Quantification of Environmental Motion Noise Relating to Jumping Spider Mating Displays

Kristen M. Snowden, David J. Morris, Nathan I. Morehouse

MOREHOUSE LAB

Introduction

The sensory drive hypothesis predicts that animals' sensory systems and signals will adapt to maximize efficacy according to local environmental conditions. This hypothesis explains why courtship displays are likely to change in different environments, eventually causing reproductive isolation and speciation (Endler 1992, fig. 1). Understanding processes - like sensory drive- that generate species diversity is critical in the face of climate change and widespread habitat destruction.

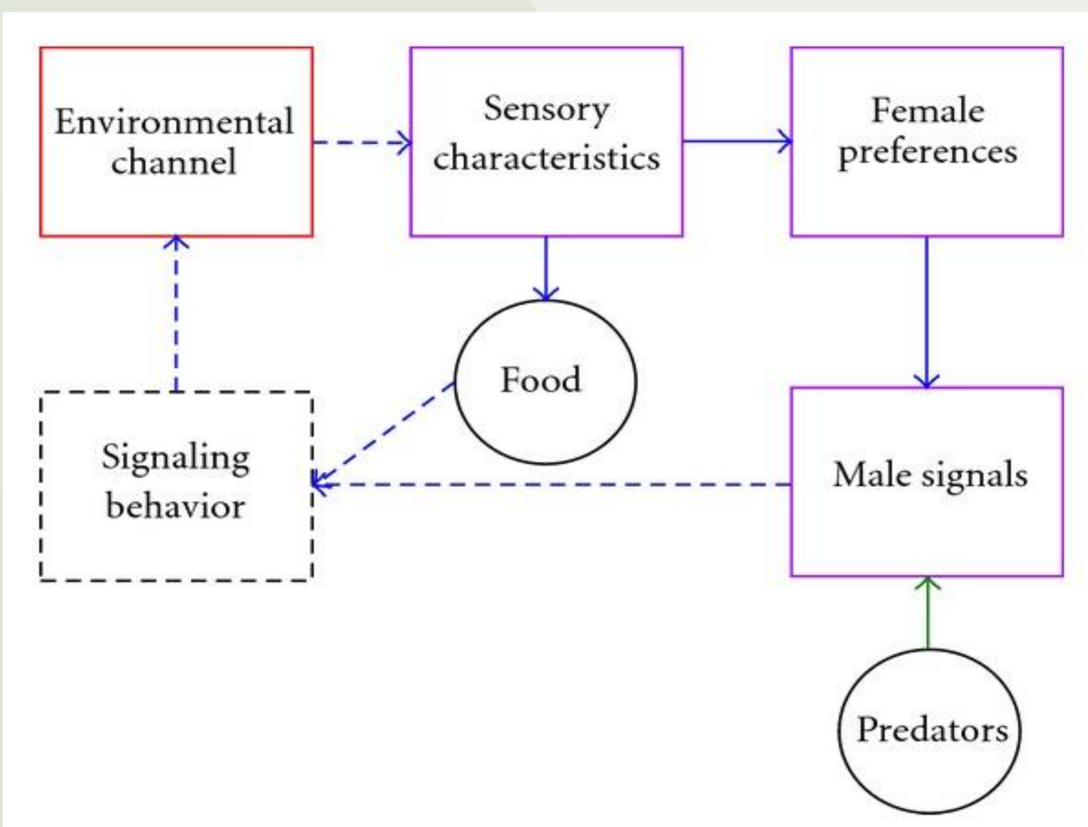

Figure 1: Relationships between different factors included in the sensory drive hypothesis

While there has been extensive research investigating certain types of signals and environments, like color vision and marine systems, other signaling modalities and environments remain critically understudied (Cummings and Endler 2018, fig. 2). Terrestrial habitats and motion signals both require additional study in order to understand how these components fit into the sensory drive framework.

Figure 2: Anoles use dewlap bobbing as a motion signal; (Pallus and Fleishma , 2009)

The jumping spider genus *Habronattus* is speciose, found across North America in diverse habitats, and males use elaborate courtship displays to convince females to mate. Like all jumping spiders, they have multiple pairs of eyes with segmented vision. Where some eye pairs are dedicated to motion sensing and orientation, their primary eyes have better resolution and color vision capabilities (fig. 3). Males initiate courtship displays with waving motions that should be visible to female secondary eyes, allowing the female to direct her primary eye pair towards the male to allow for further mate evaluation (fig. 4). We hypothesize that these male alert displays have evolved to maximize contrast between the motion signal and environmental background noise.

