Electrocommunication and Social Coordination in Weakly Electric Mormyrid Fish

Leo Farber, Rachel Miller, & Krista Perks
Department of Biology, Wesleyan University

Introduction

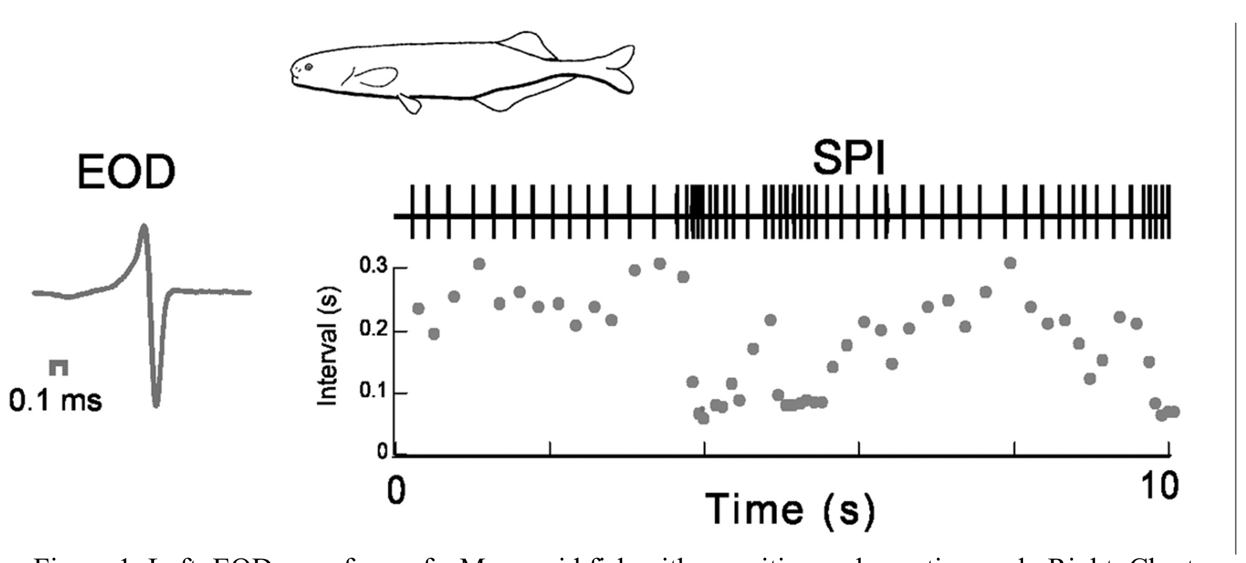

Figure 1: Left: EOD waveform of a Mormyrid fish with a positive and negative peak. Right: Chart displaying inter-pulse or spike-pulse intervals of EODs over 10 seconds(Sullivan, John. ("How to Record EODs." How to Record EODs | Mormyridae - African Weakly Electric Fishes)

Weakly electric Mormyrid fish are nocturnal and are native to the murky fresh waters of Africa. As an evolutionary adaptation to their environment, Mormyrid fish generate pulse-type electric organ discharges (EODs) from an electric organ in their tail (Figure 1). EODs are used to locate objects in their surroundings and communicate with other fish. Knollenorgan electroreceptors only respond to EODs from other fish[1]. Consequently, the knollenorgan pathway is critical for investigations of electrocommunication in Mormyrid fish.[3]

While the amplitude and duration of individual EOD pulses are relatively stable over time and convey information about an individual's species and sex, the inter-pulse-intervals (IPIs) of a series of EOD pulses changes moment-by-moment (Figure 1).[3] Previous research has found that IPIs vary in association with different behavioral contexts, such as aggression, hiding, mating, and exploration.[1] Previous studies have also found that pairs of fish coordinate their EOD timing and IPI patterns during mating or agonistic encounters.[1,2] Due to technical limitations, however, research into the role of electrocommunication in larger groups of freely swimming fish has been limited. This study aims to fill such gaps by by utilizing synchronized EOD and video recordings, along with markerless automated tracking and by developing an assay for social cohesion in mormyrid fish.

Research Questions

As the basis of interaction between individuals, communication signals are key features of animal social behavior. Social cohesion and the coordination of communication signals are inextricably linked. We are interested in the mechanisms enabling such coordination. For example: What role does electrocommunication play in social behavior in large groups of freely swimming fish? How are IPIs coordinated, and what determines the allocation of social attention in such encounters? In this study, we are starting by designing a behavioral assay for group cohesion. The assay is aimed towards investigating how interactions with a novel environment change in accordance with group size, and how such changes are related to electrocommunication.

