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Using Visual Feedback to Enhance Intonation Control within Electrolaryngeal Speech

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A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Health and Rehabilitation Sciences
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Abstract

This study evaluated the effectiveness of visual feedback in facilitating pitch control using a pressure sensitive electrolarynx (EL). This proof-of-concept pilot study was a single-subject design that included two healthy adults (1 female aged 23;6 years old, and 1 male aged 67;0 years old). Both participants were provided with visual feedback over two consecutive weeks. Changes in pitch and force control accuracy over 4 hours were analyzed. The results demonstrated that both participants showed an improvement in force control accuracy from the first to the last training session. The results of this proof-of-concept study are a preliminary step towards the development of a clinical training protocol for the use of a pressure sensitive EL. Further, these results highlight the importance of developing a clinically relevant tool for the improvement of a laryngectomee's quality of life postlaryngectomy.

Keywords: laryngeal cancer, laryngectomee, electrolarynx, artificial larynx, intonation, pitch control, pressure sensitive electrolarynx

Co-Authorship Statement

The primary author of the work contained within this thesis was Noor Al-Zanoon. However, I, Noor Al-Zanoon, acknowledge that this work would not have been possible without the collaboration of both Dr. Philip Doyle and Dr. Vijay Parsa. The contribution of the co-authors, Dr. Philip Doyle and Dr. Vijay Parsa was primarily through research and theoretical guidance; supervision; data interpretation and analysis; editing; advising and support.

Acknowledgments

I would like to first acknowledge my supervisor, Dr. Philip Doyle for his continued guidance and support from the very beginning to the final days of this work. I am humbled and thankful for having the opportunity to work with a great supervisor, who pushed me to be creative and innovative. Thank you so much for having faith in me and for guiding me throughout this process.

Secondly, I would like to thank Dr. Vijay Parsa for his unwavering support. This project would not have been possible without the technical expertise that Dr.Vijay Parsa brings to the table. I would also like to thank Xinya Lin for her efforts in the programming aspect of this project.

Thirdly, I would like to thank my family for their enormous support through this entire project. I am appreciative of my brother Saleem, for his great help in the engineering and programming aspect of this project. I am also very lucky to have a supportive sister Sama who pushed me through all of the tough moments throughout this process. Many thanks to my parents (Eman and Hisham), for their continued support and faith in me.

Finally, thank you to my best-friends Sophia Tang, Vanessa Tang for enduring many hours of ranting and complaining! I could not have reached the finish line without this support and love.

Table of Contents

List of Tables

List of Figures

List of Appendices

Chapter 1

Introduction and Review of Literature

Overview

Total laryngectomy (TL) is a highly aggressive surgical treatment for advanced laryngeal cancer. The Canadian Cancer Society estimated that 1050 new cases of laryngeal cancer would be diagnosed in 2016. Not only does laryngectomy impact the physical well-being of an individual, but it also has severe consequences on overall quality of life (QOL). In 2001, the World Health Organization defined QOL as, "an individuals' perceptions of their position in life in the context of culture and value systems in which they live and in relation to their goals, expectations, standards and concerns" (p.3). Common treatment options and preservation techniques as a response to laryngeal cancer include radiation therapy, chemotherapy, chemoradiation therapy and partial laryngectomy (Pfister et al., 2006). Although the goal of laryngeal cancer treatment is to ideally preserve as much of the larynx as possible, advanced tumors (T3 lesions or greater) require a total laryngectomy (TL) to ensure safe surgical margins (Doyle, 1994). As described by Doyle (1994), "total laryngectomy involves the surgical removal of the laryngeal valve from the superior aspect of the airway. The trachea is then brought anterior to the midline of the neck and sutured into place. This results in the complete and total functional separation of the primary airway and the oral, pharyngeal, and upper digestive pathways" (p.58). As a result of the complete removal of the larynx including the vocal folds, individuals are faced with verbal communication challenges. The loss of the normal voice production mechanism and speech secondary to TL often leads to withdrawal and isolation, which negatively impacts an individual's rehabilitation and treatment (Doyle & Keith, 2005; Doyle, 1994). This is specifically impactful for individuals who have undergone a TL because their voice, a personal characteristic and a component of individual identity, has been lost. Consequently, a new atypical or “alaryngeal” method of voice and speech production will now need to replace the once normal voice that characterized the person before TL. The following sections outline the common, post-operative communication methods and their associated advantages and disadvantages.

Communication Options Post-Laryngectomy

At present, there are three primary methods of post laryngectomy voice and speech production: esophageal speech (ES), tracheoesophageal (TE) puncture voice restoration, and electronic artificial laryngeal or electrolaryngeal (EL) speech. These three alaryngeal modes can be further classified into intrinsic (vibratory source is created by biological tissues) and extrinsic (the vibratory source is created through a source outside the body). Both ES and TE are classified as intrinsic methods while EL speech is an extrinsic means of communication.

ES speech. ES involves redirecting air within the oral cavity and vocal tract into the esophagus. By doing so, this air can be used volitionally to vibrate tissues that form the region between the esophagus and the pharynx; this region is called the pharyngoesophageal (PE) segment (Diedrich, 1968; Gates, Ryan & Lauder, 1982; Uemi, Ifkube, Takahashi & Matsushima, 1994). One of the advantages of using ES speech is that it is a hands-free method of speech; which allows for more effective verbal communication and expression (Keith & Doyle, 2005). Other advantages include the fact that no external equipment or maintenance of devices is required for ES speech (Keith &

Doyle, 2005). However, for many laryngectomees[1], this method of speech production requires extensive training from qualified instructors and may be difficult to acquire proficiently (Goldstein, Heaton, Kobler, Stanley, & Hillman, 2004). The literature has suggested that the acquisition of ES may be associated with a varied success rate ranging from 26 to 40 percent (Gates, Ryan & Cooper, 1982). However, Doyle and Eadie (2005) have suggested that failure to acquire ES may be due to physiological reasons; and these reasons can be remediated. In addition to potential difficulty in learning ES, several acoustic shortcomings also have been associated with ES such as reduced speech intensity (Smith, Weinberg & Horii, 1980), decreased word/speech rate (Baggs & Pine, 1983; Robbins, 1984) and lowered pitch (Robbins, Fisher, Blom & Singer, 1984; Bennett & Weinberg, 1973).

TE speech. TE puncture voice restoration involves the surgical creation of a controlled fistula in the common anatomical wall between the trachea and the esophagus (Singer & Blom, 1980; Doyle & Keith, 2005). The fistula is necessary for the insertion of a one-way valved prosthesis. To produce voice, the patient occludes the stoma and redirects inhaled air to vibrate the PE segment (Singer, 1983; Pou, 2004). Compared to ES speech, TE speech has been found to be more efficient relative to speech intelligibility (Cullinan, Brown & Balock, 1986; Doyle, Danhauer, & Reed, 1987; Moerman, Martens, Vander Borgt, Peelman, Gillis, & Dejonckhere, 2006), intensity (Baggs & Pine, 1983;

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[1]The reference to a person who has undergone total laryngectomy as a a laryngectomee is the preferred term within this population and field of communication sciences.

Robbins, et al., 1984; Gates et al., 1983) and fundamental frequency (F_0) (Robbins, Fisher, Blom & Singer, 1984). Despite these acoustic advantages, TE speech requires the use of the thumb to occlude the stoma each time the individual wants to speak (Cocuzza et al., 2013). Finally, the prosthesis does require regular maintenance and replacement on a variable time schedule. In a study by Cocuzza et al., (2013), the mean prosthesis life among 40 laryngectomees was 355 days for the latest model of a specific TEP device (Provox).

EL speech. Compared to ES and TE speech, studies report that more than half of laryngectomees use EL speech as their primary mode of communication (Mendenhall et al., 2002). One of the reasons for this high level of use is because it provides a means of communicating immediately after laryngectomy (Mendenhall et al., 2002; Morris, Smith, Van Denmark & Maves, 1992; Gray & Konrad, 1976; Hillman, Walsh, Wolf, Fisher, & Hong, 1998; Ward, Koh, Frisby & Hodge, 2003). However, the continued use of the EL as a primary means of verbal communication is common (Hillman et al, 2005). Yet it is often used as a secondary device by TE and ES speakers in noisy communication situations, for communication over the telephone, and/or if primary modes of alaryngeal speech malfunction (Uemi et al., 1994; Doyle, 1994; Hyman, 1995).

EL speech involves the use of a device called an electrolarynx (EL). An EL is a hand- held, battery operated device that externally vibrates air molecules so that they can then be articulated into speech. These excitations or vibrations are either transmitted into the oral cavity by a tube placed within the mouth (transoral EL devices) or through the neck tissues (transcervical EL devices); the transcervical method is the most common method for those who use the EL (Doyle & Keith, 2005). Transcervical EL produces sound using a mechanism that operates like a piston hitting a drum head. Doyle and Keith (2005) have provided a clear description of this internal mechanism: “when the electromechanical driver is activated, it forces a small cylindrical head mounted on a diaphragm (like a piston) to strike against a rigid plastic disk (like a drum head), thus producing a series of impulse like excitations” (p.574). Once the air is vibrated and moves into the vocal tract, the oral articulators can manipulate it to produce speech sounds (Meltzner, Hillman, Heaton, Houston, Kobler & Qi, 2005).

In addition to the internal mechanism of the transcervical EL, on the external surface of any device is an on-off control button that allows an EL user to control when to turn on a device for speaking and when to turn it off. A volume control dial is also included. Some ELs have two buttons (e.g., Servox) allowing for binary adjustment of two frequency (pitch) sources: high and low. Other models include a potentiometer that allows for the adjustment of pitch using finger pressure (e.g., TruTone™ Electronic Speech Aid, Griffin Laboratories). Figure 1 provides an example of the basic components on the external surface of a TruTone EL. The technological design of the EL provides the user with several advantages and disadvantages. These will be discussed in the following sections.

Figure 1. TruTone™ Electronic Speech Aid: A) sound head, B) pressure sensitive on/off button C), volume knob, and D) battery cap. Adapted from "TruTone Electronic Speech Aid" by Griffin Laboratories, 2008. Retrieved from http://www.griffinlab.com/ Products/TruTone-Electrolarynx.html

Advantages. The most critical advantage of EL speech is that it can provide a means of communicating immediately post-surgery while other speech methods require a period of adaption and acquisition (Doyle 1994, 1999; Lauder, 1970). Further, Rothman (1982) found that an EL can be used in a variety of communication environments. For example, EL use has been found to be effective in communication over the telephone and in noisy environments (Doyle, 1994; Hyman, 1995).

Disadvantages. The overall, reduced perceptual quality of the speech signal produced when using an EL is directly caused by several factors: 1) low frequency deficits in the EL source signal, 2) signal transmission loss that occurs due to the transfer of sound from the device through neck tissues, 3) noise that accompanies the EL voice from the vibration of the individual's neck tissues (Espy-Wilson, MacAuslan, Huang, & Walsh, 1998), and 4) the EL has a voice quality that is robotic, mechanical, and monotone sounding. Each acoustic property will be discussed in further detail below.

Low frequency deficits. Qi and Weinberg (1991) reported an identifiable low energy frequency output of an EL. Specifically, for a tone to be transmitted across an individual's neck tissue, most EL devices use a single oscillator (Qi & Weinberg, 1991). The single oscillator creates a tone which optimally passes through neck tissue, but also results in low frequency deficits. That is frequencies that are lower than 400-500Hz are acoustically dampened (Weiss, Yeni-Komshian & Heinz, 1979). The decreased frequency range may underlie the mechanical, robotic voice quality of EL speech (Weiss et al., 1979). Therefore, an EL should ideally produce a range of frequencies that approximate the acoustic patterns of a laryngeal tone (Barney, Haworth & Dunn, 1959). Qi and Weinberg (1991) have confirmed the impact of this low frequency deficit on audio-perceptual ratings of EL voice quality. That is, listeners were found to prefer EL speech samples in which lower frequencies were acoustically enhanced.

EL noise. In addition to the decreased frequency range, EL speech is accompanied by a "buzzing" sound. This sound is a result of the electromagnetic transducer found within the EL device (Niu, Wan, Wang, & Liu, 2003). When EL speech is produced, some of the sound does not pass through the speaker's throat but is reflected by the device and/or surrounding neck tissues (Niu et al., 2003). Barney, Haworth, and Dunn (1959) found that this radiated background noise had an intensity range of 20-25dB when the speaker's mouth was closed. These researchers also reported that the most radiated background noise resulted from the surrounding neck tissues. Other studies report that the amount of radiated background noise varied with different EL speakers (Weiss, Yeni-Komshian, & Heinz, 1979). The background noise associated with EL speech has been reported to decrease voice quality and intelligibility, especially when combined with environmental noise. For example, Holley, Lerman and Randolph (1983) found that as environmental noise increased, EL speech intelligibility decreased. Finally, the impact of radiated background noise is highlighted in a study by Niu et al., (2003). In this study, EL speech was enhanced by filtering the radiated background noise associated with the device. Audio perceptual ratings of the filtered EL speech by naïve listeners revealed a significant increase in acceptability and intelligibility.

Non- variation of f_0. Apart from very few devices (e.g., TruTone, Griffin laboratories), most EL's do not allow the variation of pitch. In addition to radiated background noise and low frequency deficits, the lack of F_0 variation has been found to be a strong contributor to the robotic, monotone voice quality of the EL (Ma, Demirel, Epsy-Wilson, & MacAuslan, 1999; Meltzner & Hillman, 2005; Gandour, Weinberg, Petty, & Dardarananda, 1988; Liu, Wan, Ng, Wang, & Lu, 2006; Ng, Gilbert, & Lerman, 2001; Uemi, Ifkube, Takahashi, & Masushima, 1994). Watson and Schlauch (2009) investigated the effect of F_0 variation on the intelligibility of EL speech. In their study, a single EL speaker read declarative sentences with variable F_0, using a pressure sensitive EL device. As a control, these sentences were acoustically modified to flatten the F_0 contours. Results showed that sentences produced with a variable F_0 were better understood by naïve listeners. Gandour, Weinberg and Rutkowski (1980) reported that EL speakers had difficulty producing F_0 contrasts in questions and declarative statements. In this same study, listeners also struggled to differentiate between the two types of sentences. These studies demonstrate the importance of F_0 variation and particularly its impact on speech intelligibility.

Bennett and Weinberg (1973) further argue that the lack of F_0 variation has severe consequences for an EL speaker because of listener expectations of naturalness. More specifically, these researchers argue that EL speakers are penalized for having a voice that deviates greatly from the expected F_0 variations of a laryngeal voice. Laures and Weismer (1999) hypothesized that F_0 variation directs listener's attention to important words or parts of sentences. Therefore, a potential explanation is that a flattened F_0 may hinder intelligibility of EL speech, because listeners may have more difficulty segmenting sentences.

In summary, the reduction in EL voice quality as a consequence of the aforementioned acoustic factors, particularly the reduced F_0 variation, severely impacts both the speaker and the listener. First, EL users cannot produce the necessary contrasts in pitch needed for effective verbal communication; and second, listeners cannot distinguish between these contrasts. The listener-speaker paradigm can be summarized in terms of several major factors including speech intelligibility and speech acceptability. The robotic sound quality of an EL deteriorates the quality of the speech signal and by default, a listener's understanding, or perception of that signal. Further issues caused by reduced F_0 variation are discussed in the following section.

Issues Caused by Reduced F_0 Variation

In addition to the impact on EL speech intelligibility, the robotic and monotone sound quality characterizes EL speech as strikingly aberrant or unnatural compared to laryngeal speech. The aberrant and mechanical sound quality affects a laryngectomee's perception of their own voice and a listener's acceptance of EL speech. Despite this known and well-documented relationship, there is no established protocol for addressing the problem of reduced F_0 variation in EL speech. To further investigate why EL speech is robotic and monotone sounding, it is important to understand the following components: 1) the role of intonation in verbal communication, 2) advances in current EL technology that allow for F_0 variation, and 3) the role of motor learning in using EL technology with the capacity to vary F_0. Each of these components will be discussed in detail in turn.

Intonation

Both intelligibility and listener acceptability ratings are influenced by the lack of the F_0 variation. This limitation emerges because of the role that F_0 plays in the transmission of the speech signal. F_0 is one acoustic correlate to speech intonation, which involves rule governed changes in the 'melody' of an utterance (Hart, Collier, & Cohen 1990). In general, the function of intonation in English verbal speech is to: 1) express emotional states, 2) distinguish between different types of utterances (questions or statements), and 3) highlight or emphasize key words in utterances (Vaissière, 2004). These factors collectively create a melodic signal that allows for enhanced verbal communication. Intonation is expressed through the following phonemic linguistic parameters: a) perceived pitch, b) loudness, c) vowel and voice quality, and d) relative length of segments, syllables and words (Grice, 2006). These critical linguistic parameters map onto the following acoustic correlates: a) estimated F_0 over time b) relative intensity c) spectral quality (formant bandwidth and spectral tilt) and voice source d) relative duration in milliseconds (Grice, 2006).

In addition, intonation can manifest at both the word and sentence level. At the word level, intonation is referred to as word stress, for example, in the word “object”, if there is a change between the first and second syllable (Jilka, Mohler & Dogil, 1996). Sentence level intonation represents a change in perceived pitch that does not occur on individual words, but rather the F_0 changes over the entire the sentence. For example, Lieberman (1967) asked participants to read statements (e.g., Joe ate the soup.) and questions (e.g., Joe ate the soup?). Analysis of participant recordings revealed that statements had a decrease in F_0 at the end of the sentence while questions had an increase in F_0. Similarly, other studies have evaluated single words articulated as either a statement or a question. Majewski and Blasdell (1969) presented the word “farmer” said as a statement or a question to listeners. Again, their results demonstrated that questions and statements can be differentiated based on an increase or decrease in the final F_0.

EL Pitch Control

Most EL devices can be pre-programmed with the ability to adjust internal pitch, allowing a potential difference in pitch levels for males and females. Females tend to have a higher pre-set pitch than males (Watson, 2009). This pre-set pitch remains unchanged during a conversation and does not produce dynamic pitch fluctuations necessary for the creation of linguistically meaningful contrasts. As a result, several studies have attempted to improve the design of the EL by including a dynamic pitch control option. Dynamic pitch control allows an EL speaker to produce changes in pitch throughout a conversation. In contrast, static pitch control wherein pitch is pre-set and remains the same throughout a conversation. Thus, the ability to actively modulated pitch has considerable implications to the communication process.

Three general types of pitch control have emerged: 1) expiration-control, 2) electromyographic (EMG), and 3) finger (Liu & Ng, 2007). Uemi et al., (1994) introduced an expiration type of EL pitch control by inserting an air pressure sensor onto the stoma wherein expired air is used to modulate pitch. To modulate pitch, the EL speaker expires air and covers the air pressure sensor with both hands. In contrast, an example of the EMG pitch control can be found in a study by Goldstein et al., 2004, where an EL was designed to be hands free and controlled through the EMG signals of the neck muscles. The neck muscles produce EMG signals which are detected by a superficially attached electrode. Pitch is then controlled through the adjustment of the suprathreshold of EMG energy. That is, a higher amount of EMG energy produces a higher F_0 (Stepp, Heaton, Rolland, & Hillman, 2009). Finally, the finger control method can be further divided into two categories: 1) the control of an EL pitch with finger pressure directly (e.g., the TruTone EL, by Griffin Laboratories, Temecula, CA), and 2) the control of EL pitch using a denture based intra-oral vibrator, a wireless fingertip switch, and a controller (Liu & Ng, 2007). In the first category, pitch control is modulated by an increase or decrease of direct finger pressure on an on-off control button, wherein finger pressure is measured by a force potentiometer (Liu & Ng, 2007). In the second category, pitch is controlled via binary commands that are pre-programmed based on the amount of finger pressure. These pre-programmed commands are implemented by the controller within the EL to generate different pitch patterns (Liu & Ng, 2007). Both methods permit the direct control of pitch using finger pressure or manual control.

