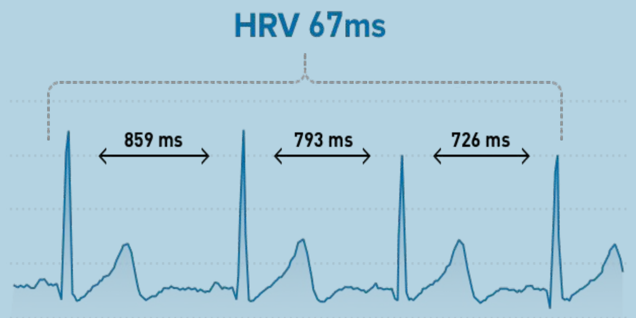
Development of an Autonomous WatchOS Application that uses HRV and Vibrational Pulses to Reduce Stress

Literature Review

- Over 70% of people's mental and physical health suffer due to effects of stress and conditions that may arise from it (Bethune, 2021)
- Heart Rate Variability (HRV) is a measure of the variation in time between each heartbeat (Campos, 2017)



- HRV is recorded through cardiac monitors such as ECG/EKG (Shaffer & Ginsberg, 2017)
  - For low HRV, time between each subsequent heartbeat is shorter
  - For high HRV, time between each subsequent heartbeat is longer
- HRV directly correlates with stress and other physiological attributes (Lehrer & Gevirtz, 2014)
  - Such as regulating heart rate, blood pressure, or breathing
- Upward HRV trends indicate overall health improvements (Deusen, 2019)
  - Lower HRV trends tend to mean more stress while higher HRV trends tend to mean less stress (Schubert et al., 2010)
- Stress relieving activities take valuable time away from the task that is trying to be completed (Segal et al., 2021)
- Vibrational pulses made people focus more clearly than without vibrations (Azevedo et al., 2017)
- A fast rhythm creates a more energetic feeling while a slower rhythm creates a more calming feel (Webster et al., 2005)
- STAI, or State-Trait Anxiety Inventory, questionnaire measures participant reported stress and anxiety levels (Spielberger et al., 2010)
- Heart Rate (HR) is a measure of the rate of which the heart beats (Silva et al., 2018)

Purpose Statement

- The purpose of the project is to develop an autonomous WatchOS application that uses HRV and vibrational pulses to reduce stress without taking time away from the task that is trying to be completed

Previous Research

- Coded WatchOS application that would send pulses based on active HR
- Gave task of summarizing an article
  - Found there were too many variables
  - Some were better at reading/writing
  - Rubric was bias on reviewer's judgement
- VAS questionnaire
  - Not very accurate in measuring stress
- Inconsistent heart rate data
  - HRV data was simplified and averaged out as RR intervals were derived from bpm
- Results found that Group with pulses scored better on task and had lower HR and higher HRV
  - Group with pulses also self-reported having more stress than the control group
- Low participant size of 4 participants due to COVID-restrictions

Methods

Developed WatchOS application and iOS companion app in Xcode

- Application emits vibrational pulses based on the user's current HR and resting HR until the user's current HR matches their resting HR
- HR data is automatically stored after each haptic session to the iOS companion app for viewing
- Mentors gave feedback on the development of the application and gave suggestions on the experimental design

Testing Application

- Based on of our mentor's previous experiment (Azevedo et al., 2017)
- *Group 1: Did not receive pulses, Group 2: Received pulses*
- For both groups, participants wore the watch on their non-dominant wrist with the application active
  - CorSense sensor was attached to their non-dominant hand's index finger to monitor cardiac activity
- All participants were given a control of 5 untimed practice problems in which the vibrations were not emitted
- Participants were then given 10 minutes to complete 50 Algebra 1 based math questions
- Participants also completed an STAI questionnaire before and after the stressful task to record reported stress levels

