Project Details

- Under Prof Kenny Choo (ISTD) and MIBd Student Ethan Lim
- Aim: To realise avatar interaction as a viable alternative medium to deliver psychotherapy intervention

Tasks

- Did research on the scientific and technological aspects of Kubios (a HRV measurement software) to understand the biological/physiological relations to HRV (eg: PNS/SNS Index, RR intervals) as well as the scientific concepts behind the various calculations (eg: Poincaré plot, TP, FFT etc). This tied in strongly with my knowledge of Digital Signal Processing from polytechnic
- Got a chance to set up the pilot study (30 min interaction with counsellor with avatar, 30 min without avatar) and experience the pilot study as both a participant and researcher

Key Findings

- Learnt more about the field of Human-Computer Interaction, biological/physiological relations to mental health conditions (specifically anxiety), and running a research study
- Strengthened my passions in using technology in the field of healthcare (mental health)
- Gained another new perspective on how technology could be used in healthcare fields (eg: expressive avatars, in this case)

Report

For this part of the UROP, we aimed to understand the Kubios HRV readings in more detail. Below shows a typical report generated in Kubios.

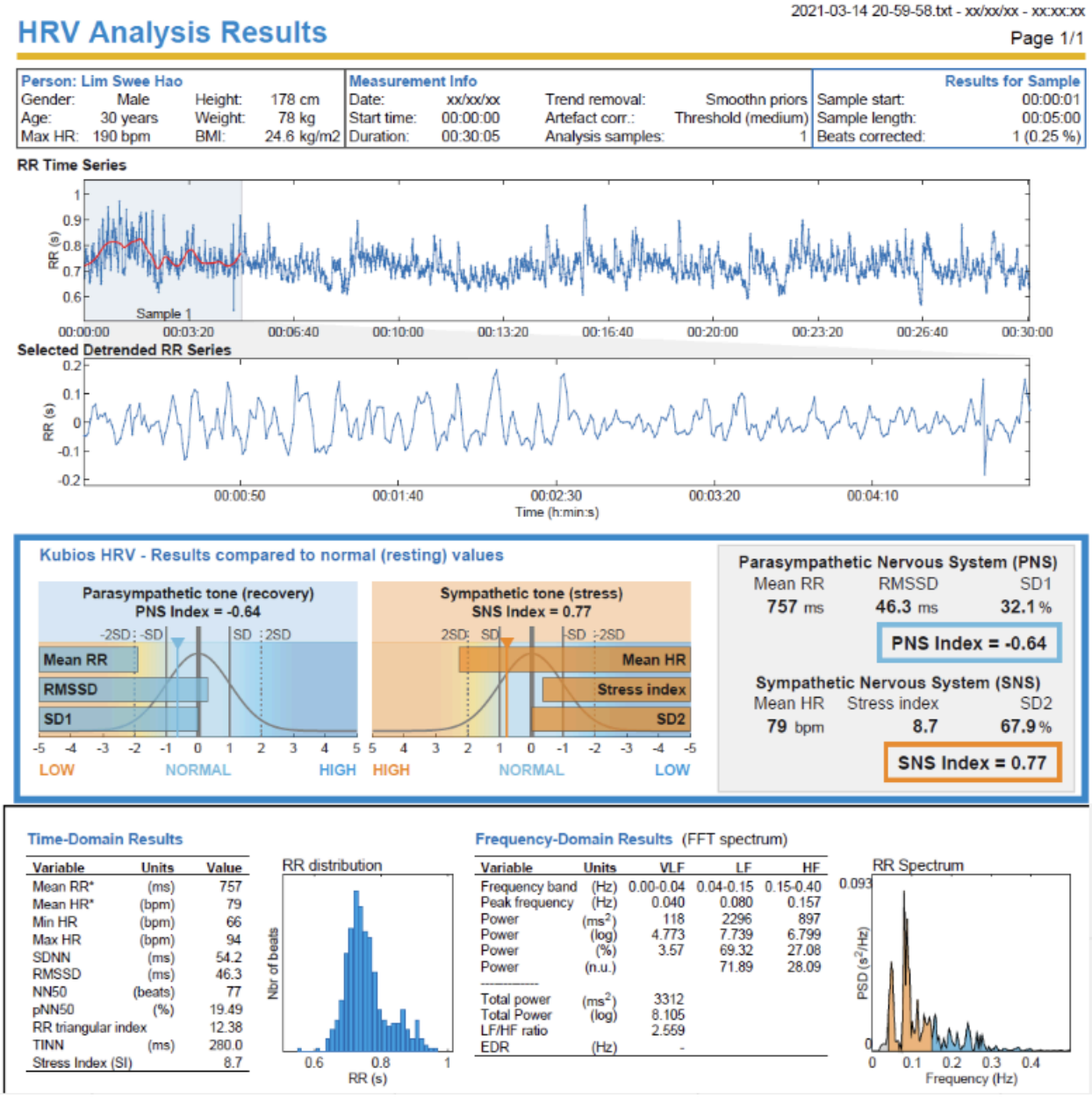