Although all three primary pitch control options outlined previously come with their relative advantages and disadvantages, one common problem emerges, that is, the simultaneous coordination of a certain movement (e.g., finger pressure, EMG activity, or expired air) to control pitch. This problem exists throughout the different control types despite the technological enhancements in EL design. This problem persists even in a newly developed EL called the TruTone™ (Griffin Laboratories). The TruTone™ provides dynamic pitch control using a pressure sensitive button (overlaying a potentiometer). That is, the harder a user presses the on button, the higher the pitch. Even though this technological feature allows for the dynamic control of pitch, learning to use this pressure sensitive button remains a problem for many EL users and in fact user exploitation of this feature may be limited.

A potential explanation for the low acquisition rate of pitch control using a TruTone ™ stems from a general criticism of the finger control type EL's. More explicitly, the finger is not normally used in the production of speech. For example, Heller (2009) compared the naturalness of speech when participants produced pitch change via EMG control and finger control of EL speech. Heller (2009) explained that EMG based pitch control was rated as more natural sounding by naïve listeners for paired question and sentence stimuli. It was suggested that this finding occurred because the EMG pitch control used more speech related muscles (submental area, residual suprahyoid and tongue root musculature). More specifically, as speech related muscles are intuitively used for speech control in healthy individuals, Heller (2009) claims that the use of these muscles in an EMG-EL could facilitate pitch control. Similarly, Nagle and

Heaton (2016) also found that EMG-based pitch control was perceived, by naïve listeners, as sounding more natural than the finger controlled type.

In contrast to the results reported by Heller (2009), Gandour and Weinberg (1983) found that an EL speaker using finger control was able to produce intonation contrasts. Gandour and Weinberg (1983) recorded paired questions and declarative statements produced by three EL speakers using a Western Electric #5 EL. Of the three EL speakers evaluated, one was able to produce a contrast between questions and statements using intonation. In doing so, this speaker varied the rate and the extent of the initial rising portion of F_0 contours. For example, when the declarative sentence “Bev loves Bob.”, is produced with a rising F_0 contour on the word “Bob”, it is perceived by listeners as a question.

The capacity to differentiate between questions and declarative statements is a basic and fundamental communicative contrast. Studies that have artificially improved the F_0 of EL speech recordings have found an increase in listener ratings of EL speech acceptability. For example, Meltzner and Hillman (2005) showed that the addition of normal F_0 variation to EL speech resulted in the largest enhancement compared to the manipulation of other acoustic parameters (e.g., reduction in radiated background noise and increasing low frequency energies). In an investigation by Ma et al. (1999), they replaced non-variable F_0 contours produced by EL speakers with variable F_0 contours. This replacement significantly improved the perceived sound quality of EL speech. Taken together, these studies provide support for the importance of improving F_0 variability and the influential role it plays on the perception of the spoken signal by the listener.

Therefore, it is important to understand how a lack of F_0 variability impacts an EL's intelligibility and acceptability by listeners. However, despite the evidence provided by these studies, the current literature does not operationalize a specific training protocol for the control pitch using a hand held and manually controlled EL. Therefore, the development and validation of an operationalized protocol may enhance the EL speech signal while at the same time lessening the communicative burden on listeners to decode a low-quality voice signal.

Motor Learning

It is unclear whether speech related muscles are the key component to increased speech quality or if the problem lies elsewhere as in the training of EL users to better control intonation. The acquisition of intonation using a pressure sensitive control is akin to the acquisition process of any motor skill. Schmidt and Lee (2005) describe motor learning as, "a set of processes associated with practice or experience leading to relatively permanent changes in the capability for movement (p.302)." Schmidt and Lee (2005) further argue that motor learning cannot be observed directly, as the underlying processes leading to changes in behavior are internal to the learner. Motor learning can only be measured using the external behaviors that are thought to lead to the internal processes. Therefore, it is important to understand how learned motor behavior is measured and what motoric factors influence the learning process. One factor is the provision of "feedback" or information given to an individual about the motor task that they are seeking to acquire. Feedback as a factor can be broken down into several components: 1) modality type (e.g., audio, visual or verbal), 2) the age of the participant receiving feedback, 3) the distribution of practice, and 4) the type of instruction(s) given. Each of these factors will be presented briefly in the subsequent sections.

Modality. Two types of feedback are described in motor learning literature: inherent feedback (IF) and augmented feedback (AF). IF is information gained by a participant about his/her movement through multiple sensory channels (e.g., touch, vision, and hearing) (Schmidt & Lee, 2005). AF refers to information that is only learned through an external source, that is, by a trainer or display (Schmidt & Lee, 2005; Schmidt &Wrisberg, 2008; Utley & Astill, 2008). AF can be provided through various modalities such as vision (e.g., screen displays), hearing (e.g., speakers) and haptics (e.g., robots) (Sigrist et al., 2012). Importantly, research has indicated that individuals can use AF feedback to learn new motor tasks through the emphasis and breakdown of a motor task into its various components (Schmidt & Wisberg, 2008; Wulf & Shea, 2002).

Several studies report that the use of visual feedback in learning complex force production tasks. These tasks generally involve a participant practicing force production, while simultaneously receiving visual feedback in the form of displayed bars or force time plots. The force time plots allow the participant to visualize their individual deviation from the target force production. For example, Snodgrass, Rivett, Robertson and Stojanovski (2010) asked students to apply mobilisation forces to the cervical spine with real time visual feedback. Their results showed that students receiving feedback had less deviations from the target force than did those in the control group. Similarly, Lee, Moseley, and Refshauge (1990) found that students who received visual feedback while learning a joint mobilization task out-performed those in the group who received no feedback. These studies corroborate the use of visual feedback in the enhancement of motor skill acquisition.

Critically, there is motor learning literature to support the development of a training protocol that uses finger force pressure and real time visual feedback. Therrien and Balasubrmaniam (2010) used a force transducer, a small device that measures the pinch grip force between fingers. This device was used to measure participant responses to specific instructions to press a sensor with a specified manual force. Participants who did not receive visual feedback on the force they applied tended to overestimate or underestimate the amount of force needed to satisfy the trial instructions. In contrast, participants with online visual feedback were able to respond with the appropriate amount of force. This study further supports the role of visual feedback in improving the acquisition of specific motor skills.

Age of the participant. Wishart (2002) investigated age related differences and the role of visual feedback in learning a bimanual coordination pattern. In that work, Wishart (2002) manipulated whether the frequency at which old and young adults received visual feedback after each trial (concurrent) or after the five trials (terminal). Results demonstrated that older adults benefitted from concurrent feedback. In contrast, younger adults benefitted from both concurrent and terminal feedback. Wishart (2002) argued that older adults compared to younger adults were more sensitive to the structure of the practice, and specifically the availability of the concurrent visual information. Other studies using a variety of tasks (e.g., pressing a key on a keyboard to a metronome) demonstrated that older adults can use augmented visual feedback in the same manner as younger adults (Carnahan, Vandervoort, & Swanson, 1993, 1996). Crucially, van Dijk Mulde, and Hermens (2007) compared the acquisition of a force production in two groups: young adults (20-35 years) and older adults (50-70 years). Both groups were provided with visual feedback on their force productions. van Dijk et al. (2007) reported no significant interaction between age and the acquisition of the task. This study highlighted that the effect of augmented visual feedback on motor learning is similar for both old and young adults.

Distribution of practice. The amount of practice compared to rest periods is a critical component of motor skill acquisition. Research on the distribution of practice is generally divided into two extremes, massed practice and distributed practice (Schmidt, & Lee, 2005). Massed practice refers to practice periods that are close together with very few breaks between sessions (Schmidt, & Lee, 2005). In contrast, distributed practice refers to sessions that have longer intervals of rest between practice sessions (Schmidt, & Lee, 2005). Several studies have found a relationship between the length of rest periods and motor skill acquisition. An example of massed practice can be found in a study by Bourne and Archer (1956), where participants were asked to perform a pursuit rotor tracking task. This task involves a small circular target on a turntable. The participant must try and keep a hand held stylus in contact with the small circular target, as the turntable rotates. Bourne and Archer's experiment consisted of a total of four groups performing the pursuit rotor task, with varying rest periods. The first group had no rest between practice trials, while the other three groups had increasing, interspersed rest period (30s, 45 s and 60s). The results showed that the longer the rest period, the better the performance on the rotor tracking task. The study by Bourne and Archer (1956) demonstrates a key finding about the relationship between massed practice and motor skill acquisition: longer breaks between practice sessions enhance motor skill performance and acquisition, compared to short breaks.

In contrast to massed practice, literature on distributed practice more directly applies to clinical and therapeutic environments. It is important to the clinician, for example, to compare the effect of a single session and practice sessions distributed over several weeks on motor skill acquisition. Murphy (1916) asked right handed subjects to learn to throw a javelin with their non-dominant left hand. Murphy's experiment consisted of two groups: massed practice and distributed practice. The massed practice group practiced the task on 5 consecutive days for 7 weeks. The distributed practice group practiced three times per week for 12 weeks. Results demonstrated that the distributed practice group outperformed the massed practice group on a retention test, performed three months later. Similar results were found in another study by Baddeley and Longman (1978) who asked four groups of subjects, on varying practice schedules, to learn to use a keyboard. In this study, subjects were trained for 60 to 80 hours on four different schedules. A 1 to 2-hour practice session was conducted either once or twice per day. Results showed that the group with a massed practice schedule had severely diminished performance on a several retention tests conducted after one, three and nine months. Taken together, these studies highlight that benefit of distributed practice schedules on motor skill acquisition.

Nature of tasks in practice sessions. Not only is it important to understand the scheduling of practice sessions and rest periods, it is equally critical to investigate the nature of the tasks being practiced. Blocked practice refers to a practice session in which all tasks are kept constant and the same in consecutive trials (Schmidt & Lee, 2005). For example, if the participant was practicing how to press the “m” key on the keyboard, this would be done consistently and repeatedly in a blocked practice session. In contrast, random practice involves never repeating the same task in consecutive trials (Schmidt & Lee, 2005). For example, the participant may practice the “m” key, and then click on the mouse as another task within the same session. Shea and Morgan (1979) asked participants to perform three different rapid arm movements. Some participants were given a blocked practice session while others were given a random practice session. Results showed that participants who were exposed to blocked practice, outperformed the random practice group on an immediate test of skill acquisition. However, the random practice group outperformed the blocked practice group in two delayed retention tests: 10 min and 10 days after practice. This blocked –random effect has been replicated across other tasks such as badminton serving (Goode & Magill, 1986), volleyball skills (Bortoli, Robazza, Durigon, & 1992) and baseball batting (Hall, Domingues, Cavazos, 1994). One explanation is that random practice removes the repetitive nature of blocked trials, which enhances motor acquisition and performance (Schmidt & Lee, 2005). In contrast, other studies involving complex tasks do not replicate the advantageous effect of random practice on motor skill learning. For example, Moreno et al., 2003 found no difference between blocked and random practice sessions for the acquisition of a dart throwing task.

Similarly, Smith, Gregory and Davies (2003) found no significant difference between practice sessions for participants acquiring gymnastic skills.

Finally, there is evidence to suggest a combination of the two types of practice session may be beneficial. For example, in a study by Al-Ameer and Toole (1993), subjects were asked to perform a rapid arm movement in pre-determined patterns. Subjects were separated into block practice and random practice groups. Their results replicated the findings of Shea and Morgan (1979). However, Al-Ameer and Toole (1993) added two group of subjects who received a combination of random and blocked practice trials. These groups practiced one task for a set of trials, before randomly switching to another task in the same session. Results showed that the group who received a combination of practice types outperformed the random practice group in retention and acquisition. These studies demonstrate the importance and influence of practice session types on motor control acquisition.

Not only is the type of practice (random versus blocked) critical, the actual content of the practice task is important. One common approach to training a practice technique is referred to as “part-practice” wherein a large motor task is broken down into smaller tasks (Schmidt & Lee, 2005). For example, an individual learning to swim might be asked to first learn how to manipulate his legs and then arms (Schmidt & Lee, 2005). Research on whether practicing a task as a whole is more effective than breaking it down into components has demonstrated that effectiveness is dependent on the nature of the task (e.g., Lee, Chamberlin, & Hodges, 2001). Studies on tasks that are serial in nature have found that breaking down motor skills into parts is beneficial. Serial tasks are tasks that can be broken down into smaller, sequentially organized components (Schmidt & Lee, 2005). For example, Seymour (1954) investigated the effect of part-practice on a series of tasks revolving around the larger task of working a lathe. The smaller tasks ranged from easy to difficult. Seymour found that when subjects practiced the difficult tasks in isolation, acquisition of the larger task as a whole was improved. One explanation for these findings is that part-practice allows subjects to focus on smaller, more difficult skills and ignore already mastered skills (Schmidt & Lee, 2005). This increases efficiency and learning of a serial motor task.

In contrast to serial tasks, continuous tasks involve components that may occur at the same time and involve considerable coordination (Schmidt & Lee, 2005). For example, arms and legs must be coordinated in the action of walking (Schmidt & Lee, 2005). Briggs and Waters (1958) asked participants to perform a lever positioning task that required the coordination of direction and positioning in two dimensions. Their results demonstrated that practice on this task as a whole was more beneficial than practicing each isolated skill. One explanation for this finding is that separating the task into smaller parts hinders the subject's ability to understand the interaction between the components (Schmidt & Lee, 2005). A lack of understanding of the interaction between all components may then lead to poor performance as the task requires coordination of all dimensions as a whole (Schmidt & Lee, 2005).

Similar to the previously mentioned findings on continuous tasks, the effect of part-practice on discrete tasks seems negligible. Discrete tasks involve tasks that have a defined beginning and end (Schmidt & Lee, 2005).

For example, in a study by Lersten (1968), subjects were asked to learn a hand movement task that could be broken down into two components. The first component involved a circular hand movement, wherein the subject had to grasp a handle and rotate it through a horizontal plane. The second component involved the release and movement of the handle to knock over a barrier. One group of subjects were told to practice each component in isolation, while the other group practiced the task as a whole. Results showed that there was no difference between the groups, suggesting that part-practice may not offer any advantages for discrete task acquisition. However, factors related to how instructions are provided may provide additional insights into motor learning.

Instructions. Many studies in the literature report the importance of designing instructions in such a way that capitalizes on the motor concept, for example, the focus of attention. More specifically, this concern seeks to identify where attention is focused when a participant is learning to perform a specific motor skill (Wulf, Shea, & Lewthwaite, 2010). Studies have demonstrated the effect of directing the attention of a learner towards the effects of an action (the external focus), rather than to the movement of their body parts (internal focus) is more effective for motor learning (Wulf et al., 2010). Using a physical analogy, it has been shown that a more efficient means way of improving an individual's golf swing would be to focus on the swing of the club rather than the fact that the club and the arm should move in synchrony (Wulf et al., 2010). This advantageous effect of external focus on motor learning has been shown across numerous populations of different levels of expertise and populations such as children and individuals with motor disabilities (Wulf et al., 2010). That is, directing a participant's attention to the overall outcome of a motor skill to be acquired is more effective than focusing on the individual muscles involved in the skill.

In summary, the aforementioned studies highlight the importance of understanding the effect of feedback on motor acquisition. Motor acquisition is influenced by the type of feedback modality. There is clear evidence corroborating the advantageous effects of using visual feedback to learn motor skills. This enhancement by visual feedback is further influenced by the age of participants. That is, older adults benefit from concurrent visual feedback rather than terminal feedback. Furthermore, motor acquisition is influenced by the type of practice, wherein previous literature corroborates the use of random practice sessions rather than blocked practice sessions. Finally, instructions that direct a participant's attention to the motor skill as whole, were found to be the most beneficial for motor learning. The specific influence of each component on motor acquisition further highlights the need to design therapeutic training protocols with motor learning principles in mind.

Statement of Problem

TL results in the complete loss of normal voice production. This loss of normal voice production will negatively influence one's ability to communicate verbally.
After a laryngectomy, the EL acts as an external vibratory sound source for voice production. Normally, the emotional aspect of speech is conveyed through what is termed intonation prosody; however, this capacity to vary the voice signal is completely lost when using the EL. Speech intonation involves rule-governed changes in the frequency of the speech signal and it is important for basic communication distinctions such as questions and declarative statements.

Previous research stresses the importance of increasing intonation control and its effect on the intelligibility and naturalness of EL speech (e.g., Meltzner & Hillman, 2005; Gandour, Weinberg, Petty, & Dardarananda, 1988; Liu, Wan, Ng, Wang, & Lu, 2006; Ng, Gilbert, & Lerman, 2001). To address this critical intonation issue, new EL models include the capacity to vary pitch through various methods, including a pressure sensitive button; the harder an EL user presses, the higher the pitch. Despite emerging technology that permits the capacity to vary pitch, EL users still have difficulty mastering its use.

Because using an EL with the capacity to vary pitch control involves learning to control finger pressure, the development of a training paradigm using visual feedback may enhance motor skill acquisition. The findings of both Gandour and Weinberg (1983) and Therrien and Balasubrmaniam (2010) support the development of a new training paradigm for pitch control using a finger activated EL. The findings of Gandour and Weinberg (1983) corroborate that finger type or manual control of pitch using an EL is possible to learn and that doing so can lead to meaningful linguistic contrasts. Therrien et al.'s (2010) findings are based on a participant's ability to learn to control force produced by the index and thumb and, therefore, directly apply to the manual control requirements of an EL. Therrien et al.'s (2010) experiment also incorporated online visual feedback which significantly improved the acquisition of finger force control.

Using the critical findings of both of the previously outlined studies, the current research was designed to investigate another means of controlling intonation using TruTone's pressure sensitive button. This was achieved by providing online visual feedback on how well EL users match intonation by changing the pressure on the EL. The stimuli were composed of sentences that are contrastive in their final intonation pattern; a rising final intonation characterizes a question while a lowering intonation characterizes a declarative sentence.

The interpretation and understanding of the results from this study are an initial step towards the development of a clinically applicable training paradigm. As such, the goal of this study was to first provide evidence, as a proof of concept, that visual feedback can lead to an enhancement in pitch and force control.

Experimental Question

Based on information from past literature, and in an effort to gather information on issues related to active pitch control for the use of the EL, the following question was addressed in the present investigation:

> Will the use of online visual feedback facilitate the acquisition of a) force control and, b) pitch control using an EL?

Chapter 2
Methods

The design and validation of the training paradigm required two experiments. Experiment 1 involved creating specific training stimuli that were designed to isolate the desired F_0 changes. Experiment 2 involved the automatization and design of an EL training protocol using the previously validated stimuli set from Experiment 1. As the validated stimuli set was used in Experiment 2, the results of Experiment 1 were included in the methods section. Both experiments will be outlined in the sections to follow.

Experiment 1: Validation of Experimental Speech Stimuli

Participants

Participant-Speakers. Two adult, normal speakers, 1 male and 1 female, served as speakers in Experiment 1. At the time of their participation, the female speaker was 64;6 years old, and the male speaker was 60;11 years old. Both speakers identified themselves as native English speakers and reported no history of speech, language, or hearing deficits prior to their participation.

Participant-Listeners. Fifteen (3 males, 12 females) self-reported native English-speaking students were recruited from the University of Western Ontario. All participants reported no history of speech, language, or hearing deficits. Participants were considered as naïve since they were unaware of the experimental purpose, and had no formal training in voice or voice related disorders, or in voice research.

Development of Experimental Stimuli

Stimuli design parameters. As the goal of the present experimental training paradigm was to enhance a speaker's acquisition of EL intonation control, the training stimuli were created using proprietary, echoic questions and declarative statements.

Echoic questions are sentences that are identical to their declarative pair, but differ in F_0 at the end of a sentence. For example, the following sentences form an echoic question and declarative statement pair: “Joe ate the soup.”, and “Joe ate the soup?” The echoic question only differs from the declarative sample by the rise in the final F_0 on the word “soup” (Lieberman, 1967). This rise in terminal F_0 and its contour permits coding of the sentence as an interrogative, rather than as a declarative statement. In addition, the training stimuli were specifically designed to limit other acoustic parameters related to the nature of EL speech. Thus, 8 question and statement pairs were created using the following acoustic parameters: speech rate, word and sentence level stress, phonemes, and syntax (Appendix A).

