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**Multimodality Assistive Technology for Users with Dyslexia**

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ABSTRACT

To assist dyslexic users with reading and writing, several approaches have been explored to convey text to users using text-to-speech technology (TTS), and to transcribe what the user dictates using speech-to-text technology (STT). The currently available assistive technologies suffer from limitations around compatibility with digital-only formats, and the necessity for speaking out loud to use speech synthesis, and dictation out loud, thus creating social stigmas. If we think beyond singular modal solutions and expand the possibilities to include solutions that are multimodal and multisensory, it opens up the door for creative ways to help people with dyslexia. An alternate approach would provide assistance with reading all text, regardless of format, in a way that is inaudible anyone other than the user, and provide a user the ability to transcribe their thoughts without the need to speak out loud. This work explores a multimodal wearable device for assistance with reading and writing for users with dyslexia, using augmented reality for input, and neuromuscular signals picked up by electrodes and bone conduction for output. This device would recognize text from digital, printed or environmental sources, highlights the copy being read, and reads that text aloud to the user utilizing bone conduction output, so the sound would be audible only to the user. For transcription, electrodes in the device can pick up neuromuscular signals in the jaw and face that are triggered by internal verbalizations, requiring users to only say words “in their head.” This would all take place through a device that is barely discernible from the average pair of glasses, reducing stigma a dyslexic user may experience when needing to read or write in social situations.

BACKGROUND

The International Dyslexia Association defines dyslexia as “unexpected problems of neurobiological origin in accuracy and rate of oral reading of single real words, single pseudowords, or text or of written spelling” (Berninger, 2008). It is a language-based learning disability that refers to a cluster of symptoms that result in people having difficulties with language skills, particularly reading and writing. It is characterized by difficulties with word recognition and issues with decoding and spelling. Those with dyslexia often experience difficulties with both oral, written, and other language skills (International Dyslexia Association).
The International Dyslexia Association states that 15% to 20% of the population have a language based learning disability, and dyslexia is most common. In the United States, National Institute of Health research has shown that dyslexia affects 20%, or 1 in every 5 people. Some people may have more mild forms, while others may experience it more severely (Dyslexia Help, umich.edu). Females and males are effected equally by dyslexia, as are people from different ethnic and socio-economic backgrounds.

Dyslexia can be debilitating and can slow the overall progress of traditional education. Other consequences include problems with reading comprehension, resulting in limited reading experience, that can in turn impede vocabulary. (Lyon, 2003).

**READING**

There are many forms of dyslexia and not everyone diagnosed with it experiences is the same way. There is no single pattern of difficulty that person with dyslexia will experience as every case is unique and different, which is part of what makes dyslexia to complex. A person with dyslexia may experience any of the following when reading:

- Letters that are backwards or upside down
- Text appearing to jump around on a page
- Difficulty discerning between letters that are similar shape
- Letters appear jumbled or out of order;
- Letters and words may appear crowded together;
- Letters and words may appear backwards
- Inability to connect the letters to the sounds they make
- Unrecognizable words
- May not be able to make sense of sentences
- Skipped words
- Different words inserted

**WRITING**

Because dyslexia is a language-based learning disability, many who have it struggle with writing. A person with dyslexia may attempt to write with words they can spell rather than the words that they truly want to use and written tasks can become daunting and difficult for a person dyslexia. Studies have shown that students with dyslexia who do overcome reading problems will often then face significant problems in spelling and writing, and are unable to fine assistance for those writing problems after they have learned to read (Berninger, 2006).

**CURRENT LANDSCAPE**

Technological advances that have happened to date have produced tools and programs to help individuals with reading, spelling, and writing. Many of these assistive technologies have been successful
to a degree in helping people with dyslexia overcome some challenges and save time. The specific tools available range from voice recognition programs that let users dictate thoughts, and watch them appear on a screen, to tools that read written words from digital sources out loud to users. These available tools do have a positive impact for people with dyslexia, but they also have their limitations. When considering the landscape of the tools available and the greatest needs of dyslexic users, they can be broken down into two categories; reading (input) and writing (output) (Appendix A).

