VR Accessibility
Survey for People with Disabilities

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Overview and Major Themes

There's a phrase used in the disability rights movement, "Nothing about us, without us." This is true for the development and design of VR. This report presents the experiences and expertise of 79 people with disabilities around the world that use VR. They are creative, passionate, and innovative when using VR and other types of technology, providing specific recommendations on improving VR.

As savvy users and innovators, people with disabilities are experts on accessibility from their own interactions and the shared experiences from their communities. Here are a few major themes that emerged from the survey responses:

1. Accessibility shouldn't be an afterthought. It should be integrated and considered at the beginning every time

2. Provide maximum flexibility and customization in any software/hardware and have this as the standard default

3. Interrogate and expand normative standards regarding functions and abilities while diversifying representation in VR experiences

4. People with disabilities want to use and have access to VR. The survey participants believe in the potential of VR to enrich their lives

5. People with disabilities are not a monolith -- accessibility and inclusion is different for everyone. People with disabilities are also from diverse communities. Biases toward race, gender, age, impact people with disabilities too

6. Hire disabled people. Embed them at every level of VR development. Support STEM education and training for people with disabilities. A diverse workforce is an accessible workforce

Major Accessibility Issues

When asked about the major accessibility issues with VR, the participants highlighted the following areas:

- Overuse of motion tracking in VR experiences with few accessible options

- Lack of options and flexibility with other hardware (e.g, inability to use a gamepad with a VR headset)

- Hardware 'locked' by manufacturers

- Lack of customization of UIs, menus, controllers, headtracking, space sizes (e.g., too small for wheelchair users, no options for mono sound, no options for non-roomscale controls, controllers that don't allow re-mapping)

- Body motions based on non-disabled abilities and functions (e.g., gestures, standing, using 2-hands)

- Inability of VR to motion track 'non-standard' bodies

- Energy and stamina requirements based on non-disabled bodies that exclude people with fatigue and pain (e.g., holding hardware or an arm for long periods of time)

- Need to accommodate people with varying levels of reflexes, dexterity, or range of motion

- Wires and cords that can be difficult to manage

- Lack of visual, audio, or haptic cues

- Lack of flexibility to modulate VR environments to prevent cognitive or sensory overload

- Lack of redundancies

- Incompatibility with assistive technology and devices currently used by people with disabilities

- Motion sickness, vertigo

- Cost

This report will give a summary of the results and specific examples and recommendations by participants based on their experiences with VR.

Methods and Background

In consultation with the clients in December 2016, there was an agreement that an online survey would reach as many VR users as possible and elicit useful qualitative data. The researcher used Google Forms since it allows easy sharing and tracking of data.

The focus of the survey[1] was on people with disabilities who use VR. Questions covered the following topics:

- User experiences of VR

- Accessibility issues with VR

- Attitudes and ideas about the potential of VR for people with disabilities

- Assessment of and experiences with "Trials on Tatooine"

Eligibility criteria of the survey required participants to be an adult 18 years or older who identifies as a person with a disability (this is left open to their interpretation to be as inclusive as possible). Survey participants were not obligated or required to try "Trials on Tatooine" in order to participate.

The survey launched on January 3 with a deadline to participate on January 31, 2017. Social media posts by ILMxLAB and the Disability Visibility Project™ facilitated the recruitment of participants, gathering a snowball sample.

The researcher reached out to various VR advocates, professionals, and bloggers on Twitter to re-tweet the call for participants[2]. People with disabilities in gamer, tech, and accessibility communities were also targeted for recruitment. The researcher created and used the hashtag #VRaccess to encourage people with disabilities to share their selfies and experiences as another way to generate interest for the survey.

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[1] Original survey URL:
https://docs.google.com/forms/d/e/1FAIpQLScKkpxMwB5dHiE6k_73xpQCNL1hxCUR0xxnpTiDGLvl5U6jhQ/viewform
[2] Original call for participants URL: https://disabilityvisibilityproject.com/2017/01/03/vr/

Description of Survey Participants

Within the month of January 2017, 79 people participated in the online VR Accessibility Survey. Here is a breakdown of the survey sample's demographics.

