F.R.A.M.E - FACIAL REMOTE ACTIVITY MONITORING EYEWEAR

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ABSTRACT

We take for granted the ability to smile, kiss, or close our eyes at night, all of which can be affected by facial paralysis. This condition may strike anyone at any time, regardless of age or gender. The project aims to develop a pair of glasses that discreetly provides real-time feedback to the wearer about their facial muscle function, helping them practice their rehabilitative exercises regularly and correctly, thereby speeding recovery of normal, symmetric facial expressions.
The glasses will contain all the required EMG sensors in a compact form factor, they will provide sensor data to a mobile application installed on a mobile phone or tablet. The mobile application will provide daily exercises and feedback to allow the patients to monitor their own progress through the rehabilitation process and will also pass on valuable information to therapists via a website. Therapists will monitor the progress of their patients and adjust exercise routines as required. They will also provide feedback through in application messaging and feedback tools while providing in depth analysis tools to spot potential problems such as synkinesis.

KEYWORDS

Bell's Palsy, Wearable Technology, Mobile Application, Electromyography, Cloud Computing, Facial Palsy

1. INTRODUCTION

Facial paralysis results in weakness of the facial muscles, typically on one side of the face, affecting the facial function, appearance and communication of emotions. Patients experience issues with speech, swallowing and blinking, plus significant psychological difficulties such as anxiety and depression.

Bell's Palsy represents 60% of facial palsy cases, resulting in up to 25,640 new cases in the UK annually. Approximately 8,000 of these new Bell's Palsy cases are left with a permanent disability each year – estimated figures of over 100,000 people living in the UK with permanent facial problems are likely to significantly underestimate the problem. There are approximately 152,000 new strokes per year in the UK, with an estimated 26,000 of these patients suffering from residual facial problems after their stroke. The benefits for these patients of 45 minutes daily physiotherapy in the early recovery period are well known but the costs to the NHS of providing such therapy are large (around £2,600 per patient or £62,400,000 per year).

Studies show that following facial paralysis rehabilitative exercises speeds recovery improving the end result. Patients usually have limited awareness of the abnormal movements their faces display so, without feedback their facial function may worsen, developing permanently abnormal movements.

Currently, patients are shown their exercises in clinics and are expected to practice alone at home using only a mirror for feedback. Many patients dislike having to work with their own reflection as it reminds them of their condition and many get discouraged.

Wearable technology that provides real-time facial muscle information to patients and therapists promises a significant improvement in the rehabilitation of facial paralysis (Nicastri et al, 2013), allowing wearers to practice their exercises discreetly and correctly whilst completing other daily activities

2. PROJECT AIM

Facial muscles contain few intrinsic sensory receptors, which fundamentally limits the patient's ability to sense and optimise their own muscle tone. Biofeedback therapy for facial palsy increases the patient's awareness of facial muscle posture and movement, particularly where there has been aberrant re-innervation following facial palsy. Typically, biofeedback is provided via a mirror or else electromyography (EMG) techniques are employed using facial electrodes and accompanying auditory/visual biofeedback that measures muscle contraction and teaches patients to maintain facial symmetry. Patients maintain symmetry during volitional movement by incorporating the information perceived through the EMG although improvements are often temporary.

The aim is to develop and trial a prototype (through proof-of-concept clinical studies) inconspicuous, wearable glasses that are indistinguishable from normal spectacles and provide discreet feedback on facial muscle movement, thereby allowing patients to continuously practice facial muscle exercises. F.R.A.M.E. (Facial Remote Activity Monitoring Eyewear) incorporates advanced non-invasive sensors bringing clinic based EMG into a wearable home-use device. Feedback is via an application on a patients' smart device through wireless tracking of exercise intensity and regularity, enhancing patient motivation (Van der Weegen et al, 2013), whilst allowing specialist physiotherapists to monitor progress, speed patient recovery, provide direct NHS cost savings, time benefits and offer patients significant improvements in their facial function and quality of life.

3. BACKGROUND

There are over 30 causes of facial palsy, all classed as rare diseases, with cumulatively over 100,000 affected in the UK (Julian and Partridge,2008). Recent UK Strategy for Rare Diseases published by the Department of Health, UK stresses the importance of timely access to care. However, patients are still not receiving optimal treatment (Morales et al, 2013).

