Response to referees’ comments

Manuscript ID: Sensors-384146

Title: Oxygen Saturation measurements from Green and Orange Illumination of Multi-Wavelength Optoelectronic Patch Sensor

We appreciate the comments given by the reviewer 2. As indicated by the evaluation, we have carefully reviewed and answered the questions as requested.

The reviewer 2:

This paper proposes the use of green/orange wavelengths in recording reflectance photoplethysmography (PPG) signals to estimate blood oxygen saturation level (SpO2). The motivation to use green/orange wavelengths, as noted in the paper, is a less sensitivity to motion artefacts affecting PPG signals for example during physical exercise. Although this is a good motivation, the results do not completely support the claims. Based on this, I have two major concerns.

Q: The exercise has been performed under normal conditions in this research. In an old study:

- H. Benoit, "Accuracy of pulse oximetry during intense exercise under severe hypoxic conditions", 1997. Hypoxic conditions are proposed to make various levels of SpO2 (e.g. 70%-100%). This condition is not explored in this paper since all SpO2 levels are well above 90%. This can affect the interpretation of accuracy.

A: Benoit’s work as mentioned by the reviewer, had a clear purpose to evaluate reading accuracy of pulse oximeter. The protocol in Benoit’s study was specifically designed and implemented in a gas chamber (a breathing room with controllable % of O2 and N2) to evaluate the SaO2 (%) readings of a pulse oximeter against the radial artery blood sampling under hypoxic conditions where arterial oxygen saturation SaO2 (%) was below 75%, simulating exercise at extreme altitude. This was merely hypoxic exercises and not physical exercises.

Thus, the purpose of our study is to explore the mOEPS competence in different scenarios such as rest and during physical activities. Our protocol has applied a combination of green and orange illuminations from mOEPS to improve robustness to subjects’ movements in the extraction of SpO2 readings.

Q: The benchmark data has been collected using TempIRTM pulse oximetry. Pulse oximeters usually have an error of 2-3% for estimation of SpO2 at rest condition. During the exercise, pulse oximeters might not be accurate enough to estimate SpO2. The authors can provide detailed information from the device whether they have used regarding human controlled desaturation studies and been conducted at rest/exercise.
A: 2-3% of current SpO2(%) readings is commonly acceptable in a clinical patient monitoring as the trend of SpO2(%) readings is vital for front-line clinicians to alert the SpO2 (%) variations of patient’s metabolism.

In the first sub-protocol, the subjects were sitting and gently moving their hands and the green and orange illumination were compared and validated against the commercial pulse oximetry for the SpO2(%) readings.

In the second sub-protocol, the subjects completed the cycling and running activities, and only the mOEPS was used to compare the SpO2(%) of different wavelengths during the designated exercises.

Minor comments:

Q: The last plot of Figure 6 is a good plot with promising results (probably not the two first plots). The axis labels are a bit confusing e.g. Number of 15 subject readings.

A: The axis labels represented the number of readings of all the subjects together. Each subject has many readings of SpO2 (%) in the experiment as mentioned in the section of Methodology, a time window of 10s duration was used to calculate SpO2(%).

Q: In Figure 7, the number of points considering one subject is limited, therefore; not the best presentation using bland-altman.

A: Removed the individual plots of Bland Altman as requested.

Q: Figure 9 is also a good figure. However, this figure shows that red/infrared also produce good estimates for SpO2. The authors can compare green/orange wavelengths to red/infrared PPG signals in great details and see how the signal quality index can be different for different wavelength under physical exercise and rest.

A: We appreciate your suggestion. In this study, we explored the mOEPS Sensor competence via the implementation of designated protocol with two different scenarios as stated above, to extract oxygen saturation SpO2(%).

In the forthcoming study, we will carry on the following work:

I. Investigation of physiological variations during physical activities to related to their parameters, e.g. heart rate, oxygen saturation SpO2(%), and respiration rate with the illuminations of green/orange wavelengths against red/infrared wavelengths.

II. Find out a relationship between the respiration rate and oxygen uptake (V’O₂) during rest and physical activities.
Q: The authors might have a look at: http://www.nihonkohden.de/uploads/media/SpO2-Report_03.pdf for SpO2 monitoring: a pulse oximeter accuracy study. There are missing papers in the references. The authors should refer to recent papers for SpO2 estimation using reflectance PPGs.

A: The following paper has been added to the list of references: