HIGH DENSITY FACIAL MAPPING FOR ALTERNATIVE EOG ELECTRODE PLACEMENT FOR THE DISABLED

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ABSTRACT

A small potential difference of between 1 and several mV exists between the cornea (+) and the retina (-) of the eye which is dependent on the ambient light level. This phenomenon, known as the resting potential or corneal-retinal potential (CRP), has been known for over 150 years, [1] and has led to the eye being modeled as an electrical dipole. The measurement of this signal, electrooculography (EOG), is used not only for diagnostic studies in clinical settings, but also for use in assistive technology (AT) as a control input for external devices for the disabled.

A large percentage of end users of EOG in AT are patients who have developed amyotrophic lateral sclerosis (ALS) and that use bi-level positive airway pressure (BiPAP) devices for breathing assistance. These devices cover a large portion of the face, especially the areas most commonly used for EOG signal acquisition (area surrounding the eyes).

This paper serves to present alternative locations for EOG acquisition through the use of electrode facial mapping. A high-density electrode array system is used to gather information on the signal integrity on the face and surrounding area and is weighed against the apparent benefits with respect to BiPAP mask obstruction and general aesthetics. These results are used as a stepping stone towards the development of a new low powered, portable EOG device that will be applicable to any user, despite possible facial obstructions or aesthetic concerns.

INTRODUCTION

The use of EOG as a control input in AT may be a last and only resort when it comes to late stage ALS patients. When interacting and working with patients at this low functioning level it has become apparent that alternative electrode site locations are a necessity for a successful design of a portable, low powered EOG device for control of external devices (call bells, computer mouse, etc.). The varying types of masks used for BiPAP devices often cover locations typically used for placement of electrodes at the outer canthus of the eyes. Furthermore, despite the apparent benefits of external device control, many patients have denied use of EOG due to the lack of aesthetic appeal of electrodes placed on the face.

Previous research has demonstrated the usefulness of colour maps to provide a visual representation of high-density EMG data in an effort to identify the ideal electrode placement locations [2]. This study will follow a similar approach for EOG signals to provide a better understanding of the variations in potentials around the face.

METHODOLOGY

To facilitate a true comparison of signal integrity over the surrounding areas of the face without relying on the repeatability of eye movements, a high-density bio-potential acquisition system was used (Refa™, TMS International).

Experimental Protocol

Fifty-three electrodes were placed from the hairline at the forehead down to the area surrounding and including the ears, along with a reference electrode at the back of the neck (Figure 1). The subject was then instructed to perform a predetermined set of eye movements including:

- Sharp left glance with return to center
- Sharp right glance with return to center
- Sharp up glance with return to center
- Sharp down glance with return to center
- No eye movement

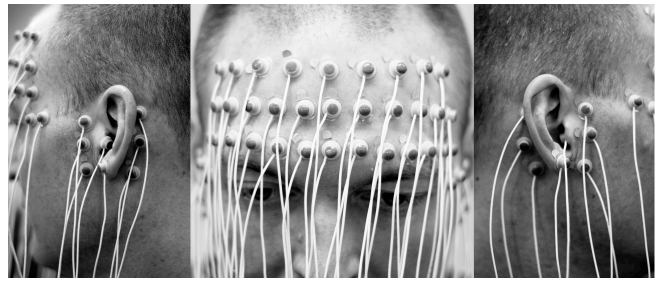

Figure 1: Electrode placement

Data Processing

The recorded data were then processed to take the average peak value for each of the 53 electrodes during respective eye movement. These values were then used to create a coloured contour map that was overlaid onto pictures of the subjects face for each eye movement scenario including the 'no-movement' case (Figure 2).