The muscles of facial expression are anatomically and neurophysiologically different to other muscles, due to their roles in modulating and protecting the main sensory organs, coupled with voluntary and involuntary control mechanisms. In addition to a proportion of the 150,000 annual new UK stroke sufferers, facial palsy affects almost 30,000 new patients annually. Of this latter group, almost a third are left with life-long devastating consequences: inability to close the affected eye; difficulties with eating, drinking and speech; social isolation; and, psychological sequelae (Morales et al, 2013). Two common clinical pictures are: over activity of the muscles on the unaffected side leading to distortion of the facial anatomy and function; and, aberrant re-innervation of the affected side resulting in pain, disability and abnormal movements secondary to increased resting muscle tone.

Currently, there is minimal technology available for rehabilitation of patients affected by facial palsy. During patient assessments, electromyography (EMG) is used to measure the muscle responses when attempting different expressions. This method requires the use of needle electrodes inserted into the facial muscles or large adhesive electrode patches to be attached to the face to detect the activity of underlying muscles.

Patients are frequently able to make impressive progress within a facial rehabilitation session when guided by the feedback provided by the surface EMG. However, these sessions (typically every 3-4 months) make up a tiny fraction of possible rehabilitative time.

The current preferred method uses a mirror for visual feedback while performing rehabilitation exercises. Whilst this is better than no feedback, this method provides no quantitative information. Patients frequently report frustration about their perceived lack of progress.

Alternatives identified during initial research involve the use of facial tracking software and cameras to track the facial movements of users, we found these solutions were accurate but failed to spot Synkinesis. Synkinesis can be detected using muscle tone and we will use EMG sensors to detect this during rehabilitation, this is identified as crucial in the treatment of Bell's palsy.

4. HARDWARE DESIGN

Hardware design is crucial to achieving the goals of this project. Hardware is designed to be indistinguishable from a standard pair of glasses; it will contain the sensors within the frame design so that the patient can use these glasses in everyday activities.

Dry EMG sensors are inserted into the frame and located over the muscles identified during our research. The frame is designed to ensure that a firm contact between the users' skin and the EMG sensor is achieved. It is important that the frame be designed so that as it moves during facial activity the EMG sensors remain firmly against the skin.

To analyse the data we are using the facial action coding system (FACS)(Ekman, P. et al, 1978) to translate the data into Action Units(AU), these will be used to analyze and translate the data into usable datasets. EMG sensors are prone to background noise and interference created from nearby muscle movements and overall sensor movement. To detect movement and to filter out background interference an inertia measurement unit (IMU) was added to the prototype to analyze the activity of the wearer. IMU data is then used to filter out noisy results caused by user activity.

Transmission of data collected from the headset to a mobile device is achieved using Bluetooth LE technology, this was chosen as many mobile devices contain Bluetooth LE capabilities allowing easy integration with a wide range of devices on the market. The technology is for low power wireless transmission, which is essential in designing a battery-powered device.

5. SOFTWARE DESIGN

Software is required to analyse the facial movements of patients' and to interpret this data into a set of landmarks; landmarks represent the patient's facial morphology and are converted into FACS action units. Therapists use action units to diagnose and monitor patients during treatment for many facial conditions, providing this feedback from the system will therefore be preferable.

A mobile application is being developed to run on common platforms in use today (Android/IOS). The mobile application provides exercises and feedback during treatment, messaging functionality is planned, allowing two-way communication between therapist and patient.

Many patients dislike seeing their own face during exercises as they find this distressing. FACS action units are valuable in replicating the patient's facial movements for use in alternative visual feedback methods such as bars, gauges and avatars.

The application will provide background services to pass data to a remote server via the internet connection on the mobile device. This data will be accessible to therapists via a web portal and will provide a valuable link between therapist and patient. This system uses SSL encryption to secure the data and prevent the data being stolen during transmission. Any images of patient's are encrypted and data stored in the online database will not contain any identifiable details that allow an intruder to identify patients on the system. A secure database system will be used where access to the database will not be permitted from sources outside of the server ecosystem; access to the database will be done via a web service running within the server ecosystem. API's will be designed to pass the collected patient data one-way, up to the server. The mobile application will not download previously collected data; this will add an extra layer of security to patient information.