Speech rate. This parameter is defined as the number of words (or syllables) per minute produced by a speaker. Speech rate is influenced by phonemes, syllables, words, and pause time. Rothman (1978) found that highly proficient EL speakers had a speech rate of 12 words per minute, with an overall time 3.86 seconds compared to poor EL speakers. Based on Rothman’s data, poor EL users tended to pause more often between phrase groups which resulted in speakers treating each phrase group as a new sentence. Thus, if poor EL speakers are treating each phrase group as a new sentence, their speech rate decreases. This is because EL speakers are pausing more frequently than alaryngeal speakers. Therefore, the stimuli set was designed with phrases that can be said in a single breath group (i.e., no sentences will have syntax that requires a comma or semi-colon that would denote a need for linguistic pausing).

Word and sentence level stress. Intonation can manifest at both the sentence and word level. At the word level, intonation is referred to as word accent; for example, in the word "object", if the first syllable is stressed "OB" compared the last syllable "JECT." Sentence level intonation represents a change in perceived pitch that does not occur on individual words, but rather, F_0 changes across the entire sentence. For example, in English, F_0 increases at the end of a question, "Sandra is going to school today?", and decreases at the end of a declarative sentence, "Sandra is going to school today." (Liberman & Prince, 1967; O'Shaugnessy, 1979). As the objective of the proposed study was to enhance intonation control at the sentence level of a phrase, it was important to control for word level stress. To do this, the majority of words contained within the stimuli sentences were monosyllabic (i.e., composed of a single syllable). For example, the word "zoom" has one syllable compared to the three-syllable word "tomorrow".

Phonemes. Intonation is not the only acoustic issue that can influence EL speech. Research has demonstrated that EL speakers have a difficulty producing specific phonemes (units of sound) (Doyle & Keith, 2005; Weiss & Basili, 1985; Yemi-Komshian, Weiss, & Basili, 1983). In particular, voiceless stop plosives (e.g., /p/) and affricates (e.g., /ʃ/) are not easily distinguished from their voiced counterparts (e.g., /b/ and / ʒ/, respectively). Therefore, to isolate F_0 in this experiment, all words used in the experimental sentence stimuli were composed of voiced phonemes and continuants (non-stop sounds).

Syntax. In creating these stimuli, the questions and declaratives must be grammatically equal and only differ in their intonation.

For the question stimuli, “wh-question” words (e.g., what, where, and why) were not used as these words would change the grammatical structure of the sentence. Therefore, echoic sentences and question pairs were chosen as they contain the same word order and grammatical structure (Table 1).

Table 1

Summary of Stimuli Parameters

Parameters/ Sample Sentence	***Lee loathes the zoo.***	***Lee loathes the zoo?***
Speech Rate	No commas or semi colons that denote pauses are present.	No commas or semi colons that denote pauses are present.
Word and Sentence Level Intonation	Each word is monosyllabic.	Each word is monosyllabic.
Phonemes	Only voiced phonemes are present (e.g., /r/ and /w/) and they are all continuant sounds.	Only voiced phonemes are present (e.g., /r/ and /w/) and they are all continuant sounds.
Syntax	Same word order and sentence structure.	Same word order and sentence structure.

Recording of speech stimuli. All recordings were acquired in a professional sound recording booth in the Voice Production & Perception Laboratory, Elborn College, at the University of Western Ontario. A head set microphone (Shure SM10A) and a preamplifier/digitizer (M-AUDIO ProFire 610, 24bit/192kHz) were used for all recordings. Recordings were sampled at 44.1 kHz. The headset microphone was adjusted to an optimal distance from the corner of the participant speaker’s mouth. Audacity 2.1.2 was used to record and save all voice samples. A total of 92 voice samples (2 speakers X

23 sentences X 2 frequency profiles) were recorded by both the male and female participant speakers.

Procedure

A forced choice listening experiment was programmed using MATLAB® and administered on a desktop computer within the Voice Production & Perception Laboratory. The listening experiment required approximately 15 minutes and was administered in a single session. In this experimental task, participants were presented with 104 voice samples in total: 92 voice samples and 12 reliability samples. The reliability samples were comprised of 12 voice samples taken from the larger pool of 92. Participants initially listened to each sample binaurally using Sony Stereo headphones (MDRXD100). The loudness level was set by participant listeners prior to perceptual evaluation at a comfortable level. This level was based on the listener's judgment. Participants were asked to identify each voice sample as being either a question or a statement based on what they perceived to be the speaker's intention. Participants were asked to focus on the speaker's intention rather than the perceived meaning of the statement itself. In order to complete this experimental task, the following instruction was given to participants: "categorize each voice sample based on whether you think the speaker is asking a question or declaring a sentence." Once a voice sample was played, listeners categorized a sample by clicking on either a button, presented on the computer screen, for 'sentence', 'question', or 'replay'. Each voice sample could be played as many times as needed in order to make a decision, but once an identification was made, listeners could not return to that sample or change their response.

Data Analysis and Results

A total of 104 responses per participant were analyzed in Excel; 92 voice samples and 12 voice samples were repeated for reliability.

For the analysis of the number of correct responses per item, a simple 1 or 0 coding system was used. If the participant identified the stimulus item correctly as being a question or declarative statement, they received a score of 1. If the participant did not correctly identify an item, they were given a score of 0 for said item. For each stimulus item, the number of correct identifications per participant was added to retrieve a total score out of 100. Question and statement pairs that received a score below 90%, were excluded from the final stimuli list. Additionally, if stimulus items were replayed more than three times by the participant during the listening task, they were excluded. All stimulus items met both criteria and a final list of stimulus items can be found (Appendix A).

Intra listener reliability was measured using a point by point correlation method. During the listening task, participants categorized 8 additional reliability samples. If the participant gave the same response for the reliability item and the stimulus item, they received a score of 1. If there was a mismatch between the reliability and stimulus item response, the participant received a score of 0. This was done for all 8 reliability stimuli. A total score for each participant was calculated out of 8. Participants who achieved a reliability score below 90% were excluded. All fifteen listeners achieved a score of 90% and above and were found to be reliable.

Experiment 2: Automatization and Design of EL Training Protocol

Participants

Two participants were recruited, 1 female and 1 male. At the time of the experiment, the male was a 67;0 years old and the female was 23;6 years old. Both participants identified themselves as native English speakers and reported no history of speech, language, or hearing deficits. Both participants were non-laryngectomized, healthy controls.

Stimuli

To create the visual target displays necessary for training, the force required to a produce a certain F_0 on the EL was determined. This relationship was determined by applying a known force to the on-off button on the EL and recording the associated F_0. Recordings were done using a microphone (AKG C4000 B Condenser), preamplifier (M-AUDIO, ProFire 610, 24bit/ 192kHz) and Audacity 2.1.2 software. To measure force during each recording session, one FlexiForce™ A201 sensor was placed on the pressure sensitive button of the EL and held at a specific force. A description of the sensor and its calibration can be found in the Methods "Procedure" section of Experiment 2. As the pressure sensitive on-off button was held at a constant force, the audio was recorded using Audacity 2.1.2. The force was recorded using MATLAB® through a program designed specifically for this experiment.

The same recording set-up described in Experiment 1 was used for measuring and recording the force values in Experiment 2. For each force and frequency recording, an average was calculated in Excel over a period of 20s (Table 2). A scatter plot with a line of best fit was then created. A linear equation was generated: $y = 0.0165x - 1.1667$ with an R^2 value of 0.8078. The y-value in this equation represents force (mV)[2] and the x-value represents F_0 (Hz). A positive linear relationship was found between force and frequency: as force increases, F_0 increases (Figure 1). Thus, the harder an individual presses, the higher the pitch produced using the pressure sensitive EL.

Table 2

Average Frequency and Force values

Average F_0 (Hz)	**Average Force (mV)**
145.97	0.88
145.62	0.91
145.24	1.02
145.33	0.94
150.32	0.98
145.43	0.88
147.17	1.01
145.34	1.03
145.77	1.0
190.89	1.82
179.96	1.94
175.53	1.88

[2] The unit for force is Newtons, however the FlexiForce™ A201 sensor hardware set-up converts the measured force into mV.

166.21	1.89
155.99	1.83
191.77	1.91
243.70	1.99
219.11	2.72
155.55	2.90
296.90	2.85
274.34	2.80
237.51	2.82
268.23	2.92
207.00	2.81
225.66	2.90
283.78	3.75
299.46	3.72
271.42	3.84
276.79	3.72
283.32	3.82
304.55	3.77
266.60	3.86

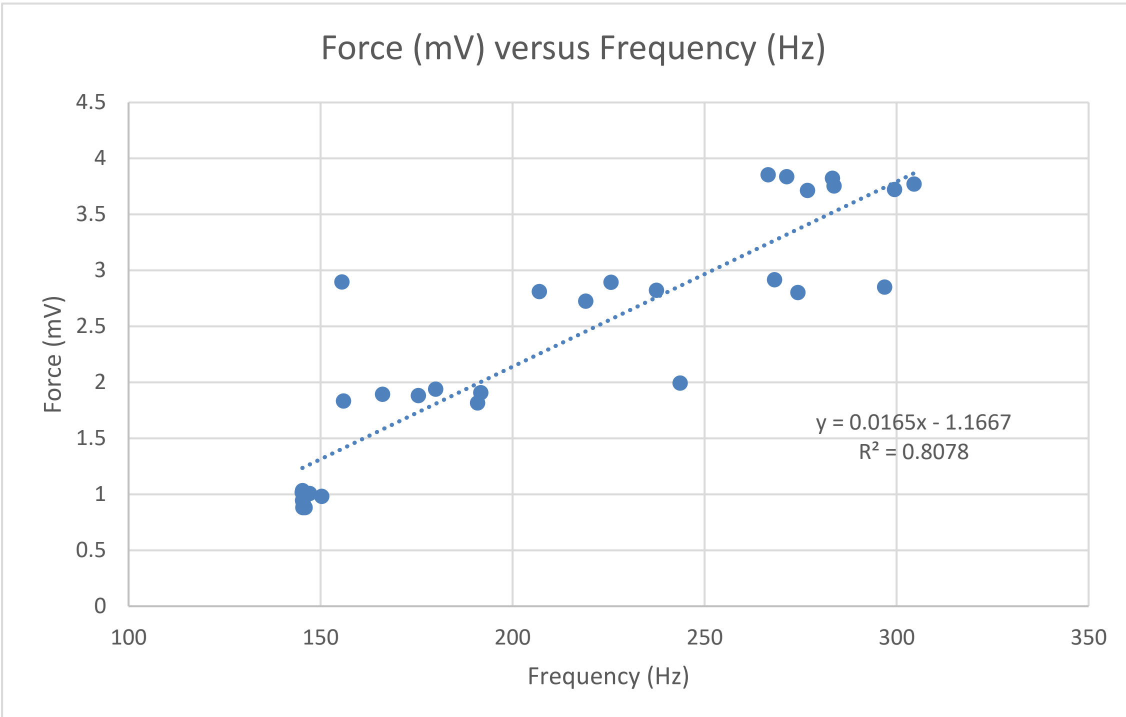

Figure 2. Force-Frequency relationship

After determining the force-frequency relationship, the open access software acoustic analysis program PRAAT (version 6.0.28) was used to extract the average F_0 of each of the validated stimuli from Experiment 1. These values were then converted into their corresponding force values, using a predetermined force frequency equation y = 0.0165x - 1.1667, where y is the force (mV) and the x is F_0 (Hz).

Observations during experimental training. During the pilot, it was discovered that although high frequencies were achievable using the device, an intelligibility trade off was observed. Force levels above 0.4mV that corresponded to higher pitches were not intelligible when using the EL device. Because of this, all force values were divided by a factor of 4 to reduce all force values to a range below 0.4mV. This created a force range with an upper bound of 0.4mV and a lower bound of 0.05mV. The final stimuli and associated force values can be found in Appendix A. Thus, the stimulus frequency range was 104 Hz to 120 Hz and resulted in intelligible speech using the EL. This is despite the EL device F_0 range which was found to be 77.8 Hz to 208.7 Hz. The EL device F_0 range was measured by recording the F_0 when the on-off button was pressed with maximal and minimal pressure. Recordings for this component were done using the same conditions described in Experiment 1.

Procedure

Experiment Set-up

Sensor. One FlexiForce™ A201 sensor (Tekscan Inc., Boston, MA) was placed on the pressure sensitive button of the TruTone™ EL. This allowed for the measurement of the finger force generated by the participant. The participant's finger force was then converted and digitized, and then displayed on a computer screen using the MATLAB® program.

Sensor calibration. To calibrate the sensor, a 5-point calibration plot was generated (Figure 3). The generation of this plot was done using the recommended calibration sequence by Tekscan, Inc. A copy of the calibration sequence is provided in the Appendix B. This method involved placing weights on the FlexiForce™ sensor and reading the associated sequential voltage output: 0, 0.7, 1.4, 2.1, and 2.8 lbs (Table 3). A positive linear relationship was found between the voltage output (mV) and weight (lbs): as the added weight increased, the voltage output also increased (Figure 3). This calibration sequence was repeated 10 times and only the best three attempts were recorded.

Table 3

Sensor Calibration Values

Weight (lbs)	Voltage Trial 1 (mV)	Voltage Trial 2 (mV)	Voltage Trial 3 (mV)
0	0.14	0.08	0.13
0.7	1.31	1.22	1.36
1.4	2.55	2.50	2.082
2.1	2.89	3.77	2.94
2.8	4.86	4.86	4.86

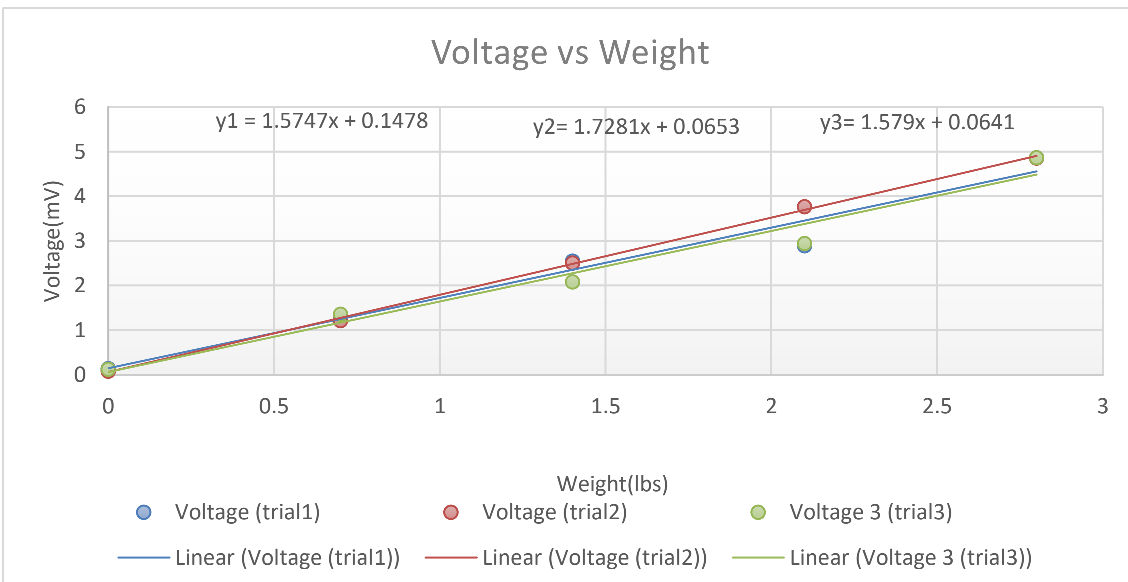

Figure 3. Sensor calibration.

Sensor circuit board and connection to PC. An Arduino Uno (LC-066) board was used to connect the sensor to a desktop computer via USB port (Figure 4).

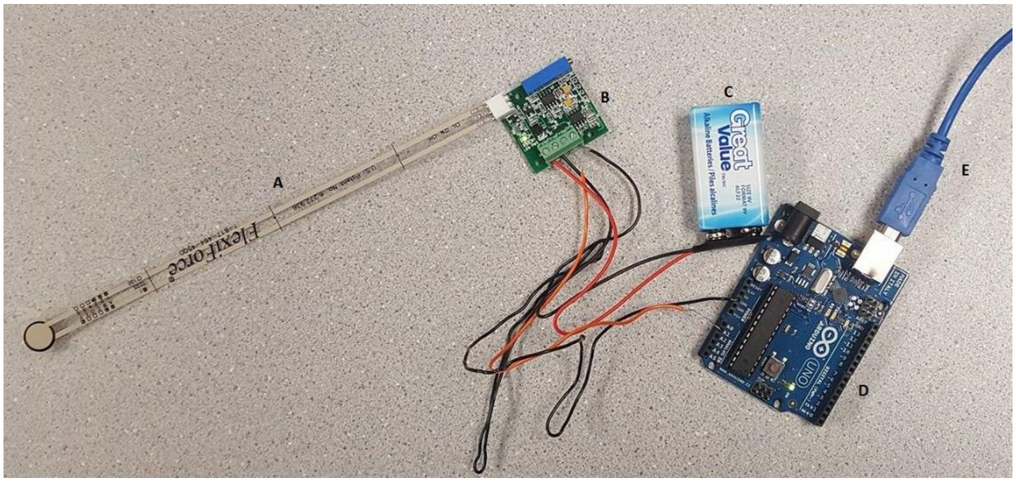

Figure 4. A) FlexiForce™ sensor, B) FlexiForce™ Quickstart board, C) 9V battery, D) Arduino Uno (LC066), and E) USB connection.

Visual display. MATLAB® was used to display these force values on a force versus time graph for each stimulus. All stimuli were displayed on a computer screen with a 1050 by 1060 screen resolution. All text displayed on the force versus time graph was size 30 Arial font. Target bars were pre-set with a line width of 30 to ensure clear visibility during the training protocol. Time in seconds is represented on the x-axis. Force in mV is represented on the y-axis in mV (Figure 5).

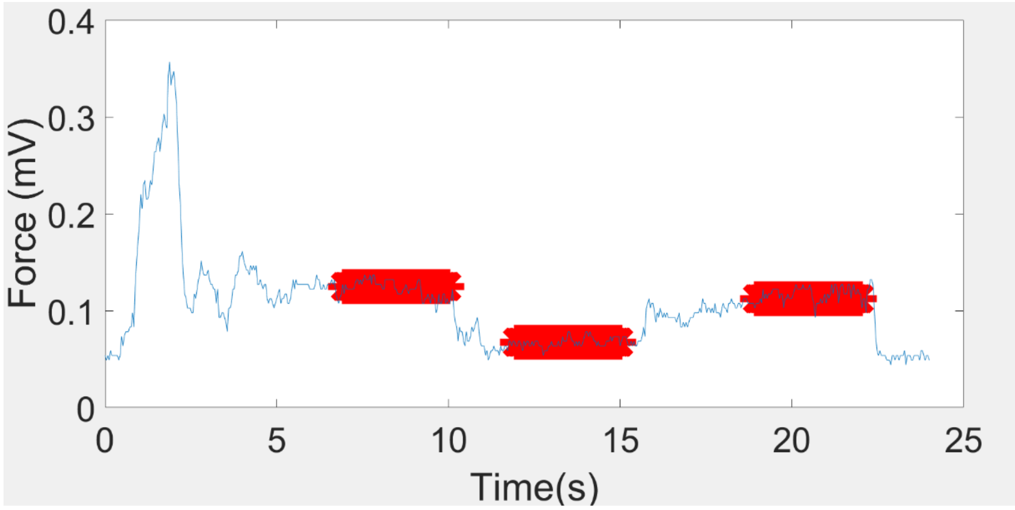

Figure 5. Sample force versus time graph

Recording set up

With the exception of the placement of the EL and the microphone, the recording conditions for this experiment remained the same as described in Experiment 1.

