Making Electroretinography Accessible to All

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ERG Background and Project Motivation

Full Field Electroretinography (ffERG) measures retinal function. Light of a predetermined intensity, wavelength, and duration is shined into the eye. This induces predictable action potentials within the retinal layers that can be detected with electrodes placed on the skin inferior to the eye to generate an electroretinogram (ERG). ffERG is currently the clinical standard to evaluate suspected retinal dysfunction. Recent research is also revealing the value of ffERG to detect early-stage diabetic retinopathy prior to fundoscopic changes and vision loss.[1] If introduced as part of standard diabetic screening protocols, ffERG may guide early detection of patients who would benefit from further ophthalmological workup.[2] Clinical adoption is limited by substantial per-unit cost, facility requirements for photopic and scotopic retinal testing, portability, and staffing requirements.

The primary aim focused on developing a goggle device would incorporate all aspects of the ffERG in a goggle device that would isolate each eye in a light-controlled environment, perform simultaneous binocular testing, and reduce ERG technician time burden.

The secondary aim focused on developing a portable light isolation tent for ffERG testing meant with the goal of bringing ffERG testing to mobile testing centers and/orophthalmology outreach programs.

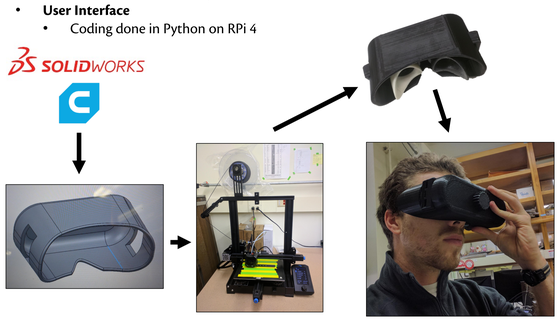
1) Deng X, Li Z, Zeng P, Wang J, Liang J and Lan Y (2021) A Diagnostic Model for Screening Diabetic Retinopathy Using the Hand-Held Electroretinogram Device RETeval. Front. Endocrinol. 12:632457. doi: 10.3389/fendo.2021.632457
2) Al-Otaibi H, Al-Otaibi MD, Khandekar R, Souru C, Al-Abdullah AA, Al-Dhibi H, Stone DU, Kozak I. Validity, usefulness and cost of RETeval system for diabetic retinopathy screening. Trans Vis Sci Tech. 2017;6(3):3, doi:10.1167/tvst.6.3.3

Methods

ffERG Goggles:

As a first prototype, the goggles were designed and built specifically with functionality, rapid prototyping, and cost effectiveness as the primary goal.

- **Materials:**
  - Universal fit polyurethane foam eye pieces with infused black mica pigment Flexible thermoplastic polyurethane and rigid polylactic acid shell
  - 6080 white reflectance coating in the Ganzfeld dome
  - Cree RGBW and IR LEDs
  - Raspberry Pi 4 8GB RAM Model B.
  - Raspberry Pi NoIR Camera Module V2
  - Custom designed printed circuit boards
- **Rapid Prototyping**
  - Creality Ender-3 V2 3D printer
- **User Interface**
  - Coding done in Python on RPi 4

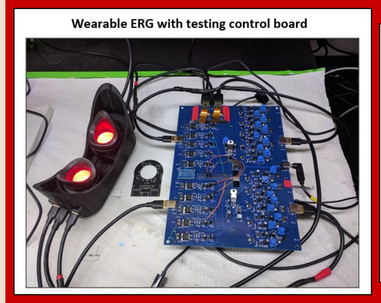


ffERG Portable Light Isolation Tent:

As a first prototype, the tent is meant as a quickly deployable and climate-controlled means to create a light-tight environment for ERG testing no matter the testing location.

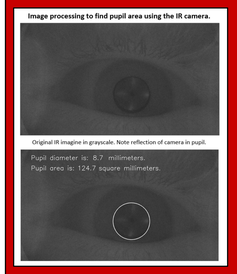
- **Frame**
  - Collapsible PVC tubing for frame
  - 3D printed joints
- **Covering**
  - Light-weight rip-resistant and non-insulating covering
- **Climate control**
  - Light-tight intake and exhaust fans.

ffERG Prototype



The wearable device is currently illuminating red LEDs only for purposes of this picture. LEDs can display red, green, blue, white, IR, or any combination of these colors.

The blue PCB board allows for voltage and current control to each of the LEDs. This allows for precise analog control of light intensity. Further light intensity control is done using pulse width modulation (PWM) where the LEDs are turned on/off at an extremely high frequency imperceptible to the retina.



Shown above is the pupil diameter measurement. This is used to calibrate light intensity to standardize luminosity while avoiding the need for pupil dilation.