**TEXT-TO-SPEECH & SPEECH-TO-TEXT:** Within the input of language, or reading solutions, many currently available technologies rely on text-to-speech (TTS) technology. TTS is the artificial production of human speech. TTS technology reads digital text, such as the words on computers, smartphones and tablets, aloud to the user. There are a wide variety of apps and programs that use a speech synthesizer to provide a TTS service. Nearly all smart phones, tablets and computers come with some basic TTS services and tools. Many TTS tools can speak letters, words and sentences as a user types them. Some TTS programs can highlights the words as they are dictated. This helps focus attention, and helps with the understanding of the content. Research shows this multisensory reading experience combining seeing and hearing text when reading improves word recognition, increases focus, and helps with recognition of errors in writing (The Understood Team, Understood.org).

Some of the major limitations of TTS technologies is that the material is limited to digital content, and there are no capabilities with printed words, for example within books, or that a person may encounter in their everyday life such as signs, and menus. Another limitation is that a user must either be able to put headphones on, or need to leave a group classroom or work setting and move to a location where they can listen to the text out loud without disturbing others, which may be stigmatizing and isolating.

Speech-to-text (STT) allows users to use their voices as input to the computer to dictate for writing. The latest smartphones and tablets offer STT directly from the keyboard. There are some major limitations with the current STT solutions. In a classroom or work environment when writing may be an activity that happens in such a group setting, using STT technology can be very difficult for a user as they will often need to remove themselves from the group setting to be able to speak aloud and dictate to the technology. This can again be isolating and stigmatizing.

**GAPS WITH CURRENT TECHNOLOGIES**

Both the TTS and STT solutions, which are the most popular assistive technologies for people with dyslexia, can create isolating situations for the user. Rosemary Scott (2004) considers that “isolation
is one of the worst effects of being dyslexic, and is the principal cause of both adaptive and maladaptive coping strategies. Those who escape isolation and who are well integrated socially have fewer problems but some dyslexics spend their entire lives isolated from others.” People with dyslexia become isolated in many ways. According to Scott, people with dyslexia often report feeling isolated and different from other people starting at a very young age. "I would suggest that this sense of feeling different from everyone else, of being the eternal wallflower at the great human party, is the most common reason for the dyslexic client to seek counseling. It is certainly the one unifying source of pain” (Scott, 2004).

EPLORATION OF ENABLING TECHNOLOGIES

When considering the greatest needs - reading and writing, and what they represent - input of information and output of information, I began to explore two underutilized and under-considered ways to address those needs. Augmented reality for the input, and mind reading for the output.

AUGMENTED REALITY GLASSES: Google Glass was of the earliest pairs of Augmented Reality glasses widely available to consumers. They were smart glasses which had a head-mounted display, with the mission of producing a ubiquitous computer. They provided a limited subset of information, similar to what a user could expect on their smartphone. When released, Google Glass seemed like it could augment human capabilities with computing power in a useful and impactful way. However, Google Glass failed to gain commercial success. Most assess they failed because it wasn't clear to the customer what user need they solved or what the benefit to the user would be (Altman, 2015). Glass made people around the user feel uneasy because they felt the technology was intrusive and impacted people’s privacy. Google ceased production on Glass in 2015. According to the Guardian, “If you believe that technology has the potential to improve human lives, then your feelings were mixed. Clearly Glass was not going to work as a consumer product. But it still could be a powerful aid to human effort in some areas” (Naughton, 2017).
Following Google Glass was the development of Intel’s augmented reality smart glasses, named Vaunt. According to The Verge “The most important parts of Intel’s new Vaunt smart glasses are the pieces that were left out” (Dieter, 2018). They learned from Google’s mistakes and did not include a camera as to not make people uncomfortable with security concerns, and had no buttons, no gesture area to swipe, and no speaker, or microphone. They looked very much like traditional eyeglasses. When a user would wear them, they would see a stream of information projected onto their retina. The reports were that wearing them was indistinguishable from wearing regular eyeglasses.

In 2018, a company acquired the patents and tech behind Intel’s Vaunt AR glasses and released North glasses. These glasses are now emerge with designs that are even more indistinguishable from a regular pair of prescription eyeglasses, which would be key for utilization within a technology for which the goal was to not stigmatize the user.

