Augmentative Communication Device

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Department of Biomedical Engineering
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Prachi Agarwal, BWIG
Erin Devine, Communicator
Brian Mogen, Team Leader
Steve Wyche, BSAC

Client
Dr. Lawrence Kaplan, M.D
Department of Pediatrics, UW School of Medicine and Public Health

Advisor
Professor Brenda Ogle, Ph. D.
Department of Biomedical Engineering

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Abstract

Neuromotor disabilities, most notably cerebral palsy, often make speaking very difficult for affected individuals. This is a cause of great frustration because many have the mental capacity but not the vocal abilities to communicate with other people. Existing technology currently on the market is not desirable for a number of reasons: it is too difficult to use, the output delay is too great, the user cannot express emotions, and it is very expensive. Our client, Dr. Lawrence Kaplan, has expressed a desire to create a device which would allow cerebral palsy patients to be actively involved in conversations and to “shape” the sounds of their voices. Our design incorporates the use of a Kaossilator pad and a talkbox to hopefully achieve these goals. Future work on this design includes testing of the various components, assembly of the prototype, reduction of its weight, and integration of the system.

Background Information

Neuromotor dysfunction presents itself in a number of forms, one of the most common being cerebral palsy. This occurs in approximately 2 to 2.5 out of every 1000 people and is a result of abnormalities in the growth and functioning of the brain. This leads to uncontrollable reflex movements and moderate to severe muscle tightness. Cerebral palsy can be caused by head trauma after birth, but this is relatively rare. It is more common for the brain to be affected before or during birth.

Four main types of brain damage contribute to the majority of cerebral palsy cases[1]. The first is periventricular leukomalacia, which is damage to the white matter of the brain. This is usually responsible for transmitting signals throughout the brain and body, but small holes in this white matter that form before birth do not allow this to develop properly. Another cause of cerebral palsy is cerebral dysgenesis, or abnormal development of the brain. During the first 20 weeks of development, the fetal brain is very vulnerable. Any interruption in the growth of the brain causes abnormalities that interfere with the transmission of signals. Mutations in genes, infections, fevers, or trauma could contribute to this interruption. Intracranial hemorrhage, or bleeding in the brain, is also a possibility. If blood flow is blocked by blood clots in the placenta, the baby may suffer a stroke, leading to blocked or broken vessels in the brain. The final key development malfunction is hypoxic-ischemic encephalopathy, or intrapartum asphyxia. More commonly referred to simply as asphyxia, this is a lack of oxygen in the brain. Tissue in the brain, most notably in the cerebral motor cortex, can be destroyed, and this causes cerebral palsy.

Motor functions are affected differently in everyone; some have a slight limp, while others are completely wheelchair-bound. Those with spastic hemiplegia are mostly affected in the arms and hands; those with spastic diplegia are more affected in the legs and feet[2]. The most severe form is spastic quadriplegia, where one has severe stiffness in the limbs, is usually completely wheelchair-bound, and has extreme difficulties speaking. Cerebral palsy is a non-progressive disorder, meaning the disease will not worsen, but later physiological disabilities are very common.

Design Motivation

One of the common dysfunctions associated with cerebral palsy is a difficulty speaking. This is often a source of great frustration because the disorder does not always affect one's mental capacity. The affected individual may actually be very smart, but is unable to convey this to anyone because he/she cannot speak normally. In one-on-one conversations, it takes a long time to say something, and the speech is usually very difficult to understand. In large groups, the individual's voice is simply not heard. The existing technology in assisting the speech of people with cerebral palsy is not very effective. It does not speed up the process of speaking, it is difficult to use, and it does not allow one to express any emotions. This does not solve the problem of actively participating in a conversation. It has long been the desire of affected individuals and clinicians to have a device which allows spontaneity of speaking; a device which allows the user to not only have instantaneous output, but also be able to "shape" the sound of his/her voice.

Client Requirements

One of the biggest complaints from patients with communicative disorders is that the devices out there to help them speak are slow and lack the ability to add emotion to what the user is trying to say. This delay, between when the user thinks a phrase and when they are able to actually communicate, can make the user feel unintelligent or feel that they are being perceived as unintelligent. It can also leave them out of a conversation since they cannot produce language within the normal pause of a conversation. In addition, they are unable to add emphasis or inflection to what they want to say. These are the issues that our client, Dr.

Lawrence Kaplan, has asked us to address. Every day he encounters patients that are frustrated with the means of communication to which they are limited. Many of his patients give up trying to speak and let others do it for them. Our client is looking to break away from the conventional communicative devices that are on the market today. He would like us to come up with something new that allows the user to have more spontaneity when they speak, as well as the ability to demonstrate emotions, like irritation or excitement, when they communicate. By doing this, we can hopefully “bridge the gap” for people with communicative disorders and help them to communicate in a way that feels more natural and comfortable.

The particular communicative disorder on which Dr. Kaplan would like us to concentrate is Cerebral Palsy. Most people with Cerebral Palsy are of normal intelligence and cognitive function. The disability lies in the neuromotor disorder that makes speaking difficult. Some patients have a paralyzed diaphragm, which makes it difficult to produce the air current necessary to create sound. Most patients have poor oromotor function. These patients can create sound but have difficulty with their tongue and mouth when they try to shape the sound into language. Our client has challenged us with creating a device that can help people with Cerebral Palsy create a clearer, more understandable sound quickly. Another consideration that our client has asked us to take into account is that the patient may or may not be wheelchair-bound, so our device should be portable enough that someone could walk around with it, but also have the ability to be mounted to a wheelchair.

Existing Devices

The devices currently available on the market today consist mostly of touch screen tablet PCs or handheld devices. These devices have pre-programmed common phrases and keyboards to enter in custom sentences. In order to give the user the ability to speak more quickly, the devices usually prompt possibilities for the next letter or word, but typing what they want to say is still a laborious task and is frustrating because it is time consuming.

One such device is the Tango. It is geared towards children and uses images and icons to direct the child to what they want to say. This device, however, is limited only to pre-programmed phrases. While useful for kids who can't speak, this device stifles a child's creativity in that they cannot produce their own sentences. It does not allow children to expand their vocabulary and limits them to what is programmed into the device.

Another device on the market is the Dasher. This device uses some sort of pointer, whether it is a joystick, a mouse type apparatus or a slider, to point out letters to form words. The program prompts the user with possible and common letters to follow the first in order to speed up the input process. While this is a great interface for someone that cannot use a standard keyboard to type, this is still very slow and makes the user less likely to say something that would be time consuming. In our client's experience, people then tend to limit their speech and vocabulary to the minimum that is required for what they want to communicate. In this way, devices like this limit self-expression in addition to being unable to add inflection or emphasis to the words.

Another manufacturer, DynaVox, produces touch screen devices that have some pre-programmed common phrases and a keypad input system. This interface is also slow, cumbersome, and lacks the ability to add emotion. While these devices come in small handheld versions or full size tablet PC based on the preference of the user, they are still limiting because they are slow and users encounter the same frustration as they do with other devices. Users pay a lot of money for these expensive devices, and then tend to not use them because they are not an efficient means of communication.

Problems that are common to all the existing devices on the market are that they are slow, inefficient and lack emotional expression. They make users feel unintelligent because they delay the time between the thought and the speech, and they just are not efficient enough to offset their cost. In other words, people just do not use them. Our challenge this semester is to come up with an idea for a device that addresses at least one of these problems in order to help people with communicative disorders to have a more natural-feeling means of communication.

Palm Pilot Alphabet Device

Our first design is based on the single-stroke alphabet implemented by Palm Pilots. The device would be run on a tablet laptop platform off of LabVIEW or similar software. The user would use simple single strokes with a stylus on the touchscreen to create letters (See Figure 1). The screen will be arranged with a central writing pad surrounded radially by punctuation marks, a delete, and a playback button. The user would type in a sentence and then play back the sentence to be heard.