Figure 1.
- UI of application
- Shows HR and time

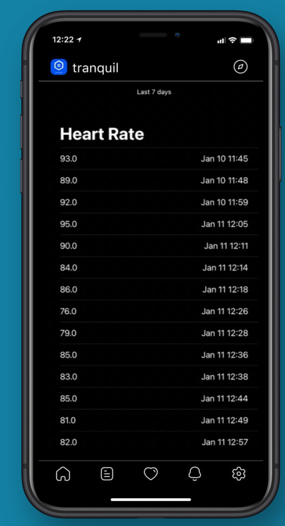


Figure 2.
- iOS companion app to monitor HR for the user

Results

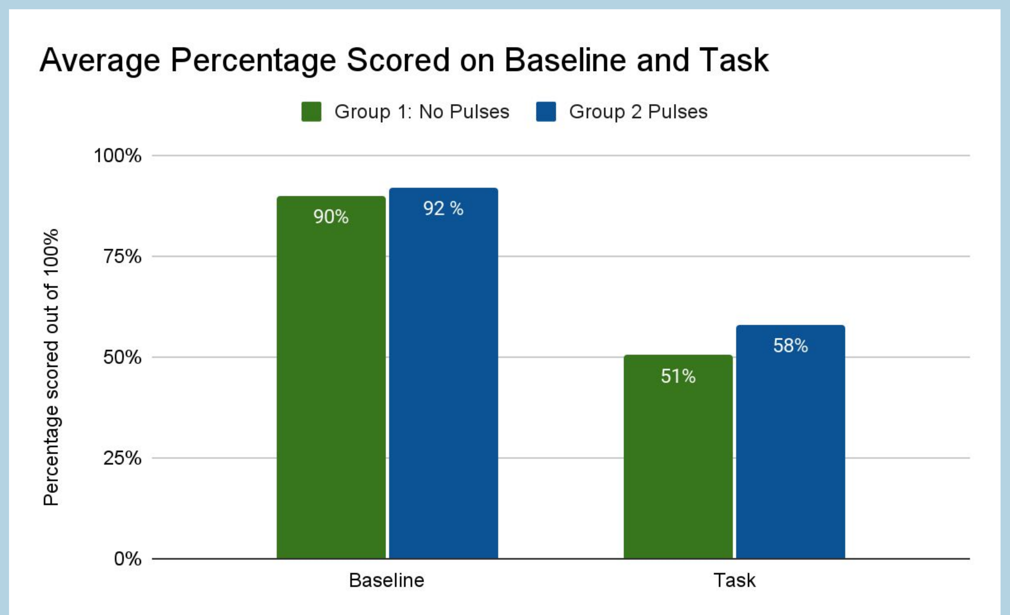


Figure 3: Results of average baseline scores and average 10-min task performance for Group 1 and Group 2

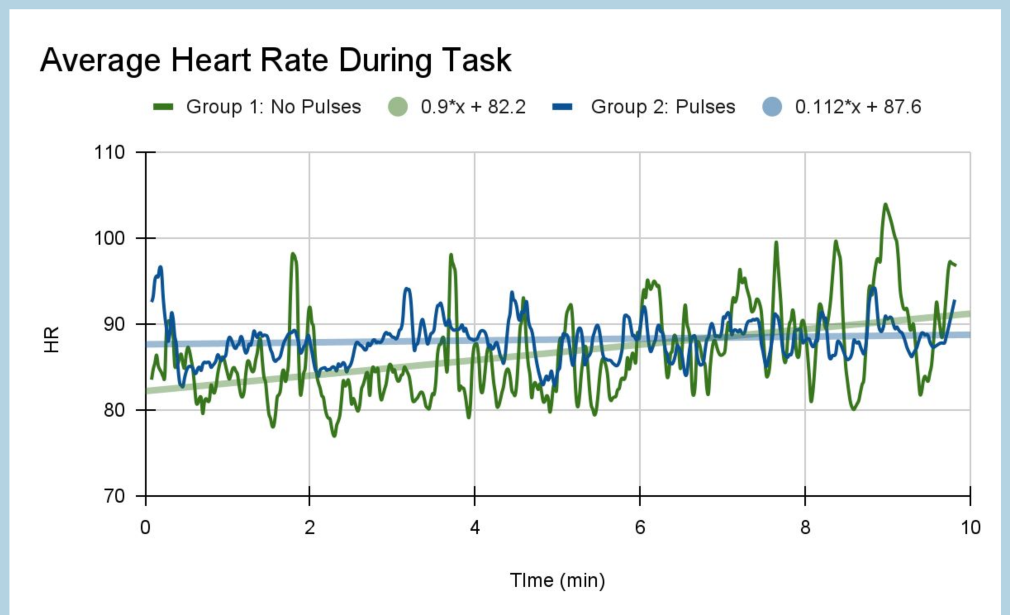


Figure 5: Results of moving average HR trends for Group 1 and Group 2 during 10 min task

