Problem Statement/Research Question and Background

In the modern age, being able to interface efficiently with a computer is necessary in order to complete many everyday tasks. For individuals lacking manual dexterity, the task of using standard computer peripherals can prove to be nearly impossible. As technology becomes more integrated into different aspects of our society, being able to effectively use the internet is no longer just a matter of luxury or convenience but is instead closer to a basic right as a human being. Developing technology that can enable individuals to access the internet not only makes them more independent but can also aid in the advancement of our society.

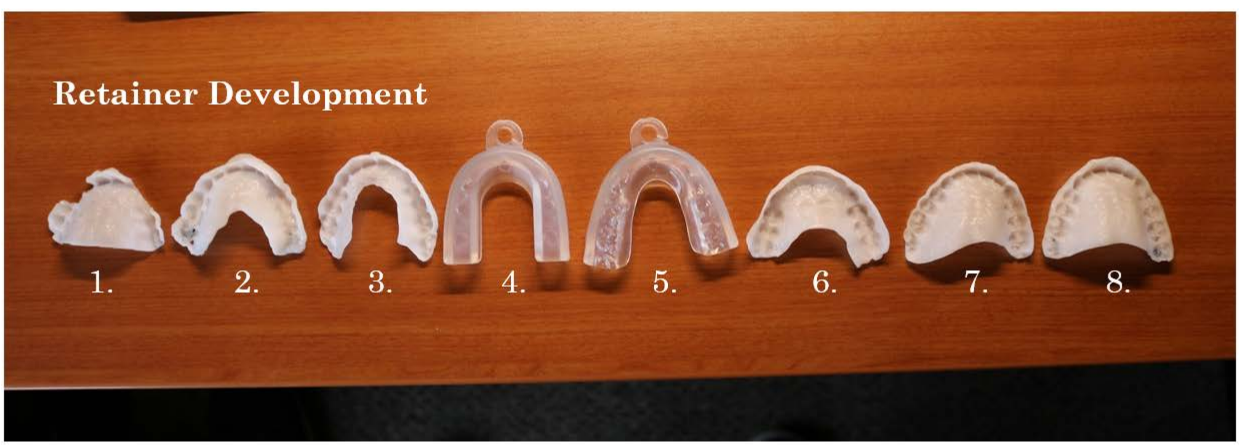
With a vast majority of modern jobs requiring workers to possess basic computer skills, there exists a market to produce assistive technology for individuals who are unable to effectively utilize conventional peripheral devices. Several current products fulfill this need, yet are often costly, restrictive, and undoubtedly have room for improvement. One of the oldest input mechanisms developed for individuals with quadriplegia, or ALS, is the "Sip-and-puff" device which was originally used to control a typewriter by allowing the user to sip or blow into a small tube.[1] First prototyped by Reg Maling in 1960, it was the beginning of a long line of similar devices, some of which are still in use today. Other, simpler solutions involve passive pointing devices that are held within the mouth or mounted to the head that can be used to type characters on a keyboard, commonly referred to as a "mouth stick" or a "head pointer". Although these tools are rudimentary, they remain to be some of the most popular assistive devices due to their simplicity and low price. However, even with practice these tools cannot offer the high levels of productivity that is required in many jobs. [2] Modern technologies such as gaze interaction and eye-tracking software can provide greater efficiency when it comes to accomplishing tasks on a PC, but as a consequence the price is dramatically increased. This presents an even greater issue when considering the lifetime costs of living with such a condition can easily exceed 1.35 million dollars. [3]

All of these existing tools grant their user greater capability, yet each device brings along with its various negative side effects. Examples of such effects for a toggle and sip-and-puff device might be restrictive equipment fixed around the users' head or mouth that is required for a fixed toggle to function; the fact that the user's posture has to conform to the device, causing fatigue in extended use; or the inability to talk while the device is operated. Alongside the costs, eye tracking equipment requires lots of calibration to be used effectively and avoiding subconscious eye movement requires constant focus from the user. We aim to provide a cheaper solution that allows for greater comfort and can unlock a wider range of uses for the user.

Methods/Approach/Solutions Considered

Our initial design was centered around an optical sensor sourced from a computer mouse that could be integrated into a retainer such that the user could control a cursor by swiping their tongue across a small sensing window. As prototyping began, a number of technical issues quickly became apparent. Firstly, the surface of the tongue needed to remain precisely at the focal length of the optical sensor, which was difficult to achieve within a small working area. Secondly, repeated swiping actions of the tongue was not only an inaccurate method of control, but also induced fatigue relatively quickly. Another method that was tested was the use of a small tracking ball that could be operated in a similar manner to a trackball mouse but with the tongue. In practice problems arose with the ball seizing from a buildup of saliva, and sanitization of the device was difficult.

