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Supplementary Information for

Evidence for mutual allocation of social attention through interactive signaling in a mormyrid weakly electric fish

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Figs. S1 to S8

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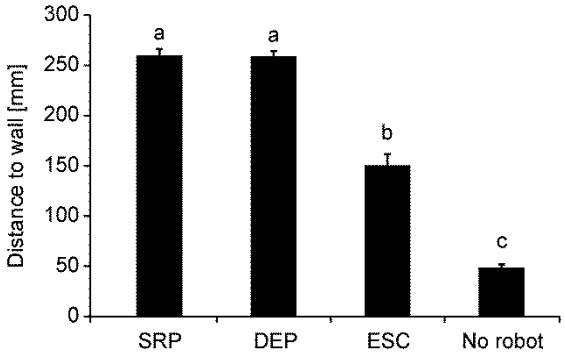

Fig. S1. Influence of the mobile robot on wall-following behavior. The introduction of the mobile robot resulted in an increased average distance between *n* = 23 fish and the tank wall, indicating a decrease in wall-following behavior. This effect was statistically highly significant (repeated-measures ANOVA with Greenhouse-Geisser correction: $F_{(1.837,\ 40.422)} = 247.26$; $P < 0.001$, $\varepsilon = 0.61$). Categories not sharing a common superscript letter differ significantly based on Bonferroni-corrected pairwise comparisons. Playback type did not influence the distance between fish and tank walls. SRP, static random playback; DEP, dynamic echo playback; ESC, electrically silent control.