Figure 1: A typical HRV Analysis Report in Kubios

From top to bottom, Kubios HRV Analysis returns these parameters: RR time series and a detrended RR time series, Parasympathetic Nervous System (PNS) and Sympathetic Nervous System (SNS) index, and various time and frequency-domain results.

The results screen also gives other information like HR and PNS time zones and energy expenditure, as shown in the figure below.

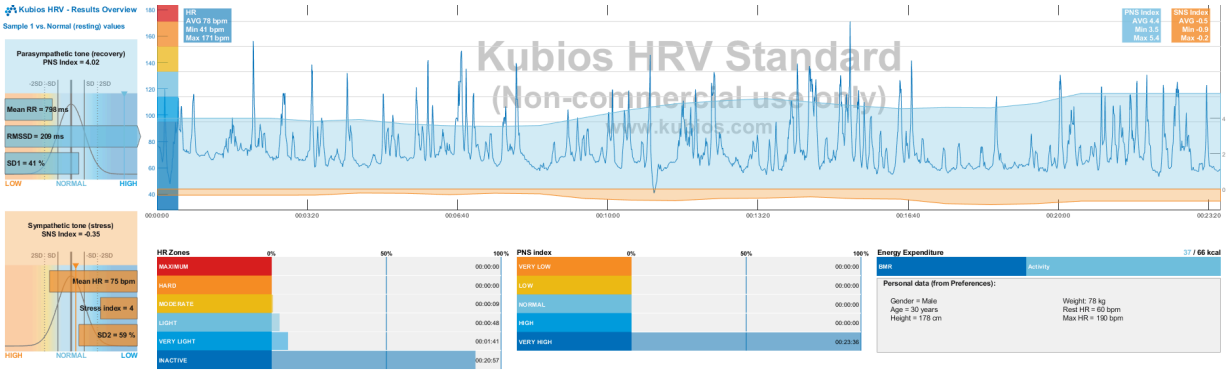


Figure 2: Results screen in Kubios

HR and PNS zones give us a gauge of whether HR and HRV are high or low. This is determined based on information on the test subject, which can be adjusted. Kubios will take this information and compare it against normal values based on a database of people of similar demographic collated in a quantitative systematic review by Nunan et.al 2010.

In this report, we will be focusing on PNS and SNS Index, Heart Rate Variability and how these relate to stress and anxiety levels.

It is instrumental that we get a clearer understanding of Heart Rate Variability before moving to other parts of the report. Heart Rate Variability (HRV) can be defined as variance in time between the beats of your heart. An example can be seen in the image below.

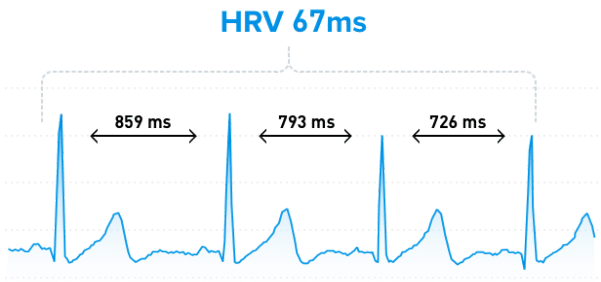
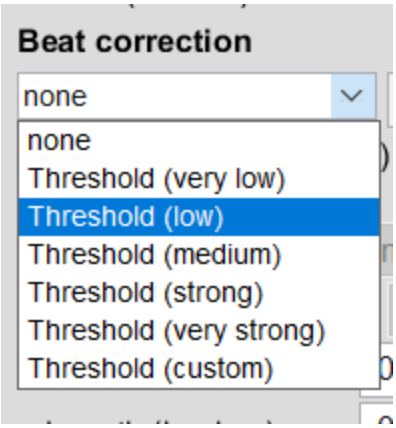


