly shown in Trevarthen's double-monitor experiments with infants[2,3] and in Lenay's perceptual crossing experiments.[1] In Trevarthen's experiment, a mother and her baby are placed in separate rooms and allowed to interact only through video screens that display their faces to each other. During 'live' interaction, mother and infant engage in coordinated utterances and affective expressions. However, if a recorded video of the mother is displayed to the baby, the baby becomes withdrawn and depressed. This shows that it is not sufficient for the baby to sustain interaction that the mother's expressive actions be displayed on the monitor, but the mother is required to react 'live' to the baby's own motions in order for the interaction to continue. It can be assumed that the most important clue during interactions is its ongoingness which has to be shared between the subjects and is therefore a property of the dyadic system.

Lenay et al. have studied social interaction by means of a minimal perceptual crossing paradigm. In their experiments, two blindfolded subjects interact in a virtual one-dimensional space. Each subject moves a receptor field using a computer mouse and can get all-or-nothing tactile sensation when the receptor crosses an object or the other subject's receptor. Subjects are constantly 'followed' by a shadow object that mimics their movement and, from their partner's perspective, is indistinguishable from their receptor. Their task is to find each other without becoming fixated on static objects or on the partner's objectively identical shadow. Subjects can achieve this goal thanks to how mutuality influences the global dynamics of the task since becoming fixated on a shadow that does not respond to one's own movements does not cause one's partner to stop the search and the interaction breaks down.

The common idea in these experiments is that subjects are exposed to behaviours that are identical in motion to a 'live' interaction but do not have a subjective control to respond to the subject's motions. Human subjects (even infants) easily discriminate the two conditions by engaging in interaction and thus investigating whether a partner has a subjective control of their motion. This dynamical enquiry produces an experience of confronting another subject, *an agency*. This suggests that the presence of another subjectivity is not located anywhere in the quality of the motion themselves but it is rather in the ongoingness of interactions shared between subjects.

The aim of our study is to explore ongoing dynamical aspects of minimal interaction between embodied agents. We investigate how embodied agents can establish a live interaction and discriminate this from interactions with dummy agents, which have the same motions but can not react live. The issue we want to test is *whether such a discrimination requires a complex perceptual strategy on the part of the discriminating agent or whether simpler solutions emerge from the interaction process itself.*

Agents are required to discriminate whether another agent is a live interaction partner or a recording of the agent's behaviour by using minimally restricted sensors (a linear visual array) and motors for 1-D displacement (agents face each other in a walled environment, Fig. 1). Agents are controlled with a continuous-time recurrent

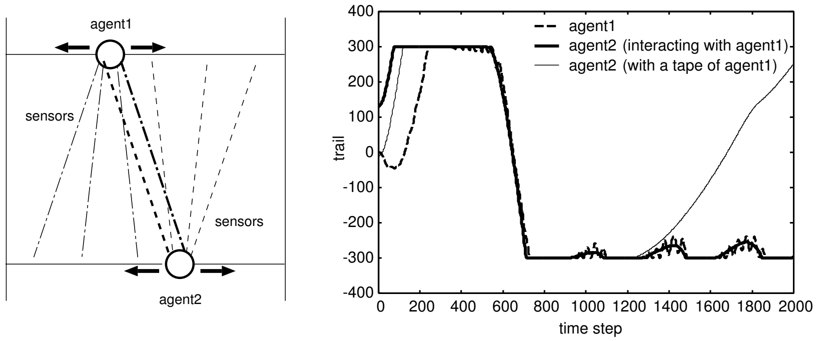

Figure 1. Left: environmental settings. Right: spatial trail example.

neural network, all parameters of which are set by a genetic algorithm. The fitness is calculated on the basis of two factors. One is how much the agent can cross its central position with that of a live interacting agent (live interaction). The other is how much the agent can stay away from a dummy agent which only replays the motions of their partner as recorded in the first stage (one-way interaction). Agents retain no memory after either test. In this way, the motions of the dummy and the live agents are the same as in the double-monitor and the perceptual crossing experiments.

Evolved agents successfully acquired the capacity to discriminate between the two conditions. Figure 1 shows trajectories for both agents (live interaction) and a trail of the bottom agent when starting from a different initial position and interacting with the recorded trail of the top agent (one-way interaction). At the start of the interactions, the bottom agent behaves similarly in both cases. During this phase, crossing of the agents' positions does not happen so much. Afterward, in the live interaction, the crossing coordination is established in the way that the bottom agent moves away a little from the wall while the top agent oscillates around the position of the bottom agent. In contrast, a bifurcation suddenly happens in this phase in the one-way interaction. It happens when the bottom agent moves away from the wall a little. In the live interaction, at this time, the top agent 'catches' the movement of the bottom agent and provokes a return to the wall through its oscillatory interaction. However, a slight difference of the timing of the movement away from the wall is enough for the recorded trajectory of the top agent not to be able to 'respond' in time to 'catch' the bottom one. This unexpected event causes the breakdown of the coordination and the lack of mutuality makes this breakdown irrecoverable. It is also found that this bifurcation could happen even if the initial positions of the bottom agent are exactly same in the live and one-way interaction since slight differences in trajectories accumulate due to sensor noise. The agents can suppress the effect of noise and sustain coordinated behaviours under the live interaction while the noise is not suppressed by a single adaptive agent in the one-way interaction causing it to break down eventually.

This simple model answers our question. It is sufficient to exploit properties of the mutuality of the live interaction, such as increased robustness to noise and timing differences, to produce a different behaviour in the case of a one-way interaction. This suggest that the recognition of the presence of another's subjectivity need not lie in complex cognitive individual mechanisms able to integrate past information, but rather in the situated ongoingness of the interaction process itself, in its dynamic landscape, and its robustness to noise. These simulation results show the possibility of embodied modelling to deal with matters as complex subjectivity and ongoingness without the models themselves being complex.

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