EVALUATION OF STRESS AND RESILIENCE QUANTIFICATION AMONG UNIVERSITY STUDENTS USING HEART RATE VARIABILITY

MOHD SUFIAN BIN ABDUL HAMID

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

Malaysia-Japan International Institute of Technology
Universiti Teknologi Malaysia

DECEMBER 2021

DEDICATION

To papa and mama, the most important people in my life.

ACKNOWLEDGEMENT

I want to express my biggest gratitude to my family, especially my parents (Abdul Hamid bin Yup Aziz and Noraini binti Mohd Saad), who have raised and took care of me throughout my life. I am where I am right now because of their utmost support and they are a big part of my life.

I would like to thank my supervisor, Dr. Kamal, Dr. Hatta, Miss Farhanah and all the members of Bio-cognition Laboratory of Bio-inspired System Technology research group and Malaysian-Japan International Institute of Technology (MJIIT) for their ideas, feedback, and encouragement.

Special shout out to my friends, notably Azleen, Nabil, Qayyum, Arina, Yuni, Hajar, Amirah, and Fakhrul for their encouragement, physically and mentally. Their intakes and advices have also been very crucial in guiding me to finish my research.

I am also thankful to Mrs. Nurzima Zaihan binti Pi'i, Mrs. Hasdiana binti Hussin, the fourth-year students that were involved as the subjects, and all the staff of MJIIT counselling centre for collaborating with me in the conduction of the experiment for this research.

ABSTRACT

Malaysia has recently been rocked by the news on the 1708 suicide cases from January 2019 to May 2021. The ongoing neglect of adolescents' mental health is taking its toll as 51% of the total suicide cases are made up of teenagers between 15 to 18 years old. It is also reported that young people especially university students are affected by Covid-19 prolonged lockdown had the tendency of experiencing mental exhaustion. Notable causes for mental health problems are improper stress management and the lack of psychological resilience. Previously, stress and resilience levels were evaluated using questionnaires. Although questionnaires provide a fair result, there are arguments about their validity due to the existence of bias. The invention of multiple Heart Rate Variability (HRV) devices has made it possible to nullify the bias effect but it is under utilised. Therefore, this study proposed to investigate the effect of HRV through a slow breathing technique. The goal of this study is to improve stress and psychological resilience levels among university students. The methodology involves two stages of data collection: two questionnaires namely Depression, Anxiety, and Stress Scale-21 Items (DASS-21) and Brief Resilience Scale (BRS) were distributed to 240 engineering students; two experiments involving 70 students were conducted to examine the stress and resilience levels. The students were picked as the subjects for each experiment according to their scores obtained from the two questionnaires. The changes of the subjects' heart rhythm pattern and coherence scores, before and after the intervention were observed using the HeartMath EmWave device. The analysis demonstrated that the proposed HRV using a slow breathing technique as an intervention had contributed a positive impact in managing stress and improving psychological resilience. After implementing the intervention, the total average coherence score increased significantly by 74.3% for Experiment 1 and 52% for Experiment 2. The findings from HeartMath emWave were further analysed using Kubios HRV software. The analyses from the software showed that human nervous system can be manipulated by a suitable intervention. The mean Stress Index, which is heavily linked to Sympathetic Nervous System activities, managed to reduce by 65% and 56.2% with respect to Experiment 1 and Experiment 2. The results from both experiments also provided fruitful insight into the relationship between HRV, stress, and resilience quantification. This study shows that HRV devices and variables are effective in managing stress and improving resilience.

ABSTRAK

Malaysia baru-baru ini telah digemparkan dengan berita mengenai 1708 kes bunuh diri dari Januari 2019 hingga Mei 2021. Pengabaian berterusan terhadap kesihatan mental remaja memberi kesan yang buruk dimana 51% daripada jumlah kes bunuh diri terdiri daripada kanak-kanak berumur antara 15 hingga 18 tahun. Ia juga dilaporkan bahawa golongan muda terutamanya pelajar universiti yang terjejas oleh penyekatan berpanjangan COVID-19 mempunyai kecenderungan untuk mengalami keletihan mental. Penyebab utama masalah kesihatan mental ialah pengurusan tekanan yang tidak terurus dan kekurangan daya ketahanan psikologi. Sebelum ini, tahap tekanan dan daya ketahanan dinilai menggunakan soal selidik. Walaupun soal selidik memberikan hasil yang memuaskan, namun terdapat pertikaian tentang kesahihannya kerana wujudnya kecenderungan. Penciptaan pelbagai peranti Kebolehubahan Kadar Jantung (HRV) telah memungkinkan untuk membatalkan kesan kecenderungan tetapi ia kurang digunakan. Oleh itu, kajian ini mencadangkan untuk menyelidik kesan HRV melalui teknik pernafasan perlahan. Matlamat kajian ini adalah untuk memperbaiki tahap tekanan dan daya ketahanan psikologi dalam kalangan pelajar universiti. Metodologi melibatkan dua peringkat pengumpulan data: dua soal selidik iaitu Item Depresi, Kecemasan, dan Skala Tekanan-21 (DASS-21) dan Skala Ketahanan Ringkas (BRS) telah diedarkan kepada 240 pelajar kejuruteraan; dua eksperimen yang melibatkan 70 orang pelajar telah dijalankan untuk mengkaji tahap tekanan dan daya ketahanan. Pelajar-pelajar tersebut dipilih sebagai subjek bagi setiap satu eksperimen mengikut markah yang diperoleh daripada dua soal selidik. Perubahan corak irama jantung dan skor koheren subjek, sebelum dan selepas intervensi diperhatikan menggunakan peranti HeartMath emWave. Analisis menunjukkan bahawa HRV yang dicadangkan menggunakan teknik pernafasan perlahan sebagai intervensi telah menyumbangkan impak yang positif dalam menguruskan tekanan dan meningkatkan daya ketahanan psikologi. Selepas melaksanakan intervensi, jumlah purata skor koheren meningkat dengan ketara sebanyak 74.3% untuk Eksperimen 1 dan 52% untuk Eksperimen 2. Penemuan daripada HeartMath emWave telah dianalisis dengan lebih lanjut menggunakan perisian Kubios HRV. Analisis-analisis daripada perisian tersebut menunjukkan bahawan sistem saraf manusia boleh dimanipulasi menggunakan intervensi yang sesuai. Purata Indeks Tekanan, yang berkait rapat dengan aktiviti Sistem Saraf Simpatetik, berjaya dikurangkan sebanyak 65% dan 56.2% untuk Eksperimen 1 dan Eksperimen 2. Hasil daripada kedua-dua eksperimen juga memberikan gambaran yang bermanfaat tentang hubungan antara HRV, tekanan, dan kuantifikasi daya ketahanan. Kajian ini menunjukkan bahawa peranti dan pembolehubah HRV berkesan dalam menguruskan tekanan dan meningkatkan daya ketahanan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANS	-	Autonomic Nervous System
AMo	-	The mode amplitude presented in percent
BPM	-	Autonomic Nervous System
BRS	-	Brief Resilience Scale
DASS-21	-	Depression, Anxiety, and Stress Scale-21 Items
ESC	-	European Society of Cardiology
HRV	-	Heart Rate Variability
HR	-	Heart Rate
HF	-	High Frequency
IBI	-	Interbeat Interval
LF	-	Low Frequency
LF/HF	-	Score of Low Frequency and High Frequency
Mo	-	Mode for the most frequent RR interval
MxDMn	-	Variation scope that reflects the degree of RR interval variability
NN50	-	Number of successive RR Intervals that differ by more than 50ms
n.u.	-	Normalised Units
pNN50	-	Percentage of successive RR Intervals that differ by more than 50ms
PNS	-	Parasympathetic Nervous System
PSD	-	Power Spectral Density
RR	-	Respiratory Rate
RMSSD	-	Root Mean Square of Successive Differences
SNS	-	Sympathetic Nervous System
SI	-	Stress Index
VLF	-	Very Low Frequency

LIST OF SYMBOLS

Hz	-	Frequency
ms	-	Millisecond

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background Research

Malaysian now sees an alarming increase in the rate of suicide. Figure 1.1 shows the suicide cases recorded for the past 3 years in Malaysia. Royal Malaysia Police (PDRM) has reported that there was a total of 872 young people who committed suicide from January 2019 to May 2021 [1]. In that period, 51% of the total 1708 suicided cases were made up of teenagers between the age of 15 to 18 [2]. The current COVID-19 pandemic and lockdown have had negative effects on the mental health of many Malaysians, including the youth. Mental health issues have long been identified as a neglected part of well-being wellness. This could potentially become a very serious issue if it is not being dealt with quickly. Previously, around the year 2017, National Health and Morbidity Survey have declared that 1 out of 10 teenagers is in a stress state, 2 out of 5 teenagers are anxious, and 1 out of 5 teenagers is depressed [3].