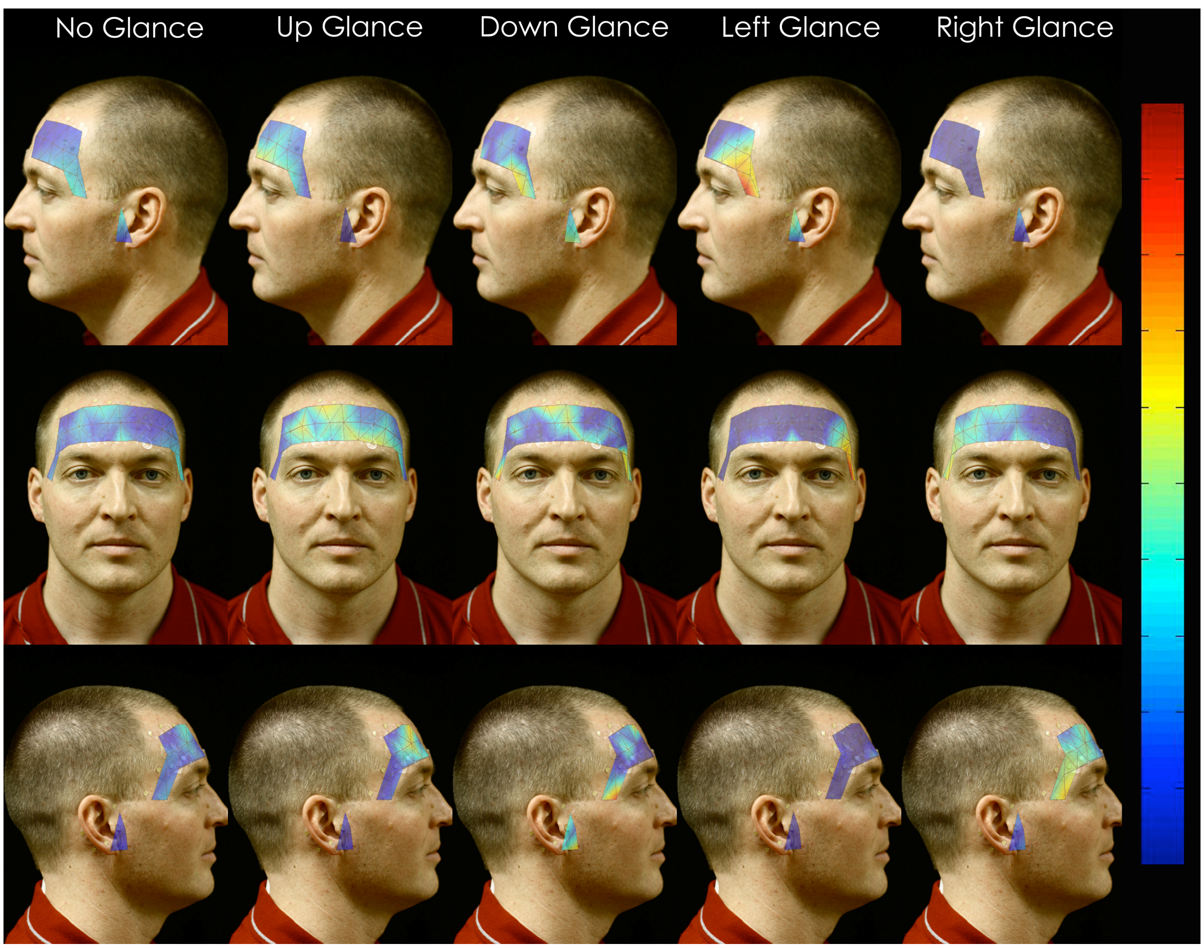

Figure 2: Coloured contour map of EOG signal over face and surrounding area

RESULTS

The contour maps shown in Figure 2 give a visual representation of not only signal strength throughout the facial region, but also how the EOG signal's potential varies with the movement of the eyes. Each of the four defined eye movements along with a 'no-movement' case are presented with contour maps overlaid on three angles of the face (front, right side and left side) to ensure a full view of all electrodes used in the study. Presenting the results in a coloured contour manner provides immediate visual representation of how the signal strength varies and changes throughout the facial region for varying eye movements without the need to sift through multiple data plots. Contour colours are normalized by the largest signal strength variation of any measured electrode for the desired glance types.

DISCUSSION

The first area of interest arises in the 'no-movement' case where the resting potential measured at all electrode locations show little variation in colour other than a slight deviation most likely due to the subject not looking directly ahead but instead somewhat up and to the left. Next we note that as the eyes move to the right, left, upwards or downwards, the potentials measured at each electrode rises or falls based not only on distance from the eyes, but also based on the direction the eyes are pointing. However, we also note certain locations that appear to be insensitive to the movements of the eyes. These locations appear where the electrode was placed in line with the axis of horizontal rotation of each eye (directly above the center of the eyes). This result fits in line with our understanding of the dipole–like behavior of the eyes such that any potential changes measured at any given location are a direct result of a change in distance from the more positively charged cornea with respect to the retina. Therefore if we place our electrodes in line with the axis of rotation of the eyes, the movement of the cornea with respect to those electrodes is minimal.

Finally we see that, aside from the aforementioned electrodes placed in-line with axes of rotation, that all locations exhibit a change in potential (colour variation) as the eyes rotate. This means that nearly all electrode placement locations are viable based purely on signal integrity. Of most interest, the variations measured in potential at the earlobes, although small, were present and discernible. With no BiPAP masks known to cover the earlobe and with the aesthetically pleasing nature of the location, future development will focus on this location.

CONCLUSION

The case study presented illustrates that nearly every area on the face, not directly in line with the axis of rotation of the eyes, is a viable location for electrode placement. More notably, the earlobes were presented as a prime candidate for any future developed EOG control device based on not only signal integrity but also aesthetic appeal.

Future work towards a commercial device will require careful electrode selection to ensure long term use without skin irritation and to mimic the signal acquired with the Refa's™ Ag/AgCl electrodes.

REFERENCES

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