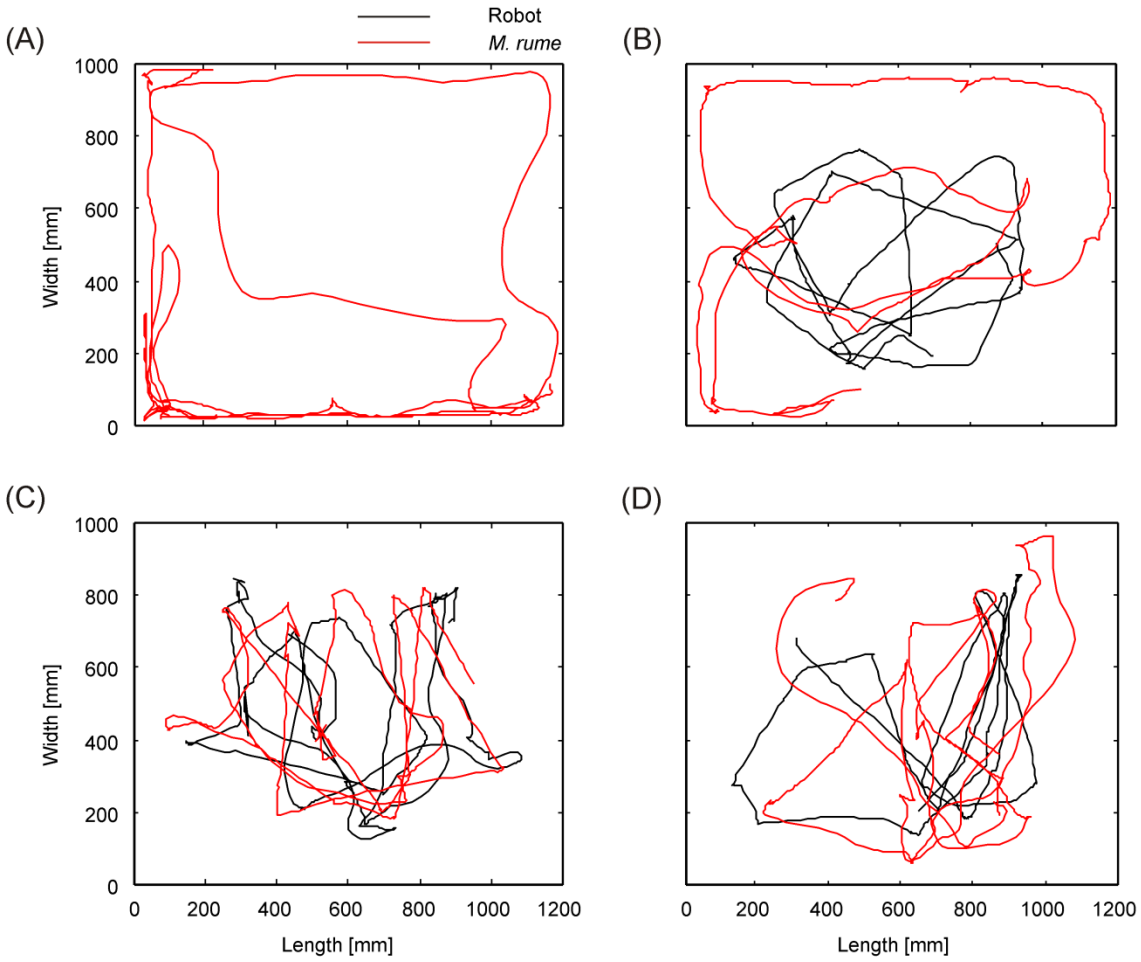

Fig. S2. Swimming trajectories and following-behavior. Exemplary trajectories of the robot (black) and a single individual of *M. rume* (red) covering 45-s experimental trials. (A) With no robot present, fish spent most of the time in proximity to the tank walls. (B) Control trials with an electrically silent robot (ESC) evoked occasional interest and following of the replica's trajectory by the test fish in addition to wall-following. Wall-following was virtually absent during trials with SRP (C) and DEP (D), during which animals mostly followed the replica and roughly reproduced its trajectories.