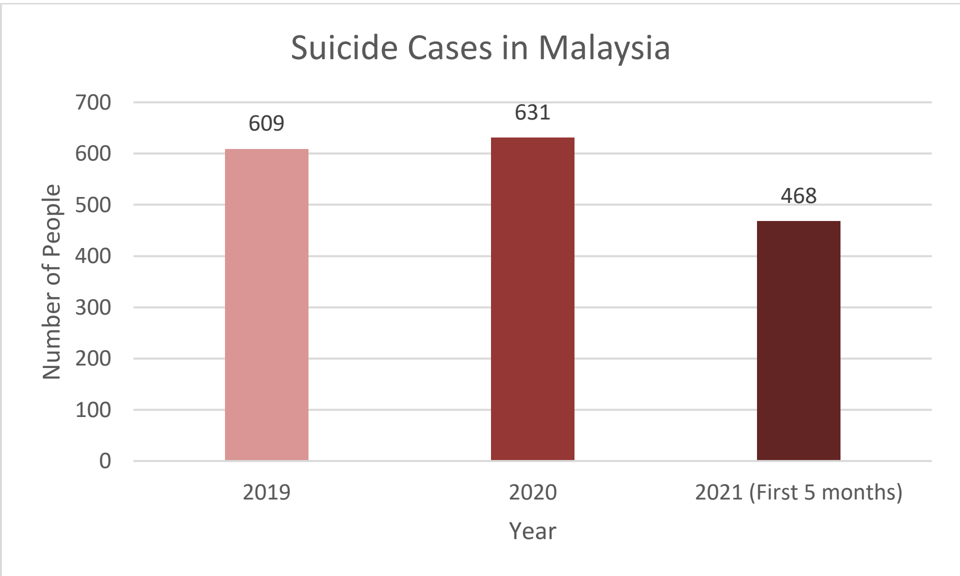

Figure 1.1 Suicide cases recorded for the past 3 years [1]

Moreover, in 2019, the National Health and Morbidity Survey has found that 2.3% of Malaysian adults, which is about half a million people are depressed [4]. This is a warning shot for all Malaysians to do more for our mental health and give the attention it needs. Heart rate variability or most commonly known as HRV is a kind of measurement that indicates the variation of heartbeats within a specific timeframe. HRV has been deemed to be useful in anticipating morbidities from mental and physical diseases such as depression, anxiety, fatigue, and chronic pain. It is designed to reduce autonomic reactivity and regulate homeostatic physiologic mechanisms [5]. Previous researches have shown that emotional intelligence contributes significantly to variations of heart rate. It involves deep rhythmic breathing, as the intervention allows the participant to inhale until their heart rate rise, and exhale as their heart rate begins to fall again [6] Higher HRV is commonly associated with greater emotional well-being. Heart rate variability measures beat-to-beat heart rate variability, which is an important physiologic index of stress and the body's regulatory capacity and adaptability.

Physical and mental tensions are usually caused by any kind of demand or threat. Due to this, stress will be generated as one of the ways the body reacts to changes and adjustments. Stress can be both positive and negative depending on the situation [7]. It is considered positive when it helps us to stay focused and aware of the surroundings thus, enhancing one's ability to perform better. However, it becomes negative when stress starts to disrupt most of the systems in the body making it vulnerable to much bigger problems such as anxiety and depression. Stress is an inevitable aspect of modern life. Failing to overcome stress could lead to mental illness. For this reason, the ability to manage stress is essential to build inner strength and resilience, which prepares an individual for greater challenges in the future [8]. At the moment, COVID-19 travel restrictions prevent everyone from carrying out their typical stress-relieving activities such as traveling and socializing with friends. Self-care has been identified as an effective way for stress-relief therapy. The reason for this is because it is considered flexible particularly during the current lockdown. After all, it can be done anytime, anywhere, and does not cost anything. From a physical health perspective, self-care intervention has been medically proven to increase self-awareness as shown in Figure 1.2. By doing so, emotional intelligence can be improved as self-awareness is the root of positivity and success.

Figure 1.2 Difference in proper stress management [9]

Resilience is a process and can act as a measurement to measure how to cope well and bounce back from certain difficulties in life [10]. When faced with these kinds of situations, one either keeps one's composure and handles the pressure well or breaks down and loses control. Having higher resiliency means that having the ability to deal with the pressure efficiently and to manage to think rationally and positively. Some people seem to have this ability naturally while others need to control and improve it. With the help of advancing engineering technologies, HRV can be used to analyse self-regulation and transformation through heart coherence practice as an intervention, transforming the emotional state from negative to positive. Hence, this analysis may act as an important assistive tool for the measurements of stress and resilience levels to achieve the desired well-being outcome.

1.2 Problem Statement

Having good physical health is not the sole contributor to optimal human well-being. It is proved by many studies that, to form human wellness, the three aspects of physical, emotional, and mental wellness need to be considered [11]. For day-to-day undertakings, humans have to be physically and psychologically positive. The ability to withstand all the pressure and hold composure is referred to as resilience and the people who can do so are known as resilient. Psychologists are taking mental health problems as a very serious issue and in previous studies, psychometric questionnaires have so far been the only measurement for quantifying the level of resilience and stress through various scientific research and experiments. One problem that occurred when using this method is that the questionnaire results are doubtful because stress and resilience are subjective from one to another. It can be misleading due to the existence of bias. Participants might be choosing the answer that is not accurately representing what they are feeling. This type of practice may not disclose a person's personality when they are under stress. Hence, the results are most likely partially valid and do not thoroughly reflect the resilience and stress level.

The next problem that needs to be solved is that the number of studies that used a clearly defined standard to address the psychometric properties of resilience measurements is limited. HRV has been used in multiple areas and treats diseases such as Posttraumatic stress disorder (PTSD), sport and physical activities, fibromyalgia, hypobaria, hemorrhage, kidney failure, mental stress, and cardiovascular disease. There is a huge potential of applying HRV as the index of psychological resilience, but there is a little attempt on doing so. Emotional reactions and psychological experimentation are getting more attention among researchers, especially during the current COVID-19 pandemic. Many believe that improving resilience is one of the solutions to deal with chronic stress because stress and resilience are quite affiliated to each other. With the advent of electronic systems engineering, primed heart rate biomarkers have been recently introduced as the tool to quantify resilience and stress. Even though many HRV devices are used to promote self-intervention for resilience enhancement, the public is unable to utilise them and becomes unaware of their emotional health. Thus, self-therapeutic care is not popular despite its medically proven benefits, and the studies that relate the HRV relationship with resilience and stress are still lacking. Therefore, stress and resilience quantification are necessary to demonstrate that human emotion regulation can be influenced and impacted by heartbeat variations. These results are right on track as it proves that to achieve human wellness, HRV, which controls the human Autonomic Nervous System (ANS) can be trained by using the right intervention.

1.3 Research Questions

The research questions are:

i. How HRV can be used to nullify bias?
ii. What is the relationship between heart rate variability, resilience, and stress?
iii. How does the slow breathing technique affect the Autonomic Nervous System in reducing stress and enhancing resilience?

1.4 Research Hypothesis

The hypothesis formed for this research are:

i. There is a significant improvement in the subjects' level of stress and resilience after implementing the slow breathing technique.
ii. There is a substantial relationship between heart rate variability, stress, and resilience in reducing stress.
iii. There is significant progress on the ability to manipulate Autonomic Nervous System (ANS) after implementing the slow breathing technique.

1.5 Research Objectives

The main aim of this project is to examine the effect of Heart Rate Variability (HRV) analysis and intervention on stress and resilience quantification. To show the relationship between resilience and the subjects' level of stress with the role of heart rate variability and intervention, these are the research aims and objectives for this proposal:

i. To evaluate the level of resilience and type of stressors (depression, anxiety, and stress) among engineering students using two sets of questionnaires and HRV devices.
ii. To analyse the changes of the subjects' heart rhythm and coherence score and compare the results with control groups by using the HeartMath emWave device.
iii. To validate the impact of slow breathing technique in manipulating Autonomic Nervous System (ANS) for the improvement in stress and resilience level by using Kubios HRV software.