Methods Development

We are developing a behavioral assay that will enable us to quantify the relationship between group cohesion and the high-dimensional coordination of EODs among a group of fish. In this assay, we will manipulate group size during the exploration or foraging in familiar versus novel environment. We will acquire the time of EODs from each fish as well as the position of multiple body parts.

- Animals: weakly electric fish of the species Gnathonemus *petersii*.
- Housing: We have designed a custom-built tank to control the environment in a way that enables us to introduce fish to a novel/familiar environment in groups of different sizes (Figure 2). (Currently, max group size = 8).
- Data Acquisition: A custom-built array of electrodes enables the recording of EODs. The signals from the array of electrodes are processed and digitized with an Intan 16-channel differential amplifier headstage and an OpenEphys acquisition system.[4] Video is recorded using a Basler acA1300-200um USB3 camera.

Critically, studying electrocommunication in large groups of freely swimming fish requires the ability to identify which EOD is generated by which fish, which has been an outstanding major technical limitation. To overcome this technical limitation, we are developing the tools to synchronize motion-tracking software and EOD recording from a multi-electrode array.

- Video Tracking: Rachel Miller has been working on implementing video tracking (see accompanying poster).
- Synchronization: The open-source Bonsai-rx reactive programming package[5] is used to simultaneously record the data-streams from the camera and the electrode recording system. Offline synchronization of video and electrophysiology data is currently accomplished by driving the emission of an LED in-view of the camera with a voltage pulse that is recorded through an unused input of the Intan headstage.
- Multichannel electrode array: We custom-built an electrode array that is spatially arranged with pairs of orthogonal differential electrodes (Figure 2).

