DEVELOPMENT AND VALIDATION OF A PHOTOPLETHYSMOGRAPHY-BASED SYSTEM FOR HEART AND RESPIRATORY RATE MONITORING IN FREELY MOVING RODENTS

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2 Context

The understanding of physiological biomarkers associated with neurological diseases such as epilepsy requires reliable and minimally invasive monitoring tools that can operate under free-behavior conditions in animal models. In epilepsy research, developing chronic multimodal setups has enabled researchers to acquire real-time electrophysiological and behavioral data in rodents. Photoplethysmography (PPG) has emerged as a promising optical technique capable of extracting cardiovascular parameters such as heart rate (HR) and respiratory rate (RR), and it may provide new insights into autonomic function during seizures and neuromodulation procedures.

Previous work within our research group has resulted in two crucial advancements: (1) the derivation and implementation of algorithms for heart rate (HR) and respiratory rate (RR) estimation from photoplethysmography (PPG) signals in rats, and (2) the design of a wearable PPG collar prototype featuring dedicated analog front-end circuitry for high-fidelity signal acquisition. However, no fully integrated solution currently exists that combines custom-designed hardware and signal processing for real-time monitoring within our chronic recording platform, which considers a complete control system to facilitate reliable HR and RR estimation during noisy recordings (e.g., animal movement, collar positioning variability).

Given the limitations of commercial PPG solutions regarding configurability and integration, there is a clear opportunity to develop a dedicated, validated device tailored to rodent physiology and experimental constraints. Such a system would enhance current research capabilities and support the exploration of autonomic biomarkers in the context of epilepsy.

3 Work

This thesis project aims to develop and validate a complete PPG monitoring solution for rats, including custom hardware and embedded signal processing algorithms. The proposed work plan is structured as follows:

Phase	Duration	Objectives	Deliverables / Milestones
3.1 Requirement Specification	Month 1	Review prior projects; define technical and physiological requirements	Requirements document, risk analysis
3.2 Hardware Development	Months 2-3	Finalize 3D-printed collar design; develop analog front-end circuit; PCB layout and assembly	Rev A prototype, BOM, schematics
3.3 Signal Processing Design	Months 3-5	Adapt and optimize algorithms for HR and RR extraction; implement embedded processing logic	Algorithm modules, simulation results
3.4 System Integration	Month 6	Integrate hardware and software; ensure compatibility with existing recording infrastructure	Integrated system, interface documentation
3.5 Bench and In Vivo Tests	Months 7-8	Perform benchtop testing and pilot in vivo recordings; analyze signal quality and stability	Validation report, comparative metrics
3.6 Thesis Documentation	Months 9-10	Compile results, write thesis; prepare oral presentation	Final thesis draft, slides, defense rehearsal

4 References

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