1.6 Research Scope

This research focuses on methods for reducing stress and improving resilience among engineering students from the Malaysia-Japan International Institute of Technology (MJIIT). This research also concentrates on the changes for short-term HRV measurements. Universiti Teknologi Malaysia Kuala Lumpur. This study utilises two questionnaires to measure the students' stress and resilience level which are known as Brief Resilience Scale (BRS) and Depression, Anxiety, and Stress Scale-21 Items (DASS-21). The students consist of first until fourth-year students aged between 20 to 25 years old. The data for stress and resilience level were collected from a total of 240 students. Since the objective is to observe the improvement in stress and resilience level, low resilience and high stress score subjects were focused on. Students with high resilience and low stress score were selected as the subjects for the control group while students who obtained low resilience and high stress score were picked as the subjects for treatment group. The spatial test was used as a stimulus and a slow breathing technique (6 breaths per minute) was used as the biofeedback intervention. HeartMath emWave device was used to observe the changes in heart rhythm and coherence of the subjects during the whole phases of the experiment. The in-depth data analysis was run using the Kubios HRV software. By limiting to this research scope, the efficacy of heart rate variability on improving stress and resilience level can be distinguished through the slow breathing technique.

1.7 Research Methodology

First of all, this research started with the literature review stage. For the literature review, the fundamental main topics within the research scope were inquired such as HRV, stress, and resilience. This process was done repeatedly to ensure the validity of the knowledge and improve its understanding.

Currently, a questionnaire that combines both stress and resilience scale is unavailable. Thus, two questionnaires called the BRS and DASS-21 were used to evaluate the stress and resilience level of 240 MJIIT engineering students. Based on the scores obtained from both of the questionnaires, 70 students were chosen as the subjects. The students were divided into two groups: the control and treatment groups. Out of the 70 students, 60 students with low resilience and high stress scores were classified as the treatment group while the other 10 students with high resilience and low stress scores were categorised as the control group. At the end of the experiment, the results for the treatment group were compared to the control group, so that the effectiveness of the slow breathing technique in improving the subjects' stress and resilience level can be observed.

Two experiments were conducted to compare the difference between low resilient subjects and subjects with high stress scores. Moreover, these experiments observe the changes of the subjects' heart rhythm pattern and coherence score using the HeartMath emWave device across three phases of the experiment: baseline, stimulus, and intervention phase. The baseline phase was run to justify the questionnaire results of both the control and treatment groups for both experiments from bias effect. The stimulus phase was solely carried out in Experiment 1 to trigger the subjects' stress using the spatial test. It is also to monitor how the subjects adapt through the stimulus. Contrary to Experiment 1, Experiment 2 had no stimulus phase because the subject's stress level was already identified by the DASS-21 questionnaire. For the baseline phase, an intervention was given to help the subjects to become calm and relaxed. The data collected from this phase was used as a comparison with the baseline data of the control group. This comparison was made to observe the significance of using the slow breathing technique in reducing stress and improving resilience. It is also to make sure that the results of the treatment group were satisfactory and adequate.

After that, the heart rhythm pattern and coherence score data were transferred to Kubios HRV software for a more comprehensive data analysis. The data from the HeartMath emWave device need to be converted from a JSON file into an XSL file so that the interbeat interval (IBI) for each subject can be gathered. There are a few analyses in the Kubios HRV software that can be used to explore the relationship between the manipulation of the nervous system and the improvement in stress and resilience levels. Some of the analyses are ANS index, time-domain analysis, and frequency-domain analysis. The ANS index demonstrates the activation of PNS and SNS activities throughout the experiment. The time- and frequency-domain analyses present the changes of the HRV over some time and display how much of the signal exists within the range of frequencies a given. As mentioned earlier, the results of 10 subjects were analysed and compared to observe the changes of HRV parameters before and after implementing the slow breathing technique.

Finally, the effectiveness of the slow breathing technique in manipulating the ANS in improving the stress and resilience scores were validated using the data obtained from previous studies that are related to this study. This is to ensure that the results are in the range of the HRV normalised parameters. Figure 1.3 portrayed the overall methodology that was done in this study, as explained in the statement above. The research was conducted according to the flow chart to achieve the objectives of this study.

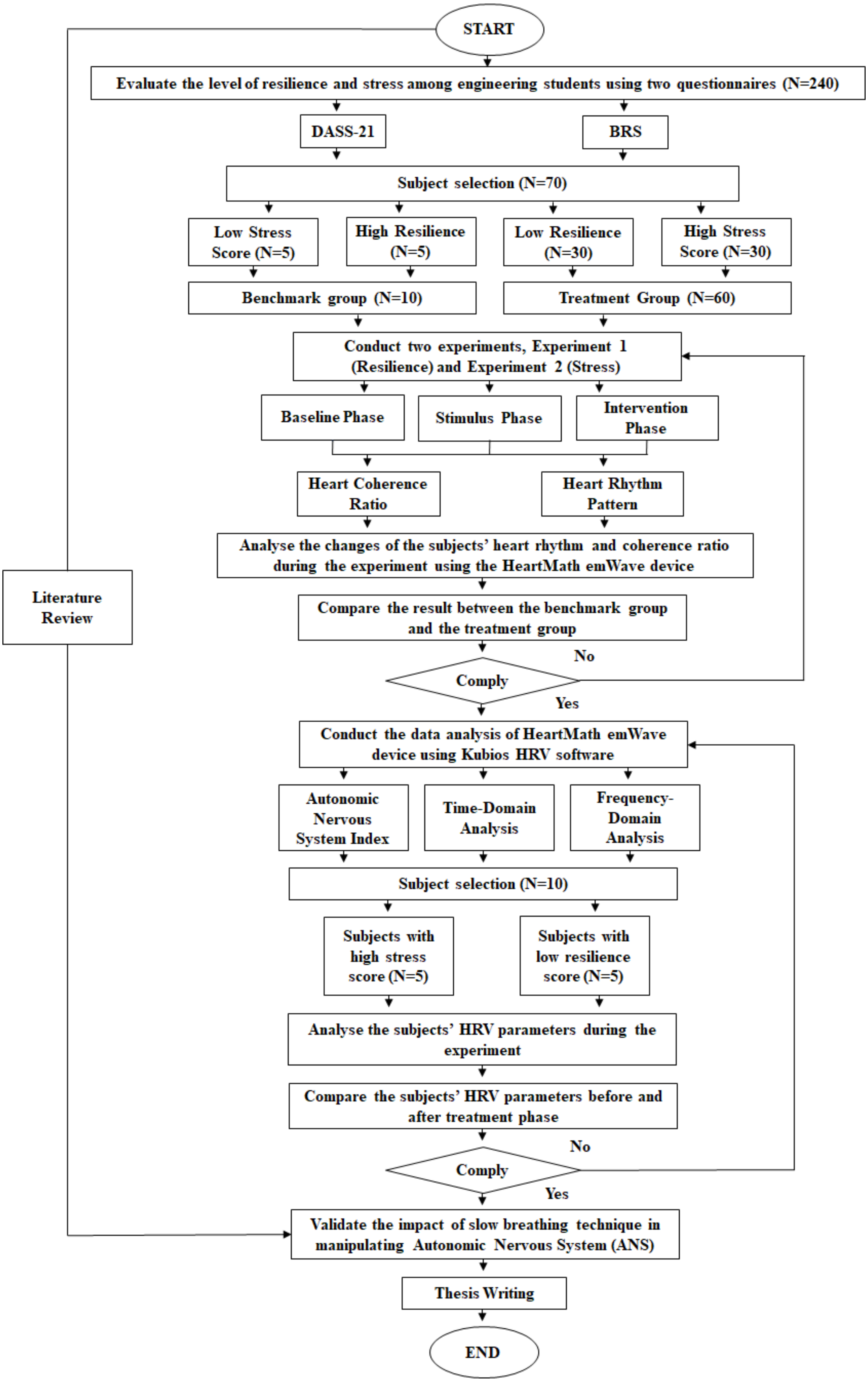

Figure 1.3 Research Methodology Flowchart

1.8 Research Contribution

This study provides a significant amount of knowledge that can be used for stress and resilience studies. These are some of the potential contributions of this study. The first one is eliminating the bias effect obtained when answering questionnaires. Questionnaire has always been the only method to quantify stress and resilience. The values are needed for monitoring daily mental health conditions, but it is misleading because of bias. Therefore, the addition of HeartMath emWave device is required to justify the questionnaires result and nullify the bias effect. The result from this research shows that resilience and stress can be quantified using HRV through visual graph of the heart rhythm pattern and heart coherence score in real-time, thus making it possible to quantify the level of resilience and stress on regular basis.