Advantages

This device would provide a means of communication to individuals who suffer from severe motor disabilities because the user interface is significantly larger than that of devices currently offered.

Disadvantages

Because it is computer based, this device will be inherently expensive. It will also be very difficult to prototype as very advanced computer programming skills would be required. It will also be bulky and large which will hinder its use. The device requires that the user input every single letter of a word or phrase, so the device will be comparable in speed to some of the slower devices already on the market.

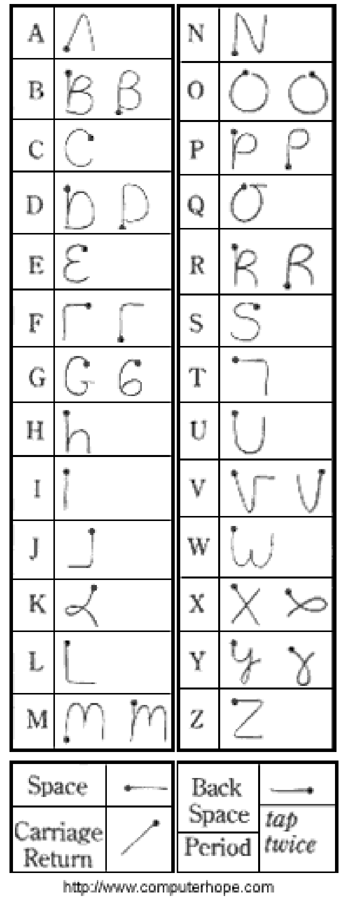

Figure 1. Palm Pilot Alphabet consisting of single strokes[3]

Phonetic Alphabet Device

The English language has 144 phonetic sounds, all of which are used in daily language. Our second design also incorporates a touch screen interface with a button for each sound. There would also be user control of inflection and volume through a number of potential methods. The device would have immediate feedback, outputting sound as soon as the user pressed a button. For controlling inflection and volume, the user will have many options for inputs. We could use a pressure sensor that the patient holds and squeezes to affect a change in frequency. We could also use any combination of sliders or levers, either on the touch screen, or mounted to the side. This design is very adaptable in that regard and would be a great step for people who can move well. All of the phonetic sounds would be incorporated into a database that the buttons would call on.

Advantages

This device allows for complete control of language. Users would be able to control all aspects of vocal communication, most importantly volume and inflection, which is a feature missing on all existing devices.

Disadvantages

Like our first device, this would be limited by the ability of the user to move quickly between buttons. There are several syllables per word, and several sounds per syllable. This complexity requires immense dexterity on the part of the user to find the correct buttons on the screen and press them accurately. The device is also limited by the method of inflection and volume control. This design would be comparable to a keyboard with ten times the standard number of buttons, as well as additional levers, or pressure sensors that may require manual dexterity to operate. The device is also computer based so there will be significant cost limitations and limitations in our programming ability.

Kaossilator/Talkbox Device

In a radical departure from our first two designs, the third is a device based on a frequency generator and a frequency modulator. The Kaossilator Pad (See Figure 2) is a small touch screen-driven frequency generator with many options of output sounds. One of the options, L.14, is digital talk. Originally built for the music industry, this feature produces very recognizable voice-like sounds. Users could learn the trace patterns that produce an individual sound. The Kaossilator pad will be connected to a Rocktron Talk Box (See Figure 3). The talkbox uses a midrange horn driver to produce sound that is fed through the attached tube and into the user's mouth. Inside the users mouth the sound can be modified and fed into a microphone attached to the Talk Box tube. This allows the user to modulate speech without creating any sounds, simply manipulating sound produced by the Kaossilator/Talk box combination. From the microphone sound is output to a mixer where volume can be controlled, and then out to a speaker.

Figure 2. Kaoscillator Pad[4]

Advantages

This device gives the user maximal control of speech. It also allows them to

Figure 3. Talk Box[5]

personalize their sound by allowing them to modulate frequencies. This device will give users the ability to speak spontaneously, as it is constantly on, and provides instant output. This device only requires minimal movement on the part of the user, which makes it ideal for many people with neuromotor disabilities. There is also intellectual property potential with this device, as it is a novel approach to this communicative problem.