Age

A majority of the participants are 25-44 years old (62%), people 18-24 years old (22%) made up a smaller percentage, and the smallest group was people 45 and older (15%).

Age Range	# of Participants
18-24	18
25-34	25
35-44	24
45-54	6
55-64	5
65 and older	1
	TOTAL: 79

Gender Identity

Over half of the participants are male (58%) with women a little over one-fourth of the sample (26%), and the few participants identifying as gender-fluid/non-binary/genderqueer (8%) and even fewer identifying as transgender female (3%).

Gender identity	# of Participants
Female	21
Gender-fluid / Non-Binary / Genderqueer	7
Male	46
Prefer not to say	2
Transgender Female	3
Transgender Male	0
	TOTAL: 79

Country of Origin

Two-thirds of the participants are from the United States (64%) with other countries (34%) in Europe, Australia, and North American represented.

Country of Origin	# of Participants
Albania	1
Australia	4
Austria	1
Canada	6
France	1
Germany	1
Holland	1
Italy	1
Scotland	1
Sweden	1
UK	9
US	51
Blank	1
	TOTAL: 79

Race / Ethnicity

Despite having an international sample of participants, the sample was overwhelmingly white (72%).[3]

Race	# of Participants
Afro-Caribbean	1
Asian	3
European/European American	2
Jewish	1
Latinx	3
Multiracial	3
Other	5
White	57
Blank	4
	TOTAL: 79

[3] Since race and ethnicity are defined differently by country, there were no standard categories for participants to choose from. During the analysis of the results, the researcher grouped several answers into single categories to provide a broader view of the sample. The parentheses indicate answers from respondents that were grouped into broader categories:

White (Caucasian, Anglo, Anglo Celtic)
Multiracial (Multi, Mixed race, Asian / British, mutt)
Afro-Caribbean
Asian
Blank
Latinx (Mexican American, Latina)
Jewish
European/European American
Other (human, English, non issue)

Disability

A majority of participants reported having only 1 disability (69%) with a little over one-fourth having two or more disabilities (29%).

# of Disabilities	# of Participants
1 disability	55
2-3 disabilities	14
4+ disabilities	9
Did not answer	1
	TOTAL: 79

Type of disability was open-ended in the survey because categories are culturally-based and can never fully include every type.

The participants described 98 different types of disabilities. The 7 most common disabilities were:

- Deaf (5 people)

- Arthritis (5 people)

- Scoliosis (4 people)

- Cerebral Palsy (4 people)

- Autism (4 people)

- Asthma (4 people)

- PTSD (3 people)

Frequency of VR Usage

A majority of the participants used VR at least once a day (30%) or once a week (27%). The remaining one-fourth of the participants reported using VR less than once per month (26%).

Frequency Using VR	# of Participants
Less than once per month	21
Once per day	24
Once per month	12
Once per week	22
	TOTAL: 79

Types of VR Products / Accessories Used

Participants were asked to select (all that applied to them) from a list of VR products and non-VR accessories / products that they used before. A little over three-fourths of all participants used the following hardware/features:

- 6-DOF VR Headsets (eg HTC VIVE, Oculus Rift, PlayStation VR): 79%

- Headphones: 77%

- Gamepads (non-VR, eg Xbox 360 controller): 75%

Roughly two-thirds to one-half of all participants used the following hardware/features:

- 3-DOF VR Headsets (eg Google Cardboard, Samsung Gear): 63%

- Motion sensor / Accelerometer games for smartphones or tablets: 62%

- VR Hand-held Controllers (eg HTC VIVE, Oculus Touch, Razer Hydra): 60%

- Kinect for Xbox: 45%

The hardware/features least utilized by survey participants were the following:

- VR Menus for Audio Control / Audio Description: 26%

- VR Menus for Subtitles, Text Size: 25%

- Eye-Tracking, Head-Tracking or Other Body-Motion Tracking Assistive Technology (eg Tobii): 16%