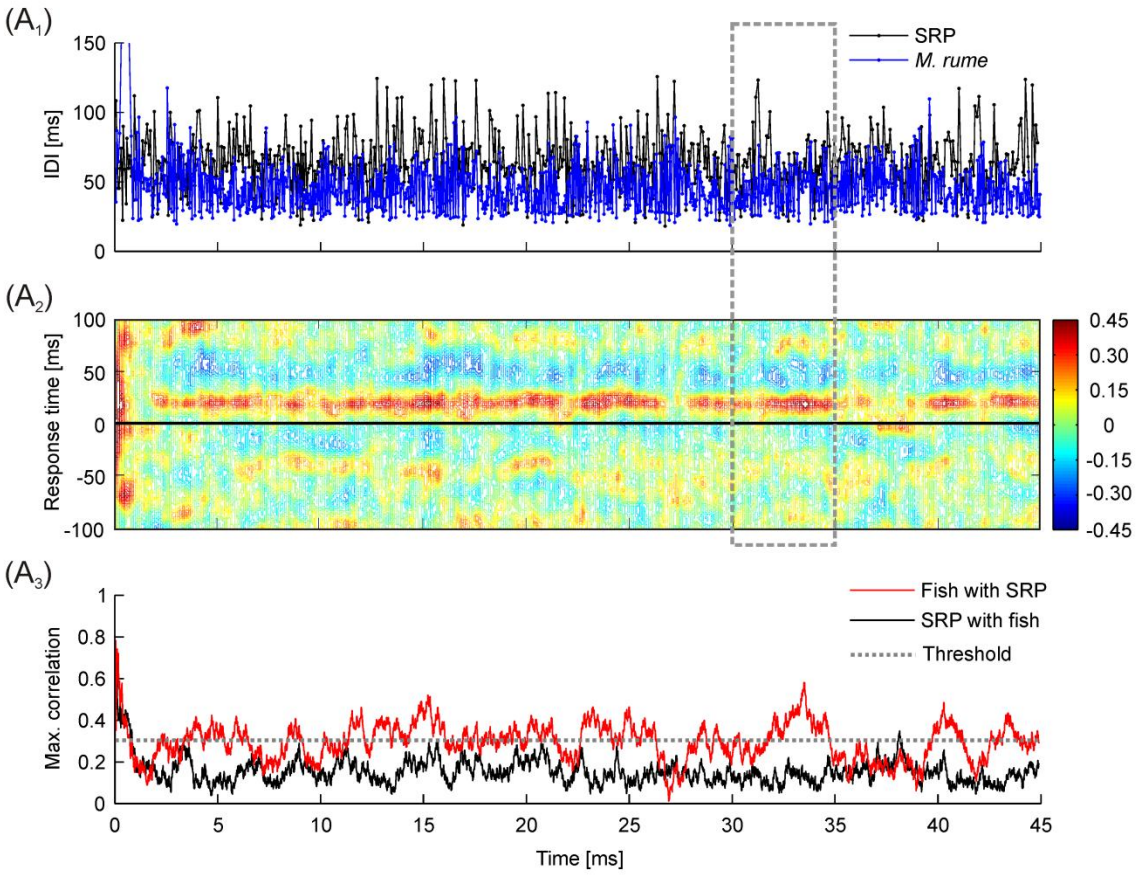

Fig. S3. Synchronization of electrical discharge activity with the static random playback (SRP). Exemplary trial performed with fish 1. (A_1) IDI sequences of SRP (black) and the fish (blue) over the 45-s time course of the experiment. (A_2) Cross-correlation diagram calculated for the two IDI sequences displayed in (A_1). Correlation coefficients of the fish's signals with the playback signals are color-coded for response times of ±100 ms over the time course of the experiment. High correlation coefficients at positive response times thus represent synchronization of the animal's signaling behavior to the playback at a latency defined by that response time. High correlation at negative response times would represent synchronization of the playback with the signaling behavior of the fish, which can only occur randomly in response to a static playback pattern. (A_3) Maximum correlation values indicating synchronization of the fish with the playback signal (red) as well as for the playback signal with the fish (black), extracted from the data underlying subplot A_2. The dotted grey line represents the 0.3 threshold indicative of relatively strong correlation. A magnification of the section outlined by the dashed grey rectangle is shown in Fig. 3A.

