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Augmented control of hands free voice prostheses

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Augmented control of hands free voice prostheses

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***Abstract*— Laryngectomy patients often use an electro-larynx to facilitate speech following a tracheotomy. Devices of this type provide the most intelligible means of communication for tracheotomy patients. However, the electro-larynx has inherent drawbacks such as the *buzzing* monotonic sound emitted, the need for a free hand to operate the device, and the difficulty experienced by many tracheotomy patients in adapting to use it. The most effective means of addressing the shortcomings of existing electro-larynges is to provide the user with a *hands-free* facility. This allows the user to perform other manual tasks whilst speaking, or simply to communicate more effectively through body language. Hands-free devices do exist but require a considerable amount of patient training as they involve the use of the shoulder muscles to control pitch. Furthermore, they are not suitable for all patients as the hands-free is suitable only for users with a certain type of tracheotomy.**

Goldstein et al in 2004 [1] produced a working prototype of a hands-free device that employed electromyographic signals to activate the device. However, it was quite cumbersome in design and failed to alleviate the monotonous sound produced.

The goal of this research is to research the implementation of a hands-free electrolarynx, using various activation methods including electromyographic signals to vary parameters of the output signal. Once a satisfactory system of initiation has been devised and tested, a method of pitch variation shall be developed.

Keywords— **Laryngectomee, electrolarynx, drawbacks, electromyographic, hands-free.**

I. Introduction

The ability for the majority of persons to communicate verbally between one another is seen as a prerequisite in everyday life. It is the core of self-expression as it enhances the level of interaction which takes place between people. When a person has undergone the procedure of a total laryngectomy (TL), having their larynx removed, either through surgical means - as a result of cancerous growths in their neck or through trauma - this valuable method of exchange is invariably lost. There are a number of striking outcomes following the surgical procedure of a total laryngectomy which create a number of unequivocal physical alterations to a laryngectomee. Not only is their means of speech profoundly affected but their physiological and means deglutition is also disrupted.

Prior to the surgery, the patient availed of the same methods of speech communication as any laryngeal speaker did i.e. the air from their lungs provided the source of power, their larynx provided a source for the sound and the pharynx provided a means of sound modification. Following a TL; the larynx is removed, therefore disconnecting the sound source, the source of air from the lungs is also disconnected from the pharynx and is redirected through a permanent aperture in the front of the patients neck , which is also known as stoma and can be seen in Figure 1 below.

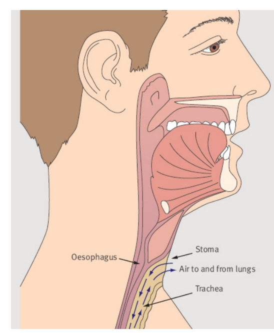

Fig. 1 Redirection of airways following a TL [2]

This procedure can understandably cause a great deal of distress and discomfort to a laryngectomee, having lost their prime source of communication. The task of a Speech and Language Therapist (SLT) is to provide the laryngectomy patient with a method of restoring their confidence, by providing them with a number of methods of communication post TL. These are classified into three main groups: Esophageal speech – where the patient drives swallowed air into the esophagus to inflate it and then forces it back out again to produce a burp-like sound: – words are produced through accentuation of the mouth cavity are using the expelled air. The length of utterances from an esophageal speaker is quite short as their lung capacity is much smaller than that of a laryngeal speaker [3].

Tracheo-esophageal speech produces a similar sound to esophageal speech but the air is transferred to the esophagus via a surgically inserted prosthetic connecting the trachea to the esophagus. This enables the user to create their esophageal speech through normal breathing patterns. The final form of communication is through the use of electromechanical devices. These are further divided into two separate groups: Intra-oral and external. Intra-oral, such as the Tokyo artificial larynx is comprised of a tube with a metal reed where one end is placed over the stoma and the other is placed into the mouth cavity. The air that is dispelled through the stoma into the tube causes the reed to fluctuate and produce a sound, which is resonated into the mouth cavity and words are produced by accentuation of the lips and teeth. The pitch is varied by tightening the reed using a grub screw in the reed-mechanism. The tube requires constant cleaning as saliva from the mouth can create blockages during speech.

The other and most commonly used type of speech prosthetic is called the electrolarynx. The modern EL used today was invented in 1963 by Harold Barney. It is comprised of a hand-held battery powered device, which incorporates a transducer to provide generated pulse that is in the range of natural human voice. The transducer is a basic electromagnet that oscillates against a diaphragm when the output signal of the oscillator is applied to the windings of the electromagnet. This pulse is placed against the throat, near to where the larynx was. This substituted sound source excites the pharynx and causes the vibrating sound to resonate within the mouth cavity and similar to the other methods, words are formed through accentuation. Some advantages of the electrolarynx are; it can be learned easily and quickly – enabling speech soon after surgery. It can be used in conjunction with an intra-oral device during radiation therapy and can be used as a substitute for esophageal speech if radiation therapy is being performed which affects the esophagus. Electrolarynx speech can be used during times of stress, excitement, radiation therapy etc. where esophageal speech may not be feasible [4]. In the 1959 patent application of Barney et al. (which was subsequently approved in 1963), he stated that the sound which was produced from the electrolarynx lacked quality or intelligibility. [5]. These shortcomings are still apparent almost 50 years later.

Following a meeting of SLT's at a head and neck special interest group in Dublin Ireland, it was conceded that the primary improvement –from electrolarynx users attending speech and language therapy clinics throughout Ireland – would be to incorporate a hands-free system. This would alleviate the need for an electrolarynx user to have one free hand at all times when they wished to speak. An additional improvement was the requirement for a natural ability of pitch variance to be incorporated into the design.