The other contribution is promoting self-care by using a flexible and low-cost intervention to reduce stress. As people are adjusting to the COVID-19 pandemic, most of their daily activities are hampered because of the lockdown restrictions. Interventions such as breathing breaks and slow breathing techniques will encourage people to apply it as a self-care method because it is simple to train and easy to do. Moreover, it is accessible to everyone as it can be done anywhere and anytime. Therefore, choosing the right intervention is important because it helps them become calmer and relaxed hence, improving their quality of life.

So far, the number of researches using Kubios HRV software is very few. This excellent software provides accurate and detailed HRV analysis for short- and long-term measurements and all kinds of study proprieties. Plus, this software can also be used for assessing stress and recovery. For that reason, the results of this research can contribute for further research using Kubios software. One notable analysis that is worth mentioning is the Autonomic Nervous System index. This analysis provides the interpretation of both the Parasympathetic and Sympathetic Nervous System branches in any situations. As a consequence, it will become easier to monitor the nervous system as it plays a huge role in guiding the daily activities and most of the aspects of the human's health.

1.9 Thesis Outline

This thesis consists of 5 chapters. Chapter 1 is the introduction of this research. It includes the background of the study, the problem statement, research objectives, and also the research scope. The significance of this study and the organization of this thesis are also given.

Chapter 2 provides the key findings of specific topics such as HRV, resilience, and stress. There is also some critical review of previous studies about HRV analysis that are related to these topics.

Chapter 3 explains the methodology and research design in this study. It describes the subject's selection, experiment procedure, data collection, software, hardware, and data analysis.

Chapter 4 demonstrates the results of the experiment based on the methodology stated in Chapter 3. The results are analysed and discussed thoroughly to provide insight into this study.

Chapter 5 presents the conclusion of this research. It summarises the whole study and presents some suggestions that can be implemented for future application and research.

REFERENCES

[1] R. M. Sarwar, “Statement on deaths by suicide among children,” 2021. [Online]. Available: https://www.unicef.org/malaysia/press-releases/statement-deaths-suicide-among-children. [Accessed: 27-Sep-2021].

[2] CodeBlue, “Malaysia records three daily suicides this year up to May,” *CodeBlue*, no. 1 July, pp. 1–5, 2021.

[3] IPH, “National Health and Morbidity Survey (NHMS) 2017 : Key Findings from the Adolescent Health and Nutrition Surveys; Infographic Booklet,” *Institute for Public Health, National Institutes of Health, The Ministry of Health, Malaysia*, no. April, p. 29, 2018.

[4] I. for P. H. IPH, N. I. of H. NIH, and M. of H. Malaysia, *National Health and Morbidity Survey (NHMS) 2019: NCDs - Non-Communicable Diseases: Risk Factors and other Health Problems*, vol. 1. 2019.

[5] R. McCraty and F. Shaffer, “Heart rate variability: New perspectives on physiological mechanisms, assessment of self-regulatory capacity, and health risk,” *Global Advances In Health and Medicine*, vol. 4, no. 1, pp. 46–61, 2015, doi: 10.7453/gahmj.2014.073.

[6] G. K. Sellakumar, “Effect of slow-deep breathing exercise to reduce anxiety among adolescent school students in a selected higher secondary school in Coimbatore, India,” *Journal of Psychological and Educational Research*, vol. 23, no. 1, pp. 54–72, 2015.

[7] L. Hamama, T. Ronen, K. Shachar, and M. Rosenbaum, “Links Between Stress, Positive and Negative Affect, and Life Satisfaction Among Teachers in Special Education Schools,” *Journal of Happiness Studies*, vol. 14, no. 3, pp. 731–751, 2013, doi: 10.1007/s10902-012-9352-4.

[8] S. M. Southwick, G. A. Bonanno, A. S. Masten, C. Panter-Brick, and R. Yehuda, “Resilience definitions, theory, and challenges: Interdisciplinary perspectives,” *European Journal of Psychotraumatology*, vol. 5, 2014, doi: 10.3402/ejpt.v5.25338.

[9] SAMH, “Coping with Stress | Singapore Association for Mental Health : Mental Wellness for All.” [Online]. Available:

https://www.samhealth.org.sg/understanding-mental-health/what-is-mental-wellness/coping-with-stress. [Accessed: 23-Aug-2021].

[10] S. MacLeod, S. Musich, K. Hawkins, K. Alsgaard, and E. R. Wicker, "The impact of resilience among older adults," *Geriatric Nursing*, vol. 37, no. 4, pp. 266–272, 2016, doi: 10.1016/j.gerinurse.2016.02.014.

[11] M. M. Hanssen, L. M. G. Vancleef, J. W. S. Vlaeyen, A. F. Hayes, E. G. W. Schouten, and M. L. Peters, "Optimism, Motivational Coping and Well-being: Evidence Supporting the Importance of Flexible Goal Adjustment," *Journal of Happiness Studies*, vol. 16, no. 6, pp. 1525–1537, 2015, doi: 10.1007/s10902-014-9572-x.

[12] J. K. Reddy, K. Menon, and A. Thattil, "Understanding Academic Stress among Adolescents," *Artha - Journal of Social Sciences*, vol. 16, no. 1, p. 39, 2017, doi: 10.12724/ajss.40.4.

[13] R. Reiner, "Integrating a portable biofeedback device into clinical practice for patients with anxiety disorders: Results of a pilot study," *Applied Psychophysiology Biofeedback*, vol. 33, no. 1, pp. 55–61, 2008, doi: 10.1007/s10484-007-9046-6.

[14] E. E. Scott *et al.*, "The autonomic nervous system in its natural environment: Immersion in nature is associated with changes in heart rate and heart rate variability," *Psychophysiology*, vol. 58, no. 4, 2021, doi: 10.1111/psyp.13698.

[15] S. M. Sincero, *Stress and Coping Mechanisms*. 2017.

[16] L. D. Kubzansky, K. C. Koenen, A. Spiro, P. S. Vokonas, and D. Sparrow, "Prospective study of posttraumatic stress disorder symptoms and coronary heart disease in the normative aging study," *Archives of General Psychiatry*, vol. 64, no. 1, pp. 109–116, 2007, doi: 10.1001/archpsyc.64.1.109.

[17] D. Koszycki, K. Raab, F. Aldosary, and J. Bradwejn, "A multifaith spiritually based intervention for generalized anxiety disorder: A pilot randomized trial," *Journal of Clinical Psychology*, vol. 66, no. 4, pp. 430–441, 2010, doi: 10.1002/jclp.

[18] N. Mguni, N. Bacon, and J. F. Brown, "The wellbeing and resilience paradox," *The Young Foundation, London*, 2012.

[19] T. D. Cosco, K. Howse, and C. Brayne, "Healthy ageing, resilience and wellbeing," *Epidemiology and Psychiatric Sciences*, vol. 26, no. 6, pp. 579–583, 2017, doi: 10.1017/S2045796017000324.

[20] B. S. Oken, I. Chamine, and W. Wakeland, "A systems approach to stress, stressors and resilience in humans," *Behavioural Brain Research*, vol. 282, pp. 144–154, 2015, doi: 10.1016/j.bbr.2014.12.047.

[21] M. E. Renna, J. M. Quintero, D. M. Fresco, and D. S. Mennin, "Emotion regulation therapy: A mechanism-targeted treatment for disorders of distress," *Frontiers in Psychology*, vol. 8, no. FEB, pp. 1–14, 2017, doi: 10.3389/fpsyg.2017.00098.

[22] A. J. Harmelink, "Pilot study of the effects of heart rate variability biofeedback on perceived stress, perceived coping ability, and resilience in accelerated baccalaureate nursing students.," *Pilot Study of the Effects of Heart Rate Variability Biofeedback on Perceived Stress, Perceived Coping Ability & Resilience in Accelerated Baccalaureate Nursing Students*, p. 1, 2016.