Placement of the EL. At the start of each training session, the optimal placement or "sweet spot" of the electro larynx was identified in a systematic way by the experimenter. The researcher and an experienced clinician determined the best sound quality via both ear and touch. Once the optimal position was identified, a peristomal attachment was placed for the rest of the training session (Figure 6). This attachment permitted the EL to be removed from the neck as needed, but also insured that the identical placement was maintained over the course of the session. A photograph of this procedure was taken to facilitate future placements. Although, a systematic approach to EL placement was taken, the researcher was unable to control each individual participant's neck impedance (Meltzner, Kobler & Hillman, 2003). Neck impedance is radiated background noise related to the contact of the EL head to an individual's neck.

Neck impedance is measured by the neck frequency response function: "…the ratio of the spectrum of the estimated volume velocity that excites the vocal tract to the spectrum of acceleration measured at the neck (Meltzner et al., 2003, p. 1036)." This is important as it affects the placement of the EL and the sound quality generated using the device. The degree of change by coupling is how the structure of the sound signal changes when it is coupled with the neck (neck resonance).

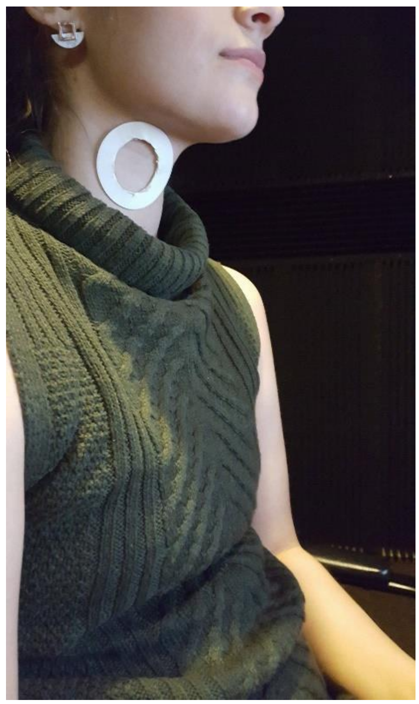

Figure 6. Transcervical attachment and coupling for systematic placement of the EL

Placement of the sensor. A Velcro harness was strapped onto the participant to allow for the placement of the sensor on the EL pressure sensitive button. The Arduino and FlexiForce™ Quickstart board were placed in separate plastic pockets lined with Velcro patches. Both of these pockets were then placed onto the Velcro harness and positioned to allow the participant to hold down the FlexiForce™ sensor on the pressure sensitive button when coupled to the neck (Figure 7). This set-up was used for all training tasks involving the EL coupled to the neck. For trials involving target bar matching without the EL coupled to the neck, the hardware set up was placed onto the desk. The FlexiForce™ sensor was placed onto the EL pressure sensitive button. The participant could then hold both the sensor and EL in their dominant hand without placing the apparatus on their neck (Figure 8). Finally, to facilitate the placement of the FlexiForce™ sensor on the EL pressure sensitive button, a shirt button was placed on the on-off button of the EL. The shirt button provided a flattened and elevated surface for the FlexiForce™ sensor and allowed for better fine motor control.

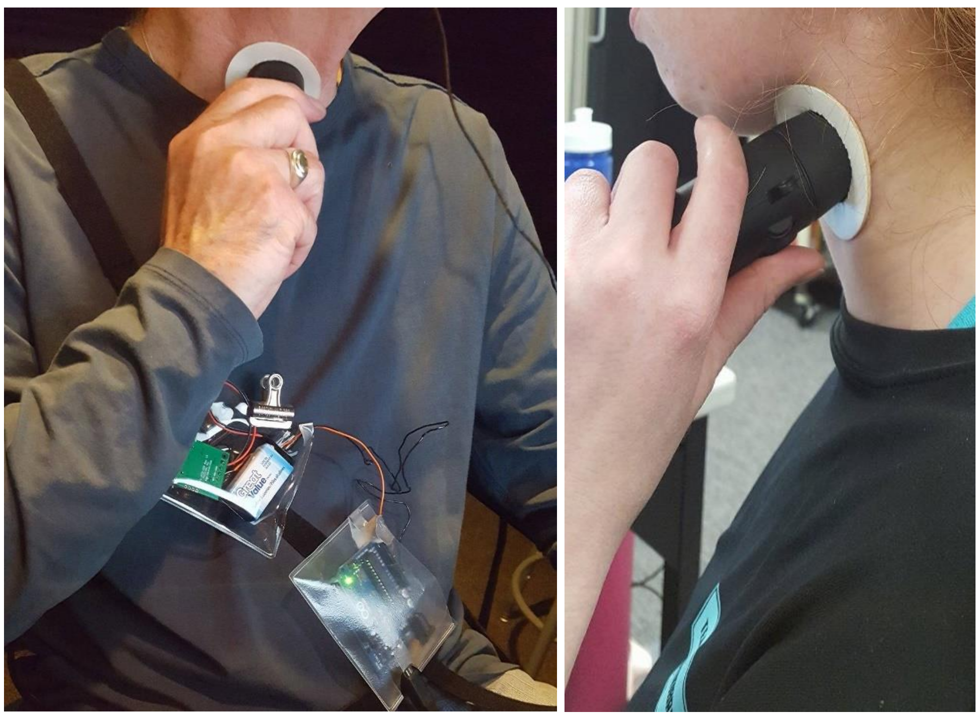

Figure 7. Sensor and EL set up when coupled with the neck.

Figure 8. Sensor and EL set up without neck coupling.

Training Sequence

Participant training took place in the Voice Perception and Production Laboratory. A clinician with more than 30 years of experience in alaryngeal voice and speech rehabilitation supervised the initial training session that involved the introduction and placement of the EL. Training using visual feedback consisted of a program that occurred over two consecutive weeks with two sessions per week, each lasting approximately 1 hour. The two sessions were spaced at least two days apart within the week. After the two weeks of training, participants were evaluated during a separate 1 hour session, for the collection of post-training data. Therefore, the total experiment time consisted of three consecutive weeks. Each session was divided into three phases: 1) Review phase: participants were given a quiz to review tasks learned and mastered in the previous session, 2) Learning phase: a new task was introduced and practiced, and 3) Preview phase: participants were given the opportunity to practice a skill to be learned the following week. Finally, all training tasks involved the placement of a sensor on the pressure sensitive button of the EL. During each session, the participant's force productions were displayed on a computer screen along with previously calculated target forces. The entire training sequence was coded and displayed using MATLAB ®. Each session contained a total of 40 trials that were distributed across each of the phases: 1) 8 trials in the review phase 2) 24 in the learning phase, and 3) 8 trials in the preview phase. In the learning phase, participants were provided three attempts for each stimulus token in the case of a technological or EL voicing issue. The following is a summary of each training session and the associated tasks:

Week 1

Session 1. Before starting the training sequences, the researcher familiarized participant-speakers with the linguistic function of intonation. After this familiarization, participants were instructed on the basic components of an EL. Next, they were asked to complete baseline measurements. These measurements included a measurement of the participants force productions with target bars that included no text, referred to as the Force Bar (FB) matching task (Figure 9). Participants were then asked to match the target bar while simultaneously speaking using the EL for 8 question and statement pairs.

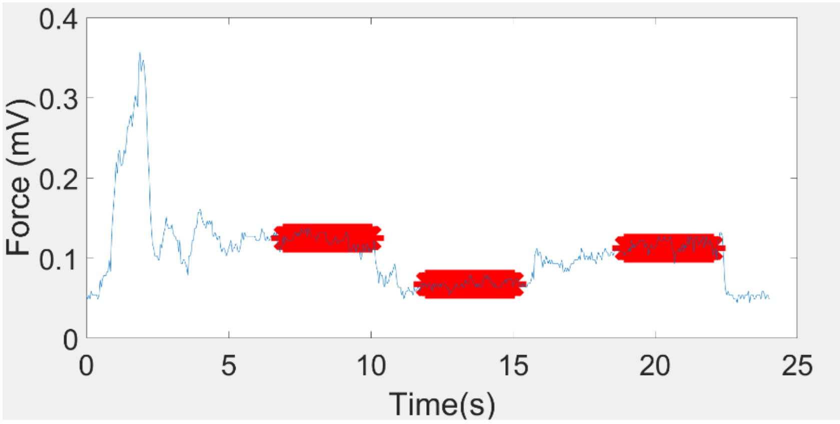

Figure 9. Force Bar (FB) matching task.

Session 2. 1) FB task: Both participants were instructed on how to use the pressure sensitive button on the EL. They were then shown the target force bar on a computer screen and asked to match the force presented using the pressure sensitive button on their EL (Figure 9). 2) EL neck coupling: Once participants mastered controlling pressure on an EL without neck coupling, they were asked to place the EL on the lateral aspect of their neck, in its natural position. The researcher asked participants to practice matching force target bars with the EL coupled to their neck.

Week 2

Session 1. Participants were given a task involving the production of single words. This was referred to as the Single Words (SW) task. These single words were taken from the same question and sentence pair stimuli set (Figure 10).

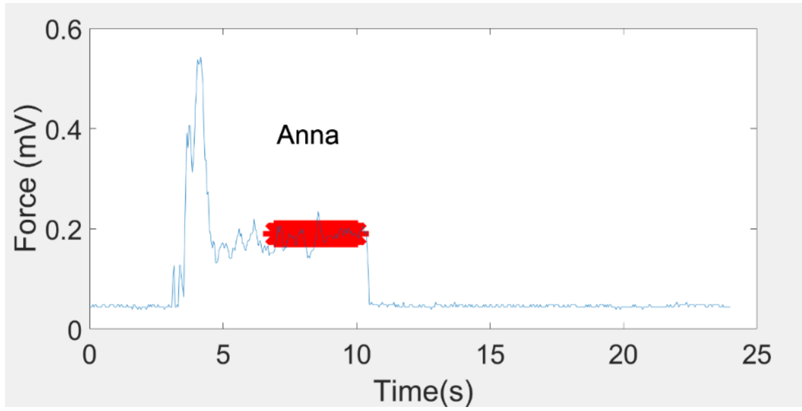

Figure 10. Single words (SW) task.

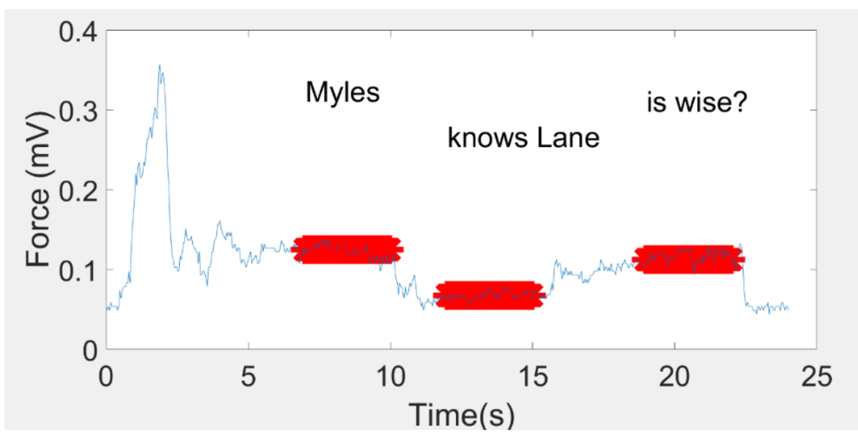

Figure 11. Sample question.

Session 2. After participants were successfully able to produce single words, they were asked produce sentence and question pairs in what was referred to as the Sentence (S) task (Figures 11 and 12).

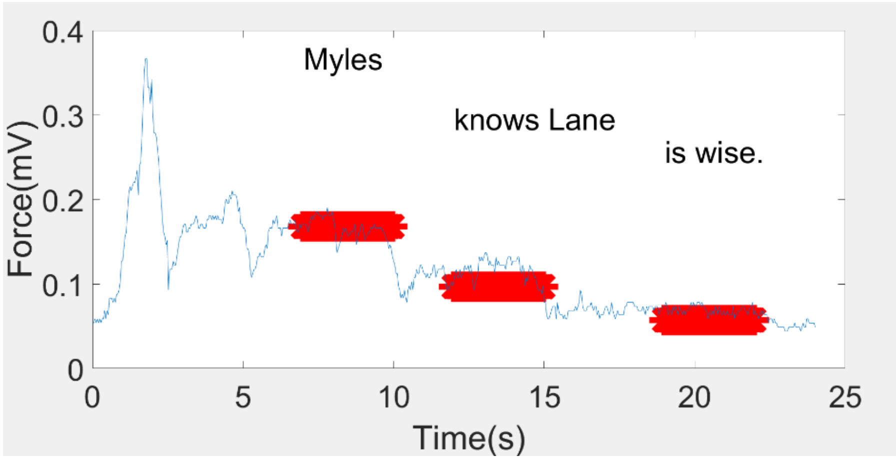

Figure 12. Sample declarative statement

Week 3

Evaluation Task: Participants were evaluated on all previously learned tasks.

Evaluation Criteria of Training Tasks

To evaluate whether a given participant was able move from newly learned skill to the next, the standard error (SE) between the target bar and their force production was calculated and converted to a percentage. The acceptable error range per trial was 0.025 mV above and below the target bar. This range was experimentally determined by the researchers and engineering team to ensure trial difficulty was at an acceptable level. SE was automatically calculated for each trial represented using MATLAB®. This calculation procedure involved the following steps:

1. Measurement of the total number of force measurements (samples) in one trial. Each trial had a fixed time of 24 (s) and as a result a maximum of 600 samples were measured per trial. The sampling period in MATLAB® was set

to 0.04 s and equates to a sampling frequency of 25 force values being sampled per second.

2. A comparison matrix is then set up by MATLAB®. For example, if a trial has three target bars: The first target bar as 50 force values, the second has 100 and the third 150. The resulting comparison matrix has three rows. The first row will be composed of 50 force values, and 100 zeros. The second row will have 100 force values and 50 zeros. Finally, the third row will have 150 force values.

3. Participant force productions were compared to the pre-determined range (0.025mV) for each target bar. For example, if a target bar range was predetermined to be between 0.375mV and 0.425 mV, then a participant force value of 0.40 mV would fall within the range. In contrast, a score of 0.7 mV would fall outside of the acceptable range. If the participant force productions were within the acceptable range, they received a score of 1. If the participant force production was outside the target range, they received a score of 0. This was done for each force production sample and for each target bar. Therefore, in the previously stated example:

    Target Bar 1 (T1): 40 out of 50 of the participant force productions were in the acceptable range. Therefore, $T_1 = 40$.

    Target Bar 2 (T2): 70 out of 100 of the participant force productions were in the acceptable range. Therefore, $T_2 = 70$.

Target Bar 3 (T3): 100 out of 150 of the participant force productions were in the acceptable range. Therefore, T_3= 100.

The sum of these three scores is referred to as the matched force value (MFV). In this example, the MFV is equal to:

$$
\begin{aligned}
MFV &= T1 + T2 + T3 \\
&= 40 + 70 + 100 \\
&= 210
\end{aligned}
$$

4. The MFV is divided by the total number of samples (TS) in the trial and multiplied by 100 to retrieve a percentage of matching (FMP). TS is calculated by the maximum number of force values in the trial. In this example, TS is equal to 450 (150 x 3):

$$
\begin{aligned}
FMP &= MFV \div TS \\
&= (210 \div 450)\times 100 \\
&= (0.466)\times 100 \\
&= 46.6\%
\end{aligned}
$$

To pass from one trial to the next, the participant had to meet and/or exceed an FMP score of 75%. If the participant's force productions fell within the predetermined SE, they could move to the next trial. If the participant's force productions were outside the predetermined SE, both the researcher and a clinician gave verbal feedback to adjust learning and conditions. Participants were informed whether they passed or failed the trial immediately after its completion.

Data Analysis

The training paradigm included repeated measurements of participant force productions over four, 1 hour sessions. As this paradigm involved repeated measurements from the same subject, analysis was performed per subject and data was not collapsed across or between subjects. Therefore, for each session, a total mean and associated SE of the FMP values was calculated. For a detailed explanation on how the FMP value was initially calculated in MATLAB®, please refer to "Evaluation Criteria of Training Tasks" section of the methods in Experiment 2. For descriptive analysis, the mean and SE of the participant matched force values were plotted on a graph of time (session number) versus the average FMP value.

An analysis of each of the three task types (target bars with no text, target bars with single words and target bars with sentences) was also performed by calculating average per session and the associated standard error of the PM value. For example, for the task of sole matching a target without text, a mean and associated standard error was calculated across all four sessions. These values were then plotted on a bar graph representing task type versus and average FMP.

Chapter 3
Results

This chapter will provide a summary of the data acquired during the EL training paradigm. The first pattern described will be the overall force matching performance which includes how closely the participant-speaker matched the target bar, regardless of the task. The percentage of force matching was reported for each participant-speaker. This is the percentage of participant force productions that matched the target bar and is referred to as "Force Match Percentage" (FMP). For a detailed explanation of this calculation, please refer to the "Evaluation Criteria of Tasks" in the methods (Chapter 2). The second pattern described will be the participant's FMP per type of task (Force Bar, Single Words, and Sentences).

Participant-Speaker A

Description of participant. Participant-speaker A was a 67;0-year-old male, who reported overall good health prior to participating in the experiment. He was a right handed, normally voiced participant-speaker. Participant-speaker A was considered naïve as he had no prior exposure to an EL, what the device is or how it is used. Additionally, he was not briefed about the purpose of the training paradigm at any point during the experiment. Participant-speaker A participated for a total of four, 1 hour sessions that spanned the length of two weeks.

Overall force matching performance. A positive linear relationship was found for the FMP over the four sessions. Thus, the FMP across sessions was found to increase from the first to the final session by a gradient of 2.7403 (Figure 13). The standard error

(SE) was found to decrease from the first session to the final session at a gradient of 0.003 (Table 4).

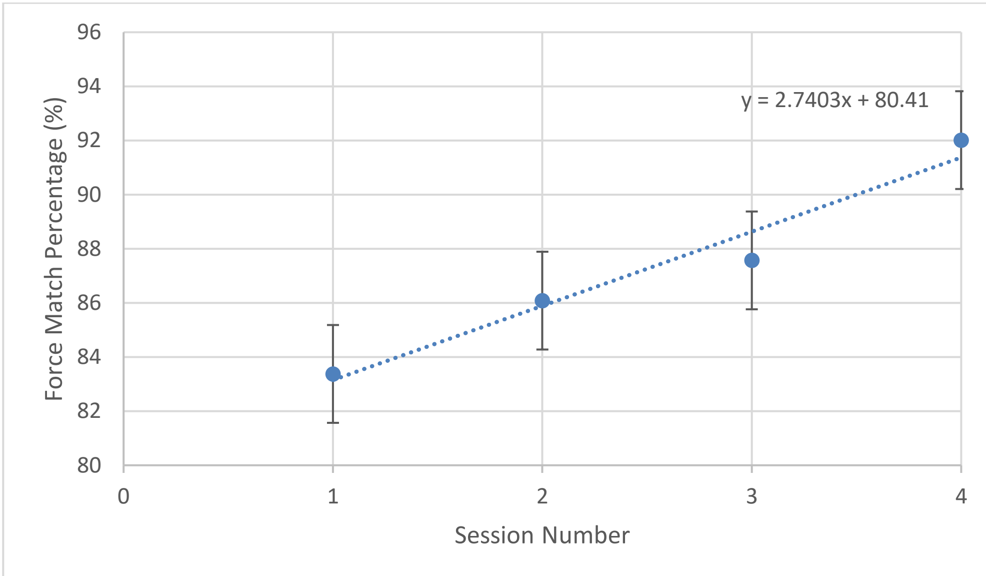

Figure 13. Participant -Speaker A's FMP over time

Table 4

Participant-speaker A's average FMP across session number

Session Number	**Average of FMP (%)**	**SD**	**SE**
1	83.375	0.134	0.024
2	86.083	0.159	0.028
3	87.569	0.094	0.017
4	92.014	0.105	0.019

Note. This table reports the standard error (SE), standard deviation (SD), and the average FMP across all four sessions.

