MAKING THE INACCESSIBLE ACCESSIBLE

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Intentional Experiences

Imagine you're 18 years old, you've grown up surrounded by all of the amazing technologies that have marked this generation: smartphones, tablets, computers, game consoles, etc. You have the entire world at your fingertips thanks to the internet and mobile internet connections.

What if you could no longer use your fingers, arms, legs, or even lungs without assistance? All of the above technologies require you to hold and touch something. An accident could take that ability away from you. You may think that this situation is a rarity with so few incidents that it shouldn't be a consideration in mobile design. Think again.

In the UK, 1,200 people on average every year suffer severe spinal cord injuries resulting in paralysis, with a current population of around 40,000 people. Of those 40,000, over 50% are between the ages of 16 and 30. Those people are likely to have had smartphones prior to their injury, and in fact their need for mobile and instant communication can be even more pressing after their injury.

The purpose of this article is to perform an analysis of the current state of mobile accessibility, and the implications for users with physical impairments and limits to their mobility. It is my intention to discover whether there is a "universal solution" which makes mobile devices accessible for users of all levels of mobility, and if not, why not?

Examining users who have had their mobility significantly decreased via accident or injury doesn't lessen the importance of those born with reduced mobility. It is merely the point of view being examined for the purposes of this white paper.

Standards for Accessibility

According to Johns Hopkins University, accessibility refers to a standard of inclusive website development based on the idea that information should be available to all people, regardless of physical or developmental abilities or impairments[(1)].

This whitepaper will describe the different standards that are currently in place for Mobile Accessibility, and then analyze how those standards relate to users with reduced mobility.

THE WORLD WIDE WEB CONSORTIUM (W3C)

As the main standards organization for the World Wide Web, the World Wide Web Consortium (W3C) seemed like the most logical place to start when doing an analysis of accessibility standards.

The first set of Web Accessibility guidelines that were released by the W3C, the Web Content Accessibility Guidelines (WCAG) were released in May 1999, with the second version being released in December 2008[2].

The WCAG are a set of standards for all web-based content, designed to make the content available to a wide range of people with disabilities. However, they were not targeted specifically at mobile devices, and as such, some of those standards are not applicable in the mobile domain.

In February 2015, the W3C released their first draft of a document that attempts to map the WCAG Standards to the Mobile Domain[3], and whilst it is not possible to create a direct correlation in some places they do reference the closest possible standard.

The document breaks the Standards for Mobile Accessibility down into the following 4 sub-groups, by theme:

Perceivable

- Small Screen Size
- Zoom/Magnification
- Contrast

Operable

- Keyboard Control for Touchscreen Devices
- Touch Target Size and Spacing
- Touchscreen Gestures
- Device Manipulation Gestures
- Button Placement

Understandable

- Changing Screen Orientation
- Consistent Layout
- Position important elements before the page scroll
- Grouping operable elements that perform the same action
- Clear indication that elements are actionable
- Instructions for custom touchscreen and device manipulation gestures

Robust

- Virtual keyboard type based on data entry required
- Easy methods for data entry
- Characteristic properties of the platform

Platform Standards

For the purpose of this article, we are only going to look at the two main mobile operating system platforms, Apple iOS and Google Android, and then compare the approaches that both platforms take to accessibility.

APPLE IOS

During a presentation at WWDC 2011, Chris Fleizach, one of the iOS accessibility team members stated that Apple believes that accessibility is:

"Using technology to create possibility"[4]

Apple includes features in all iOS devices which make the devices more accessible for users with all different types of impairments, whether it be visual, audio or physical. Some of these basic features include:

- Zoom: magnifying the entire device screen
- White on Black: inverting the colours on the display
- Mono Audio: combining the sound of the left and right channels into a mono signal on both sides
- Speak Auto-text: speaks the text corrections and suggestions iPhone makes while users type
- Voice Control: allow users to make phone calls and control playback using voice commands, Siri is an excellent example of this
- Guided Access: helps people with autism or other attention and sensory challenges stay focused on the task they are currently working on

Figure 1. Accessibility Options on iOS 9.0.1

There are two main features of the iOS accessibility package that I would like to discuss further, as they provide the greatest degree of control over the devices.

VoiceOver

At its bare bones, VoiceOver is Apple's version of a screen reader. A screen reader is a software application that enables people with severe visual impairments to use a computer, providing information about icons, menus, dialogue boxes, files and folders [5].