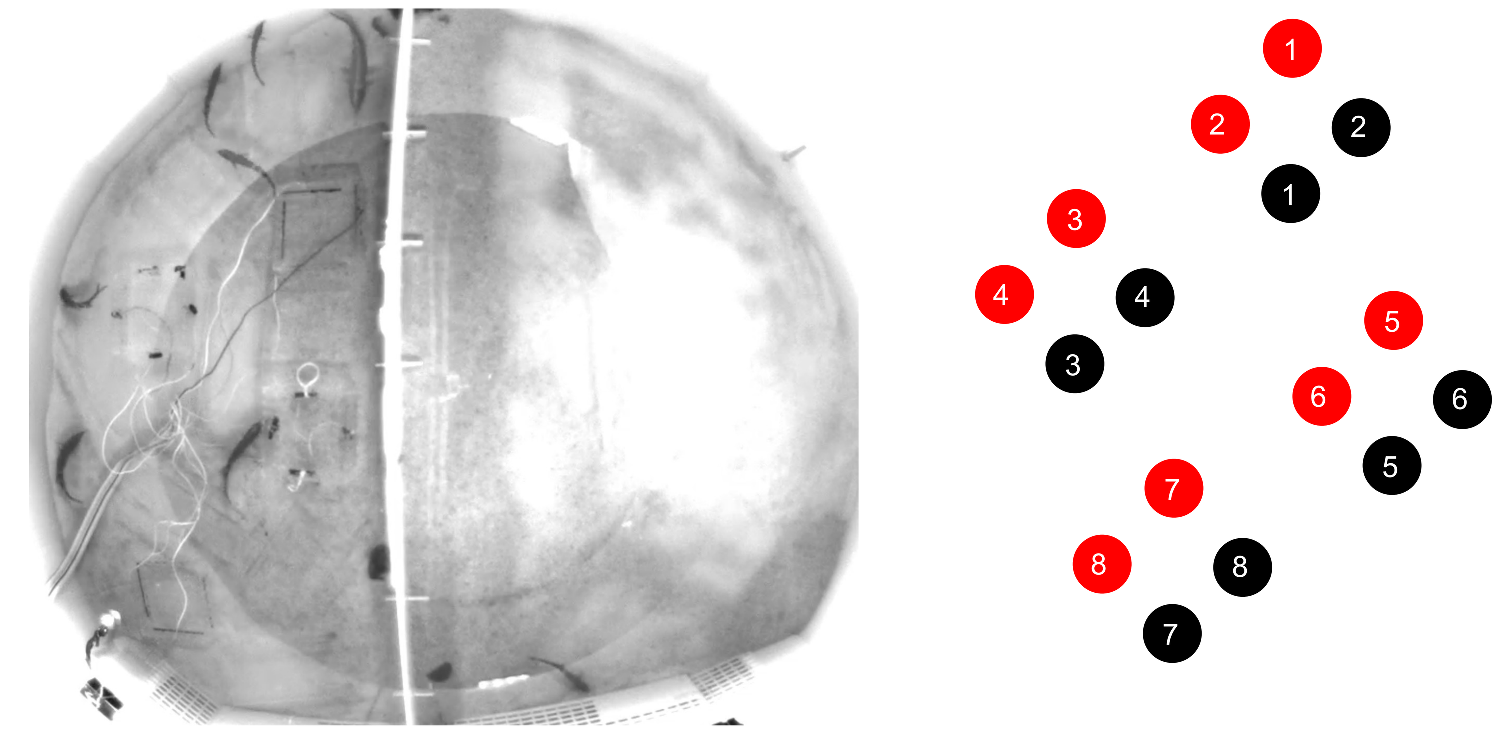

Figure 2: Left: Experimental tank. LED used for synchronization of video and EOD recordings visible in bottom left corner. Right: 8 pairs of differential electrodes are arranged in a way that will enable inference of fish position given the polarity of the recording across channels. Red = positive electrode Black = negative electrode.

Results

As the fish swim, two things happen: their distance from a given electrode and their orientation relative to its axis constantly fluctuates. Changes in distance are reflected in the varied amplitudes (heights) of single events recorded on different channels. For example, the amplitudes recorded in channels 1, 2, 7, and 8 are much greater than those of channels 3, 4, 5, and 6 at the 32 second mark. Changes in orientation are reflected in the varied polarity of single events recorded on different channels. For example, from 37.5-38.5 seconds, the polarity flips on channel 2. Also, at ~37.5seconds, the polarity of events on channel 1 and 2 are mirrored. These differences across channels enable us to identify which EOD belongs to which fish, when we have information about the orientation of each fish (Figure 4).