Goldstein et al. in 2004 created a hands-free version of the electrolarynx which used electrodes that were attached to the neck of the user via a strap. It applied the electromyographic signals that were detected by the electrodes to a processor which determined when the device would activate and deactivate. This study proved successful as the reaction time, yet somewhat slower than a regular electrolarynx, provided a good basis from which to work from in future studies. Other studies conducted on the electrolarynx concentrate on improving the output sound that is produced. Houston et al. [6] developed an electrolarynx which used digital signal processing to create a superior quality of sound. It also incorporated a redesigned transducer which operated linearly as opposed to the non-linear output of the regular electrolarynx. Shoureshi et al. [7] used neural based signal processing and smart materials to improve the sound created. Liu et al. [8] and Cole et al. [9] focused on removing the "buzzing" sound created by the transducer with the electrolarynx device. Krishna et al. [10] and Ooe et al. [11] concentrated on sound amplification of the output, using an electro-magnet and a piezoelectric transducer respectively as their vibratory sound source.

II. METHODS AND MATERIALS

A. Possible methods of activation

Electromyography (EMG)

The goal of this research is to develop an alternative method for activating an electrolarynx. A preliminary study will be to investigate the effect of the electromyographical signals produced at certain locations around the neck. Electromyographical signals are physiological variations in muscle activity produced between two electrodes placed a certain distance between each other – depending on the size of the muscle being used. It was noted by the SLT's at the head and neck special interest group in Dublin Ireland that due to certain patients receiving radiation therapy for different levels of cancers around their oral cavities may have atrophic effects on the surrounding muscles of the mouth. This could therefore possibly inhibit the electromyographic signals received. Therefore a number of studies will be conducted to test electromyography on a number of laryngectomee patients with varying degrees of radiative therapy in varying parts of their oral cavity. A

BioSemi amplifier with Active-electrodes will be used throughout the study.

Mechanomyography (MMG)

One possible method which will be investigated to wirelessly activate an EL would be to place a modified three-axis linear accelerometer onto the surface of the skin underneath the jaw bone. The accelerometer will be activated by pressing the tongue downwards onto the genio-hyoidues muscle (A in figure 2 below) which will extend the mylohyoideus muscle (B in figure 2 below). The SLT's commented that the tongue – unless affected by the cancer – would be a possible source of turning the electrolarynx on and off. The accelerometer will be configured to detect a mechanmyographic signal resulting from the movement of muscle fibres in the mylohyoideus muscle. This design should provide an electrolarynx user with a moderately inconspicuous, hands-free method of activating the electrolarynx.

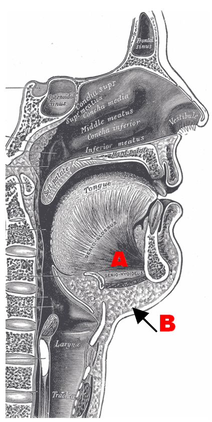

Fig. 2 Mylohyoideus and genio-hyoideus muscles [12]

Measuring extemporaneous speech:

Using two three-axis accelerometers attached to an elastic strap and placed over the diaphragm, a method for measuring extemporaneous speech will be investigated. Extemporaneous breathing in relation to speech is the subconscious and sudden breathing pattern that takes place when a person begins to initiate speech. We will measure breathing patterns of an electrolarynx user by calibrating the:

- Breath group duration
- Lung volume duration
- Lung volume termination [13]

using the accelerometers relative to each other during various actions i.e. relaxing, walking, lifting etc. The accelerometers will be mounted on an elasticated strap on either side of the users' chest as seen in Figure 3. The signal that will be produced from the accelerometers when this abrupt breathing pattern occurs will wirelessly activate an electrolarynx. When the electrolarynx users breathing pattern reverts to its relaxed state after speaking – the electrolarynx will turn off. This design will provide a hands-free, inconspicuous method of activating an electrolarynx for a user. The idea is to also provide a subconscious method, activated when the breathing pattern changes, thus allowing the user to continue on with their daily lives by talking when they want to, not when they need to.

Fig. 3 Belt design

Electroglottography (EGG)

Similar to the detection of an electromyographical signal, electroglottograms are used to identify an electrical resistance between two points on the body. In particular, electroglottography measures the variation in resistance between two specific places. In this case the thyroid cartilage. These variances are deemed to be the amount of contact that exists between the vocal cords. This system will be designed for patients who have undergone a vertical partial laryngectomy (VPL), which is seen in the figure 4 below.

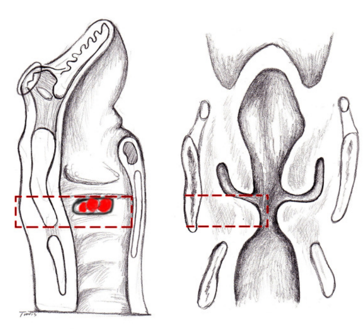

Fig. 4 Vertical partial laryngectomy [14]

Although the patients who undergo this surgery procedure have the ability to produce natural speech, it is weak, laboured and breathless sounding. Singh et al. in 2008 [15] conducted an acoustical analysis study which compared the vocal output of laryngeal speakers, total laryngectomees and vertical partial laryngectomees. Results showed that the vocal output from the vertical partial laryngectomees was poor compared to the laryngeal speakers and resembled speech to that of the total laryngectomees. It will therefore be investigated if whether this method of activation can be used on vertical partial laryngectomees as a method of activating an EL device during their speech and language therapy post surgery.

III. CONCLUSIONS

Since 1949, the same fundamental shortcomings have remained in the design and the output of the electrolarynx. In particular its monotonous sound output and its cumbersome design. With the aid of Speech and Language therapists in Ireland, this study will attempt to overcome these deficiencies through various empirical techniques.

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