[23] R. Mccraty, "Coherence: Bridging personal, social, and global health," no. July 2010, 2015.

[24] M. Joëls, G. Fernandez, and B. Roozendaal, "Stress and emotional memory: A matter of timing," *Trends in Cognitive Sciences*, vol. 15, no. 6, pp. 280–288, 2011, doi: 10.1016/j.tics.2011.04.004.

[25] F. Barbara, *Positive Emotions Broaden and Build*, vol. 47. 2008.

[26] P. Kuppens, A. Realo, and E. Diener, "The Role of Positive and Negative Emotions in Life Satisfaction Judgment Across Nations," *Journal of Personality and Social Psychology*, vol. 95, no. 1, pp. 66–75, 2008, doi: 10.1037/0022-3514.95.1.66.

[27] A. D. Rowe and J. Fitness, "Understanding the role of negative emotions in adult learning and achievement: A social functional perspective," *Behavioral Sciences*, vol. 8, no. 2, 2018, doi: 10.3390/bs8020027.

[28] R. L. Gardner *et al.*, "Physician stress and burnout: the impact of health information technology," *Journal of the American Medical Informatics Association*, vol. 26, no. 2, pp. 106–114, 2019, doi: 10.1093/jamia/ocy145.

[29] S. Brady Scott and S. Brady, "Factors Influencing Teacher Burnout and Retention Strategies," 2019.

[30] P. Marrone, "Chambers, RT," *Etica e Politica*, vol. 15, no. 1, pp. 583–605, 2013, doi: 10.1093/acprof.

[31] F. Goodman, T. B. Kashdan, and J. Doorley, "Well-being and psychopathology: A deep exploration into positive emotions, meaning and purpose in life, and

social relationships," *Handbook of well-being*, no. April, pp. 1–25, 2018.

[32] I. Papousek, K. Nauschnegg, M. Paechter, H. K. Lackner, N. Goswami, and G. Schulter, "Trait and state positive affect and cardiovascular recovery from experimental academic stress," *Biological Psychology*, vol. 83, no. 2, pp. 108–115, 2010, doi: 10.1016/j.biopsycho.2009.11.008.

[33] P. Putman and K. Roelofs, "Effects of single cortisol administrations on human affect reviewed: Coping with stress through adaptive regulation of automatic cognitive processing," *Psychoneuroendocrinology*, vol. 36, no. 4, pp. 439–448, 2011, doi: 10.1016/j.psyneuen.2010.12.001.

[34] A. Schulz, F. Strelzyk, D. S. Ferreira de Sá, E. Naumann, C. Vögele, and H. Schächinger, "Cortisol rapidly affects amplitudes of heartbeat-evoked brain potentials-Implications for the contribution of stress to an altered perception of physical sensations?," *Psychoneuroendocrinology*, vol. 38, no. 11, pp. 2686–2693, 2013, doi: 10.1016/j.psyneuen.2013.06.027.

[35] G. S. Everly, and J. M. Lating, *A Clinical Guide to the Treatment of the Human Stress Response*. 2013.

[36] P. Kandhalu, "Effects of Cortisol on Physical and Psychological Aspects of the Body and Effective Ways by Which One Can Reduce Stress," *Berkeley Scientific Journal*, vol. 18, no. 1, 2013, doi: 10.5070/bs3181020644.

[37] E. Carlsson, A. Frostell, J. Ludvigsson, and M. Faresjö, "Psychological Stress in Children May Alter the Immune Response," *The Journal of Immunology*, vol. 192, no. 5, pp. 2071–2081, 2014, doi: 10.4049/jimmunol.1301713.

[38] L. Varvogli and C. Darviri, "Stress management techniques: Evidence-based procedures that reduce stress and promote health," *Health Science Journal*, vol. 5, no. 2, pp. 74–89, 2011.

[39] A. Çivitci, "The moderating role of positive and negative affect on the relationship between perceived social support and stress in college students," *Kuram ve Uygulamada Egitim Bilimleri*, vol. 15, no. 3, pp. 565–573, 2015, doi: 10.12738/estp.2015.3.2553.

[40] M. Green, N. Decourville, and S. Sadava, "Positive affect, negative affect, stress, and social support as mediators of the forgiveness-health relationship," *Journal of Social Psychology*, vol. 152, no. 3, pp. 288–307, 2012, doi: 10.1080/00224545.2011.603767.

[41] P. Vera-Villarroel *et al.*, "Money, age and happiness: Association of Subjective

wellbeing with socio-demographic variables," *Revista Latinoamericana de Psicologia*, vol. 44, no. 2, pp. 155–163, 2012, doi: 10.14349/rlp.v44i2.1039.

[42] Z. Gheisari *et al.*, "Relationship between Occupational Stress and Cardiovascular Risk Factors Determination: A Case-control Study," *Journal of Research in Medical and Dental Science |*, vol. 6, no. 3, pp. 287–293, 2018, doi: 10.24896/jrmds.20186344.

[43] B. C. K. Choi and A. W. P. Pak, "A catalog of biases in questionnaires," *Preventing Chronic Disease*, vol. 2, no. 1, pp. 1–13, 2005.

[44] C. T. Gloria and M. A. Steinhardt, "Relationships Among Positive Emotions , Coping , Resilience and Mental Health ‡," 2008, doi: 10.1002/smi.2589.

[45] R. Jerath and C. Beveridge, "Respiratory Rhythm, Autonomic Modulation, and the Spectrum of Emotions: The Future of Emotion Recognition and Modulation," *Frontiers in Psychology*, vol. 11, no. August, pp. 1–7, 2020, doi: 10.3389/fpsyg.2020.01980.

[46] E. Puterman, J. Lin, E. Blackburn, A. O'Donovan, N. Adler, and E. Epel, "The power of exercise: Buffering the effect of chronic stress on telomere length," *PLoS ONE*, vol. 5, no. 5, pp. 1–6, 2010, doi: 10.1371/journal.pone.0010837.

[47] G. Larsson, "The Emotional Stress Reaction Questionnaire (ESRQ): Measurement of Stress Reaction Level in Field Conditions in 60 Seconds," pp. 1–14, 2010.

[48] J. Scali, C. Gandubert, K. Ritchie, M. Soulier, M. L. Ancelin, and I. Chaudieu, "Measuring resilience in adult women using the 10-items Connor-Davidson resilience scale (CD-RISC). Role of trauma exposure and anxiety disorders," *PLoS ONE*, vol. 7, no. 6, 2012, doi: 10.1371/journal.pone.0039879.

[49] J. Rossouw, P. Rossouw, C. Paynter, A. Ward, and P. Khnana, "Predictive 6 Factor Resilience Scale – Domains of Resilience and Their Role as Enablers of Job Satisfaction," *International Journal of Neuropsychotherapy*, vol. 5, no. 1, pp. 25–40, 2017, doi: 10.12744/ijnpt.2017.1.0025-0040.

[50] A. L. Simpkin *et al.*, "Stress From Uncertainty and Resilience Among Depressed and Burned Out Residents: A Cross-Sectional Study," *Academic Pediatrics*, vol. 18, no. 6, pp. 698–704, 2018, doi: 10.1016/j.acap.2018.03.002.

[51] M. A. Vallejo, L. Vallejo-Slocker, E. G. Fernández-Abascal, and G. Mañanes, "Determining factors for stress perception assessed with the Perceived Stress Scale (PSS-4) in Spanish and other European samples," *Frontiers in*

Psychology, vol. 9, no. JAN, 2018, doi: 10.3389/fpsyg.2018.00037.

[52] L. Krautscheid, L. Mood, S. M. McLennon, T. C. Mossman, M. Wagner, and J. Wode, "Examining relationships between resilience protective factors and moral distress among nursing students," *Nursing Education Perspectives*, vol. 41, no. 1, pp. 43–45, 2020, doi: 10.1097/01.NEP.0000000000000471.

[53] N. M. Noorzeli, M. Nubli, A. Wahab, and N. Noorzeli, "A Study of the Usage of Biofeedback Techniques to Improve Self Performance and HRV Profile Among Ikhtiar Malaysia Entrepreneurs," *Malaysian Journal of Social Sciences and Humanities*, vol. 1, no. 3, pp. 1–13, 2016.

