Evaluation of a Contact Electrode Incorporating a Light Diffusing Element

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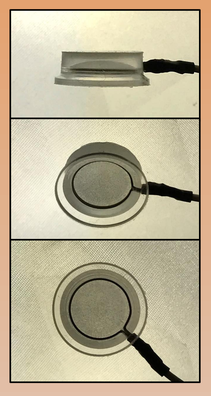
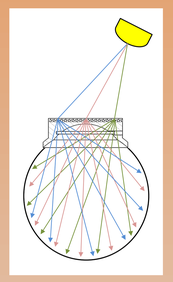
I. Introduction

- Repeatability can be a challenge in electroretinogram (ERG) recording.
- Some of the variability in full-field flash ERG responses can be attributed to unintended variability in illuminance of the retina.
- Variability in illuminance of the retina can result from variability in eye position relative to the stimulus source (due to inconsistent technique, differences in face shape, or poor fixation during the test).
- If the luminous surface viewed by the eye is incorporated into the contact lens electrode, variability in eye position relative to the stimulus source may be reduced.
- Incorporating a light-scattering element into a contact lens electrode creates a luminous surface that fills the field of view – a virtual Ganzfeld source – that moves with the eye.
- Here we evaluate an ERG contact lens electrode that incorporates a light-scattering element.

II. Methods





ERG electrode with a light-scattering element. A prototype ERG electrode (RM-Diffusing) was constructed with a layer of high-index glass microspheres embedded in the distal surface of the transparent silicone substrate.

Full-field ERG responses recorded with the RM-Diffusing electrode were compared with responses recorded with commercially available acuity-preserving electrodes.

Light scatter of the RM-Diffusing, ERG-Jet and Burian-Allen electrodes were quantified.

Light distribution at the retina resulting from Ganzfeld stimulation was evaluated in a bench-top model system for the RM-Diffusing electrode and a representative acuity-preserving electrode (ERG-Jet).

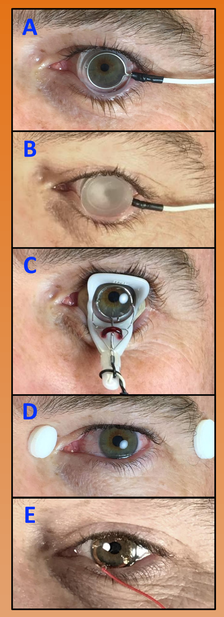
Other methodological details accompany the Results.

The goal was to test two hypotheses:

1) A light scattering layer will more effectively illuminate the peripheral retina.

2) A light scattering layer will compensate for off-target fixation, or for a stimulus source that is poorly aligned with the optical axis of the eye.

III. Summary of Comparison Electrodes



RM Electrode – Clear (RetMap, Inc., Grayslake, IL) Prototyped in 2015, with the design goals of high positional stability on the eye, high transparency, integral speculum, consistent electrode position, soft materials in contact with the eye, and disposable (i.e. low cost).

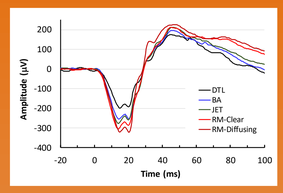
RM Electrode – Diffusing (RetMap, Inc., Grayslake, IL) Prototyped in 2016, with the design goal of improving uniformity of retinal illuminance via light scattering. The distal surface of the electrode substrate approximates an effective Ganzfeld source.

Burian-Allen Electrode (Hansen Ophthalmic Development Laboratory, Coralville, IA) A metal ring electrode contacts the cornea and a plastic speculum anchors the device within the socket [Burian and Allen, 1954]. The integral reference electrode is a conductive paint on the speculum [Lawwill and Burian, 1966].

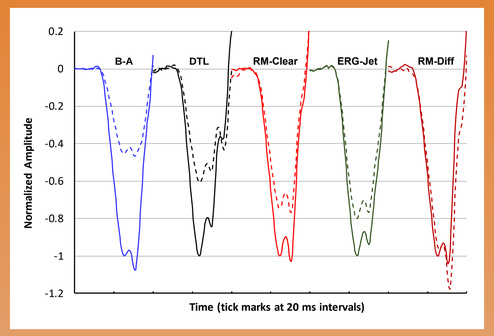
DTL (Diagnosys LLC, Lowell, MA) First described by Dawson, Trick and Litzkow in 1979 [Dawson et al., 1979]. Electrical contact with the eye is made by a conductive thread composed of nylon fibers impregnated with metallic silver. It is disposable and is generally well tolerated.