Disadvantages

The success of this device depends on the frequency output of the Kaossilator pad. Preliminary research and demonstrations have shown that many of the necessary sounds are available, but only further testing can validate the efficacy of the device. Another disadvantage of this device is the weight. The mid range horn driver in the talkbox which produces the sound waves is magnetically driven and therefore quite heavy. Without repackaging all of the individual parts, this device would be far too cumbersome to be practical. The final disadvantage of this design is that the talkbox is powered by a standard outlet plug, so the power cord would have to be spliced to interface with a 9V battery.

Design Matrix

Table 1: Design Matrix

Categories	**Weight of Category**	**Computer Touch Screen/ P.P Alphabet**	**Computer Touch Screen/ Phonetics**	**Kaossilator with Talk Box**
Ease of Use	25%	3	7	7
Speed	25%	4	4	10
Ease of Manufacture	20%	1	4	9
Portability	20%	4	4	6
Cost	10%	2	3	7
Total	**100%**	**2.95**	**4.85**	**7.95**

We rated our three designs on a scale of 1-10 in a design matrix (Table 1). Each category was given some weight depending on the client requirements as well as existing market designs. The main problem with most existing machines today is a time delay. Due to this the user cannot speak simultaneously but can only answer questions asked. This makes him/her feel disabled. Hence, while making our design matrix, the maximum weight was given to the categories ease of use and speed.

The palm pilot method received the lowest score because the user has to learn the symbolic representation of each letter in the alphabet, therefore making it difficult. For speed, we gave a score of 10 to the Kaossilator with talk box because there is no time delay. One gives an input and receives a simultaneous output. This is really important for our design as we want a device that will help people build conversations, not just reply to the questions being asked. This device earned a score of 9 in its ease of manufacture. This is because we already have the Kaossilator and talk box existing in the market. All we need to do is connect them together. Not much variability exists in the scores for portability because we cannot determine much without actually building these devices and testing them. The general cost range for these devices ranges from $800 - $2000. If we make our prototype design and package it in a plastic box, it will amount to around $1000, which is inexpensive as compared to other models.

We made calculations on the basis of the weight assigned to each category and the score awarded for each design. Table 1 clearly shows that the Kaossilator with Talk box is the clear winner with a final score of 7.95.

Future Work

Our future work includes building of our prototype, and Figure 4 represents our final design model. The user will provide inputs in two forms. His hand will be changing the frequencies on the Kaossilator, while his lips harmonize those frequencies. This frequency signal will travel into the talk box and into the mouth tube placed at the patient's mouth. The patient will harmonize the frequency by changing the shape of his lip, and then this signal enters a microphone via a mixer. This signal will enter the mid range driver, which is a transducer for the horn. This will then produce sound in the speaker located either inside or outside the talk box (See Figure 4). Once this is done, we will start the testing process. For our testing we have decided to build a database of the most common words. We will test for the sounds produced by each of these words. Once this is complete we will look for efficient ways to package the machine in order to make it portable. We have decided to do this by sealing both the devices in a plastic box and sealing

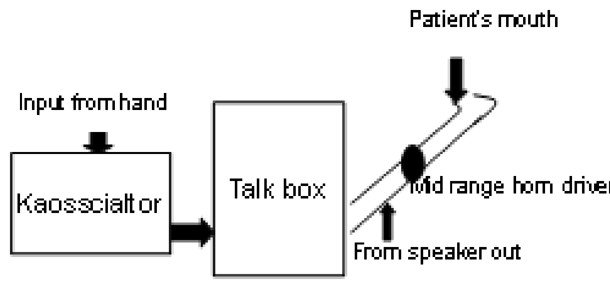

Figure 4. Setup of system

them off. While packaging, our aim will be to reduce the weight of our final design. We will remove the outside coating of these machines and work with the horn as it is the heaviest part of the talk box. This will all be completed in step processes. Hopefully, each of our steps will be successful, and we will be making modifications as required.

Works Cited

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