[54] A. L. Hassett *et al.*, "A pilot study of the efficacy of heart rate variability (HRV) biofeedback in patients with fibromyalgia," *Applied Psychophysiology Biofeedback*, vol. 32, no. 1, pp. 1–10, 2007, doi: 10.1007/s10484-006-9028-0.

[55] A. P. Sutarto, M. N. A. Wahab, and N. M. Zin, "Heart Rate Variability (HRV) biofeedback: A new training approach for operator's performance enhancement," *Journal of Industrial Engineering and Management*, vol. 3, no. 1, pp. 176–198, 2010, doi: 10.3926/jiem.2010.v3n1.p176-198.

[56] P. Melillo, C. Formisano, U. Bracale, and L. Pecchia, "Classification tree for real-life stress detection using linear heart rate variability analysis. Case study: Students under stress due to university examination," *IFMBE Proceedings*, vol. 39 IFMBE, pp. 477–480, 2013, doi: 10.1007/978-3-642-29305-4_126.

[57] A. I. M. Anuar, A. W. M. Nubli, and M. Y. N. Yusma, "The Significant Effect of Wudu' and Zikr in the Controlling of Emotional Pressure Using Biofeedback Emwave Technique," *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, vol. 1, no. 4, pp. 828–834, 2017.

[58] Y. T. Caldwell and P. R. Steffen, "Adding HRV biofeedback to psychotherapy increases heart rate variability and improves the treatment of major depressive disorder," *International Journal of Psychophysiology*, vol. 131, no. October 2017, pp. 96–101, 2018, doi: 10.1016/j.ijpsycho.2018.01.001.

[59] J. A. Naslund, K. A. Aschbrenner, L. K. Barre, and S. J. Bartels, "Feasibility of popular m-health technologies for activity tracking among individuals with serious mental Illness," *Telemedicine and e-Health*, vol. 21, no. 3, pp. 213–216, 2015, doi: 10.1089/tmj.2014.0105.

[60] J. George and T. Bhila, "The Role of Mobile Health Application on Self-

Quantification The Role of Mobile Health Application on Self-Quantification," vol. 1, no. March, pp. 47–58, 2019.

[61] N. Schull, "Sensor technology and the time-series self," *Continent*, vol. 5, no. 1, pp. 24–29, 2016.

[62] N. D. Schüll, "Data for life: Wearable technology and the design of self-care," *BioSocieties*, vol. 11, no. 3, pp. 317–333, 2016, doi: 10.1057/biosoc.2015.47.

[63] B. Ajana, "Digital health and the biopolitics of the Quantified Self," *Digital Health*, vol. 3, p. 205520761668950, 2017, doi: 10.1177/2055207616689509.

[64] J. Pols, D. Willems, and M. Aanestad, "Making sense with numbers. Unravelling ethico-psychological subjects in practices of self-quantification," *Sociology of Health and Illness*, vol. 41, no. S1, pp. 98–115, 2019, doi: 10.1111/1467-9566.12894.

[65] W. E. Pickren, "Health psychology," *The Cambridge Handbook of the Intellectual History of Psychology*, vol. 10, no. 1, pp. 495–511, 2019, doi: 10.1017/9781108290876.020.

[66] D. Selimen and I. I. Andsoy, "The Importance of a Holistic Approach During the Perioperative Period," *AORN Journal*, vol. 93, no. 4, pp. 482–490, 2011, doi: 10.1016/j.aorn.2010.09.029.

[67] D. Chandler, "Resilience and the end(s) of the politics of adaptation," *Resilience*, vol. 7, no. 3, pp. 1–10, 2019, doi: 10.1080/21693293.2019.1605660.

[68] K. Trimmel, J. Sacha, and H. V Huikuri, *Heart Rate Variability: Clinical Applications and Interaction between HRV and Heart Rate:* 2015.

[69] K. M. Jamal S and E. Kamioka, "Emotions detection scheme using facial skin temperature and heart rate variability," *MATEC Web of Conferences*, vol. 277, p. 02037, 2019, doi: 10.1051/matecconf/201927702037.

[70] G. Kaur and P. S. Pandey, "Emotion Recognition System using IOT and Machine Learning-A Healthcare Application," *FRUCT'23: Proceedings of the 23rd Conference of Open Innovations Association FRUCT*, pp. 465–470, 2018.

[71] B. Yu, M. Funk, J. Hu, and L. Feijs, "Unwind: a musical biofeedback for relaxation assistance," *Behaviour and Information Technology*, vol. 37, no. 8, pp. 800–814, 2018, doi: 10.1080/0144929X.2018.1484515.

[72] A. Barikroo, G. Carnaby, D. Bolser, R. Rozensky, and M. Crary, "Transcutaneous electrical stimulation on the anterior neck region: The impact of pulse duration and frequency on maximum amplitude tolerance and

perceived discomfort," *Journal of Oral Rehabilitation*, vol. 45, no. 6, pp. 436–441, 2018, doi: 10.1111/joor.12625.

[73] G. Ernst, "Heart-Rate Variability—More than Heart Beats?," *Frontiers in Public Health*, vol. 5, no. September, pp. 1–12, 2017, doi: 10.3389/fpubh.2017.00240.

[74] S. Massaro and L. Pecchia, *Heart Rate Variability (HRV) Analysis: A Methodology for Organizational Neuroscience*, vol. 22, no. 1. 2019.

[75] M. E. Altuncu, O. Baspinar, and M. Keskin, "The use of short-term analysis of heart rate variability to assess autonomic function in obese children and its relationship with metabolic syndrome," *Cardiology Journal*, vol. 19, no. 5, pp. 501–506, 2012, doi: 10.5603/CJ.2012.0091.

[76] A. Lischke, R. Jacksteit, A. Mau-Moeller, R. Pahnke, A. O. Hamm, and M. Weippert, "Heart rate variability is associated with psychosocial stress in distinct social domains," *Journal of Psychosomatic Research*, vol. 106, no. August 2017, pp. 56–61, 2018, doi: 10.1016/j.jpsychores.2018.01.005.

[77] J. Sacha, "Interaction between heart rate and heart rate variability," *Annals of Noninvasive Electrocardiology*, vol. 19, no. 3, pp. 207–216, 2014, doi: 10.1111/anec.12148.

[78] A. L. Wheat and K. T. Larkin, "Biofeedback of heart rate variability and related physiology: A critical review," *Applied Psychophysiology Biofeedback*, vol. 35, no. 3, pp. 229–242, 2010, doi: 10.1007/s10484-010-9133-y.

[79] S. Laborde, E. Mosley, and J. F. Thayer, "Heart rate variability and cardiac vagal tone in psychophysiological research - Recommendations for experiment planning, data analysis, and data reporting," *Frontiers in Psychology*, vol. 8, no. FEB, pp. 1–18, 2017, doi: 10.3389/fpsyg.2017.00213.

[80] U. Reimer, E. Laurenzi, E. Maier, and T. Ulmer, "Mobile Stress Recognition and Relaxation Support with SmartCoping: User-Adaptive Interpretation of Physiological Stress Parameters," *Proceedings of the 50th Hawaii International Conference on System Sciences (2017)*, pp. 3597–3606, 2017, doi: 10.24251/hicss.2017.435.

[81] A. Shearer, M. Hunt, M. Chowdhury, and L. Nicol, "International Journal of Stress Management Effects of a Brief Mindfulness Meditation Intervention on Student Stress and Heart Rate Variability Effects of a Brief Mindfulness Meditation Intervention on Student Stress and Heart Rate Variability,"

International Journal of Stress Management, vol. 23, no. 2, pp. 232–254, 2015, doi: 10.1037/a0039814.

[82] J. S. Perkiömäki, “Heart rate variability and non-linear dynamics in risk stratification,” *Frontiers in Physiology*, vol. 2 NOV, no. November, pp. 1–8, 2011, doi: 10.3389/fphys.2011.00081.

[83] N. Pinheiro *et al.*, “Can PPG be used for HRV analysis?,” *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, vol. 2016-Octob, pp. 2945–2949, 2016, doi: 10.1109/EMBC.2016.7591347.

[84] V. C. Goessl, J. E. Curtiss, and S. G. Hofmann, “The effect of heart rate variability biofeedback training on stress and anxiety: A meta-analysis,” *Psychological Medicine*, vol. 47, no. 15, pp. 2578–2586, 2017, doi: 10.1017/S0033291717001003.