Force matching performance by task. Participant-Speaker A was found to produce an average of 93.04% (*SD* = 0.06, *SE* = 0.01) on the FB task, followed by an average of 85.42% (*SD* = 0.17, *SE* = 0.03) in the SW production task. The S task was found to have the lowest FMP average of 76.01% (*SD* = 0.14, *SE* = 0.03) (Figure 14). A relative decrease of 7.62% of matching was found between the FB and the SW task. A decrease of 9.41% was found between SW and S. Finally, a decrease of 17.03% was found between the FB and S task.

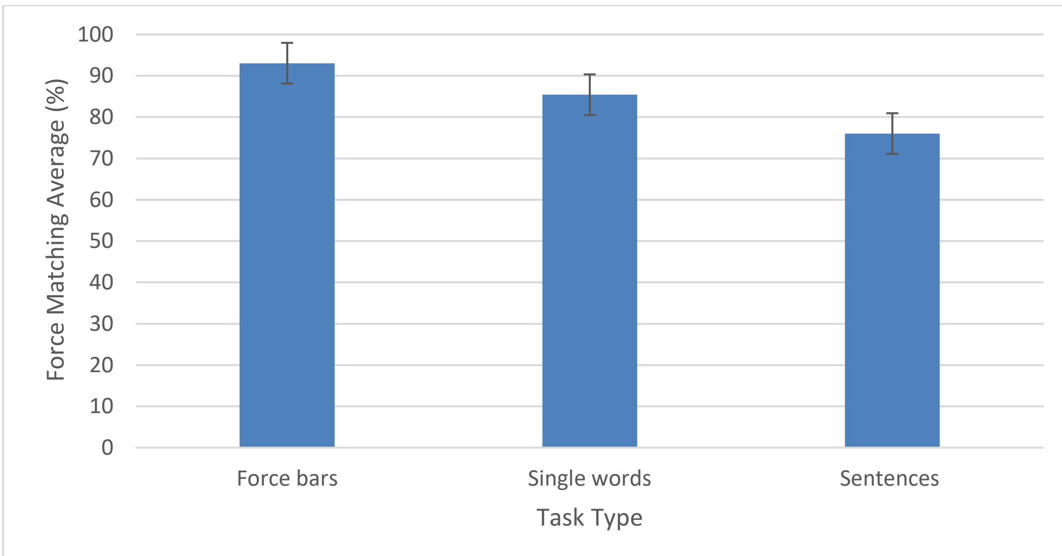

Figure 14. Participant-Speaker A's performance on each of the three tasks.

Participant-Speaker B

Description of participant. Participant-speaker B was a 23;6-year-old female, who reported overall good health prior to participating in the experiment. She was a right handed, normally voiced participant-speaker. Participant-speaker B was considered naïve as she had minimal exposure to an EL, what the device is or how it is used. Additionally, she was not briefed about the purpose of the training paradigm at any point during the experiment. Participant-speaker B participated for a total of four, 1 hour sessions that spanned the length of two weeks.

Overall force matching performance. A non- linear relationship was found for FMP across sessions. Thus, the FMP was not found to increase or decrease at a constant gradient from the first to the final session. Instead, it remained constant, with slight decreases (sessions 1 and 4) and increases (sessions 2 and 3) (Figure 15). However, the SE was found to decrease from the first session to the final session by a gradient of 0.003 (Table 5).

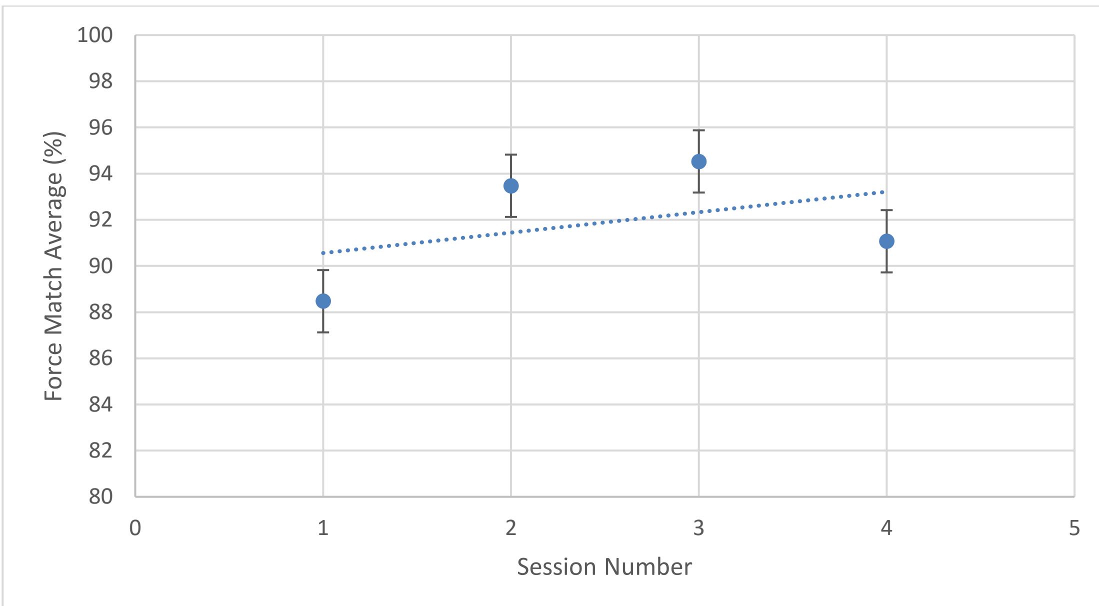

Figure 15. Participant-Speaker B's overall FMP across all four sessions.

Table 5

Participant-Speaker B's average FMP across session number

Session Number	**FMP (%)**	**SD**	**SE**
1	88.472	0.171	0.0302
2	93.472	0.0960	0.017
3	94.528	0.064	0.011

4	91.069	0.135	0.024

Note. This table reports the standard error (SE), standard deviation (SD), and the average FMP across all four sessions.

Force matching performance by task. Participant-Speaker B was found to produce an average of 96.35% (*SD* = 0.04, *SE* = 0.01) on the FB task, followed by an average of 89.94% (*SD* = 0.17, *SE* = 0.03) in the SW task. The S task was found to have the lowest force matching average of 78.09% (*SD* = 0.17, *SE* = 0.03) (Figure 16). A relative decrease of 6.41% of matching was found between the FB and the SW task. A decrease of 11.85 % was found between SW and S task. Finally, a decrease of 18.26% was found between the FB and S task.

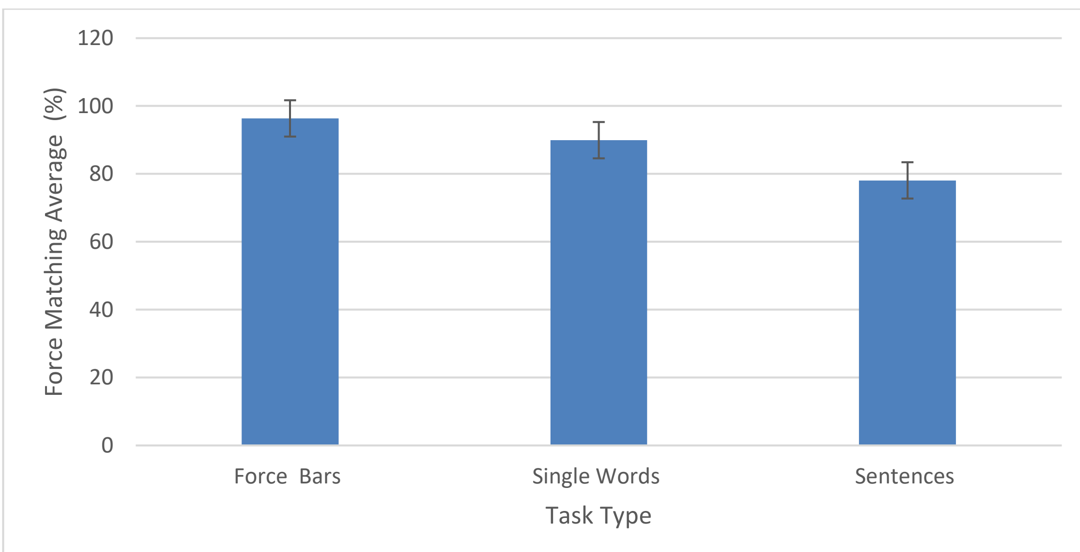

Figure 16. Participant-Speaker B's performance on each of the three tasks.

Chapter 4
Discussion

The purpose of this study sought to evaluate a novel training paradigm, that was designed to facilitate the control of intonation using a pressure sensitive EL device. The experimental training paradigm provided participant-speakers with real-time visual feedback on their ability to meet pre-established force control targets linked to an EL pitch control system. This allowed for the empirical evaluation of whether an improvement in systematic manual force control would lead to an improvement in the production of intonation. Despite the established importance of intonation in verbal communication (Vaissière, 2004) and its impact on listener assessments of EL speech (Watson & Schlauch, 2008; Watson & Schlauch, 2009), there is no extant training protocol on how to use an EL with the capacity to vary intonation. Therefore, this proof-of-concept study aimed to systematically develop and test a training protocol that may facilitate the acquisition of intonation using a pressure sensitive EL. More specifically, this study addressed the following question: Will the use of real-time, online visual feedback facilitate the acquisition of a) force and b) pitch control using an EL?

Answering this specific question is important for the improvement of EL voice and speech quality. Research has shown that EL speakers are socially penalised for having an aberrant (unnatural and robotic) sounding speech quality (Bennett & Weinberg, 1973). By improving their ability to control intonation, EL speech may sound more natural despite this electronic "alaryngeal" vibratory source. Several studies have demonstrated the benefit of adding intonation to EL speech on listener assessments of perceived naturalness and intelligibility (e.g., Binns & Culling, 2007; Laures & Bunton, 2003; Laures & Weismer, 1999; Watson & Schlauch, 2008; Watson & Schlauch, 2009). To address this important question, a four-hour training protocol that spanned over two weeks was developed and employed with two participant-speakers. The training protocol included three different training tasks that increased in difficulty over these sessions. Three main tasks were included in the training paradigm: 1) Force Bars (FB): matching target force bars without producing EL speech 2) Single Words (SW): matching target force bars and producing single words using the EL, and 3) Sentences (S): matching force target bars and producing full echoic questions and declarative sentences. All training stimuli were designed with specific phonetic and syntactic properties to isolate F_0 in EL speech. That is, the training stimuli excluded phonetic properties (e.g., voiceless stop consonants) that have been shown to cause production and perception issues when produced with an EL (e.g., Doyle & Keith, 2005; Weiss & Basili, 1985; Yemi-Komshian, Weiss, & Basili, 1983). These proprietary experimental stimuli were validated by 15 naïve, normal-hearing English listeners in a forced choice listening experiment. Finally, a single-subject experimental design was used to investigate the effectiveness of the proposed training paradigm. Two participant-speakers (Participants A and B) served in the study. Participant-Speaker A was a 67;0 years old, male, and Participant-Speaker B was a 23;6 years old, female; both were native English speakers.

The following sections will present the major findings of the study. Three main findings were observed in the current study. The first was that both Participants-Speakers A and B showed an overall improvement in force target bar matching from the first to the last training session. The second was that a linear performance pattern was found for

Participant-Speaker A, whereas Participant-Speaker B showed a non-linear pattern. The third finding was that both Participant-Speakers A and B showed a decreased performance in the SW and S tasks. However, Participant-Speaker B out-performed Participant-Speaker A on all tasks. Each of these findings will be discussed separately in subsequent sections: 1) Overall improvement in force target bar matching, 2) Differential performance patterns between Participant-Speakers A and B, and 3) Participant-Speakers force matching performance by task.

Finding 1: Overall Improvement in Force Target Bar Matching

An overall reduction (a gradient of 0.003) in standard error (SE) from the first session to the last session was observed for both Participant-Speakers A and B. This corroborates the improvement of force matching over time. That is, both participants improved their accuracy in matching the target bars from the first to the last session at a rate of 0.003. This finding is consistent with previous reports that concurrent, augmented visual feedback enhances motor learning of complex tasks. For example, Swinnen, Lee, Verschueren, Serrien and Bogaerds (1997) found that providing young adults (18-20 year olds) with continuous, augmented visual feedback improved the acquisition of a cyclical arm flexion and extension task. Wulf, Shea, and Matschiner (1998) investigated the effectiveness of augmented visual feedback on a ski simulator task with participants aged 18-31 years old. Their experiment consisted of three groups: 1) 100% feedback: participants received concurrent feedback after every trial, 2) 50% feedback: participants received feedback in a faded and delayed manner, and 3) control group: participants did not receive any feedback. The 100% feedback group outperformed both the 50% feedback and the control group on the ski simulator task. The current training paradigm using visual feedback showed similar findings to both the aforementioned studies. That is, regardless of the motor skill being acquired, an overall benefit from feedback during training was observed. This suggests that visual feedback may be exploited for the training of a variety of tasks. This would include those tasks that are related to speech production behaviors such as pressure controlled intonation which was explored in the present study. Therefore, visual feedback may provide a valuable adjunct to the development of EL training programs.

Finding 2: Differential Performance Patterns Between Participant-Speakers A and B

Although an overall reduction in SE was found, the specific learning pattern observed in the training paradigm differed between participants. Participant-Speaker A demonstrated a positive linear pattern where the force matching percentage (FMP) increased at a gradient of 2.74 per session. A positive linear pattern implies a steady improvement over time with increases at a rate of 2.74 per session. In contrast, Participant –Speaker B showed a non-linear learning pattern where FMP remained constant, with slight decreases (Sessions 1 and 4) and increases (Sessions 2 and 3). This implies that Participant-Speaker B did not progressively increase in performance at a specific rate over time despite having acquired the tasks. A potential explanation for these differences between Participant-Speakers A and B, is a dissimilar baseline. Specifically, Participant-Speaker B started with a higher FMP average than did Participant-Speaker A. However, several additional explanations are possible for the observed difference in baseline such as age and initial skill level.

As Participant-Speaker A was significantly older than Participant-Speaker B, it is possible that the fine motor skills required for the training paradigm were influenced by age. This suggested explanation is based on the fact that the current EL training protocol required extended periods of fine motor control using the thumb and index finger. That is, throughout each training session, participants needed to vary their finger force using the pressure sensitive on-off button, while simultaneously reading a sentence that appeared on the computer screen. Therefore, given the complexity of the training task, it is possible that Participant –Speaker A showed a lower initial baseline because of his older age and as a result, an associated reduction in fine motor control.

A general physiological reduction in fine motor control with age has been previously observed and documented in the motor literature (e.g., Williams, Hadler & Earp, 1990; Hackel, Wolfe, Bang & Canfield, 1992). However, the exact influence of age on fine motor control has not been determined with great certainty – individual variability does exist. Previous studies that have examined age effects related to motor skill/task acquisition report contradictory results. A study by Voelcker-Rehage and Alberts (2005) investigated age-related chan24sges in grasping force between young (19-28years) and old (67-75 years) adults. Voelcker-Rehage and Alberts (2005) asked both age groups to modulate force produced by their fingers and thumb, while tracking a sine wave figure. The results reported by Voelcker-Rehage and Alberts specifically apply to the current study because of the similarity in the motor task. These researchers found that older adults showed improvement in force control with practice that was comparable to younger adults. However, performance by older adults was overall lower than younger adults. The results of the current EL training paradigm mirror the results of Voelcker-Rehage and Alberts (2005) and, therefore, age may be an important factor to consider in clinical applications using the current EL training paradigm.

In addition**,** other studies highlight the same reduced performance in older adults compared to younger adults using force dependant motor tasks. For example, a study by Spirduso, Smith and Choi (1993) asked younger (18-23 years) and older (61-81 years) adults to complete a triangle tracing task. To trace the triangle, participants had to control the force on spring leavers with different finger combinations. Both groups of participants practiced for a total of three days. The speed at which they were able to trace the triangle was recorded and used to compare the performance of both groups. Overall, results were similar for both younger and older adults. However, the speed at which the older adults controlled the levers increased in a non-linear pattern from the first to second day of practice. In contrast, younger adults showed a linear increase in their speed from the first to the last day of practice. The results of the Spirduso et al. (1993) study are in opposition to the performance pattern found in the current study. Specifically, Participant-Speaker B, a young adult, demonstrated a non-linear pattern. Participant-Speaker A, an older adult, demonstrated a linear progression in force matching from the first to the last session. Although the Spirudso et al. (1993) study assessed improvement in speed while the current study investigated an improvement in force control, a commentary on overall motor skill performance can be made. That is, the current study found contrasting performance patterns than the patterns observed in the previous literature. Once again, individual variation in the acquisition of a variety of motor skills must be considered as an important training variable.

Finding 3: Participant-Speakers Force Matching Performance by Task

When evaluating a participant-speaker performance by task, it was found that both Participant-Speakers A and B showed a decreased performance in the SW and S tasks. SW and S tasks differed from the FB task since they required both matching force bars and simultaneously producing EL speech. A possible explanation for the decreased performance is that both tasks involve the simultaneous coordination of two activities: 1) pressing down on the force sensor with very fine-tuned control of pressure, and 2) producing EL speech. As well, both the SW and S tasks require that the EL device be coupled to the neck and held in the same position for the entire duration of the training session. This simultaneous coordination of multiple requirements increases the difficulty of the task compared to the FB task which only involved the motor skill of matching force bars without generating EL speech. Further, the FB task did not require neck coupling because it did not involve the production of EL speech.

Wulf and Shea (2002) consider a motor skill as complex if it cannot be mastered in a single session and has multiple degrees of freedom (the number of possible movements required for a specific motor skill). However, the exact definition of whether a task is simple or complex remains unclear. This is because there are many variables both practically and conceptually that muddle the definition of motor task complexity. For example, several researchers have used variables such as reaction time (RT, e.g., Klapp, 1995), movement time (MT, e.g., Fitts, 1954) and response variability (RV, e.g., Bernstein, 1967). However, none of these variables are sufficient in measuring the complexity and difficulty of a task. For example, an increase in degrees of freedom generally categorizes a task as being more difficult, but when comparing two handed juggling versus one handed juggling, this rule no longer applies. Although one handed juggling involves one degree of freedom, it is significantly more difficult than two handed juggling (Wulf & Shea, 2002).

Based on the aforementioned studies and the findings of the current study, matching force bars while producing EL speech can be considered a highly complex task. Specifically, matching force bars and producing EL speech has the following characteristics: 1) the task cannot be mastered in a single session as shown by the fact that both Participant-Speakers A and B only improved across the four sessions, 2) the task has more than one degree of freedom as evidenced by the fact that each participant needed to coordinate finger pressure and coupling the EL device to their neck , and 3) the task requires the coordination between reading sentences aloud while simultaneously activating the on-off button with the appropriate amount of force. As it is indeed a complex task, the observed reduced performance of both S and SW tasks may be explained by the hypothesis that the acquisition of simple skills differs from complex skills. That is, the acquisition of sequential and related simple skills may not transfer to a more complex skill.

Wulf and Shea (2002) emphasize that breaking down a complex motor skill into seemingly simple motor tasks does not lead to more effective learning of the complex motor skill. Specifically, Wulf and Shea argued that, “research on more complex skills shows that the manipulation of practice variables that result in enhanced learning of simple skills are actually detrimental to the learning of complex skills" (p.207). Therefore, the decreased performance observed on the current SW and S tasks may have been a result of an unnecessary break down of a complex task into seemingly simpler components. That is, the break down of the more complex task of producing entire sentences with the pressure sensitive EL into FB and SW tasks is detrimental to the learning process.

The described detriment is an ongoing debate and is specifically related to effectiveness of breaking down complex skills into their components. This breakdown of complex skills is often referred to as the "part-whole transfer" strategy; this strategy depends on 'part-practice' which the division of a task into independent skills (Dubrowski, Backstein, Abughaduma, Leidl, & Carnahan, 2005). Part practice is in opposition to 'whole practice', which is the learning of a task in its entirety (Dubrowski et al., 2005). For example, instead of learning to juggle three balls at once, the juggler learns to first juggle with one ball, then two, then three. In relation to the current training protocol, it is possible that learning to first match force target bars, then produce SW and S tasks was detrimental to the learning process. One explanation for this detriment, is that all three tasks could have been independent from one another. During the training protocol, Participant-Speaker A noted that he did not perceive a successive learning pattern across the three tasks (i.e., there was no build up from the FB task to the S task). Instead, Participant-Speaker A noted a benefit from repeating the FB, SW and S tasks over consecutive weeks of training.