A web portal will be created for use by the therapist for monitoring patients'. A website-based solution was chosen, this is accessible via any web browser based system including Windows/Mac computers and mobile devices. The portal will provide expandable sets of tools for the therapist to analyse and monitor patients' continuously and to view visual representations of patient's facial movements. The portal will provide tools for communicating with patients and assigning custom exercise routines for each patient. Looking forwards, it could provide the use of cloud computing and machine learning algorithms to assist in treatment and analysis.

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6. CONCLUSION

The research requires the development of a hardware device in the form of a pair of glasses wearable by the patient in everyday activities. The device has been prototyped to establish the best locations for the EMG sensors; there have been three prototypes developed so far and we have collected sample data from over 50 volunteers. This data has assisted us in establishing the requirement for extra sensors to detect the rise and fall of the cheek muscles. The sensor placement will be vital in providing therapists with everything they need in order to monitor the progress of patients and help detect potential problems in patient rehabilitation. We continue to explore different sensor options as we create more prototypes to address this need. Current EMG sensor placement (figure.1.0) is providing valuable data; we will miniaturize this form factor over the coming year and collect more data to continue research.

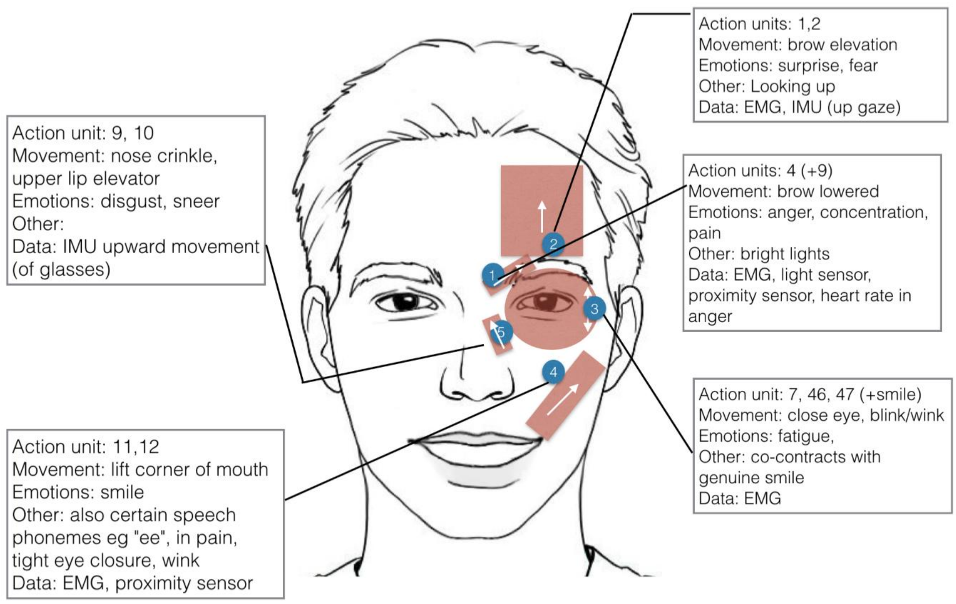

Figure 1. Selected EMG Sensor Locations

Now that we have sample data we are formatting this data so that we can transmit the data via Bluetooth to the mobile device for further processing, we can then pass this data up to the cloud. Work on developing machine-learning algorithms to process data into usable facial poses and muscle movement is currently underway.

We continue discussions with focus groups and therapists to establish and develop the required functionality into the software applications. We have held our first meetings with therapists and volunteer patients and currently analysing this data. Focus group meetings highlighted the need for communication channels between the patient and therapists, concerns were raised that in removing the requirement for a patient to attend a regular session with the therapist would demotivate the patient and cause them to seek information from elsewhere. We are investigating the option of adding features to the application such as direct messaging, video calls and contact information for approved charities.

Several hurdles need to be overcome to achieve our goals including the removal of background noise created by patient movements. The use of dry EMG sensors presents less accurate readings than could be achieved with wet sensors but are essential in achieving the goal of a daily wearable device. Research continues into the field of dry sensors and we hope to optimise and refine the results collected so that this accuracy hurdle is overcome. We continue to research into achieving optimal skin contact with the sensors when the frame itself moves on the patients face during everyday activity.

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