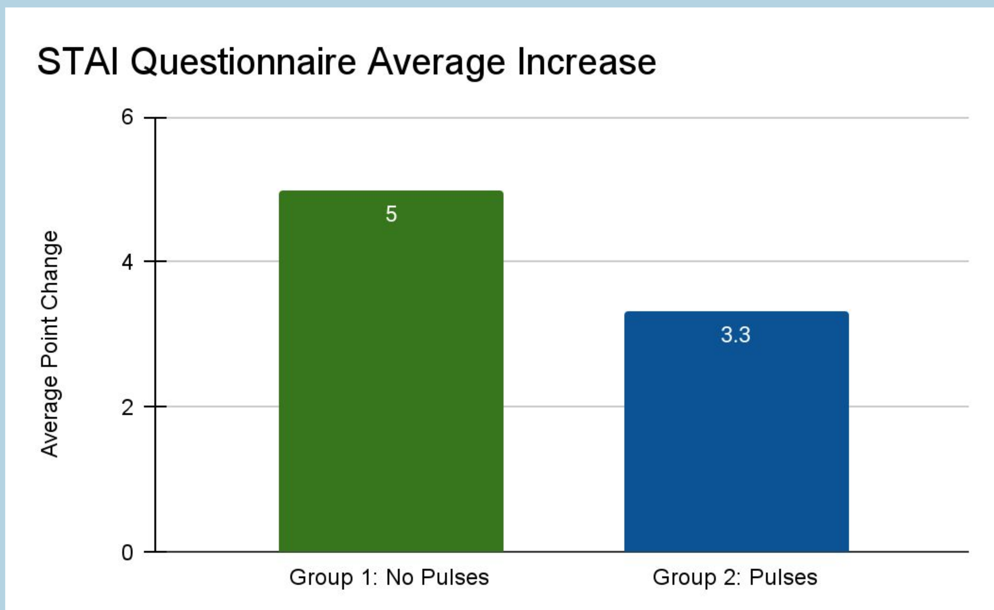


Figure 4: Results of STAI average change from before and after task for Group 1 and Group 2

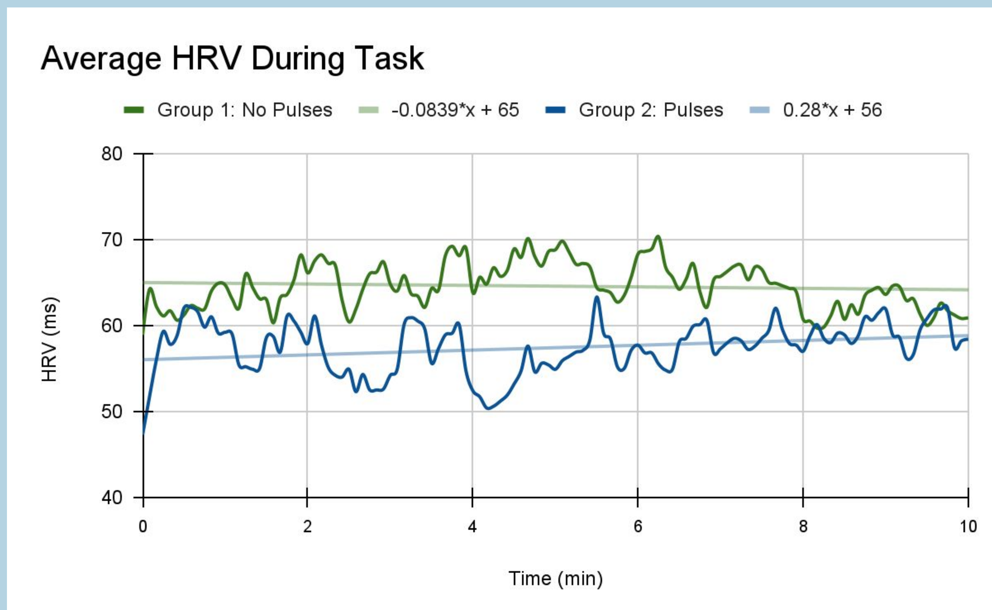


Figure 6: Results of moving average HRV (RMSSD) trends for Group 1 and Group 2 during 10 min task

Results Summary

- Group 2, which received the vibrational pulses, scored higher on the task by 7% than Group 1. A higher score by Group 2 was predicted
- Average HRV trends for Group 2 increased during the task while HRV trends for Group 1 decreased during the task. An increasing HRV trend for Group 2 was predicted
- Average HR trends for Group 2 increased less during the task while HR trends for Group 1 increased more during the task. A lower increasing HR trend for Group 2 was predicted
- STAI questionnaire average increase was lower for Group 2 by 1.7 points compared to Group 1. A lower score by Group 2 was predicted
- Group 2 scored 2% higher than Group 1 on the baseline test