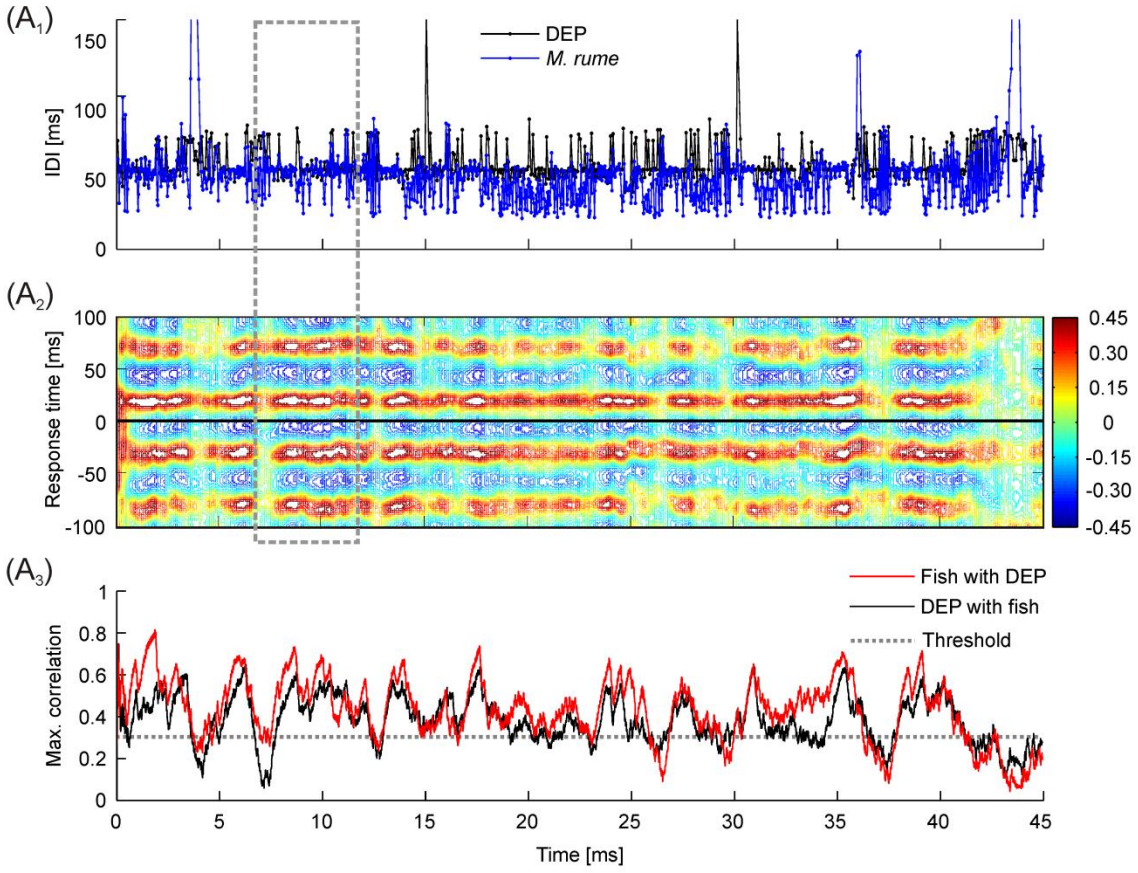

Fig. S4. Synchronization of electrical discharge activity with the dynamic echo playback (DEP). Exemplary trial performed with fish 1. (A_1) IDI sequences of DEP (black) and the fish (blue) over the 45-s time course of the experiment. (A_2) Cross-correlation diagram calculated for the two IDI sequences displayed in (A_1). Correlation coefficients of the fish's signals with the playback signals are color-coded for response times of ± 100 ms over the time course of the experiment. High correlation coefficients at positive response times represent synchronization of the animals signaling behavior to the playback at a latency defined by that response time. High correlation at negative response times represents synchronization of the playback with the signaling behavior of the fish through an interactive echo playback. This was triggered by EODs the test fish emitted near the replica. (A_3) Maximum correlation values indicate synchronization of the fish with the playback signal (red) as well as synchronization of the playback signal with the fish (black). Values were extracted from the data underlying subplot (A_2). The dotted grey line represents the 0.3 threshold indicative of relatively strong correlation. A magnification of the section outlined by the dashed grey rectangle is shown in Fig. 3B.

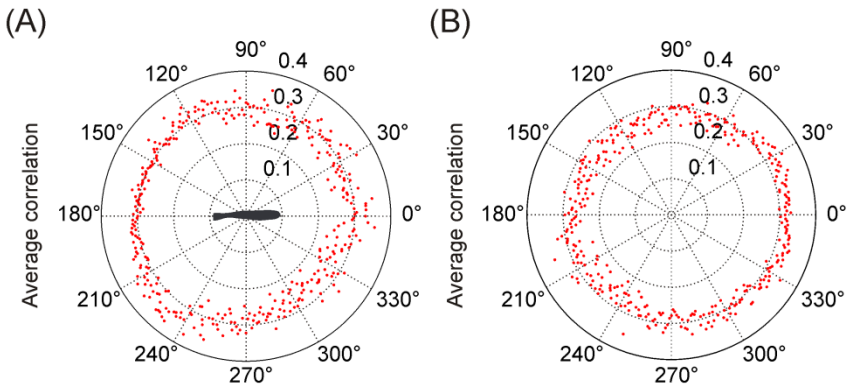

Fig. S5. Directional relationships during electric signaling. Polar plots of the average cross-correlation coefficients per 1° of (A) the angle representing the fish's bearings in the robot's egocentric coordinate system, and (B) the difference in orientation between robot and fish. A parallel orientation corresponds to a difference of 0° degree. The distance from the center of the plot represents the correlation coefficient of electric discharge synchronizations.