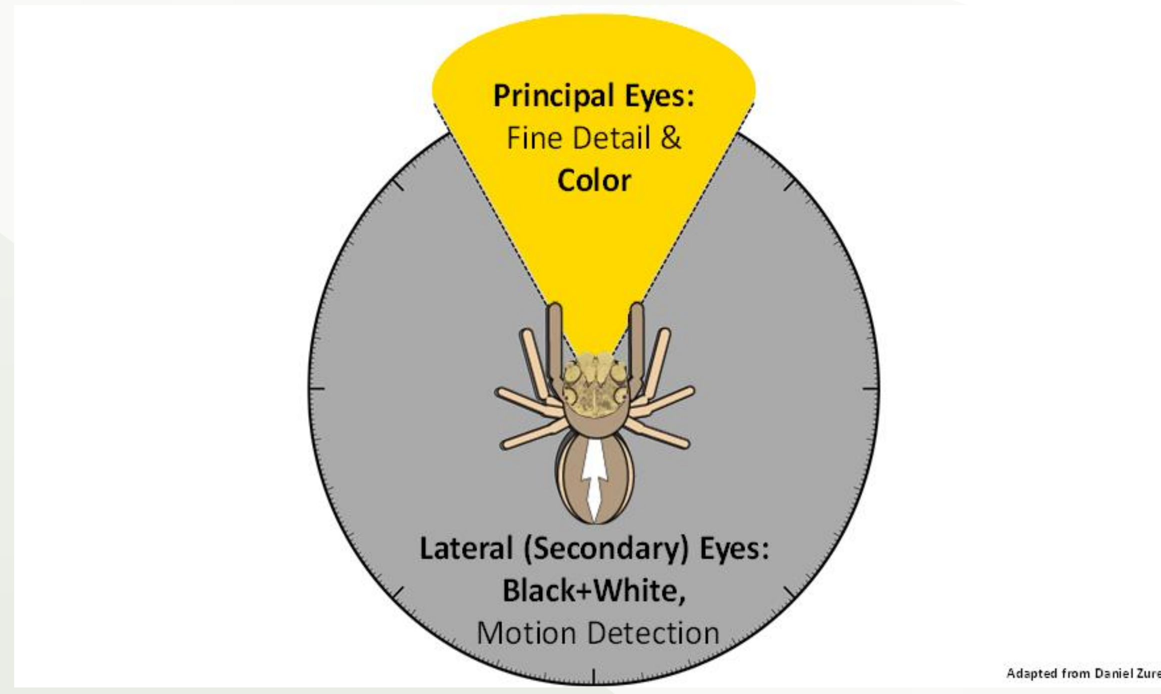

Figure 3: Division of jumping spider visual tasks; Posterior eye pairs detect motion, secondary eyes are used to orient the spider, and primary eyes are high acuity.

We collected numerous species of *Habronattus* jumping spiders, as well as habitat videos from each collection location. While we filmed male courtship displays for eventual comparative analysis, here we detail our first attempts to understand how to quantitatively represent habitat motion.

Figure 4: A male *H. pyrrithrix* proceeds with courtship after gaining female attention

Materials and Methods

We collected 20 species of *Habronattus* spiders specifically selected from diverse environments, from desert scrub brush to mountain meadows. Collection locations of individual spiders were marked with field flags. We then filmed each location in both the north and south for 30 seconds using a Panasonic GH4 camera. All videos were taken between the hours of 11:00 and 13:00 to reduce variation in brightness due to time of day.

To analyze habitat motion, we first selected the middle 15 seconds of each video to avoid any camera or habitat movement from the researchers as they moved to and from the camera. Remaining frames were blurred using a Gaussian filter to better approximate the resolution of jumping spider eyes. Each frame was then compared to the previous frame using the Farneback method to calculate the dense optical flow (Farneback, 2000). We extracted the total amount of motion per frame and plotted motion over time to determine which parts of the video were the most dynamic. We then visualized motion across those frames using circular histograms. We also represented all total motion measurements in circular histograms, and compared video motion within and between different *Habronattus* habitats.

Results

We created circular histograms to visualize the results of our habitat analysis (fig. 6).