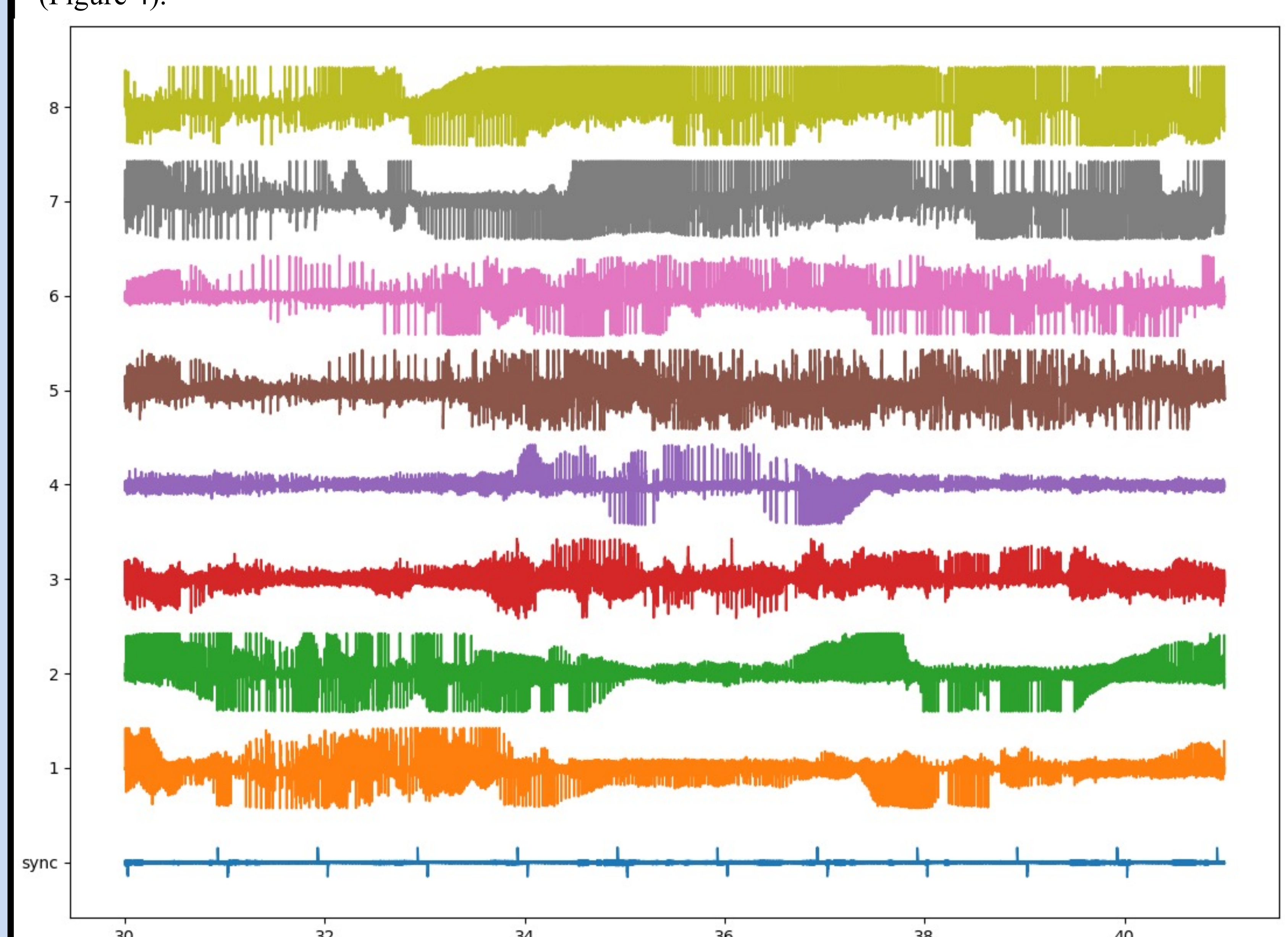

Figure 3: 1-8: 8 channels displaying raw EOD data recorded over 12 seconds from 8 pairs of differential electrodes arranged throughout the tank. Sync channel displays the upwards and downwards transients associated with the LED pulsing on and off, used for synchronization of EOD and video recordings.

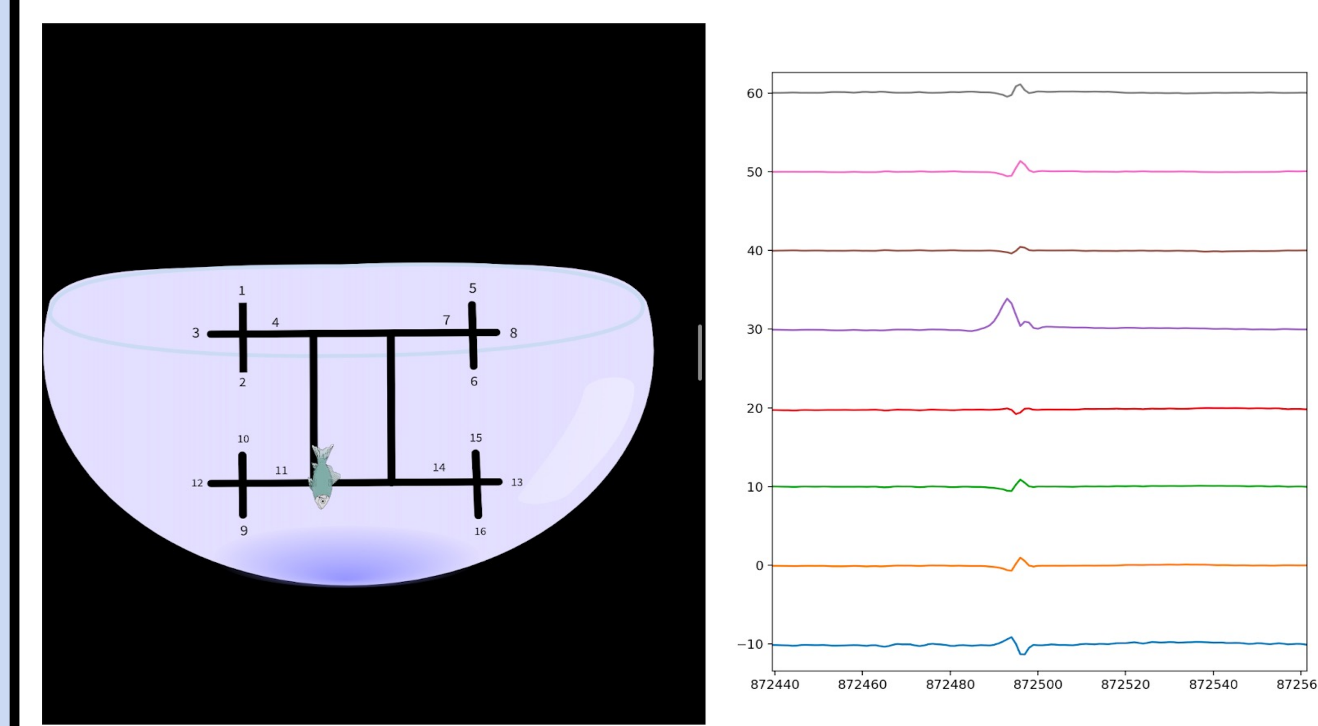

Figure 4: An example prediction that I made of fish location relative to electrode array based on varied recording of EOD waveforms at each of the 8 electrodes located at different parts of the tank. Note: in this recording, we used a different electrode geometry in the tank.