However, VoiceOver in iOS goes much further than simply describing the content of the screen to the user. It acts as a two-way communication feature, keeping the user constantly up-to-date and in control of where they are and what they're doing within the interface.

It essentially acts as the "middle-man" between the application's UI and the user's touch, giving the user both audible descriptions of elements and actions in the application. The outcome being that the chance of user error whilst operating the device is significantly reduced, while increasing their efficacy.

In order for the applications installed on an iOS device to be utilized with VoiceOver, there is a rigorous set of standards that a developer must adhere to in the creation of a new application. These are available online as part of the iOS Developer Library: developer.apple.com/library/ios/documentation/UserExperience/Conceptual/iPhoneAccessibility/Introduction/Introduction.html.

Speech recognition and control over a mobile device in this manner would seem like an ideal solution for those with motor control issues since there isn't a requirement for the user to interact with the device physically at all. The input is only limited by the number of words that the user can pronounce and that the device can recognize, so the user will have a large degree of freedom when it comes to interacting with the device.

Where this technology falls down is the same as with all speech recognition devices, they only function well in a quiet area. As soon as you add increasing levels of background noise, the recognition becomes more and more unreliable, to the point of rendering the technology useless in daily life situations.

AssistiveTouch

For those of us who have broken the Home button or the screen on our iPhones, Assistive Touch is a feature that you may recognize. It gives you access to all of the features of our devices, including the orientation, gestures, voice control and overall general control of applications through the use of an always-on menu.

However, what really makes AssistiveTouch stand out is the ability to connect external input controls to the iOS device via BlueTooth, which can be used to control the device without ever actually touching the screen.

We will discuss the alternatives of these external input devices later on, but as an example, Dynamic Controls created an application called iPortal that allows users who are restricted to wheelchairs and have limited physical mobility to utilize Apple iOS devices using the remote controls built into their wheelchairs. This, combined with the use of VoiceOver and AssistiveTouch, gives the user almost complete control over their iOS devices without the need for any external assistance.

Figure 2. AssistiveTouch Menu on an iPhone Homescreen(6)

Assistive Touch allows the use of Apple iOS for people of all ability levels as the input device can be anything that can connect to the device. This can be a users thumb all the way up to gesture tracking devices. It does mean that users who suffer from mobility problems require an input method which can be connected and can also be reliably used for a mobile device.

GOOGLE ANDROID

Google defines a product as accessible in the following way:

> "A product is accessible when all people regardless of ability can navigate it, understand it, and use it successfully. Products should aim to be accessible to the widest possible audience."[(7)]

As part of their Design Guidelines, Google includes a large section on accessibility. It begins with the developers being asked to consider if a user were to use a product in the following ways:

- Without sound
- Without colour
- With high-contrast mode enabled
- With the screen magnified
- With a screen reader
- With voice control only
- With a combination of the above

Android is at a disadvantage when it comes to controlling accessibility, as unlike Apple, apart from their own branded phones, they do not control the hardware on which the operating system is running. So the guidelines are focused more specifically on the layout and design of the OS and applications rather than the capabilities of the device itself. There is then a reliance on the hardware manufacturers to include accessibility features on top of the stock Android experience when releasing new mobile devices.

Google breaks their guidelines for accessibility down into three separate sections:

Navigation

- Touch targets at least 48px x 48px, with a minimum 8px spacing between design elements
- Mouse-free and gesture navigation, all design elements either keyboard or gesture accessible
- Navigation between screens, consistent focus behaviour after interaction with dropdowns/alerts/screens

Readability

- Product should remain usable when the font size increases
- High contrast ratio on critical text, with higher contrast on smaller text
- Colour shouldn't be the only method of conveying information, combine with shapes/patterns/textures/text
- Additional cues required to indicate relationships between elements, not just visual positioning
- Visual alternatives to sound (i.e. closed captioning and transcripts etc.)

Guidance and feedback

- Provide the most relevant information first to assistive technologies
- Use consistent terminology when naming elements in your product
- Alternative text for all images and icons
- Clear and easy to find contextual help so that the user can find how to use the features
- Give meaning to the titles of links

PLATFORM STANDARDS CONCLUSION

Having looked into the approaches to accessibility from the two main platforms in the mobile device market, we can see that there is a lot of effort being put into making these products more accessible for users with all levels of ability and mobility. Apple iOS devices conveniently come with features that make them automatically accessible to external controls, without having to actually touch the screen at all. Android, as an operating system, can't offer quite the same level of instant access, but the devices themselves should be able to.