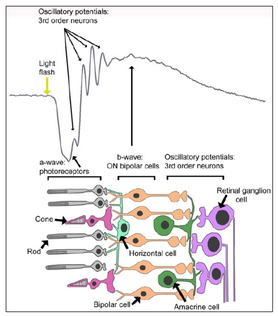
The software measures pupil diameter to within 2.5% when compared to 20 measurements of standardized controls 4 – 26 mm in diameter.

Light Isolation Tent Prototype

Seen here is a prototype of the mobile light-isolation tent used at the La Farge clinic in La Farge, WI, during the quarterly outreach clinic for the Amish population that live in that area.

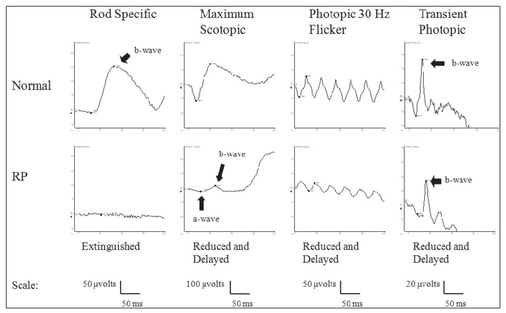
That clinic does not otherwise have the proper facilities to perform reliable ffERG testing.

ffERG Testing Protocol – International Society for Clinical Electrophysiology of Vision (ISCEV)



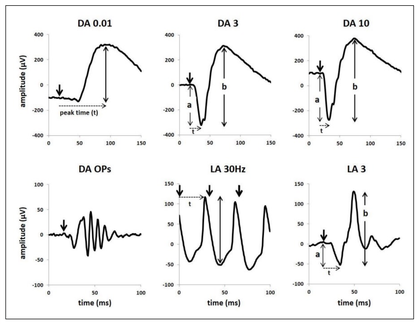
Show here are the specific cells within the retinal that generate the components or "waves" of the electroretinogram (ERG).

Morven C, Barnard A, Lucas R. The electroretinogram as a method for studying circadian rhythms in the mammalian retina. Journal of genetics. 2009; 87. 459-66. 10.1007/s12041-008-0068-5.



Normal ffERG compared to abnormal ffERG found in a patient with retinitis pigmentosa (RP)

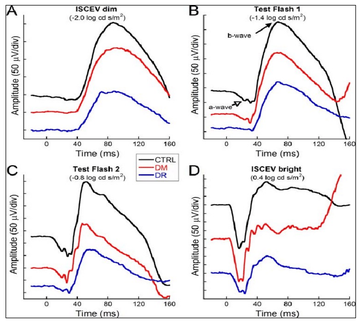
Wolpert, Kyle and Stephen H. Tsang. "1 Electroretinography." (2012). https://www.semanticscholar.org/paper/1-Electroretinography-Wolpert-Tsang/7730796c0db237a6f015507ea47e796f7933e1f3



ISCEV 6

- The **dark arrows** indicate when light was presented to the retina.
- **DA** = Dark Adapted ie sitting in complete darkness for at least 20 minutes.
- **LA** = Light Adapted ie 10 minutes of light exposure
- **OP** = Oscillatory Potentials

Anthony G. Robson, Laura J. Frishman, John Grigg, Ruth Hamilton, Brett G. Jeffrey, Mineo Kondo, Shiying Li, Daphne L. McCulloch. ISCEV Standard for full-field clinical electroretinography 2022 update.



Seen here are ffERGs of individuals with diabetes mellitus (DM) and diabetes mellitus with fundoscopically diagnosed diabetic retinopathy (DM)

Pardue MT, Barnes CS, Kim MK, et al. Rodent hyperglycemia induced inner retinal defects are mirrored in human diabetes. Tran Vis Sci Tech. 2014;3(3):6, doi:10.1167/tvst.3.3.6

Market Competitors

Market for portable ERG devices is dominated by LKC Technologies with RETeval.

Advantages:

- Portable
- Performs ffERG & VEP
- User friendly results interpretation
- Does not require pupil dilation

Disadvantages:

- Cost prohibitive for small clinics
- Single use electrode strips cost $50/pair
- Light isolation room for scotopic testing
- Cannot test both eyes simultaneously
  - Doubles testing time

Project Outcomes

Patent Rights:

- Working with the Wisconsin Alumni Research Foundation and the Isthmus Project (entity of UW-Health).

Entrepreneurship/Business Model:

- Participated in the Innovation to Market (I2M) course powered by the Discovery to Product (D2P) supported by UW-Madison.

- Explored the product market for our proposed ERG device by interviewing ophthalmology technicians, ophthalmologists, and business administrators throughout Wisconsin.

Final Outcomes:

- Created working first generation prototypes for both the goggles as well as the light isolation tent
- Explored technical feasibility and market opportunities
- Further development in progress

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