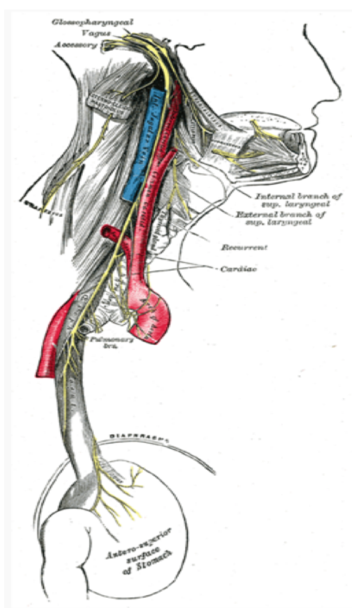
Non-Metallic Human Vagus Nerve Stimulator

Mengqiao Li, Sijian Yan, MEng ‘16
Advisor: Dr. Bruce Land, Dr. Adam Anderson
School of Electrical and Computer Engineering, Cornell University

Overview



The vagus (or “wandering”) nerve is cranial nerve 10, connecting the brain with vital organs (heart, lungs, gut).

- Vary heart rate
- Control food digestion
- Relieve stress
- Improve memory

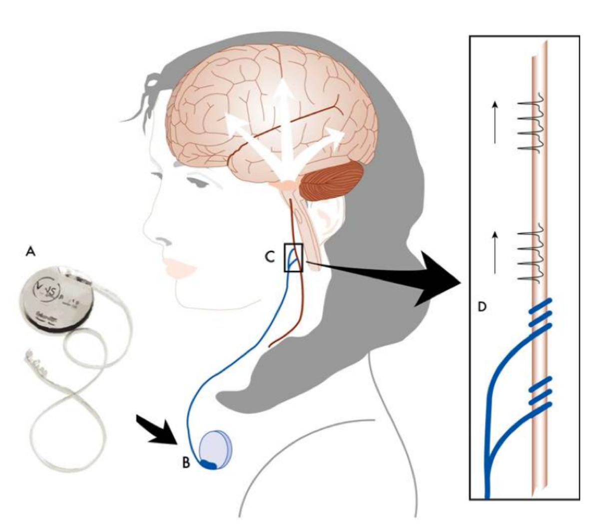
Existing highly invasive (implants between carotid and jugular) vagus stimulators has been approved by FDA for a variety of conditions, including Major Depression. But Human ecology scientists at Cornell are looking for a non-invasive device utilizing the fact that the vagus receives input from touch receptors around the ear.

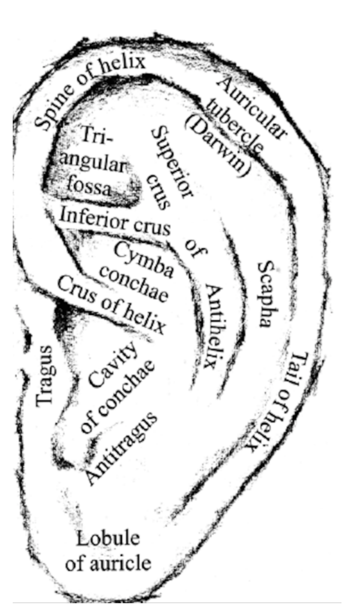
Goals of this project:

- Build an around-the-ear device that is capable of generating varying vibratory frequencies
- Discover the vibrat frequency of around-the-ear vagus nerve stimulation that has the most significant influence to human heart rate
- Figure out a way to make the device MRI compatible – non-metallic

Approach

Circuit Implementation → EKG Experiment → Statistical Analysis → Encapsulation

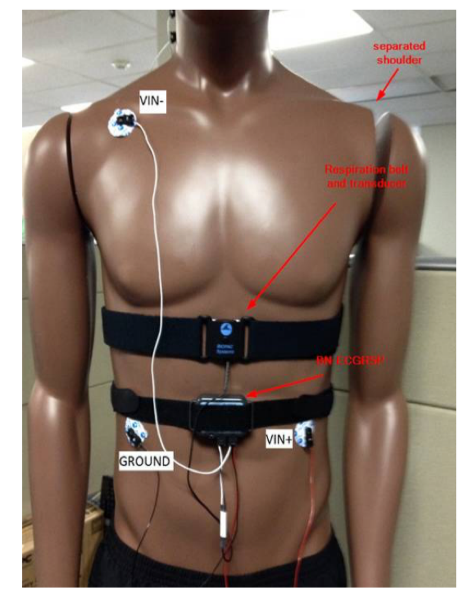




Tragus and **Cavity of concha** both contain 45% of vagus nerve receptors. **Antihelix** contains 75% and all of the receptors in **Cymba Conchae** are vagus nerve receptor.

