Remote PPG for heart rate monitoring: lighting conditions and camera shutter time

Rik J.C. van Esch, Kambez Ebrahimkheil, Iris Cramer, Wenjin Wang, Tomas Kaandorp, Federica Sammali, Angélique Dierick, Carla Kloeze, Cindy Verstappen, Marcel van ‘t Veer, Leon Montenij, Lukas Dekker, R. Arthur Bouwman, Erik Korsten, Jan Bergmans, Sander Stuijk and Svitlana Zinger

***Abstract*— We investigate the effect of lighting conditions and camera shutter time on heart rate measurement using remote photoplethysmography (remote-PPG) on healthy volunteers in a simulated ICU setting. In the used range of lighting conditions (132-548 lux), there exists a range of shutter times (5-32 ms), in which a mean 3 beats-per-minute (BPM) agreement of 90-100% with the contact PPG sensor is achieved. This range is limited by the saturation of the skin pixels. These results indicate that shutter time control is unnecessary beyond avoiding saturation.**

***Clinical Relevance*— Replacing spot checks by continuous monitoring in a hospital will lead to timely detection of adverse events. Technologies for remote-PPG will allow continuous monitoring in a clinical setting.**

I. INTRODUCTION

A recent study [1] found that to ensure good heart rate monitoring using remote-PPG with an RGB camera, the signal-to-noise ratio (SNR) of the remote-PPG signal should be maximized. To achieve maximum SNR, the skin pixel brightness is maximized using the shutter time while avoiding overexposure, as saturation of the skin pixels distorts the remote-PPG signal [1]. Our hypothesis is that maximizing the SNR is unnecessary, and that only under- and overexposure of the skin pixels needs to be avoided. In this study, we investigate the influence of lighting conditions and camera shutter time on the quality of heart rate monitoring using remote-PPG and how the shutter time should be chosen in a simulated ICU condition.

II. METHODS

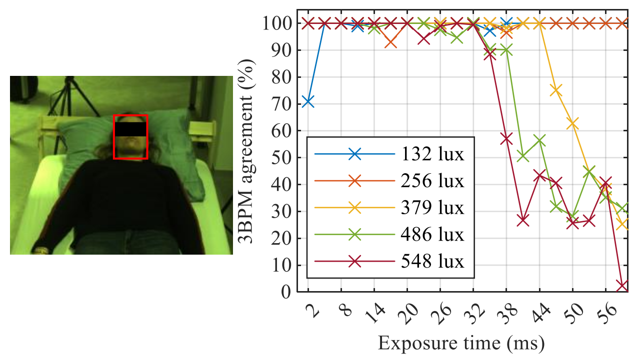
Informed consent was obtained from four healthy volunteers (Fitzpatrick scale I-II). Subjects were asked to lie in a bed in the supine position, as seen in Fig. 1a. The camera (IDS 3860CP) is placed above the foot end of the bed. Five video recordings (968×548 pixels, 15 fps) were made of each subject, each with closed window blinds and different intensities of fluorescent ceiling lighting (quantified by a luxmeter below the camera). For each recording the shutter time was increased every 30 seconds from 2 to 59 ms in steps of 3 ms. Contact PPG (Contec CMS50E) was collected synchronously. The remote-PPG signal was extracted using the POS method [2] from all pixels inside a bounding box, as shown in Fig. 1a, defined by a CNN face detector [3]. An example bounding box is shown in Fig. 1a. The heart rate was extracted from the remote-PPG and PPG signal by selecting the frequency peak from a sliding window FFT as in [2] which is approximately 15 seconds in length.

This study was approved by the ethical review board of the Eindhoven University of Technology. This work is funded by the ZonMw FORSEE project (www.dcvalliance.nl/forsee).

R.J.C. van Esch is with the Eindhoven University of Technology, Eindhoven, The Netherlands; e-mail: r.j.c.v.esch@tue.nl.

III. RESULTS

In Fig. 1b the mean 3 BPM agreement with the PPG reference can be seen for each of the five lighting conditions. A drop-off in mean 3 BPM agreement is observed for the combination of high shutter time and bright lighting and furthermore for the lowest shutter time in combination with the darkest condition. These limits are observed to coincide with respectively over- and underexposure of the skin pixels.



(a) (b)

Figure 1. (a) Snapshot of a video recording, the face bounding box is indicated in red. (b) Mean 3BPM agreement for five different mean lighting conditions, both averaged across all subjects.

IV. DISCUSSION & CONCLUSION

Our study indicates that in the range of lighting conditions (132-548 lux), there exists a range of shutter times, i.e. 5-32 ms, for which a mean 3 BPM agreement between 90-100% is achieved. This operational range is only limited by the saturation of the skin pixels and inside this range there is no ‘optimal’ shutter time. In conclusion, control of the shutter time is unnecessary beyond avoiding saturation.

REFERENCES

[1] J. Laurie et al., ‘Dedicated Exposure Control for Remote Photoplethysmography’, IEEE Access, vol. 8, 2020.

[2] W. Wang et al., ‘Algorithmic principles of remote-PPG’, IEEE. Trans. Biomed. Eng., vol. 64, no. 7, pp. 1479-1491, 2017.

[3] P. Hu and D. Ramanan, "Finding Tiny Faces," 2017 IEEE (CVPR), pp. 1522-1530, 2017.