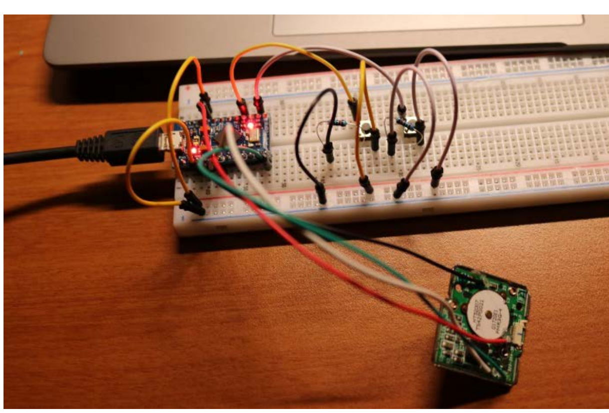
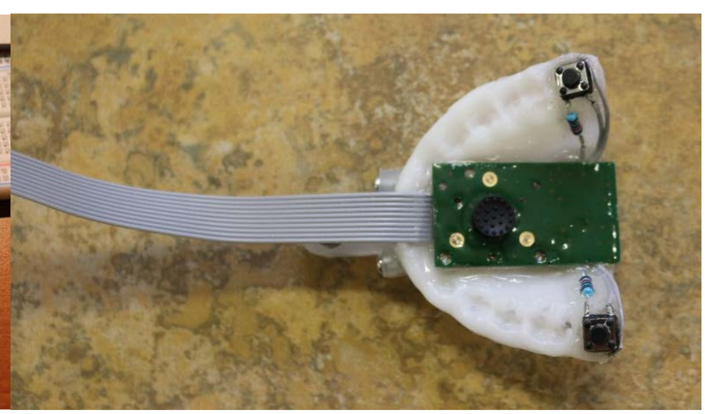
In terms of the retainer development, we tested several materials to determine which would provide a light friction fit without excessive work to mold it to the user. One of our earlier ideas was to use commercially available mouthguards intended for athletic use, though we learned that they were unable to provide a rigid enough substrate to mount electronic components to. Eventually we used polycaprolactone beads that could be softened in warm water and formed into a hard, perfect fitting retainer. The molding process involved making a “U” shaped sheet of plastic that was formed over the maxillary teeth, then quenched in cool water to set the form.



Description of Final Approach and Design

Our finalized design for the ATOM had several key components that were incorporated to solve existing problems in current related devices. Firstly, the computer mouse was designed to be controlled by the user's tongue. Being capable of sophisticated motor controls, the human tongue and masticatory muscles seemed to be the ideal controllers which the device could be centered around, especially if the intended user has limited control over their limbs. Through trial and error, we found that isometric strain gauges commonly found in a laptop keyboard pointing stick are ideal for this application. The absence of moving components allows for the device to be waterproof. When this is incorporated in the form of a small toggle, it can be pushed or pulled by the tip of the tongue to allow for fine cursor control. As for the mouse buttons, simple momentary switches were found to be sufficient.

These components are mounted to a plastic retainer that is molded over the user's teeth so that a light friction fit is all that is needed to keep it in place. The isometric toggle is fixed in the center of the retainer facing down towards the front of the tongue, and the button switches are fixed near the rear of the retainer pointing down towards the lower left and right 2nd molars, and by biting lightly on one side allows for the desired switch to be depressed. The docking station for the retainer is constructed from recycled high-density polyethylene and is designed to reach towards the user to prevent any excessive extension of the head and neck. A small neodymium magnet holds the mouthpiece in place when not in use and allows the user to easily remove the retainer hands-free by biting and pulling down lightly. The tether runs through a guide to prevent it from tangling but also allows for sufficient slack so the user can have freedom to move their head. Lateral pressure on the strain gauges within the toggle produces a change in resistance, which is read by a driver circuit and is sent to an Arduino Pro Micro via PS/2 communication protocol. The Arduino takes the PS/2 data and emulates a conventional USB mouse which can be plugged into a computer and used without setup.

