# Preliminary Evaluation of PPG Channel Selection and Preprocessing Parameter Sensitivity for Ear-Worn Respiratory Rate Estimation

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## 1 BACKGROUND

Respiratory rate (RR) is an important vital sign for monitoring cardiopulmonary health, and its continuous and unobtrusive measurement has significant clinical value. Ear-worn devices equipped with photoplethysmography (PPG) sensors provide a practical platform for in-ear physiological monitoring, as they can support relatively stable sensor placement during everyday use. However, the effects of PPG wavelength selection and preprocessing parameter settings on in-ear RR estimation have not yet been systematically evaluated. The in-ear sensing environment also presents challenges, including motion artefacts from head and facial movements and variations in sensor skin contact, which may affect different PPG wavelengths differently.

This study presents a preliminary evaluation of RR estimation from three PPG wavelength channels in an in-ear sensing context. It further investigates a parameter optimisation strategy to identify suitable preprocessing and FFT-based respiratory frequency search settings for each PPG channel.

## 2 METHODS

RR estimation was evaluated using the EarSet dataset, which contains multimodal ear-worn sensing data from 30 participants across 17 head, facial, and full-body activities. In this preliminary analysis, data from 25 participants were included, as 5 participants were excluded due to corrupted ground-truth data.

Only the left-ear PPG signals were used in the current evaluation. Three PPG wavelength channels were assessed: green light at 525 nm, red light at 650 nm, and infrared light at 940 nm. Following established signal processing methods [1], three respiration-related surrogate signals were extracted from each PPG channel: amplitude modulation (AM), frequency modulation (FM), and baseline wander (BW). These three surrogate signals were used to generate three separate RR estimates. To obtain the final RR estimate for each segment, the pairwise differences between the AM-, FM-, and BW-based estimates were calculated. The two estimates with the smallest difference were selected as the most consistent pair, and their average was used as the final RR estimate.

A systematic parameter search was then applied separately to each PPG channel to optimise two sets of parameters: the cut-off frequencies of the preprocessing bandpass filter and the FFT-based respiratory frequency search range. Mean absolute error (MAE) between the estimated RR and the ground-truth RR was used as the primary evaluation metric.

## 3 RESULTS

Preliminary results on the EarSet dataset show that channel-specific parameter optimisation reduced the mean absolute error (MAE) across all three PPG channels compared with the default setting. For the green channel, the MAE decreased from 6.44 to 4.40 breaths/min. For the infrared channel, the MAE decreased from 6.75 to 4.72 breaths/min. For the red channel, the MAE decreased from 6.97 to 4.83 breaths/min. These results correspond to an average relative error reduction of approximately 30% across the three channels.

Among the three PPG channels, the green channel achieved the best current performance, with the lowest MAE of 4.40 breaths/min after parameter optimisation. These findings suggest that preprocessing parameter selection has a substantial effect on ear-worn PPG-based RR estimation, and that applying the same default parameter settings across different PPG wavelengths may not be optimal. However, the results should be interpreted as preliminary, as the current evaluation is limited to a single dataset and has not yet been validated across independent datasets or newly collected data.

## 4 CONCLUSION

This preliminary evaluation suggests that optimising preprocessing parameters for each PPG channel can improve RR estimation from ear worn PPG signals. The observed reduction in MAE across the green, red, and infrared channels indicates that wavelength selection and preprocessing settings are important factors to consider when designing respiratory monitoring algorithms for ear worn devices.

As the current evaluation is limited to a single dataset and signals from one ear, further validation on additional datasets or newly collected data is needed to assess the generalisability of these findings. Future work will include error analysis by activity type to examine how different movement types affect the performance of each PPG channel. It will also explore the fusion of left and right ear PPG signals to investigate spatial complementarity, and the use of IMU data to denoise PPG signals and identify clean signal segments. These steps aim to improve the robustness of RR estimation under dynamic conditions.

## REFERENCES

[1] W. Karlen, S. Raman, J. M. Ansermino, and G. A. Dumont, "Multiparameter Respiratory Rate Estimation From the Photoplethysmogram," *IEEE Transactions on Biomedical Engineering*, vol. 60, no. 7, pp. 1946–1953, July 2013, doi: 10.1109/TBME.2013.2246160.