**MIND READING INNOVATION**: There are a number of large tech companies that are investing sizable resources into mind reading projects. It has been reported that Facebook currently has a mind-reading project in the works. They are working on a way for users to send Facebook Messenger messages using only their thoughts. Microsoft was granted patents for interfaces that use brain activity. HTC’s Vive X accelerator program is building a mobile headset with emotion-detection technology that
uses brainwave monitoring. Nissan has revealed a concept car that has an EEG headset which could monitor brainwaves to speed up the reaction of a car (Elgan, 2018).

The most interesting and significant mind reading advancement for the purpose of this project is the Alter Ego developed at MIT. Researchers at MIT have developed a computer interface that can transcribe words that a user verbalizes internally (meaning speaking to themselves) but they do not need to speak aloud. It performs STT conversion without requiring out loud speech, and instead uses silent speech, or subvocalization. Although this is not truly mind reading, it is the first success of subvocalization as a computer interface, which delivers a similar effect. Electrodes in the device pick up neuromuscular signals in the jaw that are triggered by the internal verbalizations that happen when a user says words in their head. The device also includes bone-conduction headphones that send vibrations to the inner ear through bones in the face. Because they don’t obstruct the ear the interfering with the user’s auditory experience outside of the device (Kapur, 2018). What has been noted is that for many reasons, users are not likely to wear this in public. Similar to Google Glass, the device hasn’t been met with great understanding around the need it would fulfill or a path for mass adoption. If this technology could be leveraged to help people with dyslexia, that need may just be found for 20% of the population.

Alter Ego has been used to control a computer interface, and was demonstrated ordering a pizza.

PROPOSED SOLUTION

With the latest advancements of technology, one would like to imagine there would be a future in which dyslexic users are afforded success in situations and ways that were once unimaginable. When considering the gaps in the technologies that are most widely adopted in current landscape, the largest issues are the stigmatization and isolation that the users are caused, and the areas that users are able to find help based on the format of content. What if there were tools, leveraging augmented reality and mind reading that better enabled dyslexic readers to expand that cross-sensory experience used with reading and writing to new and unexpected ways?
I propose a single device that aids a user’s ability to read text not only in a digital format on a screen, but also from printed formats and signage, which transmit vibrations through the bones of the face to the inner ear silently, and also provided the ability write by dictating text by merely thinking of the words, removing the need to speak aloud – within a socially accepted and commonly used form factor of eyeglasses. The multimodal device would use augmented reality for reading language input, and mind-reading for written language output. The AR component will use eye-tracking and a camera to determine what a user is reading - digital or print format, will highlight the text and read it back to them silently through bone conduction. For language output, electrodes on the device would intercept neuromuscular signals sent by the brain to the face and transcribes them into text, when a user creates “silent speech.” The device will look almost indiscernible from a pair of eyeglasses - the element for the subvocalization being the only differentiator within the form factor. Making it silent will increase the range of situations where one could use it. Below are some sketches of the early concept.
SCENARIOS: Below are scenarios demonstrating the potential use of and benefit of the technology.

Reading from a printed book would be possible with AR, eye tracking, and cameras, whereas with existing TTS solutions, the user would be limited to digital formats.

Reading menus or food labels in public would be possible with AR, eye tracking, and cameras, whereas with existing TTS solutions, the user would be limited to digital formats.
Writing silently through thoughts in a classroom setting would be possible, whereas with existing assistive dictation technology, a user would have had to move to an isolated space.

Reading from paper in a work setting such as a group brainstorm, would be possible, with AR, eye tracking, cameras, and silent speech synthesis, whereas currently there is no solution for this scenario, and this situation could induce anxiety.
This user would be able to read books, thus doing research, and wrote a paper at the library, silently without disturbing others.

This student has dyslexia. He is at the library needs to write a paper for school. He can’t check out the books and doesn’t want to disturb those around him with transcribing out loud.

With the multimodal assistive device, the books can be read to him without disturbing others, and he’s able to think about the words he wants to write and they appear on his screen.

This user would be able to read and write in an open work environment, silently without disturbing others and without the need to physically isolate himself to do so.