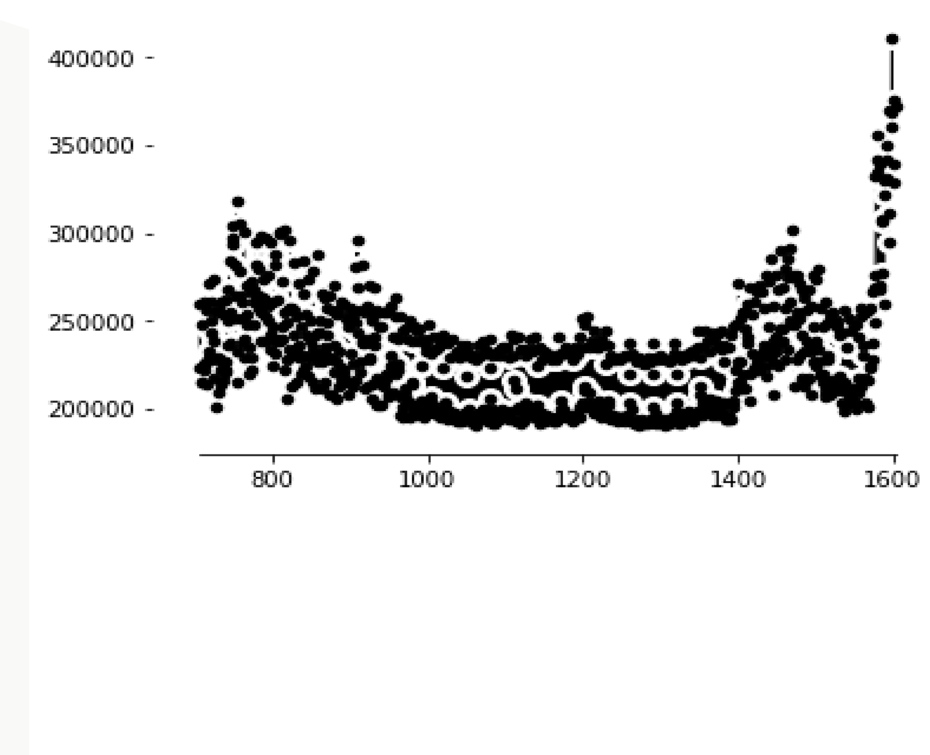

Figure 5: Scatterplot detailing the amount of motion over time in a single habitat video

We visualized information in multiple different ways. We used time series and overall motion in the video (fig. 6).

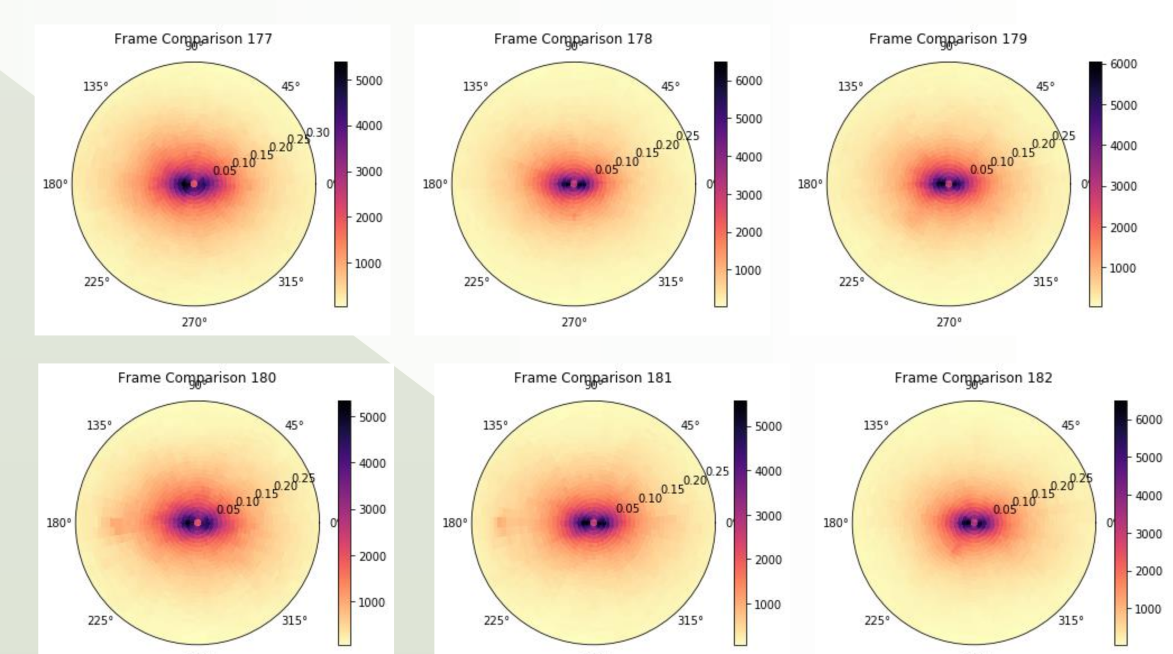

Figure 6: Circular histogram comparisons across multiple different frames in a single habitat video.

We were also able to compare the patterns of motion and the amount of motion across different habitats with different species (fig.7).

