Mantis Shrimp: Which Way is Home?

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Animals that live in a central location require the ability to navigate back home. Leaving a place of refuge means a much higher risk of being eaten, making an efficient return a high priority. One way animals can do this is through path integration. Path integration is a mechanism for an animal to orient themselves by remembering both the distance and angles of turns made during their journey away from refuge. Amazingly, these cues are constantly updated to calculate the best route for returning home. Navigation in aquatic environments is different from terrestrial as the turbidity of the water can easily disrupt visual information. Mantis shrimp live in shallow water, only leaving burrows for food and reproductive opportunities. Their ability to find home quickly and accurately lessens the probability of being preyed upon and prevents costly territorial fighting with rival mantis shrimp. Research has neglected to investigate path integration in aquatic environments, leaving a gap that Patel and Cronin (2020) address in their research with the mantis shrimp *Neogonodactylus oerstedii*.

To assess the ability of mantis shrimp to navigate, Patel and Cronin (2020) placed *N. oerstedii* in artificial burrows within a large, circular sandy arena to monitor their ability to find a way back home. The small 3-5 cm shrimp wandered around the arena until they encountered the food item placed 70 cm away. Yet they impressively took a direct route back to the artificial burrow. The researchers found interest in how the shrimp could orient themselves back home without needing to retrace their steps. To distinguish *N. oerstedii*'s methods of navigation, the researchers created a moving track that relocated the animal directionally while out with the food (Focus Fig. 1A). The results of the moving track test confirmed their suspicions – the mantis shrimp followed a return angle to where they thought their burrow would be had they not been displaced rather than to where it was after movement (Focus Fig. 1A). A corresponding shift parallel to the actual burrow location shows that the shrimp are not using other sensory information like odour or landmarks to determine where their burrow is. Otherwise, they would have accounted for the displacement.

The researchers then needed to determine whether the orientation of *N. oerstedii* was coming from external or internal cues. This time, a rotating platform was used outdoors under three different experimental conditions: clear skies, partly cloudy, and complete cloud cover. If the shrimp rely on external cues, rotation should not significantly impact their ability to find their burrow. However, internal compasses are susceptible to error, and rotation decreases navigation success. Patel and Cronin (2020) found that *N. oerstedii* had direct home paths in clear and partly cloudy sky conditions despite the 180º rotation (Focus Fig. 1B). However, under complete cloud cover, the shrimp proceeded away from their burrow (Focus Fig. 1B). Ultimately, these results show that the mantis shrimp can use sunlight cues. However, they use internal cues to navigate home when sunlight is unavailable.

So, what part of sunlight does *N. oerstedii* use as a cue? Patel and Cronin hypothesized that mantis shrimp use the sun's angle, or solar azimuth, to navigate. The authors manipulated the position of the sun while *N. oerstedii* was out of its burrow to show its dependence on solar angles. When the sun was blocked and mirrored 180º, many shrimp followed the altered sunlight direction (Focus Fig. 1C). These results confirm that the mantis shrimp can use celestial navigation to determine where their burrow is. Curiously, some shrimp arrived home accurately even after the sun was blocked and mirrored. Shouldn't partly cloudy skies prevent *N. oerstedii* from navigating if they solely rely on solar angle cues for a compass?