However, what we can see is that there is still a lot of reliance on vocal communication with the devices, whether the device is talking to the user or the user is talking to the device to control it. This next section will break down what the possible forms of interaction are for users who are not physically able to touch the screen.

Accessibility for Those With Spinal Cord Injuries

Having looked into the accessibility approach taken by these two leading market brands, we now need to consider one of the major challenges of making mobile devices truly accessible — the device's need for tactical input. Picking up our phones, making a call, sending a message, playing a game or browsing the web has become so natural in our day to day lives, but what if you suddenly lose control of your arms and are no longer able to pick up your phone, let alone send a message?

Out of the population of those living with paralysis in the UK, 55% of those are between the ages of 16 and 30[8]. Now, with the number of mobile phone subscriptions in the UK being over 90 million[10], vastly exceeding its population of around 65 million[9], there is a very high likelihood that those 1,200 new paralysis victims each year own a mobile phone.

Following their injury, they can no longer use that phone in the manner in which they are accustomed. The new young generation are heavily dependent on mobile device communication, so there is a growing need for appropriate assistive technologies to allow those people to continue using their mobile devices.

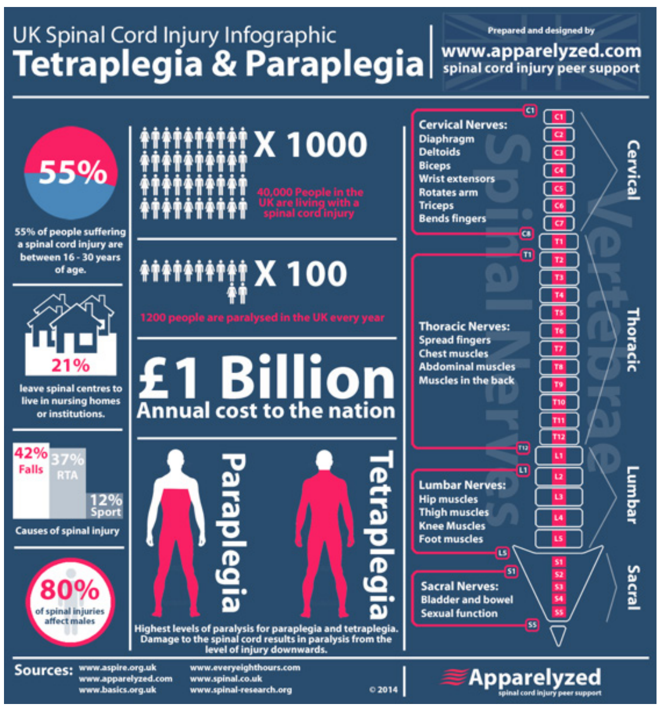

Figure 3. UK Spinal Cord Injury Infographic prepared by Apparelyzed[8]

Loss of Function

To give a better idea of the impact that a spinal cord injury can have, this section of the report will attempt to give a brief overview of what level of loss of control/paralysis can occur depending on where in the spinal cord the injury is received.

This can essentially be broken down vertebrae by vertebrae, as the nerve connections for the rest of the muscles in the body come in at different points along the spine.

The figure below gives a visual representation of which muscles are controlled by nerves in different areas of the spinal cord. For the purpose of this paper we are going to primarily focus on the outcome of injuries to the cervical and upper thoracic vertebrate. Those suffering from these injuries are referred to as Quadriplegics or Tetraplegics.