Usage of VR Technology	# of Participants
6-DOF VR Headsets (eg HTC VIVE, Oculus Rift, PlayStation VR)	63
Headphones	61
Gamepads (non-VR, eg Xbox 360 controller)	60
3-DOF VR Headsets (eg Google Cardboard, Samsung Gear)	50
Motion sensor / Accelerometer games for smartphones or tablets	49
VR Hand-held Controllers (eg HTC VIVE, Oculus Touch, Razer Hydra)	48
Kinect for Xbox	36
Hand-Tracking Technology (eg LeapMotion)	23
VR Menus for Audio Control / Audio Description	21
VR Menus for Subtitles, Text Size	20
Eye-Tracking, Head-Tracking or Other Body-Motion Tracking Assistive Technology (eg Tobii)	13

Preferred Method of Testing Accessibility of a VR Product

The survey asked participants to select (all that applied) their preferred methods of testing a VR product and the majority of participants (64%) chose demonstrations (either downloadable or in-store).

A little over one-half (59%) of the participants preferred Internet forums or social media and a little over one-third (37%) of participants preferred product reviews.

For the 8 individuals that selected 'Other,' they reported the following preferred methods:

- Buy and return the product

- Ask a friend

- Ask someone with a similar disability

- Ask someone in VR development

Method	# of Participants
Web Forums/Social Media	47
Product Reviews	30
Demos (eg Downloadable Demos, In-store Kiosk)	51
Product Storefront Specifications (eg Steam, Oculus.com, Google Play)	20
Other	8

Types of VR-Enabled Software Used

The following are names of VR software that participants cited as their favorites (in alphabetical order):

Altspace

Android Studio

Apollo 11

Assetto Corsa

Audio shield

Batman Arkham VR

Bullet Train Demo

Cardboard

Crystal Rift

Curio

DCS Huey

Discord vr chat room

DOOM3

Dreadhalls

Earth VR

Elite Dangerous

Euro Truck Simulator

Felix and Paul Studios

Gear for Samsung

Google Earth VR

Hatsune Miku

Holopoint

Hot Dogs, Horseshoes and Hand Grenades (H3VR)

Invasion

iOMoon

Job Simulator

Lucky's Tail

New Retro Arcade

New York Times VR

Oculus Guardian

Oculus Medium

Pixel Gear

quil

RBDOOM3

RecRoom and SportsBarVR

Rez Infinite

Soundboxing

Space Pirate Trainer

Summer Lesson

Superhot VR

TheBlu

TheWaveVR - (Closed Beta)

Thumper

Tiltbrush

Trials on Tatooine

UDK

Unity

Virtual Desktop

Vive Chaperone

VRChat

vTime

Whirligig

Wing lands

Young Conker

Zen pinball

Barriers to Use of VR

The survey asked people with disabilities to select a number of activities (all that applied to them) that they have difficulty with when using VR. The top five activities most participants had difficulty with are the following:

- Balancing (while standing): 43%

- Crouching: 43%

- Standing: 41%

- Locomotion (moving your entire body forwards, backwards, sideways, etc): 37%

- Raising / Extending / Moving Arms: 29%

The four activity difficulties that participants reported least are the following:

- Hearing: 16%

- Ability to wear a headset: 15%

- Tactile Touch / Sensations: 10%

- Rotating Head (up, down, sideways, etc): 7%

Type of activity difficulty	# of Participants
Balancing (while standing)	34
Crouching	34
Standing	33
Locomotion (moving your entire body forwards, backwards, sideways, etc)	30
Raising / Extending / Moving Arms	23
Rotating / Bending Upper Body (forwards, backwards, sideways, etc)	21
Holding/Gripping Objects	21
Sensitivity to Light	21
Seeing	20
Moving Fingers	18
Thinking, Remembering, or Concentrating	17
Sensitivity to Flashing Lights or Visual Patterns	17
Moving Hands	16
Hearing	13
Ability to wear a headset	12
Tactile Touch/Sensations	8
Rotating Head (up, down, sideways, etc)	6

User Experiences

We present direct quotes[4] from participants with disabilities talking about their experiences while engaging with VR.

Standing/Balancing (while standing)

"I'm unable to stand to use VR. I need to be seated with the backrest at just the right incline, and with the right padding / firmness. I've only ever found 2 seats that don't increase my pain, and currently the one that works best is my wheelchair, which obviously doesn't swivel like an office chair, so as well as being unable to stand, I'm unable to physically rotate, which is fairly frustrating and impacts the majority of the VR experiences I try."