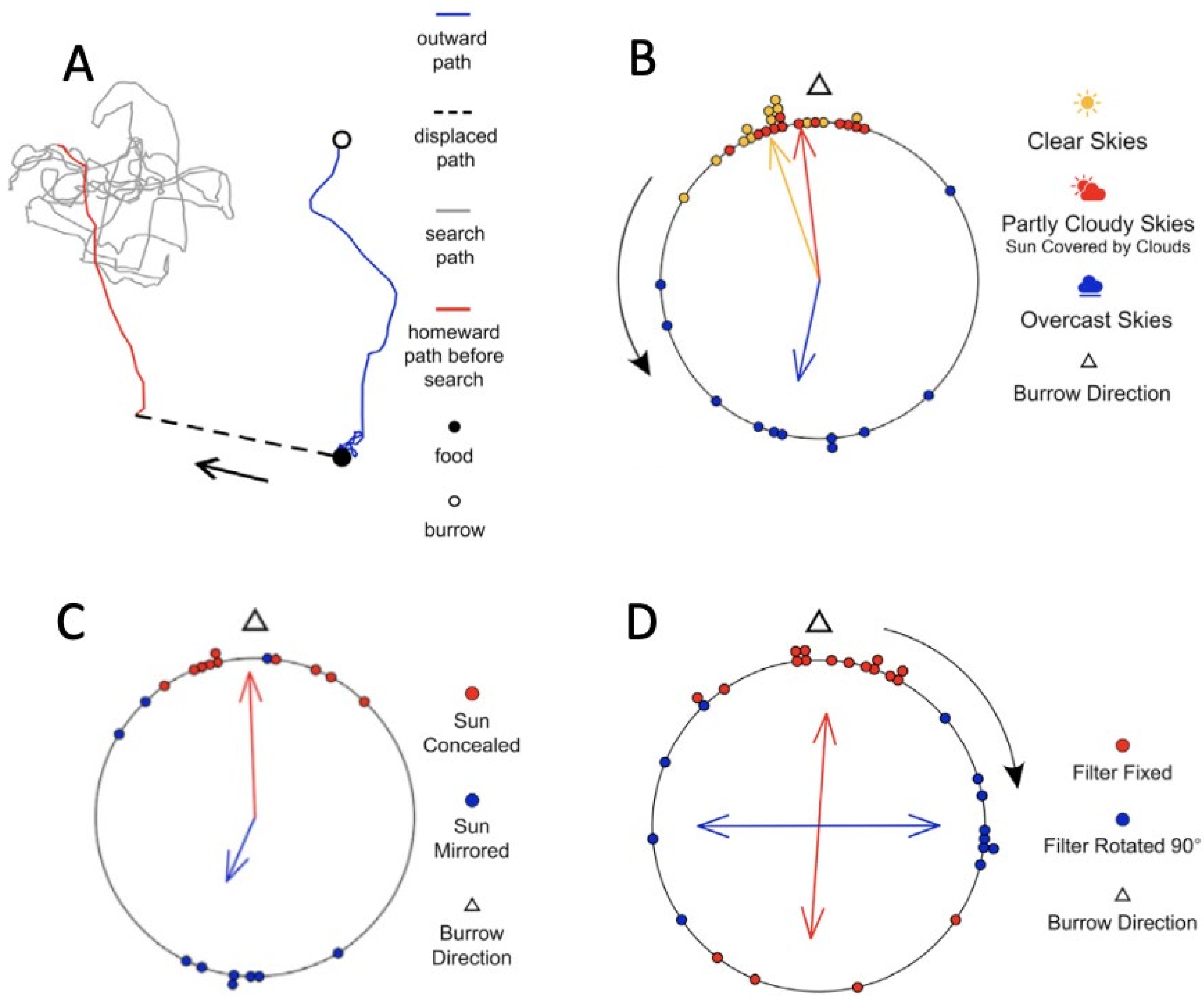
Patel and Cronin conducted one final experiment to determine what other methods mantis shrimp could use in their path integration. They proposed that *N. oerstedii* used additional celestial patterns like the polarization of light (specific directional movement of light waves, see Nag et al. 2023) to determine orientation. Polarization is visible to mantis shrimp at the water depths that they live in, making it a reliable cue to follow. They tested their theory using indoor arenas with artificial LED light wave filters. The researchers rotated the wave filter 90º once the shrimp reached the food. The shrimp followed the rotation of the polarizing field, showing their ability to perceive and follow light waves in path integration (Focus Fig. 1D).

To find their way home, mantis shrimp prefer to use solar angles, light waves, and then internal compasses hierarchically depending on the environmental context. Patel and Cronin's experiments help us understand the mechanisms behind orientation and home finding in *N.*

oerstedii. Being the first researchers to confirm path integration in an aquatic animal, they provide valuable insight into the sensory information needed for mantis shrimp to locate their burrows. *N. oerstedii* primarily live in shallow tropical waters, meaning they have relatively consistent access to solar information. Other species live in varying environments that create challenges associated with celestial cues. Rougher waters, deeper burrows, and murkier water can diminish the reliability of solar angles and waves. Previous research has shown that some aquatic animals use magnetic fields for guidance, which could be another cue for mantis shrimp. How many types of cues can mantis shrimp use? What are the neural structures responsible for generating a hierarchy of navigation cues? Looking into the complexity of aquatic invertebrate orientation systems can close our knowledge gap and increase appreciation for invertebrate complexity.

Reference List

Nag, N., Sasidharan, S., Saudagar, P., & Tripathi, T. 2023. Chapter 1 - Fundamentals of spectroscopy for biomolecular structure and dynamics. *Advanced Spectroscopic Methods to Study Biomolecular Structure and Dynamics.* pp. 1-35. Academic press. https://doi.org/10.1016/B978-0-323-99127-8.00002-7



Focus Figure 1. Directional and rotational manipulations made to determine the hierarchy of cues used in the path integration hierarchy of *Neogonodactylus oerstedii*. (A) The displacement of *N. oerstedii* on a track to determine use of path integration. *N. oerstedii* maintained the angle of homeward search after displacement, showing path integration ability (B) 180º rotational movement of the shrimp once it reached food under varying cloud coverage to determine use of celestial cues. The ability to adjust for rotation in sun exposure shows celestial cues are used. (C) Coverage and mirroring of sunlight to examine *N. oerstedii's* use of solar angles. Corresponding changes in homeward path with sun angle show the shrimp's ability to use solar angles in navigation. (D) Isolation and rotation of light polarization fields to determine the use of light waves as cues in navigation under partly cloudy conditions. *N. oerstedii* followed manipulations to polarization patterns, indicating the use of polarizing light waves in navigation.