PhD Research Proposal: Adaptive Smart Optics for Personalized Vision Therapy

Proposed by: Asadullah Rahoo · Email: asadullahrahoo98@gmail.com · Passau, Germany

Background: M.Sc. Computer Science (University of Passau), B.Eng. Electronics; QA/testing; personal experience with amblyopia.

Executive Summary

This project proposes a dual■eye adaptive optical system that modulates per■eye focus and occlusion to deliver personalized amblyopia therapy. The system integrates tunable lenses, LC shutters, embedded sensing, and host■side control to produce safe, gradual optical changes. It emphasizes conservative safety, rigorous QA, and transparent documentation suitable for academic and clinical collaboration.

Research Problem & Significance

Amblyopia treatment remains limited by static, stigmatizing patching and inconsistent adherence. Few systems combine real■time optical control with quantitative logging and adaptable therapy. By leveraging tunable optics and embedded control, this research aims to improve adherence and pave a route to personalized therapy, while keeping safety central.

Objectives

• Design and characterize a per■eye adaptive optical system with guardrails (slew■rate limits, occlusion duty caps, watchdog).

• Develop context■aware therapy algorithms and adherence metrics; support clinician configuration.

• Validate safety/usability with healthy volunteers; draft clinical protocol for partner review.

• Release an open, reproducible R&D; framework (hardware, firmware, host, calibration, CI/tests/docs).

Technical Approach & Methodology

Phase 1 (Months 1–12): System Development. Hardware: tunable lenses (Optotune/Varioptic), LC shutters, ESP32■S3, ToF/ALS/IMU sensors. Firmware: BLE telemetry; AC shutter drive; safety watchdog; conservative defaults. Host (Python): lens driver interface; context engine; therapy scheduler; calibration; logging & reports.

Phase 2 (Months 6–18): Therapy Protocol Development. Literature review; design of intermittent occlusion and contrast■balancing modes; parameter bounds; operator workflows; adherence measures.

Phase 3 (Months 12–24): Safety Validation & Testing. Risk assessment; optical/electrical safety checks; watchdog and bound tests; usability with healthy volunteers; documentation of adverse event criteria.

Phase 4 (Months 18–36): Clinical Validation (collaborative). Ethics approval; pilot with adult participants; analysis of visual function and adherence outcomes; refinement of protocols; publication.

System Architecture Overview

Embedded Layer (ESP32■S3): sensors, BLE, LC shutter drive. Host Layer (Raspberry Pi/PC): therapy policy engine, lens control, logging, reports. UI Layer: mobile/web interface for configuration and monitoring.

Safety Framework

Safety is enforced at multiple layers: slew■rate limits on diopter changes, occlusion duty caps and fades, watchdog fallback to neutral focus and transparent shutters on fault, AC drive for LC shutters (no DC bias), and operator abort. Data contain no personal identifiers; ethics review precedes volunteer studies.

Workplan & Milestones

S1 Foundations → shutters+sensors+BLE; S2 Single■eye lens + calibration; S3 Dual■eye + context + logs; S4 Therapy + safety + reports; S5 Wearable rig + comfort; S6 Eye tracking + analytics (stretch).

Expected Outcomes & Impact

A characterized prototype with reproducible pipeline; validated safety/usability procedures; open documentation and code enabling collaboration; potential to improve adherence through personalized, gradual training. Academic outputs include 1–2 publications and a reusable open framework.

Interdisciplinary Collaboration

Targets: ophthalmology/vision science labs; biomedical optics/biophotonics groups; embedded/wearable health engineering teams. The project is intentionally modular to integrate with existing clinical workflows and optical test equipment.

Qualifications & Readiness

M.Sc. in CS with embedded systems focus (Passau) and B.Eng. in Electronics; QA/testing experience; working repository with CI; strong motivation from personal experience; ready to coordinate with clinical and optics partners.

Resources & Budget (indicative)

Equipment (lenses, drivers, sensors, rig): €50–75k; Personnel/training: €120–150k; Total: €170–225k over three years with potential industry/clinic co■funding.

Next Steps

Identify supervising lab; align scope and milestones; initiate ethics planning; begin bench validation and documentation suitable for pre■study review.

Contact: asadullahrahoo98@gmail.com · GitHub: github.com/AsadRahu60/eye-adaptive-lens