Tongue-Computer Interface Technology

Our project aims to improve the lives of people suffering from Spinal Cord Injury by enabling independent living. To do so, we envision a tongue interface capable of controlling technology and help these people perform their everyday activities in a simpler manner.

1. PROBLEM AND SOLUTION OVERVIEW

Life as a tetraplegic or paraplegic can be very tough. These conditions are the result of a spinal cord injury which drastically changes the lives of people who suffer it. While the standard of living heavily depends on the severity of the injury - some patients have some limited movement while others have none at all - the truth is that independent living is in a wide range of cases not possible. This is exactly the problem that we want to address. We envision an interface that stays inside the mouth, hidden either behind the teeth or in some not easily visible location. This interface interacts with the tongue and enables it to control a variety of technologies wirelessly. As an interface that stays within the mouth, we anticipate cleaning requirements; like contacts or retainers the interface may be removed or cleaned on a frequent basis.

2. CONTEXTUAL INQUIRY CUSTOMERS

One of the early challenges of our proposed project is the fact that finding people with spinal cord injury to interview is not easy. We explored multiple channels for interviews: longer term medical channels through professors with an interest in medical technology, and more immediate channels though the Christopher Reeves Foundation and its community.

We spoke with a representative of the Christopher Reeves Foundation who was very helpful in finding people to interview. She provided us with a list of different communities we could reach out to, including their own forum, a SCI patients email list, and other online sites. After contacting members of these communities we received mixed responses. One one hand some people seemed very eager to talk to us, while others expected some sort of compensation for their time and were not very receptive of the idea of interviewing at all.

So far we have completed 3 interviews and have a couple more aligned for this coming week. **Unfortunately, due to the constraints of location and availability, these interviews could not be done in person**. Instead they were conducted either by phone or video chat.

Interview #1 - Larry Willis

Larry Willis is a 62-year-old C5 quadriplegic since 1971, when he had a diving accident that changed his life forever. Although he is currently retired, he was able to get a job after his accident as a school teacher for 30 years. During his first years as a quadriplegic he used a push wheelchair to get around, until he obtained an electric wheelchair with a joystick. Mr. Willis is currently located in Kentucky. Because of this, his interview was carried out over the phone.

Interview #2 - Eddie Castle

Eddie Castle is a quadriplegic who has a heavy dependency on technology to get around. He uses a wrist fork in order to eat, uses trackball as an interface with technology, and voice recognition for typing on computers. He reads from the

internet everyday. He lives in an area with a lot of sand, and when going out his wheelchair can get stuck. Mr. Castle is currently located in New Mexico. Because of this, his interview was carried out over the phone.

Interview #3 - Richard Kratt

Ricard Kratt is a 65-year-old man who will never again be able to get out of bed. After his accident, he was able to move around in a wheelchair and used a Tongue Touch Keypad to get most of his everyday tasks done, almost independently. Unfortunately, the company behind the TTK went bankrupt and he could never get a replacement battery for it. Moreover, he had a gallbladder failure later on, which makes him stay in bed all the time. Due to location constraints, Mr. Kratt's interview was carried out using Skype.

3. CONTEXTUAL INQUIRY RESULTS

Common Underlying Themes

In all cases, the most difficult tasks were going to the bathroom and getting out of bed. Driving was also a difficult task for those that still had some movement of their arms/hands, though it required heavy adjustment in the vehicle. Controlling the technology surrounding them also proved to be a necessity, and though they all had different ways of achieving it, there is definitely room for improvement in the mechanisms for accessing technology for people with SCI. They all depend on someone else's help during their daily tasks.

Interview #1 results - Larry Willis

Our interview with Mr. Willis was very insightful. He explained that he feels very good about technology and is glad about all the advancements that have been made so far in wheelchairs, voice technology, accessible driving technology, brain waves, etc. He seemed to know about the different types of technology out there for spinal cord injury patients.

He explained that he was **addicted** to his arm pad, a very handy bluetooth technology pad that enables him to move around in his wheelchair. This was for him something truly life changing, since after his diving accident he was only able to move around in a push wheelchair during his first years as a quadriplegic.

He also mentioned that his fingers are paralyzed, and that when they are not cooperating he does a lot of things with his mouth, for example, opening soft drinks. He did say that he would not consider using a mouth controlled wheelchair because he is still capable of using his arms, but that he would definitely see it as something useful for others.

The **number one thing that bothers him** about technology is **expense**, putting as an example a $14,000 powered wheelchair. When asked about it more in depth, he explained that the battery was really big and that he would improve the quality of the control box on the chair (that is roughly the size of a coke can), which he actually had to replace because of faulty design. At the same time, he mentioned that servicing is a problem.

A very important factor to consider when developing new technology is **subtlety.**

Interview #2 results - Eddie Castle

Our interview with Mr. Castle was short, but he provided us with some valuable insight about things to consider when developing our project. He told us about how he used technology in his everyday tasks, and how he finds a little

complicated adapting to the use of a joystick. He also emphasized the need for him to control his air conditioner unit, his television, and opening doors easily from a distance. This need is somewhat met with a button centered remote.

He explained that when using voice recognition technology, **noise** can be annoying. Finally, in order to eat, he attaches a fork to his wrist, has a plate put on his lap, and moves his arm to his mouth. He mentioned that things can quickly get **messy**.

One the things we got out the most from this interview is the social situation in which many people with SCI find themselves in. This is something we will need to take into account in future communications, developing a sense of empathy.

Interview #3 results - Richard Kratt

Our interview with Mr. Kratt gave us a whole different perspective in quadriplegics thanks to it being conducted over Skype. We are very thankful for all the effort Mr. Kratt put into having the interview with us, since he is unable to get out of bed or move at all. We actually got to see him lying in bed, having an extensible microphone to talk to us, while drinking water from a tube next to his head to clear his throat.