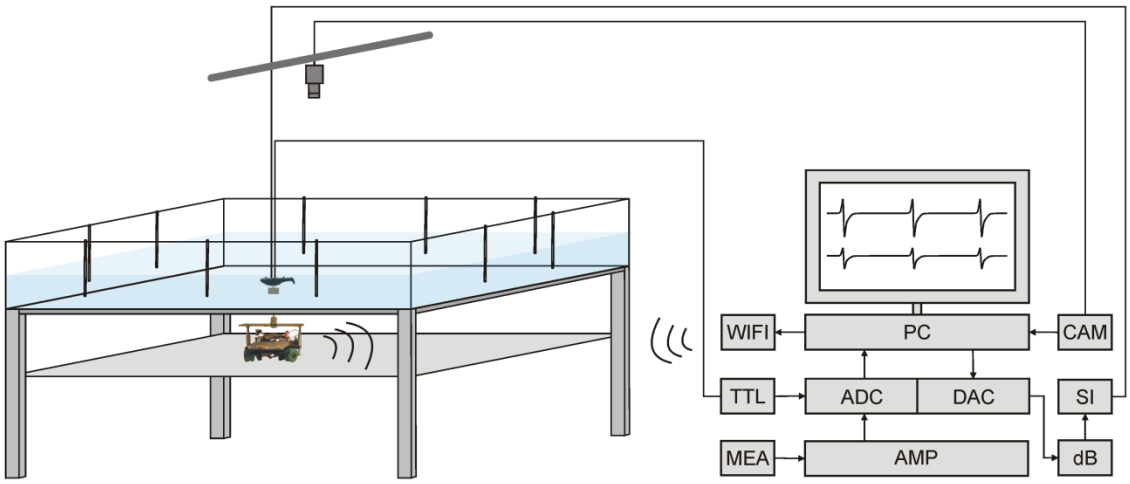

Fig. S6. Illustration of the experimental setup and technical components. The robot moves on the level underneath the tank, thus defining the trajectory of the replica via magnetic coupling. Electric signals and motor behavior are recorded by an array of five pairs of electrodes in the tank and a video camera from above. MEA, Multi-electrode array; AMP, differential amplifier; ADC, analog to digital converter; TTL, Trigger box generating a TTL pulse for each EOD registered at the replica's recording electrodes; CAM, video camera; PC, computer for data acquisition, playback output, and control of the robot; WIFI, wireless control of the robot's trajectory; DAC, digital to analog converter; dB, attenuator; SI, analog stimulus isolation unit powering the electrical playback signal.

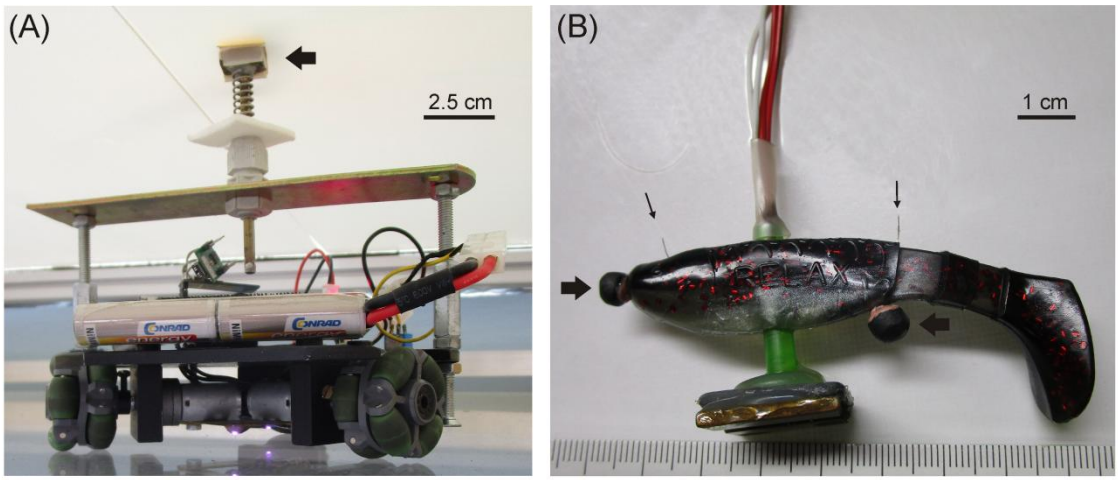

Fig. S7. Components of the mobile fish robot. (A) Remote-controlled robot on the level underneath the experimental tank with a magnet (arrow) to connect to the fish replica. (B) Fish replica mounted on a magnetic base plate, incorporating a pair of playback electrodes (thick arrows) and a pair of trigger electrodes (thin arrows). Wires connect the electrodes to the battery-driven stimulus isolator (red) and the trigger box (white).