In general, it has been found that practicing independent movements can be beneficial, but practicing a task as a whole is more effective (e.g., Briggs & Brogden, 1954; Kurtz & Lee TD, 2003). Zavala, Lock, Van and Fleishman (1965) found that the more coordination needed in a task, the more effective training a task as a whole rather than isolated parts was. The aforementioned studies corroborate the observation that the S and SW tasks within the current study required extensive coordination and that the breaking down of those tasks into successive, small tasks may have been detrimental to the learning process. This is supported by the observation that performance for both Participant-Speakers A and B reduced greatly in the S and SW tasks compared to the FB task. Thus, when training complex tasks such as those targeted in the present EL intonation study, more finely grained tasks may not always be ideal.

However, based on previous literature and the findings of the current study, no definitive conclusions can be drawn about which learning strategy (part or whole) is more beneficial for the learning of force control. However, a trend towards practicing the force production task as a whole may be supported by the observed decreased performance in both the S and SW tasks. The observation that both participants performed best on the FB task further highlights the possibility that mastery of the FB task (a simple skill) is not transferrable to more complex skills (S and W tasks). This observation is in support of the previously described “whole-practice” theory.

Although both Participants-Speakers A and B showed a similar reduction in performance in the SW and S tasks, Participant-Speaker B out-performed Participant-Speaker A on all tasks. This is in line with previous research that investigated age related differences in motor learning. In the previously described Spirduso et al. (1993) study with a triangle tracing task, it was found that older adults were significantly less accurate and required more time to complete the task.

One possible explanation for the observed difference in performance is age related changes in force modulation and coordination. Participant-Speaker A may have had more difficulty anticipating, varying, and changing force necessary to reach each target bar. Thus, the EL force pressure task may have been further complicated by having a variable force target. Other studies have found that older adults have less variability in static force production tasks (i.e., do not require increases or decreases in force production) compared to dynamic force production tasks. For example, a study by Vaillancourt, Larsson and Newell (2003) found that older adults showed greater variability in a force task that required many changes in the exerted force levels compared to a simple force maintenance task. One hypothesis for this finding is that older adults may have more difficulty increasing and decreasing force as this requires the skill of releasing pressure in a controlled manner. This hypothesis is supported by Spiegel, Stratton, Burke, Glendinning, and Enoka (1996) who found that older adults struggled with decreasing force (a releasing movement) compared to increasing force. Therefore, based on the finding of Spiegel et al. (1996), it is possible that Participant-Speaker A's reduced performance is due to the fact that all training tasks required the ability to vary force control. For example, to produce a declarative statement in the S task, Participant-Speaker A had to start at a high pressure at the beginning of the sentence, and then release the pressure to produce a lowered intonation at the end of the sentence. The opposite pattern of decreasing and increasing force was required to produce a question in the S task.

Another possible explanation for the observed difference between the performance of Participant-Speakers A and B is that older adults may process visual coordination tasks differently than younger adults. For example, Salthouse (1985) found that older adults are slower at perceptual motor tasks than younger adults, alluding to a difference in visual processing. As the task in the EL training paradigm involves visually analyzing target bars at different levels on a screen, it is possible that Participant-Speaker A had a slower visual processing speed compared to Participant-Speaker B. Other explanations related to visual processing could include the physical set-up and position of the computer screen during training sessions. Participant-Speaker A mentioned having difficulty viewing the screen and controlling the pressure sensitive button at the same time. However, future studies comparing young and old adult performance in the EL training paradigm are needed, to confirm this visual processing and tracking hypothesis.

Summary

In summary, the finding that both Participant-Speakers A and B, showed an overall improvement in force target bar matching from the first to the last training session, is consistent with previous motor literature. That is, previous studies have found that using visual feedback does facilitate motor skill acquisition. In contrast, the second finding that Participant-Speaker A showed a linear performance pattern whereas Participant-Speaker B showed a non-linear pattern was not supported by previous literature. Instead, the opposite performance pattern was observed wherein older adults showed a non-linear learning pattern compared to the linear pattern observed in younger adults. The third finding was that both Participant-Speakers A and B showed a decreased performance in the SW and S tasks. The decreased performance identified in this study is supported by previous literature on motor task complexity. Finally, the finding that Participant-Speaker B out-performed Participant-Speaker A on all tasks was supported by previous studies relating to age related differences in motor skill acquisition. Therefore, when collectively evaluated, the findings of the current study are generally consistent with previous literature on motor performance and specific skill acquisition. However, it is also important to consider the clinical implications of the present findings on EL training. These implications will be discussed in the subsequent section.

Clinical Implications

This study provides the first empirical findings related to the application of a standardised training paradigm for the control of intonation using a pressure sensitive EL. The highly organised and standardised training protocol presented in this study differs from what is typically followed in a clinical training of EL use. In a typical clinical setting, the clinician will instruct a laryngectomee on the following basic components: 1) correct placement of the EL on the neck, 2) on-off control during conversation, and 3) over-articulation or slowing of speech when using the EL (Doyle, 1994). However, a specific training protocol for the acquisition of pitch control and modulation is not typically pursued due to time constraints and the fact that it is considered an advanced goal.

Although the present standardised training paradigm differs from what it typically followed, it has several advantages. For example, the training paradigm allows for individualised rehabilitation, as participants may move at their own pace. The clinician can also provide personalised, direct, and immediate feedback based on the force time graphs provided for each participant. The clinician can then use the results to quickly analyse and track a patient's progress and suggest changes for future sessions. For example, these changes may include an adjustment of the target bars with a focus on the control of changing force from a low to high. That is, the session would focus on the necessary force and pitch productions for the generation of a question rather than a declarative statement.

Despite these potential applications, the ecological validity of the EL training protocol is unknown. More specifically, it is unknown how modulating force productions with the use of visual feedback will apply in a clinical setting, and even more importantly, in a real life verbal communication situations. For example, in a real life speaking scenario, EL users will have to ensure that the EL is correctly coupled to the neck, while simultaneously producing speech and paying attention to their pitch productions. Attending to intonational variations in speech is an unnatural task because native speakers of any language are not consciously aware of their changes intonation. Thus, the need to potentially monitor another dimension of one's speech adds further complexity to the communication process. Furthermore, it is unknown how visual feedback will be implemented in a real life speaking situation or how an EL user will be able to self - monitor their intonation productions. Based on the assumption that visual feedback will not be easily implemented outside of a clinical setting, it is important to consider the carryover effects of the training paradigm. That is, if training with visual feedback is only possible in the clinic, how will learned skills transfer in a real life speaking scenario?

How long will the skills last without visual feedback? Will patients develop a dependency on visual feedback and as a result, not be able to control pitch as accurately?

In addition to concerns about ecological validity, other potential issues arise when this training paradigm is applied to the laryngectomee population. For example, laryngectomees are often older adults (ages 45-65 years old) with the potential to have age related changes in dexterity and upper extremity function. Both dexterity and upper extremity function directly impact the application of the training protocol as it is dependent on the manual control of the EL. Laryngectomees often have neck dissections that limit upper extremity mobility due to the sacrifice of the spinal accessory nerve. Further, neck dissections and/or radiation therapy may also result in the potential limitations in the ability to successfully couple the EL to the neck with minimal neck impedance. That is, scar tissue from surgery and/or changes in the compliance of neck tissues due to lymphedema or radiation fibrosis can impede EL signal transmission across those tissues. The changes as a result of surgical treatment, coupled with the previously mentioned decline in motor control as a result of age, can further complicate the use of this training protocol. Physiological issues as noted above are not the only barriers to the implementation of this training protocol to the laryngectomee population. Laryngectomees also face psychological challenges after experiencing intensive cancer treatment. QOL studies report that laryngectomees face many negative consequences due to their treatment and newly acquired voice (Doyle & Keith, 2005; Doyle, 1994). These psychosocial factors can influence their motivation and willingness to participate in the proposed training paradigm.

Strengths of Current Study

To study the effectiveness of this novel training protocol, a certain amount of flexibility and experimentation was needed. Single-subject designs are flexible in that changes based on findings during a piloting (baseline) phase are permitted and encouraged. This design offered a much-needed flexibility in manipulating design parameters throughout the two condensed weeks of highly organised training. By studying one subject at a time, it was possible to isolate in detail, the effectiveness of different components of the training paradigm. It was also possible to receive immediate and detailed feedback about the training protocol from participant-speakers. Receiving feedback and making day-to-day changes are critical components of testing the effectiveness of a training protocol. Furthermore, the use of single-subject design directly applies to the clinical environment. For example, the fact that each patient will have different needs and outcomes lends itself well to the use of a single-subject design. Single-subject designs allow for the detailed observation of an individual participant and this flexibility permits individual programming of instructions. In contrast, group designs only allow for more general or “average” observations which do not directly apply to the individual or the clinical setting in which individualised patient care is key. As noted in prior sections of this discussion, a number of individual factors may come into play as part of training. Such factors would need to be considered and addressed on an individual basis, hence, the ability to structure unique training sequences may be of value.

A secondary strength of this study is the automatization of training paradigm using MATLAB®. The coded experiment afforded participant-speakers with immediate, personalised feedback. Each participant’s force productions were calculated, using a highly accurate multistep process. The coded experiment afforded both the researcher and participant with an organised and systematic way of collecting force production data. In addition, this automatization allows the program to be applied to all participants immediately for basic training.

Finally, the stimuli used in the current study were specifically designed and validated to isolate F_0. The use of echoic questions and declarative statements reduced the interference and probability of other acoustic shortcomings related to the EL device itself. The use of echoic declarative statements and questions controlled for any potential influences of grammar and or word changes on the production of intonation. As pairs of echoic statements are identical, they allowed for a direct comparison between a fall and a rise in terminal F_0.

Limitations of Current Study

While the preliminary results of this study are promising, several limitations emerge and these can be divided into the following categories: 1) Training protocol tasks, 2) Technical limitations, and 3) Strict Participant Inclusion Criteria. Each of these categories will be discussed subsequently.

Training protocol tasks. The design of each of the three experimental training tasks (FB, SW and S) allowed for a hierarchical and systematic acquisition of the desired skill. However, it is entirely possible that this systematic break down of intonation control hindered its more effective acquisition. That is, the combination of intonation control and force pressure creates a continuous, non-discrete task. It has been demonstrated in motor literature that breaking down a continuous task into discrete components can hinder its acquisition (e.g., Wulf & Shea, 2002). Therefore, future studies should replace the discrete tasks used in this study with more continuous ones. For example, instead of using three static force bars, it may be beneficial to ask participants to match a curve like target figure. Further, instead of using single words, the task should be kept at the sentence level. One explanation for this observation is provided by Binns and Culling (2007) who argue that F_0 variations that produce meaningful contrasts in intonation are at the sentence level in English. These variations are more easily controlled at the sentence level because they are much slower than changes at the syllable level. Based on previous literature and the current findings of the study, a change in task progression may include: 1) initial practice with the curve like target figure (doing so will allow the participant to master controlling the pressure sensitive button without including the complication of producing speech), and 2) practice with echoic declarative and question statement pairs while simultaneously modulating force.

Technical limitations. There were many limitations associated with the hardware used to collect the force data. The first limitation was the physical set up of the hardware on the participant speaker. This set-up was somewhat awkward as most of the hardware was strapped onto the participant speaker. Although placing the instrumental array on the participant was minimally uncomfortable, this did require the participant-speaker to remain in a relatively still, unnatural and somewhat rigid position for the duration of the training session. This set-up may be remedied by having a wireless connection between the force sensor and the desktop computer. If a wireless connection is established, it will allow participants to sit comfortably and move freely within the session. Improving comfort level could potentially increase the control of the pressure sensitive button as it offers more freedom for positional adjustment. This would approximate how EL users are usually able to move around when using their device. Furthermore, participant-speakers felt that it was difficult to simultaneously hold the EL on the side of their neck and modulate the pressure sensitive button. Future studies should investigate the use of a remote -controlled pressure sensor, which allows the participant to control pressure independent of neck coupling.

The second technical limitation was in the F_0 range of the EL device. During the training protocol, it was observed that although the EL device had a broad F_0 range (77.8 Hz to 208.7 Hz), only productions within the lower bounds of F_0 produced intelligible EL speech (104 Hz to 120 Hz). This intelligibility trade-off is not in alignment with previous studies that investigated intonation control with a pressure sensitive EL. For example, Watson and Schlauch (2009) used the same EL device as was used in the current study and found a range of 50 Hz to 180 Hz. These researchers further reported an adjustable dynamic frequency range of 300Hz. Finally, Watson and Schlauch (2009) found that speech understanding was on average 14% better with variable F_0 control found within the predetermined range. Other studies that have investigated the effect of intonation contours on sentence intelligibility have reported similar results to Watson and Schlauch (e.g., Laures & Bunton, 2003; Laures & Weismer, 1999).

Similarly, Hillenbrand (2003) used a source filter synthesizer to investigate the effect of pitch movement on sentence intelligibility. The source filter synthesizer was used to generate three different stimuli: 1) control pitch condition in which the F_0 matched an original utterance, 2) a monotone condition in which F_0 was held constant, and 3) an inverted pitch condition, in which a rise in F_0 value was changed to a fall, and vice versa. Thirty listeners assessed sentence intelligibility in all three conditions. Hillenbrand (2003) reported a reduction in intelligibility in both the monotone and inverted pitch conditions compared to the original utterance. Based on these contradictory results, it is important to investigate the potential intelligibility trade off observed in the current study, and the associated underlying factors that contributed to this finding.

The third technical limitation was found in the sensitivity of the transducer of the EL device. Participant-speakers in this study showed difficulty in applying pressure quickly enough to transition between low and high F_0's. This problem in rise time and fall time of F_0 is related to a limitation in the transducer of the EL device. Future EL devices should include a transducer that has a more flexible rise and fall time. In addition, it is important to understand how much F_0 variation is required to produce a perceivable, acoustic contrast. Participant-speakers in the current study were limited to changes in F_0 at the end of each sentence pair. This design was implemented based on commonly observed linguistic contrasts between declarative and interrogative statements in English. In line with this reasoning, Watson and Schlauch (2009) found that although some extreme variability in F_0 was produced, an overall rising and falling pattern was observed in the acoustic analysis of their participant speaker. Both the findings of the Watson and Schlauch (2009) and the current study are based on observational, single-subject data. Therefore, studies investigating the amount of F_0 variation necessary for meaningful contrasts is needed to confirm these preliminary findings.

In addition, it is important to understand whether F_0 variability itself underlies the enhancement of EL speech. More specifically, is the enhancement of EL speech due to more dynamic control of F_0 and not tied to the linguistic role of intonation? The answer to this question requires that the definition of speech enhancement be specified. This is because there are many factors that influence a listener's assessment and rating of speech. For example, it is possible that a listener may rate EL speech as less acceptable because of intelligibility, rather than the quality or sound of the speech itself. Therefore, it is important to understand what dimensions of EL speech (e.g., intelligibility, naturalness, etc.) might differentially influence listener assessments. In Hillenbrand's (2003) study that was previously described, a second experiment was conducted to further investigate the interaction of intelligibility and intonation on normal speech. The three sentence conditions of the first experiment (control, monotone and inverted) were filtered through a 2-kHz low-pass filter to further reduce intelligibility. Listener intelligibility was lowest for the inverted intonation condition. The results of Hillenbrand (2003) seem to underscore the linguistic importance of intonation on sentence intelligibility. However, future studies investigating the specific role of intonation in EL speech are needed.

Finally, the production of intonation in verbal communication is the result of a complex set of coarticulatory events. Thus, there may have been a mismatch between coordinating finger pressure and the coarticulatory events necessary to produce intonation. One potential explanation for this mismatch is that the finger is not normally used in the production of speech. Heller (2009) investigated the influence of EMG and finger controlled pitch on naturalness ratings of EL speech. EMG based pitch control was rated as more natural sounding by naïve listeners. Heller (2009) argued that this was because EMG pitch control used more speech related muscles (submental area, residual suprahyoid and tongue root musculature). Nagle and Heaton (2016) also found that EMG-based pitch control was perceived, by naïve listeners, as sounding more natural than the finger controlled type. Based on the findings of the aforementioned studies, as well as those of the current study, it is important to investigate the impact of using speech related muscles, compared to non-speech related muscles in a standardised EL training paradigm.

Strict participant inclusion criteria. It was observed during training that each participant needed to have a stable sweet spot or position on the neck where the EL is coupled. This was necessary as the entire training protocol was dependent on finding and maintaining efficient contact with the neck. Not only did participants need a ‘sweet spot’, they also needed to have minimal neck impedance to allow for the production of EL speech. Given that both participants exhibited normal necks, the ability to achieve effective EL device and neck coupling was facilitated. However, in those who undergo TL and who have fibrosis or lymphedema, challenges in applying the training protocol may be encountered. In such cases, online adjustments and modifications in training may be required. Based on these neck related challenges, it is worth investigating how the current training paradigm applies to an intraoral EL device. In addition to fibrosis and lymphedema, participants who have manual dexterity issues or motor control issues may not be able to participate without considerable modifications. Finally, because motor control continues to decline with age, and as most laryngectomees continue to be older adults (between the ages of 45-65 years old), this factor will pose an additional limitation on the implementation of the training protocol.

Future Directions

Based on the findings of the current study, three directions for future studies emerged. The first is testing the training protocol with laryngectomees as participant-speakers, i.e. the target population (Testing with the target population). The second is the understanding of clinical outcomes in terms of QOL, and investigating the audio perceptual evaluation of the EL speech post training (Clinical outcomes). The third direction involves testing how long the effects of training last and the feedback frequency required to obtain optimal training results (Frequency of feedback).

Testing with the target population. Both participant speakers in this study were normal, healthy adults and are, therefore, not directly generalizable to the target population (laryngectomees). Future studies with laryngectomees using an EL as their primary communication device are necessary for the extension and understanding of the effectiveness of the proposed training protocol. In contrast to normal healthy adults, and as noted, laryngectomees often have limited mobility due to neck dissections and additional issues with neck impedance. Laryngectomees are also typically older adults and will, therefore, be subjected to a potential decline in motor control. Finally, it is important to consider gender as the majority of laryngectomees are male. In sum, gender, age and neck physiology are important factors that need to be considered when testing this training paradigm with the laryngectomee population.

Clinical outcomes. Although this study showed an overall improvement in force matching ability, it does not address whether this improvement is clinically relevant. It is unknown whether more accurate force matching leads to better intonation control using the pressure sensitive EL device. That is, if participants learn to better control force, does this lead to the production of more variable intonation patterns in sentences? Further, it is unknown whether training using this protocol leads to better (or poorer) listener ratings of naturalness and intelligibility of EL speech. Future studies using auditory-perceptual ratings of EL speech pre- and post treatment are needed to identify whether this protocol leads to a clinically relevant change. This change can be measured using listener assessments and ratings of speech pre- and post-training. Furthermore, asking EL speakers to self-evaluate their own voice pre- and post-training would be beneficial for the assessment of clinical outcomes.

Not only is it important to address the impact on clinical outcomes (e.g., social acceptability and listener ratings), but it is also critical to create a training protocol that is applicable within a realistic clinical time-frame. It is important to test a condensed version of this training protocol as clinicians may only see a patient once or twice for less than four hours. Clinicians may work towards a minimum criterion. For example, it may be beneficial for clinician employing this training protocol to ensure that patients display the ability to create systematic increases and decreases in force productions. Alternatively, future studies may be extended to investigate the use of an at home mobile application that provides patients with additional feedback and practice using a pressure sensitive EL.

