Computerized Heart Rate Audio Device (CHAD)

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Motivation

Our motivation is an Air Force Veteran who retired and served as a sheriff as a result developed PTSD related nightmares. These nightmares have greatly affected his ability to experience a healthy nights rest and mental health.

Introduction

The purpose of this project is to create a device to awaken veterans who are experiencing PTSD nightmares. These nightmares frequently and often impact their quality of life due to their bodies' traumatic reactions and responses. This device will detect a nightmare, confirm the input is a nightmare, and complete an output that will reach different thresholds. The thresholds will start small and slowly gain until the system registers another input that the terror has ceased and the patient is either awake or sleeping peacefully.

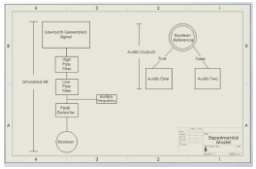
To gain a better understanding of PTSD, nightmare disorders, and instrumentation our group consulted with many experts of their respective fields. This included expertise from Dr. Maria Gerschutz, Dr. Stephen Carr, Dr. Sanjay Jain, and Dr. Andrea Mitofsky who gave advice over sensor integration, system power, respiratory and sleep risks, and coding analysis respectively. Through the year, BAE Systems provided the team with three mentors: Frank Sanchez, Scott Swymeler, and Emily McAfee who provided feedback and engineering expertise.

Project Specifications

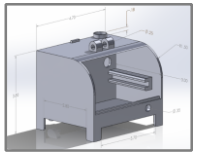
Specification	Unit	Value
Size	Inches (in.)	<8 in x 5 in x 5 in
Cost	USD	<$1500
Power Supply	*volts*	5V - 7 V
Safety	Pass/Fail	-Audibility -Power
Comfort	%	-Questionnaire >70%
Appearance	Pass/Fail	No sharp edges, loose wires, agreeable design

Modeling

The CHAD team wanted to create a proof of concept to demonstrate that an audio can be generated from a HR. In a conceptual model created in LabVIEW the team generated a simulated HR using a sawtooth graph passed through a high pass filter and low pass filter. After the two filters the graph's frequency could be multiplied in order to manipulate the outputted HR. The HR was connected to a Boolean, if the Boolean was true one audio was generated. And to prove there was no false positive, the false Boolean generated an audio as well. A model outline can be seen below in **Figure X.**

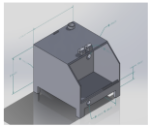


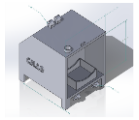
The second model created by the team was CAD for an external housing unit. These included housings for the microcontroller, soundboard and speaker system. The system was designed based off the dimensions of components that the team had selected. It includes two important housing units, the front will house the speaker and the back houses a slot where the microcontroller and soundboard will be placed.

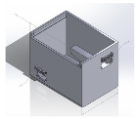


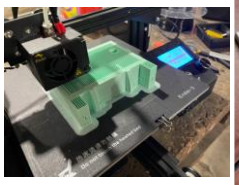
Development

System was developed through multiple CAD integrations with 3D prototyping, Code Design, and Circuitry Analysis









Verification and Validation

Sensor Accuracy:

The group took samples on four different subjects, while simultaneously taking data on the Polar HR sensor and Apple Watch. This data was then run through a paired data t-test to show that the Apple Watch and the Polar HR sensor are significantly similar.The Sensor Accuracy Testing concluded that the Apple Watch and Polar HR sensor are significantly similar (P value > 0.05) further validating that the Polar HR sensor will accurately collect HR data readings.

Apple HR (sitting)	Polar HR (sitting)
61	60
64	62
64	64

Null hypothesis H₀: μ_difference = 5
Alternative hypothesis H₁: μ_difference > 5

T-Value	P-Value
-6.93	0.990

Apple HR (Standing)	Polar HR (Standing)
70	72
76	72
70	70

Null hypothesis H₀: μ_difference = 5
Alternative hypothesis H₁: μ_difference > 5

T-Value	P-Value
-2.46	0.933

Sensor Sensitivity:

Heart rate data was collected from four subjects using an apple watch and Polar HR sensor while the subjects performed jumping jacks, running and sit-ups. A paired t-test was performed to analyze the significance. The evidence from paired t-tests (P value > 0.05). The team concluded that the Polar HR sensor is sensitive to capture changes in heart rate when the body moves in different directions and can be used in the CHAD device

Apple HR (jumping jacks)	Polar HR (jumping jacks)
115	114
138	132
157	124

Null hypothesis H₀: μ_difference = 0
Alternative hypothesis H₁: μ_difference ≠ 0

T-Value	P-Value
1.34	0.312

Apple HR (running)	Polar HR (Sit ups)
129	122
149	156
150	150

Null hypothesis H₀: μ_difference = 0
Alternative hypothesis H₁: μ_difference ≠ 0

T-Value	P-Value
0.00	1.000

Power Testing:

Though the adaptor will help assist in voltage load, the device must still fit within normal voltage ranges to meet engineering and safety standards. By calculating and testing a safe operation range, the risks of overcharging the circuit, causing internal damage, and possible fires are reduced. Utilizing a multimeter, the team measured the minimal operational voltage and compared the values in accordance to the IEC standard for voltages which further validated the safety requirements for CHAD [1].

	Measured Operational Voltage (V)		
Test	Microcontroller	Soundboard	Polar Sensor Receiver*
1	4.99	5.00	5.00
2	5.00	5.01	5.00
3	4.99	5.00	5.00
Average	4.99	5.00	5.00
Standard Deviation	0.005	0.005	0

*Voltage according to the product distributor.

Sound Testing:

The purpose of this test is to determine a range of hearing frequencies and amplitudes using a frequency generator to develop a sound gradient that will adequately wake the user from low levels of REM sleep. Since the ranges and thresholds of each subject are dissimilar, this allowed the CHAD team to effectively generate a sound gradient that is deemed to be satisfactory for the CHAD project. Test was completed following ASTM standards [2].

Conclusions

The development of CHAD allows users with PTSD nightmares to be woken from the REM sleep cycle where these vivid nightmares occur. Based on the customer's requirements and specifications, the team set and followed project goals and objectives to efficiently engineer a system that detects the stimuli of an increase in heart rate caused by a nightmare and outputs a sound stimulus that will awaken the user. While the team has a few potential recommendations for later revisions and models, the CHAD system shows great promise in its functionality and reliability.

Future Directions

Wifi chip: Currently, the CHAD device utilizes SPI to connect the transmitter from the Polar Heart-Rate sensor to receiver within the external console. This connection has a short connection distance, and can only receive data. If wifi was utilized instead, the user could use the device at a larger distance range and provide the possibility of a user interface.

User Interface: The current device can only receive data and measure it against predetermined heart rate ranges. Through the utilization of an app or screen-based interface, the user can input their heart rate ranges or read past data. This form of interface could also be utilized by healthcare professionals for information on sleeping habits.

High Grade Sensor: The team had to optimize the system for the sensor. The optimization was accounted to use of a Polar HR monitor intended for cardiovascular activities, such as exercise. Therefore, a medical grade sensor with higher accuracy and stability would greatly increase CHAD's accuracy.

Literature Cited

[1] Standard Test Method for Measurement of Sound in Residential Spaces, ASTM E1574 - 98(2014), 2014

[2] Medical electrical equipment — Part 1-11: General requirements for basic safety and essential performance — Collateral standard: Requirements for medical electrical equipment and medical electrical systems used in the home healthcare environment, IEC 60601-1- 11:2015, 2015

Acknowledgements

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Contacts