Discussion

- Due to the technical demands of the experimental set-up, we are only now approaching the beginning of the process of conducting controlled experiments and collecting data.
- The initial goal of the behavioral assay we have been developing is to study how interactions with a novel environment change in accordance with group size, and how such changes are related to electrocommunication.
- We will quantify individual fish's EOD rates and IPI coordination among fish as well as movement coordination as measures of group cohesion.
- We anticipate that EOD rates will increase during exploration of the novel environment and that changes in group size will change the demands on group cohesion. Furthermore, we expect that group cohesion in terms of movement and in terms of EOD coordination will increase as a function of group size.

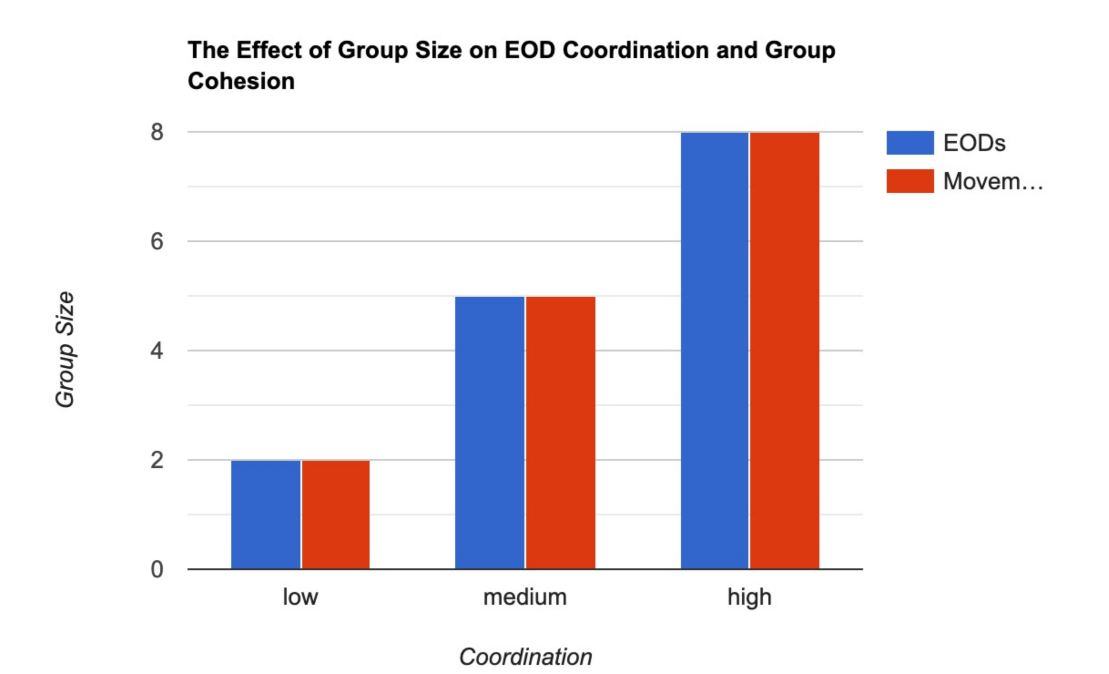

Figure 5: Predicted results of behavioral assay showing that group cohesion and EOD coordination both increase with increasing group size during novel environment exploration.

References

1. Gebhardt K *et al.* (2012), Electrocommunication behaviour during social interactions in two species of pulse-type weakly electric fishes (Mormyridae).
2. Martin Worm et al. (2017), Evidence for mutual allocation of social attention through interactive signaling in a mormyrid weakly electric fish.
3. Carlson BA. (2016), Differences in electrosensory anatomy and social behavior in an area of sympatry between two species of mormyrid electric fishes.
4. Joshua H Siegle *et al.* (2017), Open Ephys: an open-source, plugin-based platform for multichannel electrophysiology.
5. Gonçalo Lopes *et al.* (2015), Bonsai: an event-based framework for processing and controlling data streams.