Figure 2: HRV and RR Intervals

These periods of time between successive heartbeats are known as RR intervals (named for the heartbeat's R-phase, the spikes you see on an EKG), measured in milliseconds. The RR interval is a function of intrinsic properties of the sinus node as well as autonomic influences. HRV comes from 2 competing branches simultaneously sending signals to your heart - PNS and SNS. If your nervous system is balanced, your heart is constantly being told to beat slower by your PNS and beat faster by your SNS. This causes a fluctuation in your heart rate, leading to what we know as HRV. Typically, a high HRV indicates that your nervous system is balanced, and that your body is very capable of adapting to its environment and performing at its best. On the other hand, a low HRV indicates that one branch is dominating and sending stronger signals to your heart than the other. Most times, it is due to your SNS and shows that your body is under stress from exercise, psychological events, or other internal or external stressors. This leaves fewer resources available to dedicate towards exercising, competing, giving a presentation at work, and more.

Slight inaccuracies in RR intervals can affect HRV greatly, hence we use the beat correction feature to remove anomalies in readings.



PNS and SNS indices are parameters introduced in Kubios. They are calculated by considering parameters that relate to the PNS and SNS respectively, as shown in the table below.

Index	Parameters
PNS Index	Mean RR interval. Longer mean RR interval means lower heart rate and higher parasympathetic cardiac activation.
	Root mean square of successive RR interval differences (RMSSD), which is a commonly used time-domain HRV parameter that captures the quick beat-to-beat changes in RR interval. High values of RMSSD indicate strong RSA component and high parasympathetic cardiac activation.
	Poincaré plot index SD1, a commonly used approach for estimating the sympathovagal balance of the ANS to compute the low frequency (LF) to high frequency (HF) power ratio from HRV spectrum.
SNS Index	Mean HR interval. Higher heart rate is linked to higher sympathetic cardiac activation.
	Baevsky's stress index (SI), which is a geometric measure of HRV reflecting cardiovascular system stress. High values of SI indicate reduced variability and high sympathetic cardiac activation.

	Poincaré plot index SD2, a commonly used approach for estimating the sympathovagal balance of the ANS to compute the low frequency (LF) to high frequency (HF) power ratio from the HRV spectrum.

Table 1: PNS and SNS Indices, with the parameters corresponding to both

The value of the indices tells us how many standard deviations away the parameters of the sample are from the population average. A value of zero means that the parameters reflecting activity are on average equal to the normal population average. Correspondingly, a positive index value tells how many standard deviations above the normal population average the parameter values are, a negative value tells how many standard deviations below the normal population average the parameter values are. Normal readings should fall within +2 to -2, while reading can go up to as high as 5 under stress.

