**Electromyographs of Cockroach Flight Muscles in Analyzing Wing Beat Frequency and CPG**

**ABSTRACT**

For this study, we observed the wing beat frequencies between anterior and posterior wings of a cockroach to record EMGs to analyze the phase relationships between the elevator and depressor muscles. By retraining the cockroach with a post and tether rod, we drilled two holes into the both the mesa and meta of the cockroach to take *in vivo* recordings during roach flight. We hypothesized that manipulating flight conditions, of either wing pairs (anterior or posterior), would result in a decrease in functionality and wing beat frequency. Our tests included changing the direction wind currents were projected at the cockroach during flight, weighing down the anterior wings with water droplets, and lastly intoxicating our specimen with 1/11 parts EtOH. We found that, overall our hypothesis was correct due to the decrease in wing beat frequency after the any likely hindrance to the cockroach flight was applied.

**INTRODUCTION**

In this lab used *in vivo* electrophysiology to observe the flight behavior as evidence for the existence of central pattern generators in cockroaches. Through these recordings, we can analyze the wingbeat frequency to understand the phase relationship between elevator and depressor muscles of the anterior and posterior wing pairs.

We hypothesize that through manipulating flight conditions, of either wing pairs on the cockroach, will result in a decrease in functionality and wing beat frequency during flight.

**METHODS**

The methods used in this experiment can be found in the “Introduction to System and Behavioral Neurobiology,“ lab manual, under the section titled “Week 8: Electromyographs (EMGs) of the Cockroach Flight Muscles: Behavioral Evidence for the Existence of Central Pattern Generators (CPGs).”

**RESULTS**

The results of this experiment show that the beat cycles of each wing can be analyzed from numerous manipulations to determine the behavior of the cockroach’s central pattern generators.

Figures 1a, 1b, 1c, and 1d show the resulting recording of the flight pattern before anything is added or administered to the roach. The approximate beat frequency of the anterior left wing is 41.33 Hz, for the anterior right wing it is 40.54 Hz, the posterior left wing is 39.81 Hz, and for the posterior right wing it is 24.13 Hz. The greatest beat cycle difference is between the anterior left posterior right, with a difference of 17.2 Hz.

Figures 2a, 2b, 2c, and 2d display the recordings of all four wings on the cockroach as its’ flight is physically manipulated for a four second duration. In Figure 2a, we see that the normal flight pattern of the cockroach is continuous and each wing is consistently beating. Unlike 2a where the wind current is directed from in front of the roach, Figure 2b shows the resulting EMGs from projecting the wind to the left of the cockroach during flight. We can see in the figure that the frequency of the wing beat cycles is no longer continuous and has brief moments of little activity to no activity, especially in the posterior left and right wings (blue highlight shows hindered activity). In 2c the wind current is directed directly behind the cockroach. This completely inhibits the posterior right and left wings from beating; whereas, the anterior wings are experience moments of reduced beating. The final physical hindrance experienced by the cockroach is shown if 2d. Here, the cockroach’s anterior left and right wings are coated with numerous water droplets. This results in a similar effect shown in 2c. The posterior wings are inhibited, but the anterior front wings, though sporadically decreased in activity, are still able to function.

Figures 3a and 3b show the resulting EMG from the administration of 1/11 parts EtOH. In 3a, we see that 1 droplet of EtOH resulted in the beat frequency of the anterior left wing to be about 40.03 Hz, anterior right wing to be 22.28 Hz, posterior left wing to 16.54 Hz, and the posterior right wing to be 27.66 Hz. 3b shows the ingestion of 6 droplets of EtOH changed the beat frequency of the anterior left wing to 27.56 Hz, anterior right wing to 16.94 Hz, posterior left wing to 27.52 Hz, and posterior right to 28.01 Hz. The difference between the volume of EtOH ingested decreased the beat frequency of the anterior left wing 12.47 Hz, decreased the anterior right wing frequency by 5.34 Hz, increased the posterior left and right wings by 10.98 Hz and 0.35 Hz respectively.

**DISCUSSION**

The results of our experiment show that we were correct in hypothesizing that manipulating the flight conditions decreases the functionality and wing beat frequency of the cockroach during flight. This is supported by the relationship between comparing the flight EMG differences in beat frequencies of each wing from flight without any added hindrance to the recordings of flight with.

Manipulating the direction of the wind current projected at the cockroach, **Figure 2a** and **2b**, shows substantial hindrance on the posterior wings activity. The wind current was likely strong enough to prevent the cockroach from closing its’ hind wings; whereas, those in front faced some difficulty beating against the wind. The water droplets (**Figure 2c**) added to the anterior wings effected the anterior wings by adding excess weight onto them. This is turn also made it difficult for the roach to raise its posterior wings.

When we examine the first set of figures, **1a, 1b, 1c, & 1d,** we see that the anterior wings and the posterior left wing have a beat frequency of about 40 Hz. The right posterior wing, however, had a bf around 24.13 Hz. This difference was likely to result of us incompetently puncturing the roach wings during setup. We expect had that wing not been damages, each wing would beat around 40 Hz.

Comparing what was seen in the **figure 1** set, to **figure 3b**, the application of six drops of EtOH ingested by the roach, we see that the beat frequency of the anterior and posterior left wings decreased between 67 to 30 percent; whereas, due to the damage of the posterior right, the bf remained Around 26 Hz.

Overall, the decrease in beat frequency due to manipulations of the cockroach’s flight ability occurred because cockroach have not evolved to combat wing detriments because long flight is not evolutionarily beneficial in the main habitat (dark places like caves or in holes in a house) of these insects. Also, we saw from the experimentation, that wind current blowing passed the cockroach activates the central pattern generator for flight. This movement could be classified as complex (unlike reflexes) yet stereotyped (unlike directed movements), and repetitious (unlike fixed action patterns) (Hooper 2000).

Continuing studies of CPGs should focus around understanding if the CPG circuit integrates changing sensory inputs from the environments; such as, observing how the CPG changes if objects appear near or in front of the cockroach during flight.

**CITATIONS**

Bosma, Perkel, Kennedy, Canfield, Hass, Sisneros, (2016). *Introduction to Systems and Behavioral Neurobiology*. Department of Neurobiology, University of Washingtion, Seattle, Wa.

Hooper, (2000). *Central Pattern Generators*. Ohio University, Ohio, USA.