Frequency of feedback. As the study duration was condensed to two weeks, it is unclear if an enhancement in learning was being observed. More specifically, the results of this study only speak to an enhancement in performance, and is it unknown whether longer-term learning has occurred during this condensed time-frame. Learning is defined as a state of perceived permanent change whereas performance is a temporary improvement of a motor skill (Schmidt & Lee, 1999). Future studies are needed to investigate whether skills learned in the training paradigm are transferrable, and how long they last. Furthermore, it is critical to investigate how much feedback is required to enhance learning. Future studies using a faded feedback paradigm are necessary to understand the frequency and structure of feedback required to demonstrate enhanced training results.

Conclusions

Many clinicians and researchers recognised the importance of intonation in improving the quality of EL speech. For example, almost 60 years ago Barney (1958) described seven main attributes that make up an enhanced EL speech system. One of these attributes indicated that artificial laryngeal speech quality and prosody should be comparable to that of normal speech. Thus, this study sought to address the attribute of prosody approximating normal speech because of its important role in verbal communication. The findings of the current study demonstrate the importance of further exploring different means of enhancing intonation control in EL speech. The findings of the current study have highlighted that participant-speakers are able to better control force production using a pressure sensitive EL. Although an improvement in force control was observed, the findings of this study also highlight the difficulty and complexity of force control using an EL. However, this is the first step in understanding the effectiveness of a standardised and systematic training protocol. As the goal of this work was proof-of-concept in nature, it does not address direct clinical outcomes. That is force control and pitch variability using a pressure sensitive EL do not guarantee that a speaker will be able to create meaningful communicative contrasts in a real life speaking situation. Further, it is unknown whether listeners will evaluate EL speech post training as sounding more natural or intelligible. Future studies are needed to validate the training protocol with the target population and to evaluate clinical outcomes post training.

This study further underlines the importance of implementing and testing a systematic approach to learning intonation. There are many variables that need to be controlled to isolate F_0 using an EL, including types of phonemes (e.g., stops, voiceless non-continuants), word level intonation and sentence level intonation. The systematic approach used in this study allowed for the evaluation of the effectiveness of training tasks. Specifically, it is more effective to use sentence and statement pairs to learn intonation rather than to break down the task into single words. This finding gives clinicians a starting point of the types of materials that can be used in intonation acquisition and training.

In sum, the acquisition of intonation has the potential to improve the voice quality of EL speech and the clinical outcomes associated with voice rehabilitation post curative head and neck cancer treatment. The social penalty associated with EL speech underscores the importance of varied intonation in verbal communication.

Thus, while further research is required, the current study has provided the first step toward enhancing EL speech and potentially to improve postlaryngectomy outcomes in the future.

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Appendix A

Training Stimuli

Week 1- Session 1, Question Target Force Bars

Text1!	Force	Start Time	End Time
A	0.217804575	1	1.5
B	0.075046575	1.8	2.3
C	0.238306078	2.8	3.3
Text2!			
A	0.120111994	1	1.5
B	0.066987135	1.8	2.3
C	0.233129492	2.8	3.3
Text3!			
A	0.205514288	1	1.5
B	0.094974904	1.8	2.3
C	0.312321324	2.8	3.3
Text4!			
A	0.125566493	1	1.5
B	0.116899114	1.8	2.3
C	0.321266008	2.8	3.3
Text5!			
A	0.095899771	1	1.5
B	0.116899114	1.8	2.3
C	0.273409955	2.8	3.3
Text6!			
A	0.198620563	1	1.5
B	0.120781167	1.8	2.3
C	0.337670812	2.8	3.3
Text7!			
A	0.128655075	1	1.5
B	0.045984149	1.8	2.3
C	0.300080812	2.8	3.3
Text8!			
A	0.13059973	1	1.5
B	0.044071356	1.8	2.3
C	0.206742243	2.8	3.3
Text9!			

A	0.100732373	1	1.5
B	0.049571018	1.8	2.3
C	0.20895751	2.8	3.3
Text10!			
A	0.124686955	1	1.5
B	0.06740625	1.8	2.3
C	0.112060133	2.8	3.3

Note. Stimuli included are the target force bars for question statements without text

Week 1- Session 1, Declarative Target Force Bars

Text1!	Force	Start Time	End Time
A	0.110982866	1	1.5
B	0.078632946	1.8	2.3
C	0.070065994	2.8	3.3
Text2!			
A	0.16398412	1	1.5
B	0.08599312	1.8	2.3
C	0.061292751	2.8	3.3
Text3!			
A	0.163479015	1	1.5
B	0.120462725	1.8	2.3
C	0.076636358	2.8	3.3
Text4!			
A	0.168403731	1	1.5
B	0.073169329	1.8	2.3
C	0.088262401	2.8	3.3
Text5!			
A	0.110411275	1	1.5
B	0.076679984	1.8	2.3
C	0.055123712	2.8	3.3
Text6!			
A	0.190373087	1	1.5
B	0.111336437	1.8	2.3
C	0.111790338	2.8	3.3

Text7!			
A	0.171244312	1	1.5
B	0.120043076	1.8	2.3
C	0.060596304	2.8	3.3
Text8!			
A	0.164344035	1	1.5
B	0.076850722	1.8	2.3
C	0.058648481	2.8	3.3
Text9!			
A	0.180031929	1	1.5
B	0.091566145	1.8	2.3
C	0.062222676	2.8	3.3
Text10!			
A	0.167694321	1	1.5
B	0.096439752	1.8	2.3
C	0.057379206	2.8	3.3

Note. Stimuli included are the target force bars for declarative statements without text.

Week 1- Session 1, Question and Declarative Statement Pairs

Text1!	Force	Start Time	End Time
Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text2!			
Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text3!			
Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text4!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3

orzo?	0.337670812	2.8	3.3
Text5!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3
orzo?	0.337670812	2.8	3.3
Text6!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3
orzo?	0.337670812	2.8	3.3
Text7!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text8!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text9!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text10!			
Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3
Text11!			
Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3
Text12!			
Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3

Note. These question and declarative statement stimuli were baseline measurements.

Week 1- Session 1, Question and Declarative Statement Pairs

Text1!	Force	Start Time	End Time
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text2!			
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text3!			
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text4!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text5!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text6!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text7!			
Myles	0.167694321	1	1.5
knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text8!			
Myles	0.167694321	1	1.5
knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text9!			

Myles	0.167694321	1	1.5
knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text10!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3
Text11!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3
Text12!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3

Note. These question and declarative statement stimuli were baseline measurements.

Week 1- Session 2, Review Phase: Force Target Bar Matching

Text1!	Force	Start Time	End Time
A	0.190373087	1	1.5
B	0.111336437	1.8	2.3
C	0.111790338	2.8	3.3
Text2!			
A	0.198620563	1	1.5
B	0.120781167	1.8	2.3
C	0.337670812	2.8	3.3
Text3!			
A	0.164344035	1	1.5
B	0.076850722	1.8	2.3
C	0.058648481	2.8	3.3
Text4!			
A	0.13059973	1	1.5
B	0.044071356	1.8	2.3
C	0.206742243	2.8	3.3

Text5!			
A	0.180031929	1	1.5
B	0.091566145	1.8	2.3
C	0.062222676	2.8	3.3
Text6!			
A	0.100732373	1	1.5
B	0.049571018	1.8	2.3
C	0.20895751	2.8	3.3
Text7!			
A	0.167694321	1	1.5
B	0.096439752	1.8	2.3
C	0.057379206	2.8	3.3
Text8!			
A	0.124686955	1	1.5
B	0.06740625	1.8	2.3
C	0.112060133	2.8	3.3

Note. Review phase of the previous week's material. Random force target bars were used.

Week 1- Session 2, Learning Phase: Single Words Stimuli

Text14!	Force	Start Time	End Time
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Text15!			
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Text16!			
mole	0.100732373	1	1.5
mole	0.100732373	1	1.5
mole	0.100732373	1	1.5
Text17!			
mole	0.100732373	1	1.5

mole	0.100732373	1	1.5
mole	0.100732373	1	1.5
Text18!			
mole	0.100732373	1	1.5
mole	0.100732373	1	1.5
mole	0.100732373	1	1.5
Text19!			
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Text20!			
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Text21!			
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Text22!			
wise	0.112060133	2.8	3.3
wise	0.112060133	2.8	3.3
wise	0.112060133	2.8	3.3
Text23!			
wise	0.112060133	2.8	3.3
wise	0.112060133	2.8	3.3
wise	0.112060133	2.8	3.3
Text24!			
wise	0.112060133	2.8	3.3
wise	0.112060133	2.8	3.3
wise	0.112060133	2.8	3.3

Note. Single word target bar matching stimuli.

Week 1- Session 2, Preview Phase: Question and Declarative Statement Stimuli

Text1!	Force	Start Time	End Time
Anna	0.190373087	1	1.5
Anna	0.190373087	1	1.5
Anna	0.190373087	1	1.5
Text2!			
Anna	0.190373087	1	1.5
Anna	0.190373087	1	1.5
Anna	0.190373087	1	1.5
Text3!			
Anna	0.190373087	1	1.5
Anna	0.190373087	1	1.5
Anna	0.190373087	1	1.5
Text4!			
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Text5!			
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Text6!			
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Text7!			
loves	0.076850722	1.8	2.3
loves	0.076850722	1.8	2.3
loves	0.076850722	1.8	2.3
Text8!			
loves	0.076850722	1.8	2.3
loves	0.076850722	1.8	2.3
loves	0.076850722	1.8	2.3
Text9!			
loves	0.076850722	1.8	2.3
loves	0.076850722	1.8	2.3

loves	0.076850722	1.8	2.3
Text10!			
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
Text11!			
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
Text12!			
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
Text13!			
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Text14!			
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Text15!			
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Text16!			
mole	0.100732373	1	1.5
mole	0.100732373	1	1.5
mole	0.100732373	1	1.5
Text17!			
mole	0.100732373	1	1.5
mole	0.100732373	1	1.5
mole	0.100732373	1	1.5
Text18!			
mole	0.100732373	1	1.5
mole	0.100732373	1	1.5

mole	0.100732373	1	1.5
Text19!			
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Text20!			
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Text21!			
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Lane	0.096439752	1.8	2.3
Text22!			
Wise	0.112060133	2.8	3.3
Wise	0.112060133	2.8	3.3
Wise	0.112060133	2.8	3.3
Text23!			
Wise	0.112060133	2.8	3.3
Wise	0.112060133	2.8	3.3
Wise	0.112060133	2.8	3.3
Text24!			
Wise	0.112060133	2.8	3.3
Wise	0.112060133	2.8	3.3
Wise	0.112060133	2.8	3.3

Week 1- Session 2, Preview Phase: Question and Statement Stimuli

Text1!	Force	Start Time	End Time
Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text2!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3

orzo?	0.337670812	2.8	3.3
Text3!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text4!			
Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3
Text5!			
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text6!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text7!			
Myles	0.167694321	1	1.5
knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text8!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3

Week 2- Session 1, Review Phase: Force Target Bar Matching

Text1!	Force	Start Time	End Time
A	0.190373087	1	1.5

B	0.111336437	1.8	2.3
C	0.111790338	2.8	3.3
Text2!			
A	0.198620563	1	1.5
B	0.120781167	1.8	2.3
C	0.337670812	2.8	3.3
Text3!			
A	0.164344035	1	1.5
B	0.076850722	1.8	2.3
C	0.058648481	2.8	3.3
Text4!			
A	0.13059973	1	1.5
B	0.044071356	1.8	2.3
C	0.206742243	2.8	3.3

Week 2- Session 1, Review Phase: Single Words

Text5!			
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Text6!			
loves	0.076850722	1.8	2.3
loves	0.076850722	1.8	2.3
loves	0.076850722	1.8	2.3

Text7!			
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
Text8!			
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3

Week 2- Session 1, Learning Phase: Question and Declarative Stimuli Pairs

Text1!	Force	Start Time	End Time
Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text2!			
Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text3!			
Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text4!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3
orzo?	0.337670812	2.8	3.3
Text5!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3
orzo?	0.337670812	2.8	3.3

Text6!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3
orzo?	0.337670812	2.8	3.3
Text7!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text8!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text9!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text10!			
Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3
Text11!			
Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3
Text12!			
Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3

Week 2- Session 1, Learning Phase: Question and Declarative Stimuli Pairs

Text1!	Force	Start Time	End Time
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text2!			
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text3!			
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text4!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text5!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text6!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text7!			
Myles	0.167694321	1	1.5
knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text8!			

Myles	0.167694321	1	1.5
knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text9!			
Myles	0.167694321	1	1.5
knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text10!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3
Text11!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3
Text12!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3

Week 2- Session 2, Review Phase: Force Bars Matching

Text1!	Force	Start Time	End Time
A	0.190373087	1	1.5
B	0.111336437	1.8	2.3
C	0.111790338	2.8	3.3
Text2!			
A	0.198620563	1	1.5
B	0.120781167	1.8	2.3
C	0.337670812	2.8	3.3
Text3!			

A	0.164344035	1	1.5
B	0.076850722	1.8	2.3
C	0.058648481	2.8	3.3
Text4!			
A	0.13059973	1	1.5
B	0.044071356	1.8	2.3
C	0.206742243	2.8	3.3

Week 2- Session 2, Review Phase: Single Words Task

Text5!			
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Text6!			
loves	0.076850722	1.8	2.3
loves	0.076850722	1.8	2.3
loves	0.076850722	1.8	2.3
Text7!			
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
Text8!			
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3

Week 2, Session 2, Learning Phase: Question and Declarative Statement Pairs

Text1!	Force	Start Time	End Time
Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text2!			

Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text3!			
Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text4!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3
orzo?	0.337670812	2.8	3.3
Text5!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3
orzo?	0.337670812	2.8	3.3
Text6!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3
orzo?	0.337670812	2.8	3.3
Text7!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text8!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text9!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text10!			
Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3
Text11!			

Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3
Text12!			
Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3

Week 2, Session 2, Learning Phase: Question and Declarative Statement Pairs

Text1!	Force	Start Time	End Time
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text2!			
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text3!			
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text4!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text5!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text6!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text7!			
Myles	0.167694321	1	1.5

knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text8!			
Myles	0.167694321	1	1.5
knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text9!			
Myles	0.167694321	1	1.5
knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text10!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3
Text11!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3
Text12!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3

Week 3- Session 1, Review Phase: Force Bars Matching

Text1!	Force	Start Time	End Time
A	0.190373087	1	1.5
B	0.111336437	1.8	2.3
C	0.111790338	2.8	3.3
Text2!			
A	0.198620563	1	1.5
B	0.120781167	1.8	2.3
C	0.337670812	2.8	3.3
Text3!			

A	0.164344035	1	1.5
B	0.076850722	1.8	2.3
C	0.058648481	2.8	3.3
Text4!			
A	0.13059973	1	1.5
B	0.044071356	1.8	2.3
C	0.206742243	2.8	3.3

Week 3- Session 1, Review Phase: Single Words Task

Text5!			
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Orzo	0.337670812	2.8	3.3
Text6!			
loves	0.076850722	1.8	2.3
loves	0.076850722	1.8	2.3
loves	0.076850722	1.8	2.3
Text7!			
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
whales	0.206742243	2.8	3.3
Text8!			
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3
Vile	0.062222676	2.8	3.3

Week 3, Session 1, Evaluation Task: Question and Declarative Statement Pairs

Text1!	Force	Start Time	End Time
Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text2!			

Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text3!			
Anna	0.190373087	1	1.5
loves	0.111336437	1.8	2.3
orzo.	0.111790338	2.8	3.3
Text4!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3
orzo?	0.337670812	2.8	3.3
Text5!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3
orzo?	0.337670812	2.8	3.3
Text6!			
Anna	0.198620563	1	1.5
Loves	0.120781167	1.8	2.3
orzo?	0.337670812	2.8	3.3
Text7!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text8!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text9!			
Lane	0.164344035	1	1.5
loves	0.076850722	1.8	2.3
whales.	0.058648481	2.8	3.3
Text10!			
Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3
Text11!			

Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3
Text12!			
Lane	0.13059973	1	1.5
loves	0.044071356	1.8	2.3
whales?	0.206742243	2.8	3.3

Week 3, Session 1, Evaluation Task: Question and Declarative Statement Pairs

Text1!	Force	Start Time	End Time
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text2!			
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text3!			
Mary's	0.180031929	1	1.5
mole	0.091566145	1.8	2.3
was vile.	0.062222676	2.8	3.3
Text4!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text5!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text6!			
Mary's mole	0.100732373	1	1.5
was	0.049571018	1.8	2.3
vile?	0.20895751	2.8	3.3
Text7!			
Myles	0.167694321	1	1.5

knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text8!			
Myles	0.167694321	1	1.5
knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text9!			
Myles	0.167694321	1	1.5
knows Lane	0.096439752	1.8	2.3
is wise.	0.057379206	2.8	3.3
Text10!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3
Text11!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3
Text12!			
Myles	0.124686955	1	1.5
knows Lane	0.06740625	1.8	2.3
is wise?	0.112060133	2.8	3.3

Appendix B

FlexiForce Sensor Calibration

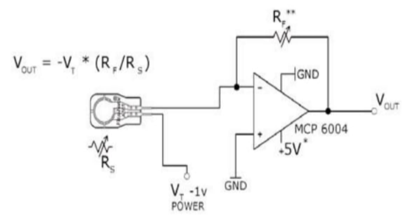
Tekscan **for FlexiForce® Sensors**

Introduction

Conditioning the *FlexiForce* sensors before every use is recommended. In addition, calibrating the sensors is recommended before initial use. Follow the procedure below to Condition and Calibrate the sensors.

This procedure is meant for use with your own electronics. For testing, Tekscan recommends using the circuit shown in the diagram at right. If no circuit is available, you can use a multimeter, and measure the resistance in kilo-ohms.

Note: Tekscan does not provide the circuit.



Part 1: Conditioning

Before using the sensors it is recommended that you condition the sensors. This process will "break in" the sensor and should be done before calibration and before every use for best results.

Place 110% (or more) of the maximum test load onto the sensor for approximately 3 seconds. For example, if the maximum test load is 10 pounds, place 11 pounds onto the sensor. Remove the load from the sensor. Repeat 4-5 times. When finished, proceed to **Part 2: Calibration**.

Part 2: Calibration for Static Forces

Step 1. Place 1/3 of the test weight on the sensor. Leave the weight on the sensor the same amount of time (before recording the output) as you will in your actual experiment. This helps minimize the drift error. Record the output, then remove the weight from the sensor.

Step 2. Place 2/3 of the test weight on the sensor, again waiting the approximate amount of time. Record the output. Remove weight from the sensor.

Step 3. Place the full test weight on the sensor. Wait the approximate amount of time again, and record the output. Remove the weight from the sensor. If using the recommended circuit, 3 sets of data are adequate. If using a multimeter, gather two more sets of data for a 5-point chart.

Step 4. Gather each set of data (Sensor Output vs Force applied) and plot the data on a graph. If using our recommended circuit or your own electronics, sensor output should be plotted as Voltage vs. Force (Chart A below). If using a multimeter, sensor output should be plotted as Conductance (1/Resistance) vs. Force (Chart B below). This gives a linear plot. You can then draw a line of best fit, or calculate one with MS Excel.

Step 5. Use the equation for the line of best fit and the sensor output to determine the force of unknown loads on the sensor during the experiment.

