Evaluation of Oxa for Cardiac Activity and Autonomous Nervous System Monitoring.

A product evaluation project

Abstract This project aimed to evaluate and improve Oxa, a smart textile garment that monitors electrocardiogram (ECG), respiratory signals, skin temperature, and acceleration. This document focuses on the validation of heart rate (HR) and heart rate variability (HRV) monitoring features. The data collection revealed good congruence of Oxa's ECG compared to a medical graded state-of-the-art ECG device and demonstrated that smartwatches are much less exact.

Introduction

Wearable devices have the potential to enhance health and well-being by continuously monitoring various physiological parameters. Nanoleq's Oxa shirt is a cutting-edge smart textile product designed to seamlessly integrate electronic functionality into garments for accurate biosignal recording. In this project, we aimed to validate the reliability and accuracy of Oxa for HR and HRV monitoring. The study involved a group of volunteers who participated to contribute to the development of Oxa.

Methods

The project involved five healthy volunteers of the Nanoleq employee pool who engaged in three different activities of varying intensity while wearing Oxa (Figure 1). Simultaneously, a medical-grade ECG monitoring system (AMEDTEC ECGpro systems) was used as a gold standard for comparison (Figure 2). The data collection process was conducted with the participants' full consent and was entirely voluntary.

Results

The study compared the accuracy of HR monitoring using Oxa, a medical ECG monitoring device and two of the most wide-spread commercially available smartwatches. The results of the project demonstrated the high reliability and robustness of Oxa in collecting ECG signals and real-time monitoring of HR (Table 2, Figures 3-4). Furthermore, RR values, used to calculate HRV metrics, show high congruence between state-of-the-art technology and Oxa (Table 2).

Conclusion

The study confirmed that Oxa performs with accuracy and precision comparable to medical-grade ECG monitoring devices. It further demonstrated that smartwatches are less exact. Smartwatch 1 and 2 had mean differences of up to 14 and 8 BPM at various resting scenarios, standard deviations to their individual averages of 19 and 7 with minor activity and were in many cases deviating by over 20BPM, while Oxa never deviated by more than 1BPM from the medical system.

Figure 1: Example ECG traces collected by Oxa at rest (top) and during running at 8 km/h (bottom).

Figure 2: The study protocol consisted of seven phases, starting with resting and then running on a treadmill with low, moderate and high intensities followed by five minutes of resting (left). Each volunteer wore an Oxa, two smartwatches and a medical ECG monitoring device with twelve electrodes as reference (right).

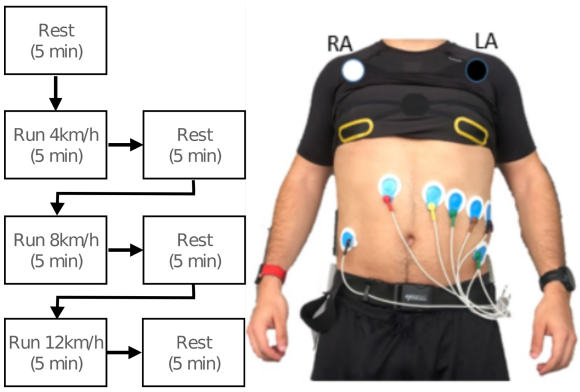
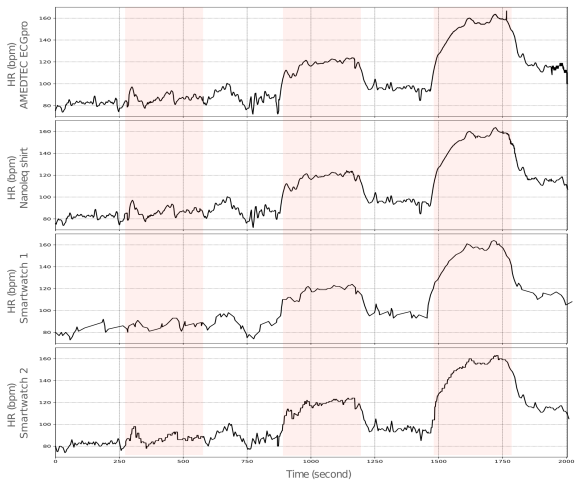


Figure 3: From top to bottom, measured heart rate by the medical ECG monitoring device, Oxa, Smartwatch 1 and 2 for a subject with high-quality signals on all four devices.



