Abstract

Non-eye-movement vestibular cells fire only in response to head movement which makes them easier to analyze than vestibular cells that respond to both eye and head movements. No two neurons respond to stimuli in the same way. Response characteristics that vary include firing rate and location of firing rate during a cycle. However, the peak velocities to which neurons respond to are very similar. The smallest peak velocity that induces a patterned response is also known as the threshold. It can be very difficult to get accurate recordings at such low velocities with spontaneous firings interfering, but by using statistical analysis, the significance of the firing rate can be calculated. The data show these neurons significantly respond to peak velocities as low as 2.5 degrees per second (dps).

Introduction

The vestibular system integrates information from receptors located in the ear and sole of the head in order to detect the position and motion of the head in space. (Kelly 584-96) It is essential to one's coordination of motor responses, eye movements, and posture. Postural reflexes allow one to maintain stability even when an unexpected movement or loss of balance occurs. (Baker 913-30) When damaged, the vestibular system may cause dizziness or nausea. (Kelly 584-96)

There are multiple types of vestibular neurons. One type is sensitive to both head and eye movements. When analyzing these neural data, one would have to account for the neuron firings due to head movements as well as firings due to eye movements. The second type is only sensitive to head movements (Non-Eye Movement cells). This makes analyzing the data easier in that there is only one stimulus that can cause a neuron to fire, aside from its spontaneous firings. (Newlands, Lin, and Wei 1388-1397)

The Rayleigh statistic calculates the significance of the data. It verifies whether or not the neuron's firings are random or patterned. The ultimate goal is to use the Rayleigh statistic as a parameter to help find a peak velocity at which the neuron is still firing with a significant response to the stimulus.

Method

The data collected for this particular analysis comes from a single juvenile rhesus monkey (Macaca mulatta) in Shawn Newlands' lab. In order to prepare the monkey for testing, two surgeries were performed. To make sure the monkey was taken care of properly, it was treated with antibiotics and intramuscular buprenorphine for pain control in compliance with and performed according to "institutional and National Institutes of Health guidelines and under a protocol approved by the Institutional Animal Care and Use Committee at the University of Texas Medical Branch." (Newlands, Lin, and Wei 1388-1397)

For recordings, the tip of the electrodes were first placed into the ventral canal with the help from a guide tube. From here, the electrodes were guided through the vestibular nuclei using a remote-controlled hydraulic microdrive. To make sure that the electrodes were placed correctly, the lab identified the abducens nucleus bilaterally. Each last neuron was first confirmed using an auditory identification of firing in phase with rotation. (Newlands, Lin, and Wei 1388-1397) The data shown here are from recordings of 0.5 Hz at peak velocities ranging from 0.5 degrees per second to 90 degrees per second. The signals were first amplified and filtered (100Hz to 10kHz) and finally stored. (Newlands, Lin, and Wei 1388-1397)

Results

There were 39 non-eye-movement neurons that were used in this analysis. There were three possible frequencies (0.2Hz, 0.5Hz, and 1.0Hz) and 10 possible peak velocities (0, 1.0, 1.5, 2.5, 3.0, 5.0, 15.0, 20.0, 40.0, 60.0, and 80.0 dps). To prevent any influence from frequency, only the 0.5Hz data were used here. Also, the 10 dps and the 0.0 dps data were not recorded at 0.5Hz so they will not appear in figures 4 and 5. The rotation of the monkey at 0.5Hz for each peak velocity allows for a fairly accurate statistical input. This helps us identify the excitatory and inhibitory phases in the output.

Figure 1 is a good example of what we are looking for in terms of neuron firing. There is an excitatory and an inhibitory phase within a single cycle of the stimulus. Figure 3A demonstrates what an excellent neuron response would look like. You can clearly distinguish which part of the stimulus is the excitatory phase versus the inhibitory phase. Not all neurons will be as clean and clean cut as this one, which is why the Rayleigh statistic is so important. In figure 3C, you can see the sinusoidal output for the two separate phases, and we confirm this with the Rayleigh statistic. The reason for these being zero spike sections is that the peak velocity is so slow, the spontaneous neuron firings are interfering. However, there is still enough patterned firings that the Rayleigh statistic will indicate a significant response in the stimulus.

As shown in figure 4 the greater the stimulus velocity, the higher the Rayleigh statistic will be. As the peak velocity approaches threshold, there is more spontaneous activity. The Rayleigh test is an approximation of a chi-square test constrained with 2 degrees of freedom, appropriate for circular distributions. (Phan, and Lencz 2007). Therefore, Rayleigh statistics > 5.99 result in a 95% confidence. ("Chi Squared Distribution Tables") The Rayleigh statistic above is 12.08 at 2.5 dps showing that the threshold is lower than 2.5 dps. The average rate of the neuron firings (spikes/sec) seems to remain constant slightly increasing from 20 dps to 40 dps and also from 40 dps to 80 dps. The sync rate demonstrates how synchronized the neurons response is with the stimulus. Along with the Rayleigh statistic, the greater the peak velocity the more synchronous the response should appear. Lastly, the angle of the response is related to the start of the analysis. Because each piece of data began on a peak (maximum velocity) the analysis uses that starting point as zero. In this neuron, the excitatory phase constantly appears between 0 and positive 180 degrees.

Comparing the neuron in figure 5 to the neuron in figure 4 there are a few similarities. The first is that it is consistent with the expected increase in Rayleigh statistic with increasing peak velocity. Similarly, the sync rate above has the same trend as the sync rate in figure 4. However, there is a slight difference in average rate as well as angle between the two neurons. First the peak velocity was not recorded at the angle above ranges between 0 and negative 180 degrees while the angle to the left ranges from 0 to positive 180. This small difference proves that each neuron will have a slightly different excitatory phase and inhibitory phase for the same stimuli.

Conclusion

The non-eye-movement vestibular cells that were recorded from and analyzed show that the threshold for significant response is around 2.5 dps. It is difficult to say if this is the true threshold since there are only 19 neurons here, but we are confident it is no higher than that, being that several neurons showed this result. One improvement that will be made in future recordings is to increase the number of cycles at each peak velocity. Instead of recording only 7-10 cycles, we will be using 75-100 cycles which will help the Rayleigh statistic become more accurate. Therefore, we can be confident that the neuron actually is not only spontaneously firing at the low peak velocities.

In the near future, the other types of vestibular cells will be analyzed as well. It will be interesting to see if there is a different trend for the cells that are sensitive to both head and eye movements.

References