Design and Implementation

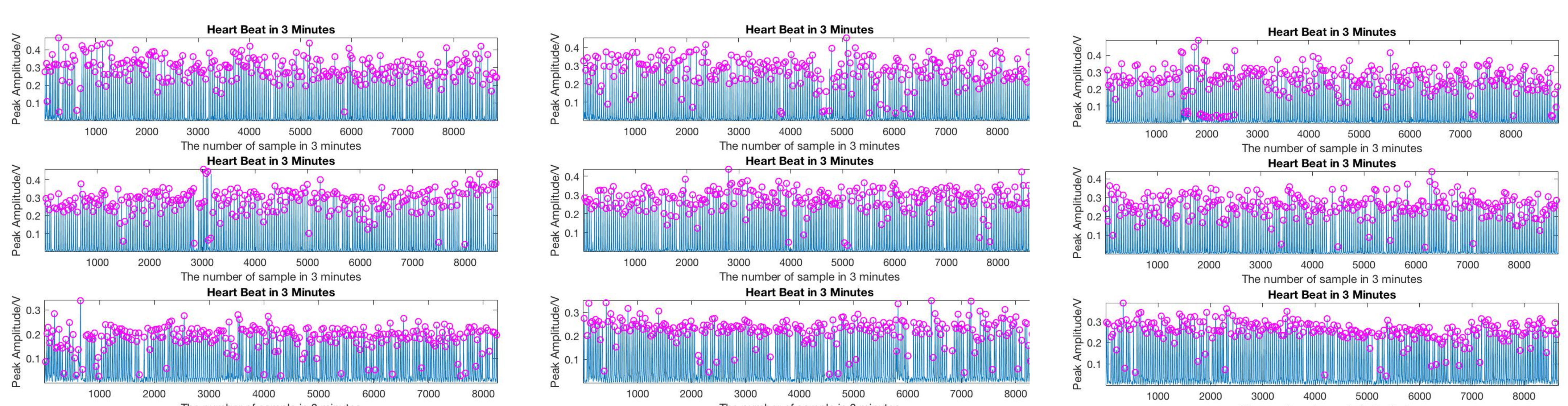
- **Circuit Board**
  - Generate Varying Frequencies
- **Experiments**
  - Circuit Testing
  - Heart Rate Data Collection under Different States
- **Statistical Analysis**
  - Pan-Tompkins Algorithm
  - Interval Distribution Analysis
- **Encapsulation**
  - Black box
  - MRI compatible materials