Chart A

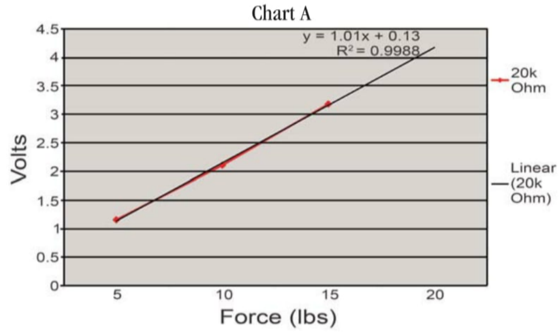
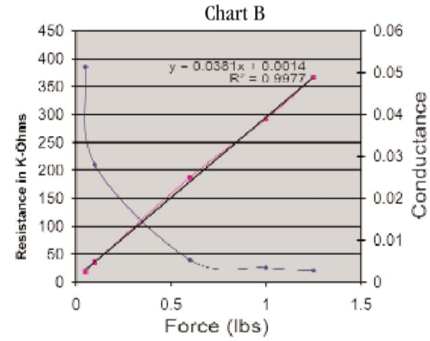


Chart B



Note: If testing involves dynamic forces instead of static force, this must be accounted for in the calibration process. This is due to a rise time associated with the output. Rise time refers to how long it takes the sensor to settle at the appropriate value within our error limits. The rise time for FlexiForce sensors is between 0.1 - 0.3 seconds (the response time is <5μ seconds). If your application involves a quick impact, the recommended method is to calibrate the sensor dynamically against a load cell with a quicker rise time. This allows you to compare the responses of both the sensor and the load cell. The amplitude of the FlexiForce sensor will be smaller than that of the load cell. The difference can be calculated by comparing the amplitudes after several tests. If a load cell is not available, the next recommendation would be to calibrate the sensor statically and use the sensor for comparative studies.

Tekscan, Inc. 307 West First St., South Boston, MA 02127
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Rev B - 01/18/11

Appendix C

Ethics Approval-Experiment 1

Western Research

Research Ethics

Western University Health Science Research Ethics Board
HSREB Delegated Initial Approval Notice

Principal Investigator: Dr. Philip Doyle
Department & Institution: Health Sciences\Communication Sciences & Disorders, Western University

Review Type: Delegated
HSREB File Number: 108614
Study Title: Listener Evaluation of Electrolaryngeal Productions

HSREB Initial Approval Date: January 18, 2017
HSREB Expiry Date: January 18, 2018

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Western University Protocol	Received 2016/12/02	
Letter of Information & Consent		2016/12/01
Recruitment Items	Recruitment script	2016/12/01
Recruitment Items	Poster	2016/12/01
Data Collection Form/Case Report Form	Received 2016/10/17	

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

[redacted]

Letter of Information and Consent

<u>Project Title:</u> Listener evaluation of electrolaryngeal acoustic productions

<u>Investigators:</u>

Principal Investigator:

Dr. Philip Doyle, PhD

[redacted]

Student Investigators: Noor Al-Zanoon (Health and Rehabilitation Science)

<u>Introduction:</u>

You are being invited to take part in this study because you have met the eligibility criteria and have shown interest in our study based on an announcement made in one of your classes and/or through an ad posted around Western University's campus. This letter contains information to help you decide whether or not to participate in this research study. It is important for you to understand why the study is being conducted and what it involves. Please read this letter carefully and feel free to ask questions.

<u>Purpose of the Study</u>

The purpose of this study is to investigate how listeners identify pre-recorded spoken sentences as being either questions or declarative statements based on how they sound rather than simply because of their content. The pre-recorded sentences will include those made by both normal speakers and those who have lost their voice box and use an artificial electronic voice source (alaryngeal speech) for speaking. Alaryngeal speakers are individuals who have undergone a surgical procedure called a total laryngectomy which involves the removal of the voice-box. As a result of this surgery, individuals must use alternative communication methods. One commonly used option is a hand held, battery operated device called an electrolarynx (EL). An EL is placed on the side of the neck, and vibrates air in the place of the lost vocal folds. As a participant in this study, you will be asked to classify sentences produced by EL speakers and normal speaking individuals. We are hoping to include 50 participants to undergo this listening task.

Inclusion Criteria:

If you are over the age of 18, and have normal hearing, can comprehend English instructions, then you are invited to participate in this study.

Exclusion Criteria:

If you are over the age of 18, and do not have normal hearing, or cannot comprehend English verbally or in writing, then you should not participate in the study. Additionally, if you are under the age of 18, you should not participate in this study.

Description of Study:

This study will take place in the Voice Perception Laboratory Rm 2200 in Elborn college (University of Western Ontario). We anticipate that the entire session will require one hour or less and will require one visit to the lab. Before starting the experiment, you will be asked to complete two short tasks:

a) Hearing screening: You will be asked if you can clearly hear a series of tones played to you over a set of headphones.
b) Reading comprehension test: You will be asked to read a short passage and answer a few questions about the passage you have just read.

After completing both tasks, you will be seated in front of a computer monitor and given a set of headphones. You will be asked to listen to recordings made by both a male and female speaker. Before the actual experiment begins, you will be presented with a practice, to ensure that the task demands are clear. You will be allowed to listen to each stimulus three times, by pressing the play button a PowerPoint slide. Then, a categorization task will be presented on the following slide. You will be asked to categorize each sentence by selecting one of four options: question, declarative sentence, neither, or unsure You will also be allowed to write additional comments about your decisions.

Potential Harms, Risks or Discomforts: Your participation in this study does not involve any physical or emotional risk. Potential discomforts can include fatigue, but you will be given as many breaks as you need as participant in the study.

Potential Benefits: By participating in this study, you are helping validate a training paradigm to help patients who have undergone a laryngectomy learn to control pitch or intonation.

Payment or Reimbursement: There will be no payment or compensation for participating in this study.

Confidentiality:

The results of this study will be used only for teaching, research, scientific publications, or presentations at scholarly meetings. Individual results are labelled only with a study code number rather than a name or other identifying information. Computer records of any measurements taken in the study and question responses are stored on password-protected computer disks. These records will be held in strictest confidence until 5 years after the results of the study are published, at which point the records will be destroyed. Only the researcher and qualified representatives from the University of Western Ontario Health Sciences Research Ethics Board may look at the records for quality assurance.

Participation:

You are under no obligation to participate. You may withdraw from the study at any time without suffering any negative consequences, even after signing the consent form. Withdrawing from the study will have no consequences on your performance in any course. If you choose to withdraw, all data gathered until the
time of withdrawal will be destroyed.

Study Debriefing:

You may obtain information about the results of the study by sending e-mail to Dr. Philip Doyle Dr. Doyle will send you an abstract of the study results.

Contact for more information: If you have questions or require more information about the study itself, please contact Dr. Philip Doyle.

If you have concerns or questions about your rights as a participant or about the way the study is conducted, you may contact:

University of Western Ontario Health Sciences Research Ethics Board

CONSENT

I have read the information presented above about a study being conducted by Dr.Philip Doyle and Msc student Noor Al-Zanoon at the University of Western Ontario. I have had the opportunity to ask questions about my involvement in this study, and to receive any additional details I wanted to know about the study. I understand that I may withdraw from the study at any time, if I choose to do so, and I agree to participate in this study. By signing this consent form, I do not waive any of my legal rights. I have been given a copy of this form.

____ ______________________

Participant’s Name Date

______________________________________ _____________________

Participant’s Signature Date

In my opinion, the person who has signed above is agreeing to participate in this study voluntarily, and understands the nature of the study and the consequences of participation in it. I acknowledge and understand that by signing this consent form, the participant does not waive any of his or her legal rights.

____ _____________________

Researcher’s Name Date

______________________________________ ___________________

Researcher’s Signature Date

Appendix E

Ethics Approval-Experiment 2

Western Research

Research Ethics

Western University Health Science Research Ethics Board
HSREB Delegated Initial Approval Notice

Principal Investigator: Dr. Philip Doyle
Department & Institution: Health Sciences\Communication Sciences & Disorders, Western University

Review Type: Delegated
HSREB File Number: 108538
Study Title: Using visual feedback to enhance intonation control in electrolarynx users

HSREB Initial Approval Date: October 25, 2016
HSREB Expiry Date: October 25, 2017

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Revised Western University Protocol		2016/10/15
Revised Letter of Information & Consent		2016/10/15
Data Collection Form/Case Report Form	Received October 15, 2016	

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

[redacted]

Appendix F

Letter of Information and Consent-Experiment 2

Letter of Information and Consent

Speakers

Project Title: Using visual feedback to enhance intonation control of electrolarynx speakers

Investigators:

Principal Investigator:

Dr. Philip Doyle, PhD

[redacted]

Student Investigator: Noor Al-Zanoon (Msc Student in Health and Rehabilitation Science)

Introduction:

You are being invited to take part in this study because you use an electrolarynx (a method of communication) as a result of your total laryngectomy or you have heard about the study through the professional contacts of the principle investigator. We thank you for considering participation in this study and we are hoping to reach our goal of five participants. This letter contains information to help you decide whether or not to participate in this research study. It is important for you to understand why the study is being conducted and what it involves. Please read this letter carefully and feel free to ask questions.

<u>Purpose of the Study</u>:

Individuals who have been diagnosed with cancer of the voice box (larynx) undergo total laryngectomy which results in the complete loss of normal voice production—a severe impact on an individual's ability to communicate verbally. The current postsurgical communication rehabilitation technology available for those who undergo total laryngectomy includes, as one option, a small, hand-held electronic vibrating device called an electro larynx (EL). After a laryngectomy, the EL acts as an external vibratory sound source for voice production. To use an EL, the individual places the device on their neck and the EL sound is transferred through neck tissues where the signal moves into the mouth for the articulation of speech sounds.

The resulting sound is often monotone, making it very hard for speakers to produce what is called intonation (more commonly known as pitch). Speech intonation is important for basic communication distinctions such as questions and declarative statements (e.g., *Sandra is going to school today?* and *Sandra is going to school today*.). However, this ability to make a distinction between questions is lost when using the electro larynx because of the limitations of the device itself in the control of intonation. Therefore, the purpose of this study seeks to implement a training paradigm that involves providing visual feedback for training participants on how to operate and EL device with the objective of producing more natural-sounding intonation.

<u>Inclusion Criteria:</u>

If you are between the ages of 45 and 65 and are in good general health and report no known health issues that would prevent you from using an electrolarynx (e.g tremor, motor disabilities etc), you are able to participate in this study. You must also be able to read, write and comprehend English. If you meet these requirements, you are welcome to participate in the study.

<u>Exclusion Criteria:</u>

If you are younger than 45 years of age, or older than 65, you are unable to participate. If you have other known health issues that would prevent you from using an electrolarynx (e.g tremor, motor disabilities etc); or if you do not read, write or comprehend English, you should not participate in this study.

<u>Description of study</u>

This study will take place in the Voice Perception Laboratory Rm 2200 in Elborn College (University of Western Ontario). As this study explores the evaluation of a training paradigm for using the EL, it will be divided into three main phases: pre-training, training, and the experimental evaluation task. Each session will run once a week for approximately 1 hour and sessions can be arranged based on your schedule. Ideally, we ask that you attend sessions over 5 consecutive weeks, but we will accommodate your schedule as needed.

Pre-training Tasks (Week 1)

Before starting the training sequences, a short session explaining intonation in English and its role will be conducted. This session will familiarize participants with the linguistic function of intonation. After the short introduction to intonation, a few small tasks will be conducted to establish y our baseline level of pitch control:

a) A 5 to 10 sentence passage will be recorded: The researcher will ask you to read a passage and while you are reading, a recording of your first attempt at this passage will be made.

b) A non-vocal pitch matching: The researcher will present you with a series of sounds and your task will be to match each pair of sounds as being either the same or different in pitch.

c) Reading Comprehension: You will be asked to silently read a passage and answer questions pertaining to the passage.

All three of the pre-training tasks will require approximately 30 minutes.

Training Task (Weeks 2-4)

During each session in the training phrase, a sensor will be placed on your index finger and thumb. The sensor will measure the amount of force you are using to press down on the pressure sensitive button on the EL. The researcher will show you how both the EL and the sensor work.

Week 2:

a) Finger force: You will be instructed on how the pressure sensitive buttons on the EL function. Then you will be shown a target force bar on a computer screen which you will assist you to match a particular signal. A demonstration by the researcher will be provided of this task.

b) Finger force and neck: Involves holding the EL on the side of the neck, in its natural position. The researcher will ask you to produce vowels (e.g., "ahh", etc.) with different pitches while keeping a constant pitch for 5 seconds. Next, the researcher will ask you to produce a lower or higher vowel sound to match the target bar on the computer screen. A demonstration by the researcher will be provided of this task.

Week 3:

c) Single words: After producing vowels, you will be asked to produce single words. For example, the word "No" can be said with different pitch to elicit either a question or a statement: "No?" versus "No."

Week 4:

d) Phrases: After you are able to produce single words with different pitches, you will be asked to produce sentences. For example, you may be asked to produce the question: "Ron won the game."

Experimental Evaluation Task (Week 5):

You will be evaluated on a small sample of all the tasks that you have been trained in during the training phase. The researcher will record your productions. With your consent, these recordings will be presented to listeners in a follow-up experiment. The purpose of the follow-up experiment is to see whether listeners can see an improvement in the pitch productions. Your name and personal information will be kept confidential; the samples used will only be identified by a number.

Potential Harms, Risks or Discomforts: Your participation in this study does not involve any physical or emotional risk. Potential discomforts can include fatigue, but you will be given as many breaks as you need as a participant in the study.

Potential Benefits: As a participant you may learn a new way of controlling pitch using an EL which may improve your speech using the device. However, the benefits of this study are more long-term in that the results help clinicians/researchers design better training paradigms for EL users following laryngectomy.

<u>Payment or Reimbursement</u>: As a participant in this study, you will receive a parking pass for all sessions.

<u>Confidentiality:</u>

The results of this study will be used only for teaching, research, scientific publications, or presentations at scholarly meetings. Individual results are labelled only with a study code number rather than a name or other identifying information. Computer records of any measurements taken in the study and question responses are stored on password-protected desktop computer to be kept in the Voice Production Laboratory (Room 2200, Elborn College, University of Western Ontario). All of these records will be held in strictest confidence for 5 years after the results of the study are published, at which point the records will be destroyed. Only the researcher and qualified representatives from the University of Western Ontario Health Sciences Research Ethics Board may look at the records for quality assurance.

<u>Participation:</u>

You are under no obligation to participate. You may withdraw from the study at any time without suffering any negative consequences, even after signing the consent form. If you choose to withdraw, all data gathered until the time of withdrawal will be destroyed.

<u>Study Debriefing:</u>

You may obtain information about the results of the study by sending e-mail to Dr. Philip Doyle.

<u>Rights of Research Participants</u>

If you have questions or require more information about the study itself, please contact Dr. Philip Doyle by e-mail.

If you have concerns or questions about your rights as a participant or about the way the study is conducted, you may contact: University of Western Ontario Health Sciences Research Ethics Board.

CONSENT

I have read the information presented above about a study being conducted by Dr. Philip Doyle and Msc student Noor Al-Zanoon at the University of Western Ontario. I have had the opportunity to ask questions about my involvement in this study, and to receive any additional details I wanted to know about the study. I understand that I may withdraw from the study at any time, if I choose to do so, and I agree to participate in this study. I have been given a copy of this form.

____ ________________

Participant's Signature Date

In my opinion, the person who has signed above is agreeing to participate in this study voluntarily, and understands the nature of the study and the consequences of participation in it.

____ ________________

Researcher's Signature Date

Curriculum Vitae

Noor Al-Zanoon

2015-Present	**Masters in Health and Rehabilitation Sciences** University of Western Ontario, London, Ontario, Canada Motor Training Paradigm for the Electro-larynx Supervisor: Dr. Philip Doyle
2013-2015	**Honors Bachelors of Arts, Cognitive Science of Language** McMaster University, Hamilton, Ontario, Canada Oculomotor movements in RAN (Rapid Automatized Naming) Supervisor: Dr. Victor Kuperman
2009-2013	**Honors Bachelors of Science, Life Science** McMaster University, Hamilton, Ontario, Canada The Start-up Effect in Reading: Physiological and Cognitive Factors Supervisor: Dr. Victor Kuperman and Dr.Gautham Ullal

PUBLICATIONS

Al-Zanoon, N., Dambacher, M., & Kuperman, V. (2016). Evidence for a global oculomotor program in reading. *Psychological research*, 1-15.

AWARDS

2016-2017	University of Alberta, Doctoral Recruitment Scholarship ($5,000; accepted)
2016-2017	Ontario Graduate Scholarship Award ($15,000; declined) University of Western Ontario, London, Ontario, Canada
2014-2015	Student Success Leader Nominee McMaster University, Hamilton, Ontario, Canada
2013-2015	Deans Honors List McMaster University, Hamilton, Ontario, Canada

PRESENTATIONS

2016-2017	Oral presentation of “Using visual feedback to enhance electrolaryngeal speech”, at Health and Rehabilitation Sciences Graduate Research Conference, University of Western Ontario, London, Ontario, Canada
2014-2015	Oral Presentation of “Oculomotor Movements in RAN (Rapid Automatized Naming)”, at Linguistics and Humanities Student Research Day, McMaster University, Hamilton, Ontario, Canada

2013-2014 Oral Presentation of "The Start-up Effect: Physiological and Cognitive Components of Reading", at McGill Canadian Conference for Linguistics Undergraduates, McGill University, Quebec, Canada

RESEARCH EXPERIENCE

2012-2015 **McMaster Reading Lab Research Assistant**

McMaster University, Hamilton, Ontario, Canada

Association between hand motor coordination and reading skill project

Principle Investigators: Victor Kuperman, Regina Henry, Jim Lyons

- Investigation of motor control and executive function in reading using pressure sensitive sensors as a physiological measure

Individual differences in the effects of semantic transparency on morphological processing

Principle Investigators: Daniel Schmidtke and Victor Kuperman

- Data collection and post hoc data analysis using DataViewer (eye-tracking data software)
- Stimuli preparation

The Interplay of Language and Emotion: Using Affective Norms to Explore Word Recognition, Motivation, and Lexicon

Principle Investigator: Amy Beth Warriner

- Data collection and experiment programming using Experiment Builder (a computer software) that allows the integration of psychological experiments with a high-speed camera. The high-speed camera tracks eye-movements during reading

TEACHING EXPERIENCE

2016-2017 **Teaching Assistant**

University of Western Ontario, London, Ontario, Canada Occupational Therapy fieldwork and professional development course

- Resume counselling and editing
- Organization of patient simulation laboratories
- Grading of oral presentations

2014-2015 **Student Success Leader Volunteer and ESL Conversation Circle**

Instructor
McMaster University, Hamilton, Ontario, Canada

- Organized and taught weekly English conversation skills

TECHNICAL SKILLS

- Proficient with Experiment Builder software for the design of eyetracking experiments using Eyelink 1000, and Eyelink II
- Experienced with the following programs: Praat (Phonetic analysis software), R Statistical software and MATLAB.

PSYCHOLOGICAL TESTING EXPERIENCE

- Administration of WASI (intelligence test), GORT, TOWER2
- Administration of STIM, Goldman Fristoe and CELF speech assessment tests
- Aphasia conversation facilitator Training (SAM Hamilton East Aphasia Group)

LANGUAGES

- French (Fluent written and oral)
- Arabic (Fluent written and oral)
- English (Fluent written and oral)

COMMUNITY INVOLVMENT

2015-Present **Team Member: Western's Graduate Students for Accessibility**
University of Western Ontario, London, Ontario, Canada

- Evaluated student accessibility for students on campus
- Attended committee meetings to resolve on campus accessibility concerns

2014-2015 **Swallowing Clinic Speech Pathology Volunteer**
St. Joseph's Hospital, Hamilton, Ontario, Canada

- Development of a database for swallowing clinic referrals using Access
- Observation of barium swallowing assessments
- Preparation of barium samples for different consistencies of food to be used in swallowing assessments.

2014-2015 **Aphasia Conversation Group Volunteer (SAM Group)**
Hamilton, Ontario, Canada

- Aphasia training with a qualified speech pathologist
- Acted as a conversation partner for clients
- Preparation of progress reports to keep track of improvement

and strategies.

2012-2014 **Elementary School Speech Pathology Volunteer**
Green Acres Elementary School, Hamilton, Ontario, Canada

- Development of an App for IPad and Android about prepositions
- Assisted with psychological assessment of grade one students in need of speech therapy, using the STIM test
- CELF and Goldman Fristoe test observations
- Performed therapeutic techniques under the supervision of a registered speech pathologist
- Performed many phonological awareness exercises with students which included compound word exercises
- Played language games and reported observations based on student teacher interactions
- Created therapy preparatory work including client specific articulation and comprehension cards