ERG-Jet (Fabrinal Eye Care, La Chaux-De-Fonds, Switzerland) First described in 1982 by Grounauer [Grounauer, 1982]. Places a gold film electrode in contact with the cornea, and keeps eye lids retracted with four posts protruding from the distal surface of the zero-power acrylic lens.

IV. Results – ERG Amplitudes

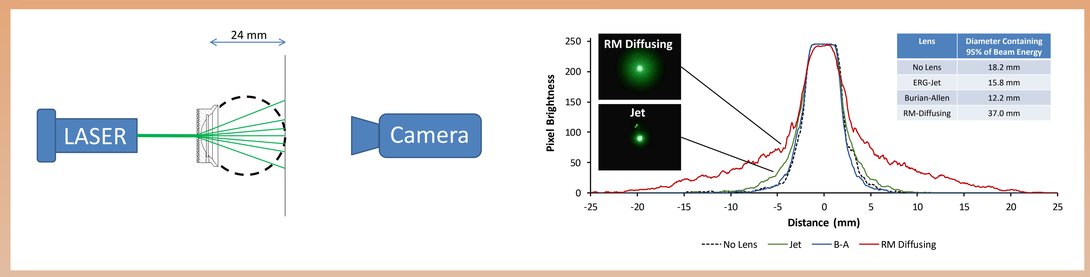


ERG responses recorded with DTL, Burian-Allen, ERG-Jet, RM-Clear and RM-Diffusing Electrodes. All waveforms the average of five responses to a 3.0 sc cd s m^{-2} flash delivered to a healthy dark adapted eye in the same subject within a one hour time period using a Diagnosys Espion ColorDome. Recording order: B-A, DTL, ERG-Jet, RM-Clear, RM-Diffusing.



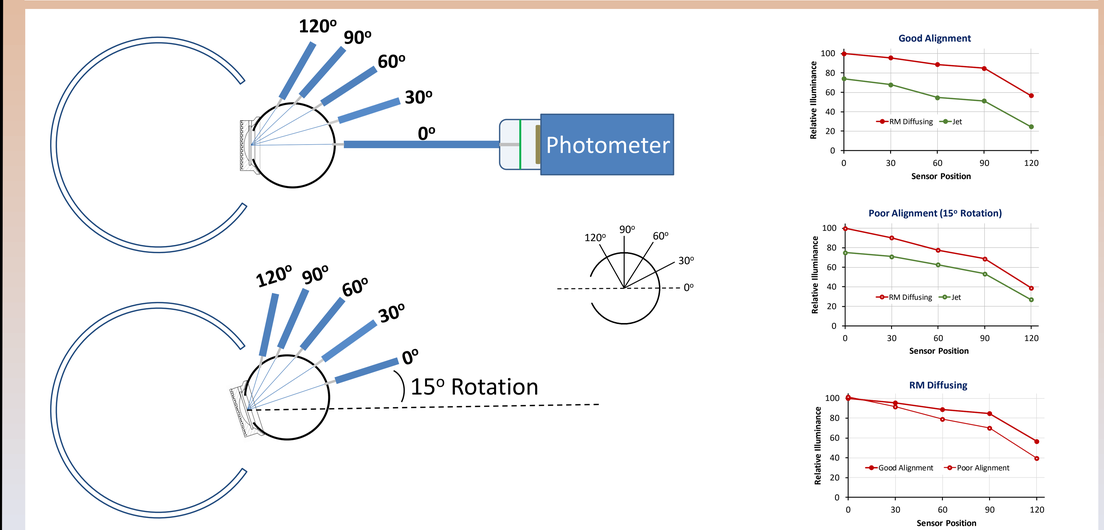
Sensitivity to fixation error. For each electrode, solid waveform plots the response recorded with proper fixation, and dashed waveform plots the response when fixation was moved to a point ~20 degrees in the nasal direction, achieved by rotating the head while maintaining contact with the chin rest and a forward-gaze eye position. Each trace is the average of five responses. Responses normalized to the first negative peak of the proper fixation response for each electrode. In contrast to the acuity-preserving electrode styles, the response obtained with the RM-Diffusing electrode was not affected by a ~20 degree alignment error.