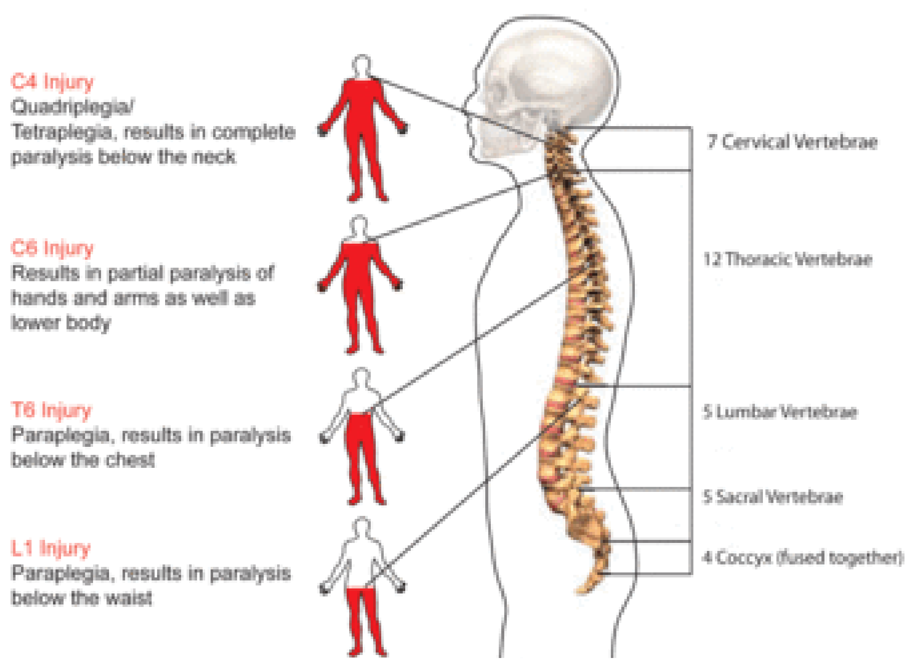

Figure 4. Visual Representation of Paralysis based on Injury Location[16]

The table below gives an idea of what level of muscle control may be available based on how low down the cervical/thoracic vertebrae an injury is received.

Injury Location	Potential Movement
C1-C4 (High Cervical Vertebrae)	› Paralysis in the arms, hands, trunk and legs › Lack of control over voluntary breathing, coughing and bowel/ bladder movements › Impaired speech
C5 (Low Cervical Vertebrae)	› Can raise arms and bend elbows › Total paralysis of wrists, hands, trunk and legs › Weakened breathing
C6 (Low Cervical Vertebrae)	› Paralysis in hands, trunk and legs › Able to bend wrists back › Able to speak and use diaphragm › Weakened breathing › Able to drive an adapted vehicle › No control over bowel/bladder
C7 (Low Cervical Vertebrae)	› Elbow and finger extension possible › Straighten arms and normal shoulder movement › Able to drive an adapted vehicle › No control over bowel/bladder
C8 (Low Cervical Vertebrae)	› Some hand movement › Able to grasp and release objects
T1-T5 (Thoracic Vertebrae)	› Normal arm and hand function › Trunk and legs affected › Use a manual wheelchair › Able to drive a modified car › Stand using a frame or braces

Figure 5. Table denoting potential movement based on Spinal Cord Injury[17]

POTENTIAL INPUT METHODS

No matter what level of physical disability, universally, we need to be able to communicate with the rest of the world and have the freedom to do so using what control is capable. This section of the article discusses some of the possible input methods, and their suitability for use with mobile devices.

As his thesis for his Master's degree at the University of Lisbon, Tiago Guerreiro analyzed some of the different types of input methods for mobile devices being used by Tetraplegic patients who have little to no mobility in any of their four limbs.

The full thesis, Myographic Mobile Accessibility for Tetraplegics, is available to download on ResearchGate at the following location: www.researchgate.net/publication/235005434

In the thesis, Guerreiro studied six different types of assistive technologies for Tetraplegics:

1. Touch Switches, Sticks and Pointers
2. Sound-Based Interfaces
3. Gaze and Motion Tracking Interfaces
4. Myographic Interfaces
5. Brain-Computer Interfaces
6. Breath-Based Interfaces

For the purposes of this whitepaper I will focus on the three input methods which I think are the most likely to offer the greatest degree of control to the largest number of users in the mobile domain.

1. TOUCH SWITCHES, STICKS AND POINTERS

Switches are regularly used computer interface devices, most often offering a Yes/No, On/Off interface, but the potential input set can be increased by increasing the number of switches. However, this does require that the user has the mobility required to be capable of operating multiple switches. Various different areas of the body can operate these switches, whether that is the hand, tongue, chin or forehead.