[85] H. Hasuo, K. Kanbara, H. Sakuma, K. Yoshida, K. Uchitani, and M. Fukunaga, “Self-care system for family caregivers of cancer patients using resonant breathing with a portable home device: A randomized open-label study,” *Journal of Palliative Medicine*, vol. 22, no. 1, pp. 18–24, 2019, doi: 10.1089/jpm.2018.0230.

[86] C. Lin and C. Yang, “Intervals and Morphological Features,” vol. 2014, 2014.

[87] P. J. Soh and G. A. E. Vandenbosch, “Monitoring,” no. May, pp. 55–70, 2015.

[88] P. A. Lanfranchi and V. K. Somers, “Control in Health and in Sleep Disorders,” *Principles and Practice of Sleep Medicine*, pp. 226–236.

[89] V. Vesterinen, K. Häkkinen, T. Laine, E. Hynynen, J. Mikkola, and A. Nummela, “Predictors of individual adaptation to high-volume or high-intensity endurance training in recreational endurance runners,” *Scandinavian journal of medicine & science in sports*, vol. 26, no. 8, pp. 885–893, 2016, doi: 10.1111/sms.12530.

[90] P. J. Lang, “Emotion’s response patterns: The brain and the autonomic nervous system,” *Emotion Review*, vol. 6, no. 2, pp. 93–99, 2014, doi: 10.1177/1754073913512004.

[91] N. Hjortskov, D. Rissén, A. K. Blangsted, N. Fallentin, U. Lundberg, and K. Søgaard, “The effect of mental stress on heart rate variability and blood pressure during computer work,” *European Journal of Applied Physiology*, vol. 92, no. 1–2, pp. 84–89, 2004, doi: 10.1007/s00421-004-1055-z.

[92] B. I. McDonald, M. Johnson, and P. T. Madsen, “Dive heart rate in harbour porpoises is influenced by exercise and expectations,” *Journal of Experimental Biology*, vol. 221, no. 1, 2018, doi: 10.1242/jeb.168740.

[93] A. Drigas and E. Mitsea, “Metacognition, Stress – Relaxation Balance & Related Hormones,” *International Journal of Recent Contributions from Engineering, Science & IT (iJES)*, vol. 9, no. 1, p. 4, 2021, doi: 10.3991/ijes.v9i1.19623.

[94] J. F. Thayer, F. Åhs, M. Fredrikson, J. J. Sollers, and T. D. Wager, “A meta-analysis of heart rate variability and neuroimaging studies: Implications for heart rate variability as a marker of stress and health,” *Neuroscience and Biobehavioral Reviews*, vol. 36, no. 2, pp. 747–756, 2012, doi: 10.1016/j.neubiorev.2011.11.009.

[95] R. Perini and A. Veicsteinas, “Heart rate variability and autonomic activity at rest and during exercise in various physiological conditions,” *European Journal of Applied Physiology*, vol. 90, no. 3–4, pp. 317–325, 2003, doi: 10.1007/s00421-003-0953-9.

[96] C. Bernard and É. D. Ed, “opérée au sein de INTERDEPENDENT RELATIONSHIPS BETWEEN THE MENTAL REPRESENTATION AND PSYCHOPHYSIOLOGICAL CORRELATES,” no. January, 2019.

[97] R. McCraty, “New Frontiers in Heart Rate Variability and Social Coherence Research: Techniques, Technologies, and Implications for Improving Group Dynamics and Outcomes,” *Frontiers in Public Health*, vol. 5, no. October, pp. 1–13, 2017, doi: 10.3389/fpubh.2017.00267.

[98] J. Thome *et al.*, “Desynchronization of autonomic response and central autonomic network connectivity in posttraumatic stress disorder,” *Human Brain Mapping*, vol. 38, no. 1, pp. 27–40, 2017, doi: 10.1002/hbm.23340.

[99] R. McCraty *et al.*, “The influence of heart coherence on synchronization between human heart rate variability and geomagnetic activity,” *Journal of Complexity in Health Sciences*, vol. 1, no. 2, pp. 42–48, 2018, doi: 10.21595/chs.2018.20480.

[100] R. McCraty, “The Science of HeartMath - HeartMath.” [Online]. Available: https://www.heartmath.com/science/. [Accessed: 04-Aug-2021].

[101] Maxson & Mitchell, “乳鼠心肌提取 HHS Public Access,” *Physiology & behavior*, vol. 176, no. 1, pp. 139–148, 2016,

doi: 10.1016/j.physbeh.2017.03.040.

[102] R. McCraty and M. A. Zayas, “Cardiac coherence, self-regulation, autonomic stability and psychosocial well-being,” *Frontiers in Psychology*, vol. 5, no. SEP, pp. 1–13, 2014, doi: 10.3389/fpsyg.2014.01090.

[103] R. Wells, T. Outhred, J. A. J. Heathers, D. S. Quintana, and A. H. Kemp, “Matter Over Mind: A Randomised-Controlled Trial of Single-Session Biofeedback Training on Performance Anxiety and Heart Rate Variability in Musicians,” *PLoS ONE*, vol. 7, no. 10, 2012, doi: 10.1371/journal.pone.0046597.

[104] F. Moss, L. M. Ward, and W. G. Sannita, “Stochastic resonance and sensory information processing: A tutorial and review of application,” *Clinical Neurophysiology*, vol. 115, no. 2, pp. 267–281, 2004, doi: 10.1016/j.clinph.2003.09.014.

[105] R. Mccraty and D. Tomasino, “Heart Rhythm Coherence Feedback : A New Tool for Stress Reduction, Rehabilitation, and Performance,” *Proceedings of the First Baltic Forum on Neuronal Regulation and Biofeedback*, 2004.

[106] F. Shaffer and J. P. Ginsberg, “An Overview of Heart Rate Variability Metrics and Norms,” *Frontiers in Public Health*, vol. 5, no. September, pp. 1–17, 2017, doi: 10.3389/fpubh.2017.00258.

[107] R. McCraty, M. Atkinson, and J. Dispenza, “One-minute deep breathing assessment and its relationship to 24-h heart rate variability measurements,” *Heart and Mind*, vol. 2, no. 3, p. 70, 2018, doi: 10.4103/hm.hm_4_19.

[108] K. Li, H. Rüdiger, and T. Ziemssen, “Spectral analysis of heart rate variability: Time window matters,” *Frontiers in Neurology*, vol. 10, no. MAY, pp. 1–12, 2019, doi: 10.3389/fneur.2019.00545.

[109] A. Voss *et al.*, “Short-term vs. long-term heart rate variability in ischemic cardiomyopathy risk stratification,” *Frontiers in Physiology*, vol. 4 DEC, no. December, pp. 1–15, 2013, doi: 10.3389/fphys.2013.00364.

[110] T. Pereira, P. R. Almeida, J. P. S. Cunha, and A. Aguiar, “Heart rate variability metrics for fine-grained stress level assessment,” *Computer Methods and Programs in Biomedicine*, vol. 148, pp. 71–80, 2017, doi: 10.1016/j.cmpb.2017.06.018.

[111] R. Mccraty, “Enhancing Emotional , Social , and Academic Learning With Heart Rhythm Coherence Feedback,” *Psychophysiological Coherence*, pp.

130–134, 2005.

[112] M. Shi, X. Wang, Y. Bian, and L. Wang, “The mediating role of resilience in the relationship between stress and life satisfaction among Chinese medical students: A cross-sectional study,” *BMC Medical Education*, vol. 15, no. 1, pp. 1–7, 2015, doi: 10.1186/s12909-015-0297-2.

[113] H. Usui and Y. Nishida, “The very low-frequency band of heart rate variability represents the slow recovery component after a mental stress task,” *PLoS ONE*, vol. 12, no. 8, pp. 1–9, 2017, doi: 10.1371/journal.pone.0182611.

[114] M. D. Costa, R. B. Davis, and A. L. Goldberger, “Heart rate fragmentation: A new approach to the analysis of cardiac interbeat interval dynamics,” *Frontiers in Physiology*, vol. 8, no. MAY, pp. 1–13, 2017, doi: 10.3389/fphys.2017.00255.

[115] D. S. Burns, “Theoretical rationale for music selection in oncology intervention research: An integrative review,” *Journal of Music Therapy*, vol. 49, no. 1, pp. 7–22, 2012, doi: 10.1093/jmt/49.1.7.

[116] G. W. Heath *et al.*, “Evidence-based intervention in physical activity: Lessons from around the world,” *The Lancet*, vol. 380, no. 9838, pp. 272–281, 2012, doi: 10.1016/S0140-6736(12)60816-2.