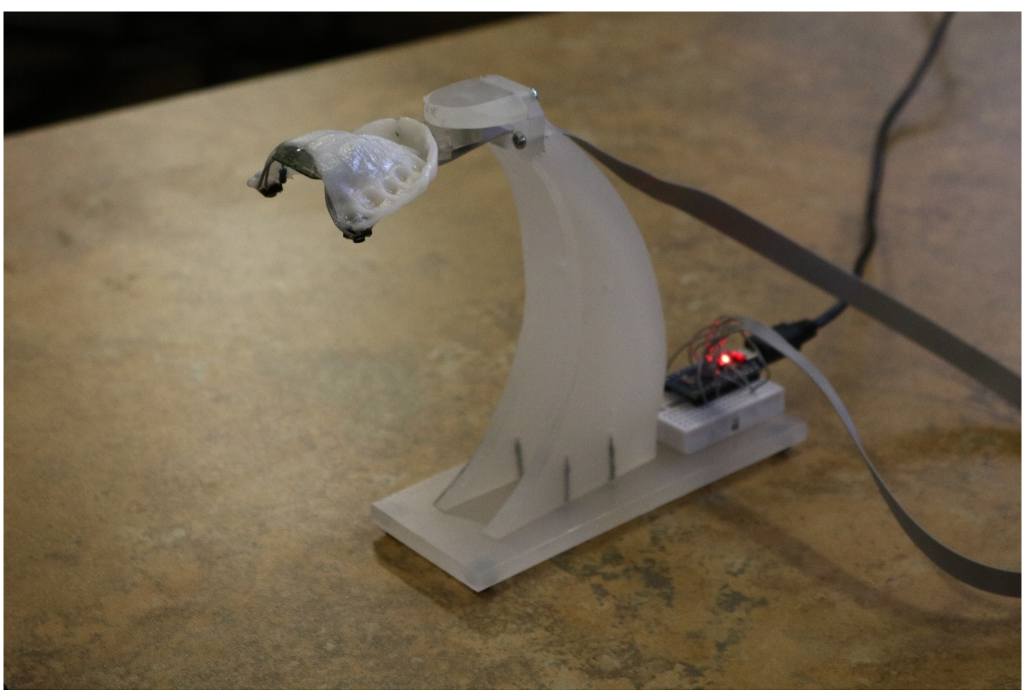



Outcome (Results of any outcomes testing and/or user feedback)

Before we began work on the ATOM, we understood the importance of user feedback in developing a viable assistive device, so efforts were made to work alongside our university's disability services department. After numerous office visits and emails exchanged, it was determined that there were not any individuals that were available to aid us in our efforts. In order to overcome this potential gap in development, we compiled all of the work we had completed thus far, along with a working prototype and presented at the UW-Stout 2018 STEMM Expo.

During this expo, we received feedback from many of the esteemed faculty members of UW-Stout, along with industry professionals in related fields, and even gained interest from the WiSys Technology Foundation. From this feedback we compiled the following project goals which were all incorporated into the final design.

- Ability for fine XY control of a cursor by use of tongue
- Ability for right and left mouse clicking by use of jaw muscles
- Ability to attach and detach device without use of hands
- Capability to easily sanitize device without damaging electronics
- Low cost of production
- Incorporate reusable and reused materials
- Improve upon existing devices (e.g. cost, functionality, ease of use, etc.)
- An aesthetic final design



Cost

One of the main goals for this project was to improve upon the affordability of existing devices, so cost was the determining factor in many of the decisions during development. Efforts were made to use components that were accessible or reused. The total cost for materials for the construction of our final prototype was $22.42. This value disregards potential costs associated with custom fitting the retainers, yet our group believes through additional development, a simplified process of forming the retainer could allow users to custom fit their device without the aid of a technician. This would eliminate a large portion of expected costs, and help the device reach a wider range of users.

Significance

According to a study conducted in 2017 by the Capital One Financial Corp., an estimated 82% of middle-skill jobs require workers to possess digital skills. [4] This figure is increasing year to year with no end in sight. With more than 250,000 people in the United States suffering from spinal cord injuries on any given year, there exists an ever-present need for improved assistive technology that can empower individuals with motor function disabilities to compete in the modern job market.[6] First year costs alone after injuries can easily exceed $500,000 so developing affordable assistive technology can have a significant impact on those affected, as well as their family and friends. Furthermore, individuals with this condition undergo major life changes, many of which can cause a significant impact on their social environment. Enabling those affected to efficiently and cheaply interface with computers can grant more opportunities to reconstruct and maintain social relationships to better fit their own needs. We believe that the ATOM can help individuals do precisely that by bridging a gap within the existing technologies by offering a high efficiency coupled with a low price.

References

[1] A journey through early augmentative communication and computer access. (2003, January). Retrieved February 24, 2019, from https://www.researchgate.net/figure/The-Patient-Operated-Selector-Mechanism-POSM-provided-multiple-ways-to-control-a_fig1_6196605

[2] Motor Disabilities-Assistive Technologies. (2012, October 12). Retrieved February 24, 2019, from https://webaim.org/articles/motor/assistive

[3] Spinal Cord Injury Facts & Statistics. (n.d.). Retrieved February 24, 2019, from https://www.sci-info-pages.com/facts.html

[4] Bradley, B., Restuccia, D., Rudnicki, C., & Bittle, S. (2017, September). The Digital Edge: Middle-Skill Workers and Careers. Retrieved February 24, 2019, from https://www.burning-glass.com/wp-content/uploads/Digital_Edge_report_2017_final.pdf