Mr. Kratt told us about his life as a quadriplegic and the different technologies he used back when he was still able to get out of bed. He explained that he used a TTK (tongue touch keyboard) that made him be **independent**. He went into detail about how it worked, explaining that there was a button that allowed him to change different functionalities, such as TV control, wheelchair movement, door opening, turning lights on and off, etc. Other buttons allowed him to call different functions for each of the devices.

He also told us about how comfortable he was using the TTK, being able to stay in his mouth for 12 hours a day without a problem. Regarding the improvements he recommended, he mentioned the fact that the battery had to be replaced by the company that developed the product every few months, and this required sending it back to the manufacturer and wait. Eventually, the company went bankrupt and he was unable to continue using the TTK. It would have been considerably better if it was a rechargeable battery, specially considering the advancements that have been made lately in that field.

We also walked him through a few of the ideas we had for our project, and he liked most of them. He mentioned however that we needed to make sure that they were well designed and that they didn't make the user stand out too much (after we mentioned the motion tracking device for the tongue that required the user to stick it out).

4. ANALYSIS OF NEW AND EXISTING TASKS - TASKS OUR APPLICATION WILL SUPPORT

We describe a few of the different tasks that users will be able to perform with our application:

- **Turning lights on and off:** currently quadriplegics need to have their environment adapted to their needs. For example, when it comes to turning lights on and off, light switches position need to be lowered. Moreover, it can still be complicated for those with limited arm movement to use these switches, making a new of accessing them necessary. Our tongue interface aims to solve this by letting the user turn lights on and off remotely. To do so, he will simply need to tap a button with his tongue.

- **Getting in and out of bed:** as many of the people we interviewed mentioned, getting out of bed is a very complicated task in which they require external help in most cases. In the case of Larry for example, he squirms with the residual arm movement he has to get a board under him and use a ramp to get himself into the chair. In the case of full quadriplegics, they absolutely need someone to help them. While our application is not going to solve this problem, it is going to act as an interface with the technology that will. For example, instead of needing to shout for someone to come help the user get out of bed, he can just use the buttons in the tongue interface to indicate the need of help. In a more ideal case, the interface would be the controller of the robotic arms that could help left the user and place him in the electric wheelchair.

- **Using the bathroom:** as a quadriplegic, its is very hard to take a shower or go to the bathroom independently. Currently they need to use a catheter to be able to urinate and, if they have residual movement, they might be able to open it by themselves. Otherwise, the need help from someone else to do it for them. It is also worth noting that most quadriplegics won't notice when their bladder is full, making it highly likely that will sometimes urinate when they don't intend to. With our interface, we envision the possibility of being able to indicate when the bladder is full, and provide a mechanism for opening the catheter using the tongue.

- **Opening and closing doors:** opening and closing doors might seem like a very simple and natural thing for us to do, but for quadriplegics it can be a challenging task. They usually come up with different techniques and tricks to open and close doors, but we believe that through our tongue interface, they will be able to do so in a much more easier way. The ability to open and close doors with the push of a button would be another task that we aim to include in our project.

- **Using the computer:** currently tetraplegics use voice recognition in many cases to be able to control their computers. We would like to provide the ability to move the computer's mouse from our tongue interface.

5. SKETCHES

We have come up with 3 different sketches of what our final result could be based on, taking into account the insight provided by the patients we interviewed.

Sketch #1 - Joystick/Ball pad with buttons

The idea in this case is using a mouth mold that can be inserted and removed easily from the person's mouth, allowing him to use the joystick to select different options

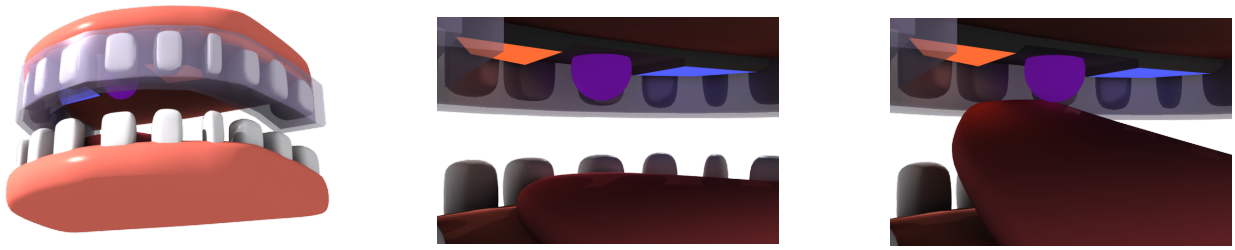

Figure 1 - Sketch for joystick with buttons

Sketch #2 - Touch pad with buttons

Our second idea is the use of a trackpad instead of a joystick, with different buttons depending on the location of the pleader the user decides to touch.

Figure 2 - Sketch for touch pad with buttons

Sketch #3 - EMG Interface

In this case we pivoted a little from the original tongue interface, in this case using EMG technology to sense the muscles near the throat based on tongue movement. This way, depending on the muscle that is moved, different actions can be performed. This allows the user to be able to eat while wearing the device, and allows for a simple, nice looking design.

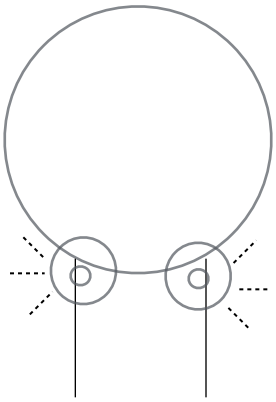

Figure 3 - Sketch for EMG Interface