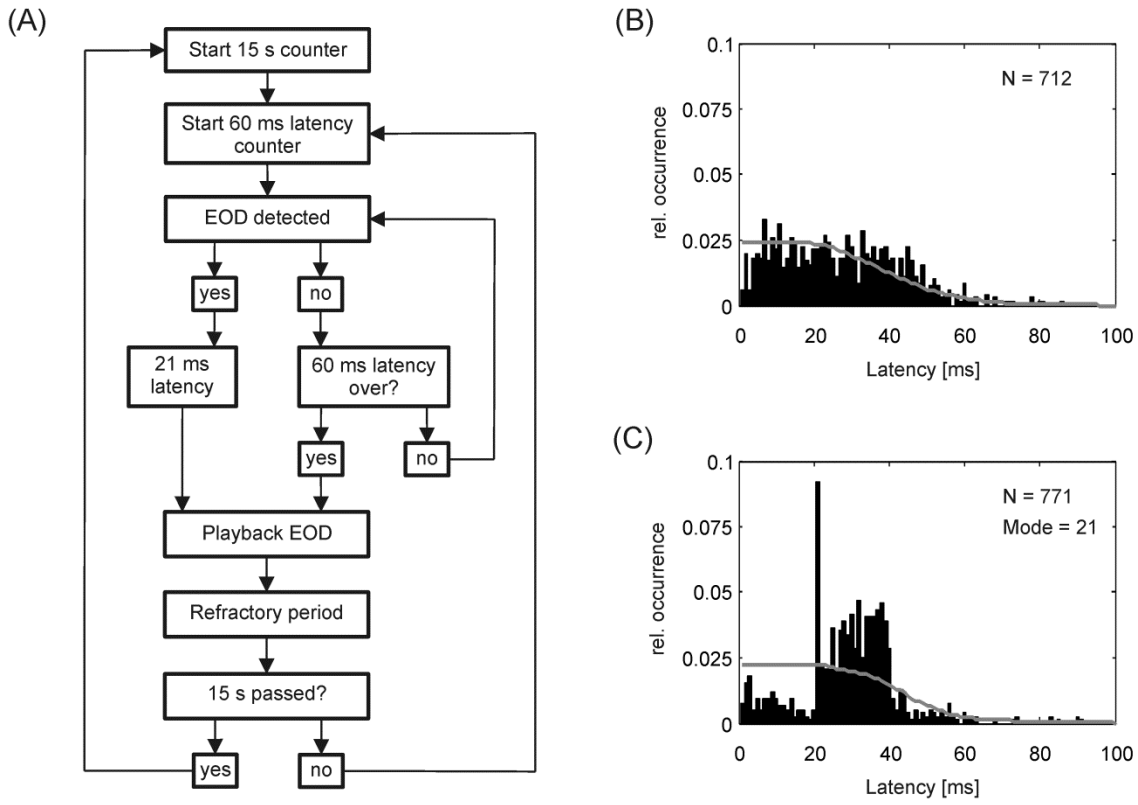

Fig. S8. Dynamic echo playback (DEP) generation. (A) Flowchart illustrating the generation of DEP based on trigger EODs emitted by fish close to the robot. (B) SRP generated EODs independent of the test fish's signals. Consequently, the latencies with which the playback followed after the fish's EODs conformed to the expected distribution of random latencies. (C) During DEP, EODs emitted within the sensitivity range of the robot's trigger electrodes elicited echo responses with a latency of 21 ms.