[117] B.-Y. Kim, M.-J. Bae, and S.-G. Bae, “A Study on Reducing Stress through Deep Breathing,” *International Journal of Applied Engineering Research*, vol. 13, no. 2, pp. 1460–1464, 2018.

[118] I. Van Diest, K. Verstappen, A. E. Aubert, D. Widjaja, D. Vansteenwegen, and E. Vlemincx, “Inhalation/Exhalation Ratio Modulates the Effect of Slow Breathing on Heart Rate Variability and Relaxation,” *Applied Psychophysiology Biofeedback*, vol. 39, no. 3–4, pp. 171–180, 2014, doi: 10.1007/s10484-014-9253-x.

[119] D. J. Noble and S. Hochman, “Hypothesis: Pulmonary Afferent Activity Patterns During Slow, Deep Breathing Contribute to the Neural Induction of Physiological Relaxation,” *Frontiers in Physiology*, vol. 10, no. September, pp. 1–17, 2019, doi: 10.3389/fphys.2019.01176.

[120] X. Ma *et al.*, “The effect of diaphragmatic breathing on attention, negative affect and stress in healthy adults,” *Frontiers in Psychology*, vol. 8, no. JUN, pp. 1–12, 2017, doi: 10.3389/fpsyg.2017.00874.

[121] M. A. Russo, D. M. Santarelli, and D. O’Rourke, “The physiological effects of

slow breathing in the healthy human," *Breathe*, vol. 13, no. 4, pp. 298–309, 2017, doi: 10.1183/20734735.009817.

[122] H. Soliman, "Effects of Zikr Mediation and Jaw Relaxation on Postoperative Pain , Anxiety and Physiologic Response of Patients Undergoing Abdominal Surgery," vol. 3, no. 2, pp. 23–39, 2013.

[123] J. O. F. Language and C. I. O. N. Upm, "Salawat and Its Effect on the Vagus Nerve," no. MARCH, pp. 2018–2021, 2018.

[124] A. R. N. Nabilah, S. K. Azami, A. K. Y. Dafhalla, M. R. H. Adibah, and Y. Naimah, "The Effect of Meditation on Brain Relaxation Incorporating Different Physiological Activities," *Journal of Physics: Conference Series*, vol. 1962, no. 1, 2021, doi: 10.1088/1742-6596/1962/1/012059.

[125] W. N. Pennington, "Releasing Stress Through the Power of Music," pp. 1–2, 2017.

[126] E. Saarman, "Feeling the beat: Symposium explores the therapeutic effects of rhythmic music," *Stanford News*, p. 94305, 2006.

[127] R. Granot *et al.*, "'Help! I Need Somebody': Music as a Global Resource for Obtaining Wellbeing Goals in Times of Crisis," *Frontiers in Psychology*, vol. 12, no. April, pp. 1–22, 2021, doi: 10.3389/fpsyg.2021.648013.

[128] The Quality Assurance Agency for Higher Education, "Arts therapy Benchmark statement: Health care programmes," p. 24, 2004.

[129] G. Palareti *et al.*, "Comparison between different D-Dimer cutoff values to assess the individual risk of recurrent venous thromboembolism: Analysis of results obtained in the DULCIS study," *International Journal of Laboratory Hematology*, vol. 38, no. 1, pp. 42–49, 2016, doi: 10.1111/ijlh.12426.

[130] Quality Assurance Agency for UK Higher Education, "Subject Benchmark Statement Education Studies," no. December, pp. 1–15, 2019.

[131] "Brief Resilience Scale," *Definitions*, vol. 15, p. 2008, 2020, doi: 10.32388/nzfa7u.

[132] S. H. N. S. Azwar, "Impact of Heart Rate Variability Biofeedback Training in Stress Management Among University Students," *Master of Philosophy, Universiti Teknologi Malaysia*, 2020.

[133] University of Wisconsin-Madison, "Depression Anxiety Stress Scale-21 (DASS21)," p. 2019, 2021.

[134] 123test, "Spatial Reasoning Test." [Online].

Available: https://www.123test.com/spatial-reasoning-test/. [Accessed: 23-Mar-2020].

[135] "6 Breaths Per Minute - Pressure Perfect - Lower Blood Pressure by breathing - YouTube." [Online]. Available: https://www.youtube.com/watch?v=4K6bI4S66Ng. [Accessed: 27-May-2020].

[136] A. Whited, K. T. Larkin, and M. Whited, "Effectiveness of emWave biofeedback in improving heart rate variability reactivity to and recovery from stress," *Applied Psychophysiology Biofeedback*, vol. 39, no. 2, pp. 75–88, 2014, doi: 10.1007/s10484-014-9243-z.

[137] C. A. Kermott, R. E. Johnson, R. Sood, S. M. Jenkins, and A. Sood, "Is higher resilience predictive of lower stress and better mental health among corporate executives?," *PLoS ONE*, vol. 14, no. 6, pp. 1–14, 2019, doi: 10.1371/journal.pone.0218092.

[138] A. D. Martins *et al.*, "Relationship between heart rate variability and functional fitness in breast cancer survivors: A cross-sectional study," *Healthcare (Switzerland)*, vol. 9, no. 9, pp. 1–13, 2021, doi: 10.3390/healthcare9091205.

[139] N. S. Moïse, A. Gladuli, S. A. Hemsley, and N. F. Otani, "'Zone of avoidance': RR interval distribution in tachograms, histograms, and Poincaré plots of a Boxer dog," *Journal of Veterinary Cardiology*, vol. 12, no. 3, pp. 191–196, 2010, doi: 10.1016/j.jvc.2010.07.001.

[140] G. Minarini, "Root Mean Square of the Successive Differences as Marker of the Parasympathetic System and Difference in the Outcome after ANS Stimulation," *Autonomic Nervous System Monitoring - Heart Rate Variability*, pp. 1–14, 2020, doi: 10.5772/intechopen.89827.

[141] C. Schubert, M. Lambertz, R. A. Nelesen, W. Bardwell, J. B. Choi, and J. E. Dimsdale, "Effects of stress on heart rate complexity-A comparison between short-term and chronic stress," *Biological Psychology*, vol. 80, no. 3, pp. 325–332, 2009, doi: 10.1016/j.biopsycho.2008.11.005.

[142] Kubios – Resources, "HRV in Evaluating ANS Function." [Online]. Available: https://www.kubios.com/hrv-ans-function/. [Accessed: 25-Jul-2021].

[143] H. B. Lee, J. S. Kim, Y. S. Kim, and H. J. Baekl, "The relationship between HRV," vol. 00, pp. 198–200, 2007.

[144] E. Tharion, S. Parthasarathy, and N. Neelakantan, "Short-term heart rate variability measures in students during examinations," *National Medical*

Journal of India, vol. 22, no. 2, pp. 63–66, 2009.

[145] K. Sasaki and R. Maruyama, “Consciously controlled breathing decreases the high-frequency component of heart rate variability by inhibiting cardiac parasympathetic nerve activity,” *Tohoku Journal of Experimental Medicine*, vol. 233, no. 3, pp. 155–163, 2014, doi: 10.1620/tjem.233.155.

[146] H. Wahbeh and B. S. Oken, “Peak high-frequency HRV and peak alpha frequency higher in PTSD,” *Applied Psychophysiology Biofeedback*, vol. 38, no. 1, pp. 57–69, 2013, doi: 10.1007/s10484-012-9208-z.

[147] J. J. Goldberger, “Sympathovagal balance: How should we measure it?,” *American Journal of Physiology - Heart and Circulatory Physiology*, vol. 276, no. 4 45-4, pp. 1273–1280, 1999, doi: 10.1152/ajpheart.1999.276.4.h1273.

[148] G. Raczak *et al.*, “Cardiovagal response to acute mild exercise in young healthy subjects,” *Circulation Journal*, vol. 69, no. 8, pp. 976–980, 2005, doi: 10.1253/circj.69.976.

[149] S. Panchal, F. Irani, and G. Y. Trivedi, “Impact of Himalayan Singing Bowls Meditation Session on Mood and Heart Rate Variability – An Observational Study,” *International Journal of Psychotherapy Practice and Research*, vol. 1, no. 4, pp. 20–30, 2020, doi: 10.14302/issn.2574-612x.ijpr-20-3213.