The user has dyslexia and feels frustrated because he needs to write a memo for work, and doesn’t want to disturb those around him with transcribing out loud.

With the multimodal assistive device, he’s able to think about the words he wants to write and they appear on his screen, without disrupting those around him or needing isolation.
## APPENDIX A:

### Popular Reading Tools

<table>
<thead>
<tr>
<th>Tool Name</th>
<th>Use of TTS</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>iOS</td>
<td>✓</td>
<td>Built in TTS. iOS has two text-to-speech (TTS) options that are useful for kids with reading issues. Speak Selection lets your child select blocks of text to be read aloud. And Speak Screen reads entire pages of text. For both TTS options, your child can choose to have the words highlighted as they are spoken. This feature can help your child follow along with her eyes as she reads.</td>
</tr>
<tr>
<td>Android OS</td>
<td>✓</td>
<td>Built in TTS</td>
</tr>
<tr>
<td>Bookshare</td>
<td>✓</td>
<td>Largest online library of accessible books in the world. All of its books are digital and can be read aloud with text-to-speech (TTS). To qualify for Bookshare, your child must have a documented print disability.</td>
</tr>
<tr>
<td>NaturalReader</td>
<td>✓</td>
<td>Paste text or import documents into the tool, press play and then listen and read along as the text is read aloud.</td>
</tr>
<tr>
<td>Online OCR</td>
<td>✓</td>
<td>Converts text in image files into digital text files using optical character recognition (OCR). Upload a file, once converted, the files can be read aloud with TTS.</td>
</tr>
<tr>
<td>Rewordify</td>
<td>X</td>
<td>Simplifies text to make it easier to understand. Paste text or a web page address into the tool. Rewordify then replaces the difficult words in the text or web page with simpler words or definitions. User can choose their reading level and choose how the simplified text is displayed.</td>
</tr>
<tr>
<td>ClaroScan Pen</td>
<td></td>
<td>App with easy-to-use tool that gives voice to printed text</td>
</tr>
<tr>
<td>Speechify</td>
<td></td>
<td>App with solid text-to-speech converter may be pricey for some.</td>
</tr>
<tr>
<td>Google TalkBack</td>
<td></td>
<td>App with built-in assistive tool helps by reading on-screen text.</td>
</tr>
</tbody>
</table>

### Popular Writing Tools

<table>
<thead>
<tr>
<th>Tool Name</th>
<th>Use of STT</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>TalkTyper</td>
<td>✓</td>
<td>Simple online dictation tool. User speaks into computer mic, the tool types out what they’re saying. The dictated words and sentences are collected in a basic word processor and can be edited with a keyboard. The finished writing can then be printed, emailed, or copied and pasted elsewhere.</td>
</tr>
<tr>
<td>Dictation</td>
<td>✓</td>
<td>Online dictation tools only work in the Chrome web browser.</td>
</tr>
<tr>
<td>Speechnote</td>
<td>✓</td>
<td>Online dictation tools only work in the Chrome web browser.</td>
</tr>
<tr>
<td>EasyBib</td>
<td>✓</td>
<td>Creates citations for books, videos, websites and other sources. So when kids are writing research reports, creating a bibliography or listing their sources, EasyBib makes it easier. Kids just need to input basic information about the source, like a book title or a web address. Then EasyBib automatically fills in the details and provides a citation in the correct format. EasyBib also puts citations into alphabetical order. Kids can download, copy and paste, or print the completed list.</td>
</tr>
<tr>
<td>iOS</td>
<td>✓</td>
<td>There are several iOS tools that can help kids with writing. The first is the built-in Dictation (speech-to-text) feature. You can activate it by pressing the microphone button on the bottom-left of the onscreen keyboard. This feature lets kids write with their voices instead of typing. There’s also built-in word prediction called QuickType in the onscreen keyboard. As kids type, it suggests words to use in their writing.</td>
</tr>
<tr>
<td>Otter Voice</td>
<td>X</td>
<td>App that can record, transcribe, and share audio recordings with peers.</td>
</tr>
<tr>
<td>Notes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dragon Dictation</td>
<td></td>
<td>Voice recognition surprisingly good, but not perfect.</td>
</tr>
</tbody>
</table>
REFERENCES