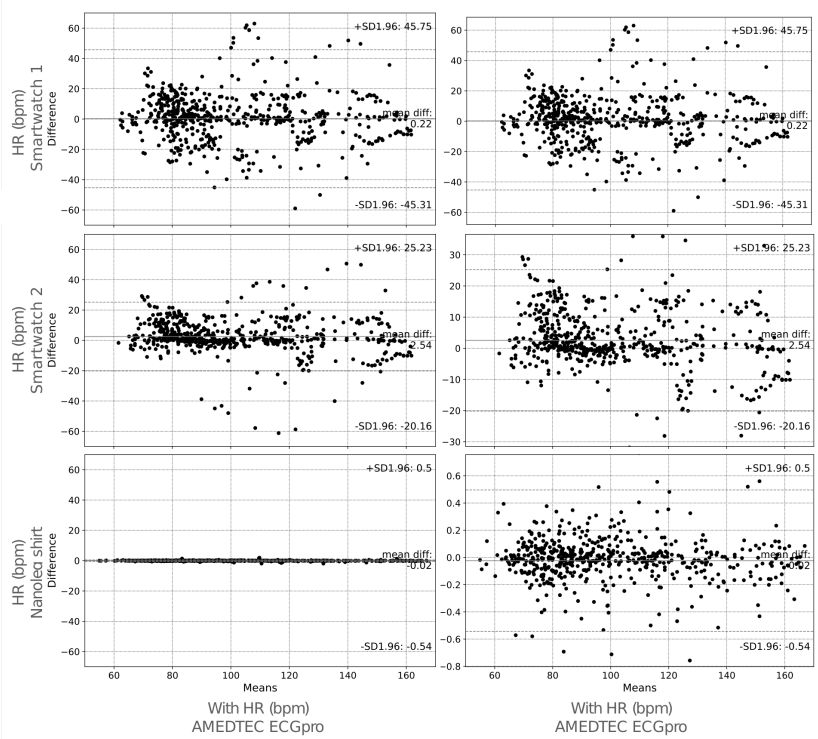


Figure 4: The Bland-Altman plot for Oxa, Smartwatch 1 and 2 versus the medical ECG monitoring device. The Left column plots have the same y-axis scale for all plots, while the right ones present the same information as the left ones with different scales to have a better view of the details.

Table 1: Quality of heart rate monitoring comparison

	Heart rate (bpm) mean± SD				Mean HR difference wrt medical ECG (SD)		
	AMEDTEC ECGpro	Oxa	Smartwatch 1	Smartwatch 2	Oxa	Smartwatch 1	Smartwatch 2
rest	75.52± 10.05	75.51± 10.05	76.95± 8.22	80.66± 8.2	-0.01(0.12)	8.22(13.79)	5.14(8.34)
low-intensity run	84.69± 8.75	84.67± 8.76	90.85± 14.41	88.46± 7.31	-0.02(0.12)	14.41(19.05)	3.77(7.52)
rest after	82.37± 10.94	82.35± 10.92	83.21± 7.12	85.73± 8.87	-0.02(0.25)	7.12(11.88)	3.36(6.22)
moderate-intensity run	118.71± 11.38	118.71± 11.38	118.06± 12.46	117.13± 13.32	0.0(0.25)	12.46(13.56)	-1.58(13.65)
rest after	101.4± 16.94	101.39± 16.9	100.44± 13.91	105.89± 17.5	-0.01(0.26)	13.91(16.21)	4.49(8.67)
high-intensity run	145.51± 15.95	145.38± 16.03	133.09± 51.66	140.08± 20.33	-0.12(0.32)	51.66(49.62)	-5.43(17.92)
rest after	121.31± 16.74	121.33± 16.73	129.55± 20.38	129.77± 20.06	0.02(0.53)	20.38(15.18)	8.47(13.83)

Table 2: RR values (seconds) in comparison between Oxa and medical ECG monitoring device.

	AMEDTEC ECGpro				Oxa			
	mean	std	min	max	mean	std	min	max
rest	0.8	0.06	0.66	1.03	0.8	0.07	0.66	1.08
low-intensity run	0.72	0.04	0.62	0.88	0.72	0.04	0.62	0.89
rest after	0.74	0.06	0.61	0.99	0.74	0.06	0.59	1.0
moderate-intensity run	0.48	0.07	0.36	0.85	0.48	0.09	0.41	1.0
rest after	0.6	0.08	0.41	0.92	0.6	0.07	0.44	0.89
high-intensity run	0.4	0.07	0.25	0.77	0.4	0.06	0.33	0.66
rest after	0.5	0.09	0.34	0.84	0.5	0.06	0.35	0.63