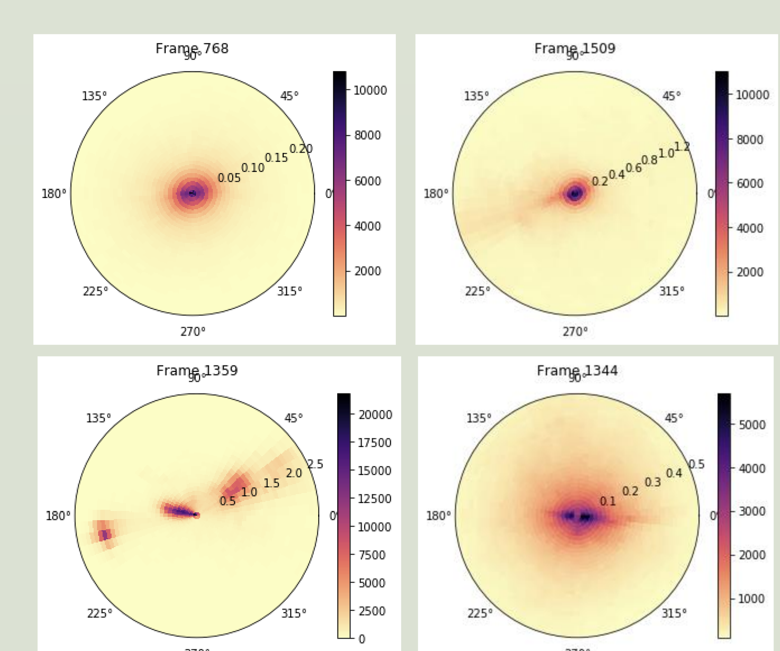

Figure 7: Each circular histogram represents environmental motion in a different habitat with a different species.

Discussion

Motion was found to be mostly bimodal, oscillating between 0 degrees and 180 degrees in the circular histograms. Within the same habitat comparisons, we were able to observe the similarities and differences between different frames. There was a clear change in motion from one side to the other, illustrating how oscillation between frames occurs. This could be due to wind or other movement of the grass or surrounding branches. While these differences in motion are clear, there were also periods of similarity in the frame comparisons. Upon comparing motion between habitats, stark differences were also observed. The difference in amount and magnitude of motion was clear. Environments that have more grass and plants had more total motion and larger magnitude of motions. Environments that are more sparsely filled with greenery had a consistent trend of less overall motion and a smaller magnitude of motion.

Figure 8: Selection of diverse jumping spider habitats

Now that we have anecdotally confirmed differences in motion, we need to statistically compare habitats. First we will perform a univariate ANOVA on total motion. Next, we will bin vectors by direction and perform Principal Component Analyses across habitats to determine which variables most contribute to motion variation. Once we determine how to best represent habitat motion complexity, we intend to use that metric as a predictive variable for male alert display evolution using phylogenetic comparative methods.

By examining the effect of habitat motion on male jumping spider courtship motion, we hope to better understand how terrestrial habitat heterogeneity fits into the broader context of sensory drive. Additionally, a greater understanding of habitat motion should allow us to better understand how changing environmental backdrops could impact the courtship success of organisms using motion cues in courtship.

Sources

1. Cummings, M. E., & Endler, J. A. (2018). 25 years of Sensory drive: The evidence and its Watery bias. *Current Zoology*, *64*(4), 471-484. doi:10.1093/cz/zoy043
2. Land, M. F. & Nilsson, D.-E. Animal Eyes. 2nd edn, (Oxford University Press, 2012)
3. Warrant, E. J. & Nilsson, D. E. Invertebrate Vision. (Cambridge University Press, 2006)
4. Harland, D. P., Li, D. & Jackson, R. R. in How Animals See the World: Comparative Behavior, Biology, and Evolution of Vision(eds O. F. Lazareva, T. Shimizu, & E. A. Wasserman) Ch. 9, 133-163 (Oxford University Press, 2012)
5. Pallus, A. C., Fleishman, L. J., & Castonguay, P. M. (2009). Modeling and measuring the visual detection of ecologically Relevant motion by AN Anolis lizard. Journal of Comparative Physiology A, 196(1), 1-13. doi:10.1007/s00359-009-0487-7
6. Farneback, G. (n.d.). Fast and accurate motion estimation using orientation tensors and parametric motion models. Proceedings 15th International Conference on Pattern Recognition. ICPR-2000. doi:10.1109/icpr.2000.905291
7. Endler, J. A. (1992). Signals, signal conditions, and the direction of evolution. The American Naturalist, 139. doi:10.1086/285308

Acknowledgments

Big thank you to all the members of the Morehouse Lab's research team, especially David Morris and Dr. Morehouse for invaluable mentoring and assistance. Funding provided by NSF (IOS –1734291) and NSF (IOS - 1831767).

Kristen Snowden
NSF Fellow
Morehouse Lab
Ksnowden2@outlook.com