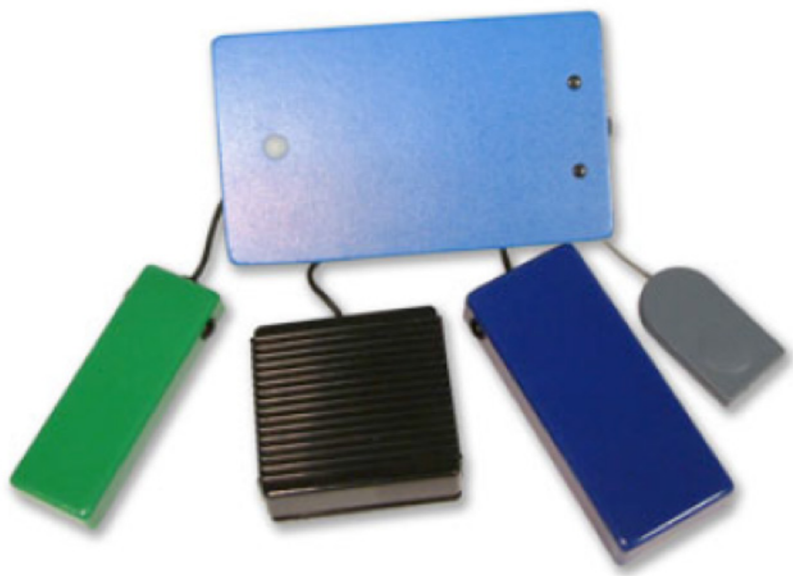

Figure 6. Trigger Input Switches[11]

With severe spinal cord injuries it is still possible for the patient to have some degree of upper arm control which would make it possible for them to lift their arms and point to some extent, even if they have no control over their fingers.

However, if users have no control over their limbs at all, which is possible with severe Tetraplegia, they may still have some control over the movements of their head and mouth/tongue.

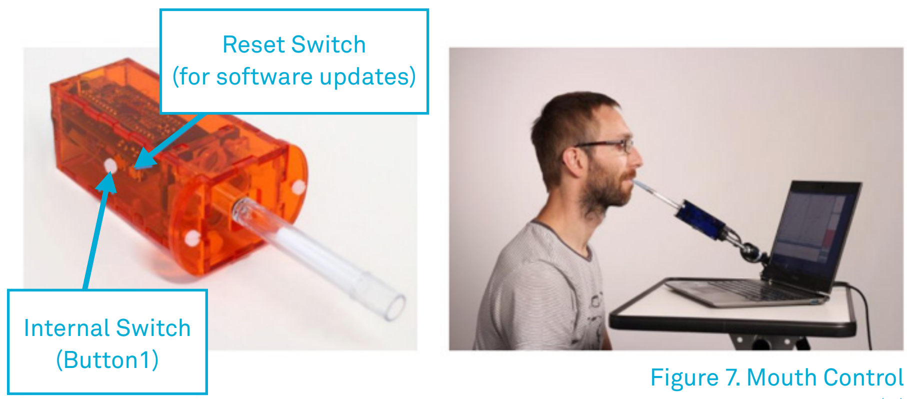

Figure 7. Mouth Control Switches[12]

The mouth and tongue are potentially good points for interaction methods as there is a lot of dexterity in the movement of the tongue which would allow for a larger input set than elsewhere.

Whilst the switches and pointers system may appear to be a logical solution due to its simplicity and close relation to the physical act of touching a screen, there is a downside. Unless the user has the capability to operate multiple switches, the input set can be quite small, making the process of operating a complex device, such as a smartphone, quite time consuming.

2. SOUND-BASED INTERFACES

Users who have received injuries in the very highest reaches of their spinal cord (C1-C3) might still retain some level of control of their speech and facial muscles, and as such, may be able to make sounds whether they are intelligible by other people or not.

Sound doesn't require the user to make any physical connection with the device, and so long as the user can communicate consistently, it should be able to be interpreted by a device as input commands.

Speech-Based

If a user is able to speak in a recognizable and consistent manner, this presents an efficient and dynamic method of interacting with a device. The input set of available commands is only limited by the users vocabulary and the identified words and phrases that the device can understand.

However, where speech-based systems fall down is that current technology does mostly require there to be a relatively low level of background noise for the recognition software to work properly. Try using Siri in a busy train station and you'll understand what I'm talking about.

What this then means is that whilst there is a large potential for input with speech recognition, it is limited in its application as a mobile device input method, as the user would have to remain in low noise level environments.

Also, there is the social acceptance issue, as there is still a level of stigma assigned to talking to a computer or mobile device. Until this is more commonly accepted, this method will potentially be off putting for users considering speech as an input method for their devices.

Sound-Based

As an alternative to the user uttering sounds, there have been studies performed on how internal sounds can be used as an interaction method. For example, a device can respond to the sound of a users tongue touching their teeth [13], or from the sound waves created by the movement of a users tongue in certain directions and at certain speeds [14].