Data Analysis

- Task
  - Paired t-test of Group 1's baseline and task performance was $p = 0.00065$
  - Paired t-test of Group 2's baseline and task performance was $p = 0.0031$
- HRV
  - Two sample t-test for Group 1 and Group 2 HRV was t-value = 19.65; p value was < 0.00001
- Heart Rate
  - Two sample t-test for Group 1 and Group 2 HR was t-value = -3.66; p value was < 0.000136
- STAI
  - Paired t-test of Group 1's STAI results before and after the task was $p = 0.00065$
  - Paired t-test of Group 2's STAI results before and after the task was $p = 0.042$

**All measures reach a statistical significance of $p < .05$*

Discussion

- Analysis shows there was a statistical significance for Group 1's baseline to task performance and Group 2's baseline to task performance
  - Supports reliability of Group 2's higher average score
- There was a statistical significance for HR and HRV comparing Group 1 and Group 2
  - Supports the trend of decreased HR and increased HRV for Group 2
- There was also a statistical significance for Group 1's STAI before and after results and Group 2's STAI before and after results
  - Supports the lower average increase for Group 2
- Data revealed minimal group differences for the baseline test
  - Shows that Group 2 doesn't overly excel in the area of the task compared to Group 1

Conclusion

- Prior studies support the results and conclusion (Azevedo et al., 2017)
  - In their study, the group that received the pulses had lower HR and measured stress levels
  - Group 2 also had similar results
    - Group 2 had better performance on the task and showed trends of lower stress through psychological and physiological measures compared to Group 1
- Limitations
  - Corsense data had a few artifacts during reading
  - Low sample size of 20 participants

Implications

Continue development of application
- More populous testing
- Add custom gestures and haptic responses

Develop application for other smart watches
- More accessible to users

Create own device
- More affordable
- Custom visual and engineering design

Research haptics
- Research into how different vibrational pulse frequencies/rhythms affect participants

Improve user's quality of life
- Help people focus and reduce their symptoms of stress and anxiety without taking away valuable time from their lives

Works Cited

Bethune, Sophie. "Teen Stress Rivals that of Adults." Apa.org, 2021, www.apa.org/monitor/2014/04/teen-stress#:~:text=Despite%20the%20impact%20that%20stress.
Campos, Marcelo. "Heart Rate Variability: A New Way to Track Well-Being - Harvard Health Blog." Harvard Health Blog, 22 Nov. 2017, www.health.harvard.edu/blog/heart-rate-variability-new-way-track-well-2017112212789. Accessed 12 June 2019.
Deusen, Mark Van. "Heart Rate Variability Graph." WHOOP, 11 Aug. 2021, 48tqxd3ngl0432pqy41i9ohn-wpengine.netdna-ssl.com/wp-content/uploads/2019/09/RR-intervals-heart-rate-variability.ms_whoop_.png.
Deusen, Mark Van. "Heart Rate Variability | The Ultimate Guide to HRV." WHOOP, WHOOP, 30 Sept. 2019, www.whoop.com/thelocker/heart-rate-variability-hrv/.
Lehrer, Paul M, and Richard Gevirtz. "Heart rate variability biofeedback: how and why does it work?." Frontiers in psychology vol. 5 756. 21 Jul. 2014, doi:10.3389/fpsyg.2014.00756
Schubert, C et al. "Effects of stress on heart rate complexity--a comparison between short-term and chronic stress." Biological psychology vol. 80,3 (2009): 325-32. doi:10.1016/j.biopsycho.2008.11.005
Shaffer, Fred, and J P Ginsberg. "An Overview of Heart Rate Variability Metrics and Norms." Frontiers in public health vol. 5 258. 28 Sep. 2017, doi:10.3389/fpubh.2017.00258
Segal, Jeanne, et al. "Quick Stress Relief - HelpGuide.org." Https://Www.helpguide.org, 2021, www.helpguide.org/articles/stress/quick-stress-relief.htm#:~:text=Yoga%2C%20mindfulness%20meditation%2C%20and%20exercise.
Silva, Diego Augusto Santos et al. "Association between Resting Heart Rate and Health-Related Physical Fitness in Brazilian Adolescents." *BioMed research international* vol. 2018 3812197. 28 Jun. 2018, doi:10.1155/2018/3812197
Spielberger, Charles D. "State-Trait anxiety inventory." The Corsini encyclopedia of psychology (2010): 1-1.
T Azevedo, Ruben et al. "The calming effect of a new wearable device during the anticipation of public speech." Scientific reports vol. 7,1 2285. 23 May. 2017, doi:10.1038/s41598-017-02274-2
Webster, Gregory D., and Catherine G. Weir. "Emotional Responses to Music: Interactive Effects of Mode, Texture, and Tempo." Motivation & Emotion, vol. 29, no. 1, Mar. 2005, pp. 19–39. EBSCOhost, doi:10.1007/s11031-005-4414-0.