"My CP affects my right body half. I have trouble standing and it makes it difficult to move my arms in a certain direction."

"I cannot stand and play vr. My back pain and lack of balance mean i miss out on a lot of vr experiences. But I develop for vr myself."

"Games that use standing motions to move the character such as step to the side or lean far to one side are not suitable for me to play. The games I play require me to be stationary at all times as I won't be able to correct my balance if I start to fall or stumble."

"Room-scale VR experience makers don't always design for seated users; even seated experiences in VR don't take reach differences into account."

"I've found that my balance issues and weak legs make it hard for me to be responsive in a timely way to VR which has lessened my enjoyment of the experience."

Locomotion (moving your entire body forwards, backwards, sideways)

"Since I'm unable to use my legs and hands, instead playing games with my feet, any VR experience that requires more than a standard controller / mouse & keyboard for input is inaccessible to me."

"Limited movement also makes some games hard. Fixed teleport points means I can't freely move around and get closer to an in-game object or enemy..."

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[4] Quotes are taken directly from the survey. They have not been edited for grammar or formatting. Trivial spelling errors have been corrected. Ellipses are used when combining relevant comments.

"I use a power wheelchair for mobility, so VR solutions that require whole-body movement aren't really usable (particularly since I need to use one hand to control the chair). A VR rig that hooks up to my chair's controller and moves it as required, however, would be great, potentially creating a better VR experience than able-bodied people can achieve."

"It's difficult to use a wired headset and a power chair. If you move around, you may catch a wire on your chair. Also, bumping into items seems to me to be a bigger issue when you use a chair than if you are walking. Finally, turning around in a small circle (a pirouette) is harder to achieve than if you are standing or sitting on a bar stool."

"The vive is hard to use because I have to hold the controllers and push my wheelchair around at the same time. Hard to turn. Easy to bump into walls even with chaperone because my radius is wider."

"Mobility impairments make use of Vive very difficult/Gear VR is much easier."

Raising / Extending / Moving Arms

"I also can't extend my arm / reach out very much, as doing so puts stress on my spine, which causes a great deal of pain. I still enjoy VR, but the experiences have to be slower paced and more observational."

Rotating / Bending Upper Body (forwards, backwards, sideways, etc)

"Given many aspects of VR require heavy use of motion, even to just look around, it's very taxing and often very painful to use. Motion controls do not help either -- though some games using VR opt for a standard controller you still have that issue of straining a head/neck/spine with the weight of most units."

Sensitivity to Light

"VR allows me to see far clearer than I do with my natural eyesight, giving me far more detail in both objects in the distance as well as holding objects up close. I also experience depth perception in VR, where normally I have diplopia (Double Vision). Dark areas in VR are also not an issue, where normally I cannot see in the dark at all. One area I do have difficulty with is if the screen suddenly goes very bright, I can be dazzled and lose focus, another being small text, or text that is tracked in the centre of my view."

Seeing

"Right now, the VR interface is highly inaccessible with assistive technology and any information conveyed through audio or other non-visual means is not enough to be able to allow a blind person to fully use VR."

"I use Windows Magnifier to read some mirrored VR content on my computer screen when I can't read text or see something in game. This helps, but also has its problems. I need to be physically facing my monitor to read it, so if text or an item is off to another direction, this technique doesn't work. Also, it's really hard to hold the headset just above my eyes, use the mouse, and try looking in the exact area to magnify something. It's clunky at best, but sometimes necessary."

Depth perception

"I'm blind in my right eye, so I don't have any depth perception in virtual reality...Certain VR software are more accessible than others because their user interface cues make depth perception easier. The most helpful thing is a haptic cue when you touch something in VR (this is standard in most titles, yes, but pronounced in the ones that don't have it)."

Peripheral vision

"I have peripheral vision only in my good eye so in VR I cannot see straight through the eye holes. It would be better for me if there were no gap between the eyes so that I could use my peripheral vision in VR without missing anything."

Colors

"Issues distinguishing colors from one another ex. blue from purple, green, red, and brown. This can be a problem when trying to determine the classification of an item that uses a color coded system or when a UI uses similar colors to show the state of something ex. to show whether something is active or not active."