The advantage of a system which involves the tongue and teeth is that there is a larger input set available than that which is possible using switches, as we are all able to individually touch our teeth with some degree of accuracy.

3. GAZE AND MOTION TRACKING INTERFACES

There are multiple examples of interfaces that have attempted to track motion from a user but for the purposes of this paper we will look at two that have the most potential for controlling a mobile device.

Optical Pointers

For users who have maintained a good degree of head control after their accident, there is the possibility for them to use an optical pointer worn on the head, which essentially acts as a mouse cursor. For desktop computers, this can then be combined with an external keyboard and receiver for the optical input (a miniature version of this could be created for a mobile device).

Figure 8. Optical Pointer[11]

Mouse clicks/finger taps could either be achieved using a time-delay holding the pointer over a specific item on the screen, or combining the optical pointer with some sort of gesture recognition.

So long as the user has a good level of head control, this could act as an effective method of input, as they will have the same level of accuracy as using a mouse on a desktop computer.

Eye-Tracking

Whilst quite a lot of work has been put into eye-tracking in a desktop environment, there is not a lot of research into using eye-tracking as an input mechanism for mobile devices.

First off, eye-tracking technology for desktop computers currently relies on the device and the user being relatively still to allow the algorithms involved to work effectively. Whereas mobile devices are very unlikely to remain as still as the people using them.

This may well not be the case for people with paralysis, as the mobile device will be mounted somewhere and the user is not likely to be moving a lot but it is a factor that will prevent future research until the eye-tracking algorithms improve.

Secondly, in a desktop environment where the device's screens are likely to be a lot larger, there is going to be a greater amount of eye movement required to view the information. Whereas with a mobile device, the amount of eye movement required is substantially less and therefore will be harder to track.

However, there are some examples where eye-tracking is being used in the mobile domain, primarily thought research being performed by students and researchers at Dartmouth College in the USA[15]. In 2010, they produced an application nicknamed the "EyePhone" which attempts to alleviate the issues with the eye-tracking algorithms by instead tracking the position of the eyes in relation to the position of the phone. This was marked as a promising step forward in eye-tracking technology.

Additionally, what has been restrictive about the use of eye-tracking technology, both in the desktop and mobile environments, has been the price. For anyone who has ever looked into running eye-tracking studies for the purpose of software analysis, you know how prohibitively expensive this can be.

As the cameras and software available within smartphones becomes more and more sophisticated, an app that allows the user to control their phone completely using eye-tracking would remove this barrier.

Conclusions and Final Thoughts

After having gone through this research, it would seem to me that the ideal method for a person suffering from severe paralysis would be using gaze/motion tracking. This method of input requires very little in the way of dexterity in the end user, and also allows for a fast and efficient method of interacting with their mobile devices. Also, it is likely to be the most socially acceptable, as it is silent and non invasive, which gives it a great advantage over the other technologies that require the user to speak or wear additional hardware.

There is one crucial problem when it comes to gaze/motion tracking for mobile devices. The technology doesn't yet exist to do it efficiently. There are multiple hurdles that need to be overcome before it can be effective. The screens are much smaller than desktop devices so eye movements will be a lot smaller compared to those required on a desktop system. The light levels are more likely to vary significantly, as the device will be used in various places indoors and outdoors. All of this makes the task of monitoring eye movement a lot harder.

We are starting to see the beginnings of it with the evolution of smart phones. For example, there are now smartphones being developed that will lock or unlock their screen based on whether the user is looking at it or not. But we are still a long way from users being able to control their devices simply by looking at it.

Until we start to see the availability of gaze/motion tracking technology for mobile devices become more mainstream, the best option (based on this research) would be the use of an optical pointer. Something small and discrete that could be attached to a pair of glasses to increase its social acceptability is likely to then increase the user's desire to use it.

Optical pointers don't require fancy technology to understand eye movements, just a reader attached to or built into the mobile device to interpret the pointer's movements.

The other solutions, discussed previously, all offer their pros and cons. Speech and sound recognition isn't really viable as an input method for mobile until the technology can work better in all environments, regardless of ambient noise levels. Whereas, pointers and switches are prohibitive as an input method for users who do not have any mobility in their limbs or torso.

The main takeaway is that there isn't a "Universal Remote" when it comes to mobile accessibility. Users have been accustomed to using mobile devices in thousands of different ways at all times of day and in all kinds of places. Developing a technology that can handle the variety of scenarios and tasks is something that engineers and designers are going to be struggling with for a good while to come.

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