IV. Results – Light Distribution



Lens	Diameter Containing 95% of Beam Energy
No Lens	18.2 mm
ERG-Jet	15.8 mm
Burian-Allen	12.2 mm
RM-Diffusing	37.0 mm

Light scatter achieved with high-index glass microspheres. Each electrode was positioned in a holder, and a green laser beam was incident normal to the distal surface. A diffusing screen was positioned 24 mm from where the cornea would be located behind the electrode (approximate length of a human eye). Beam scatter was recorded by photographing the beam from behind the diffusing screen (DinoLight digital microscope, Dunwell Tech, Torrance, CA). Brightness profiles were measured along horizontal and vertical axes using ImageJ (NIH) and averaged before plotting. The microsphere layer in the RM-Diffusing electrode resulted in greater spatial distribution of the beam energy.



Spatial distribution of illuminance at the retina. A plastic sphere (25 mm OD, wall thickness 2 mm) with an 8 mm hole in one side ("dilated pupil") was coated inside with flat black paint to minimize internal reflection ("RPE"). Five sensor holes (1.2 mm dia) were dilled along the equator, located every 30° relative to the center of the "eye" (inset). Each sensor hole was aligned to point toward the center of the pupil, to mimic alignment of photoreceptor outer segments. The RM-Diffusing or ERG-Jet electrode was affixed over the pupil hole, and the "eye" was positioned in front of a custom-built Ganzfeld source, with the pupil within the plane of the source opening. The jacket of a 1 mm optic fiber was stripped for a distance of 3.0 mm, the end polished, and introduced through the sensor holes at each location. The acceptance angle of the fiber was 26°, similar to cone photoreceptors. The other end of the fiber was coupled to a photometer. To mimic poor alignment with the stimulus source, the "eye" was rotated 15° (lower diagram) and the measurements repeated. Compared to the ERG-Jet, the RM-Diffusing electrode produced higher effective illuminance at all sensor positions, for both good and poor alignment. Poor alignment reduced retinal illuminance by <9% with the RM-Diffusing electrode (average across all sensor positions).

V. Summary

- ERG response amplitudes were consistently highest for the RM-Diffusing electrode design. This may be attributed, in part, to the efficient distribution of light over the retina surface.
- The RM-Diffusing electrode was able to mitigate the effect of poor fixation (or misaligned stimulus source) for alignment errors of 15-20 degrees.
- The large surface area of the RM-Diffusing electrode likely redirects light into the pupil that would otherwise not enter. This effect appears to counter light loss due to back-scatter.
- Minimizing response variability due to poor alignment of the eye with the stimulus would likely result in narrower normative ranges, and increased test sensitivity, especially in populations for which fixation is difficult.
- An electrode with a light diffusing element will require consideration when calibrating stimulus sources in terms of retinal illuminance (Trolands).
- Other options for achieving high forward scattering (diffusing) while maintaining high total transmission should be explored.
- An electrode with a diffusing element may prove useful in veterinary canine ERG testing, where recording is typically binocular and performed in non-sedated animals, and where precise stimulus alignment can be difficult to achieve.

VI. Conclusion

An ERG electrode that incorporates a light scattering element . . .

- Can provide larger amplitude responses and be less sensitive to alignment between eye and stimulus source.
- May be optimal for full-field flash electroretinography.
- Becomes the effective luminous surface of the stimulus system, and
- May significantly reduce the design requirements for the light source (i.e. reduced requirements for full-field geometry and spatial uniformity).

References

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Commercial Relationships

Shresta Patangay, None; Jason C. Park, None; J Jason McAnany, None; John R. Hetling, RetMap, Inc. (Code I (Personal Financial Interest))
All prototype and disposable ERG electrodes were provided by RetMap, Inc., Grayslake, IL. www.RetMapInc.com