Experimental Results

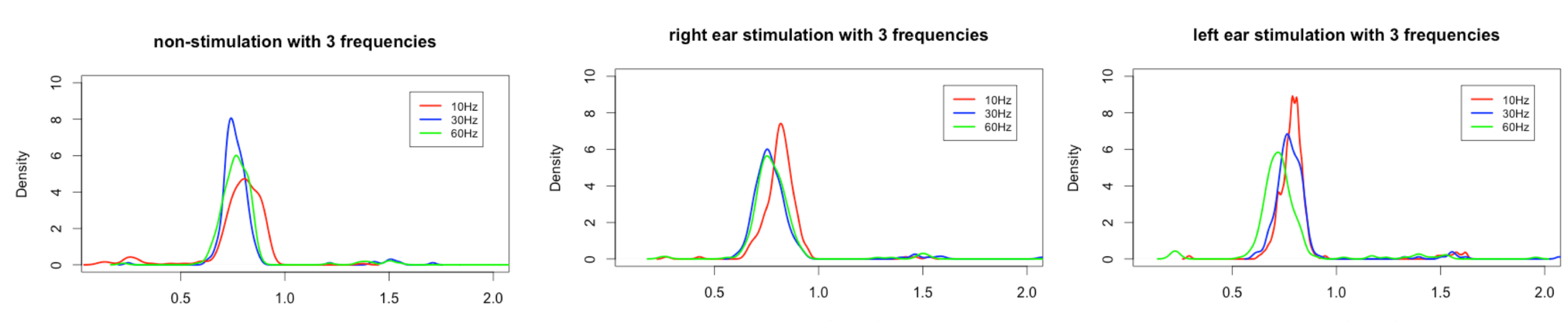
- **Pan-Tompkins peak analysis**

Peak Location – Left   Peak Location – Right   Peak Location – Still



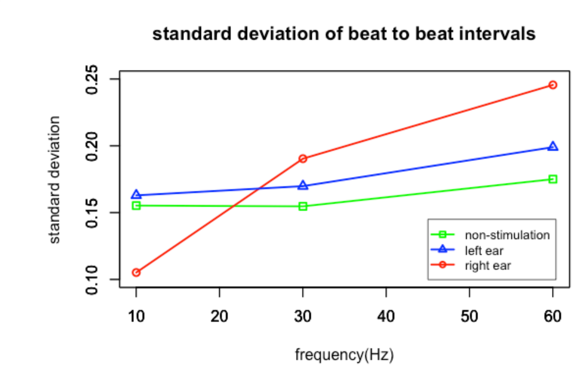
The figures above show the heart beat (from single subject) versus time. Each X-axis represents three minutes and the plots from top to bottom are measured under 10Hz, 30Hz, and 60Hz stimulation respectively.

- **Interval Distribution Analysis**



These three figures represent the heart beat interval distribution under different stimulation frequencies. Normally the wider the peak is, the more variable the heart rate is considered to be.

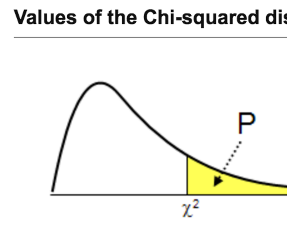
Evaluation



Greater standard deviation of beat-to-beat intervals indicates a more varying heart rate. Here we can see that heart rate varies the most when stimulating right ear with 60Hz frequency.

In order to evaluate the correlations of stimulating left ear V.S. still and stimulation right ear V.S. still, we used Chi-squared to determine whether there is a significant difference between the expected frequencies and the observed frequencies in our experiments.

Values of the Chi-squared distribution



sum_left10	1.2866e+03
sum_left30	594.2301
sum_left60	749.0761
sum_right10	1.2604e+03
sum_right30	594.2301
sum_right60	1.1400e+03

	P										
DF	0.995	0.975	0.20	0.10	0.05	0.025	0.02	0.01	0.005	0.002	0.001
1	0.0000393	0.000982	1.642	2.706	3.841	5.024	5.412	6.635	7.879	9.550	10.828
2	0.0100	0.0506	3.219	4.605	5.991	7.378	7.824	9.210	10.597	12.429	13.816
……											
225	174.116	185.348	242.631	252.578	260.992	268.438	270.681	277.269	283.390	290.925	296.288
226	174.995	186.256	243.671	253.638	262.070	269.530	271.777	278.379	284.511	292.061	297.433
227	175.874	187.164	244.711	254.699	263.147	270.622	272.874	279.488	285.632	293.196	298.579

Here the degree of freedom is 226 since the number of sample is 227. All of the numbers exceed the standard value in the table above. Therefore, it is not convincing to conclude any relationship based on Chi-Square calculation. Further test is needed.

Conclusion

Our device has achieved fundamental functions. Statistical analysis of experimental results using this stimulator doesn’t indicate a more varying heart rate under vagus nerve stimulating circumstances so more further evaluations are needed. It could because the number of testers is too small to be analyze statistically.

Further work will be to make a better shaped, more compatible end of the device, as well as test multiple subjects. Furthermore, improvement could be made to meet the need of MRI compatibility since the potential application in medial still exists.

Acknowledgements

We would like to thank our advisor Dr. Bruce Land for his advice, encouragement, and continued support of this project.
We also need to thank to Dr. Adam Anderson and his PhD student Ross Markello for their external help with using medical equipment.

References

[1] “Course and distribution of theglossopharyngeal, vagus, and accessory nerves.” Quote from: https://en.wikipedia.org/wiki/Vagus_nerve
[2] “Vagus nerve stimulation”, MAYO CLINIC. Quote from: http://www.mayoclinic.org/tests-procedures/vagus-nerve-stimulation/home/ovc-20167755
[3] “Complete Pan Tompkins Implementation ECG QRS Detector”, MathWorks. Quote from: http://www.mathworks.com/matlabcentral/fileexchange/45840-complete-pan-tompkins-implementation-ecg-qrs-detector/content/pan_tompkin.m
[4] “Values of the Chi-squared distribution”, MadCalc, Quote from: https://www.medcalc.org/manual/chi-square-table.php