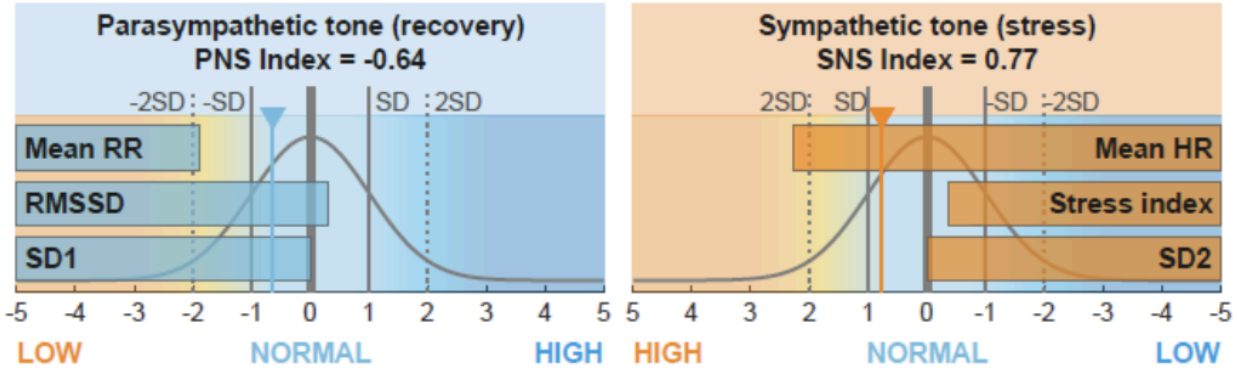


Figure 3: PNS and SNS indices, along with values of parameters that constitute them. Index values are shown on the graph as the coloured arrowed lines. In this case, both PNS and SNS indices are less than 1 standard deviation away from population average.

Next, we go on to understand the LF/HF ratio. As the name suggests, the LF component of the spectrum represents the low-frequency component while the HF component represents the high-frequency component. Just like high and low HRV, LF and HF are related to sympathetic and parasympathetic tone, with LF related to an increase in the former and HF related to an increase in the latter. These 2 frequency values are used in computing the SD1 and SD2 portions of the PNS and SNS Indices respectively. SD1 and SD2 are obtained by plotting a

Poincaré Plot, graphed by plotting every R–R interval against the prior interval and creating a scatter plot (refer to Figure 2 below). This shows how well each RR interval predicts the next.

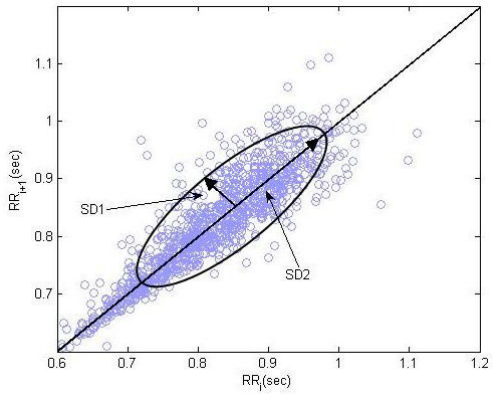


Figure 4: Poincaré Plot

In short, a greater LF/HF ratio suggests greater sympathetic drive, and a lower LF/HF ratio suggests greater parasympathetic drive.

Lastly, a growing body of literature suggests a reduced activation of the autonomic nervous system in anxiety disorders resulting in decreased HRV. As predicted by Polyvagal theory, clinical conditions associated with decreases in social functioning and capacity for social engagement are reflected in decreased regulation of ANS function or reduced HRV. This then supports the proposal that social anxiety disorder, a prototypical disorder of social avoidance and disengagement, will also be associated with reductions in autonomic cardiac control. Further, as predicted by the theory, these reductions in autonomic control may be associated with social inhibition, avoidance, and fear. Some researchers also described a higher resting LF/HF ratio in patients with panic disorder compared with normal controls.

Overall, to sum up, we see that while HRV and LF/HF ratio cannot fully predict anxiety disorders, they could be used as an indicator for anxiety disorders.

Personal Reflections

Overall, this UROP was a good learning experience for both of us. Initially, we started off this UROP wanting to learn more about the field of Human-Computer Interaction and deciding if CSD was the right pillar for us. With the extensive research done throughout the UROP, not only did we get to learn more about Human-Computer Interaction, but we also got to learn about statistics, biological/physiological relations to mental health conditions, and running a research study. Apart from doing research on the scientific and technological aspects of Kubios, we also got a chance to set up the pilot study for ourselves and experience the pilot study firsthand. It was insightful as we got to experience how our research would impact a research study/experiment, and we got to observe the pilot study in more detail to spot things that could be improved for future studies. While the pilot studies were slightly different for each of us (Constance - physical pilot study, Kellie - virtual pilot study), we found it helpful in guiding us and giving our research meaning with actual data from ourselves.

For Kellie, her passions in mental health and using technology in the field of healthcare was strengthened through this UROP, having gained another new perspective on how technology could be used in healthcare fields (eg: avatars, in this case).

For Constance, this UROP taught her useful research skills that can be applied in future projects. Although there were many restrictions to physical meetings, she found the alternative arrangement an eye-opening arrangement that worked equally well.