Menu Size

"One area I struggle with is when I open a menu and it opens too far away for me to see clearly. To resolve this I will walk to one corner of my play area then open the menu, and walk closer to it using the additional distance to make sure it's large enough to read."

"I will often walk to the edge of the tracking space and open a menu so I can walk closer to it than if I was in the center of the space. That way I can get a lot closer to them than the designers intended. This is especially useful for the Steam menu where a lot of the icons and text is too

small for me to see comfortably."

Screens / Text Size

"Each new generation of HMDs includes screens that have increased resolution and pixel density, this gives developers the ability to use smaller fonts, which can cause usability issues when menus are locked at a fixed distance from the user's eyes. This is especially true for AR headset start menus and mobile HMDs that currently lack 6DOF tracking. There are also additional problems with AR headsets, for example … a minimum focal distance that is a few feet from your eyes, so if you try to lean into a hologram to get a closer look, it disappears. Another issue is that the field of view for most AR headsets is so small, that in order to provide users with a decent amount of information on screen, it is necessary to use smaller fonts."

"It's mainly a problem with small UI elements and text. This can most often be fixed by getting closer to them in the virtual space but this of course only works if the UI is not stuck at a fixed position relative to the player avatar which some games rely on."

"I am able to use many VR experiences, but do have trouble in a few key areas. Reading text is the biggest problem. Text is often too far away, too small, or a combination of both. Head tracking for text (menus, dialog boxes, options, character upgrade screens, etc.), along with a re-center view button, is very helpful because I can move back, re-center my view, and then lean in toward the text or item to see it more clearly. Most text items like menus, tutorials, options screens don't have this."

Thinking, Remembering, or Concentrating

"Being in a fully surrounded environment doesn't allow for breaks. Seizures can be induced by cognitive load and stress. The nature of current headsets and the load that they can produce, can sometimes produce the initial stages of my seizures, although it's difficult to discern the exact reason for this."

"I sometimes become overwhelmed by all the sensory input VR creates, the 'false space' the lights, sounds, etc. The visuals seems to blur out of focus frequently for me. Sudden movements startle me, even in non-horror experiences."

Sensitivity to Flashing Lights or Visual Patterns

"I'm afraid to try and risk a migraine. I already have to avoid various media with strobe lights, flashing effects and too much blurring. My Learning Disability also affects my coordination, response time and makes me 'clumsy' so any action that takes synchronized movement is out!"

"I am sensitive to loud noises and flashing lights/images. I am not interested in VR because I won't be able to predict or control these features. I also cannot use shared headsets/gear because of the chance I could be contaminated by gluten or allergy triggers."

Moving Fingers or Hands

"The controller buttons … are hard to press especially the grip buttons because my hand are weak."

"My right arm, right hand, and the fingers on said hand are very weak compared to my left side, so I can't really use a second controller often times, due to the unique shape of the controllers."

"The controls are almost impossible if it involves both hands. I have limited dexterity with my left hand so using joysticks or analog sticks is near impossible."

"I use the steam controller as an accessibility device because the ability to use a gyro sensor and touchpad helps me make fine movements I wouldn't be able to do with a mouse due to my poor motor skills."

Hearing

"I can't hear cues/commentary in many VR apps. The headset sometimes interferes with my hearing aids due to being close in proximity, and my hearing aids often give off feedback similar to microphone feedback."

"I use hearing aids: pop-down headphones on headsets cause my hearing aids to shriek when they rub on them. I would prefer earbuds as those would provide adequate volume as a substitute. I also need captions and SDH, which many games/films do not provide."

"In social interaction games, I can tell that people are speaking to me through the headset mic but I can't talk back to them...and it can hinder the experience. All I ask is that if social interaction is included, to at least include keyboard support so we have SOME manner of communication included...On top of that, I'd like to suggest that if keyboard input is supported, then maybe do some tracking to allow us "outline" where the keyboard is sitting in front of us, so we know where roughly to reach for it...Now that I own...controllers, in some social games like Altspace VR, I now am able to gesture with my fingers to extend my index finger and point to my ears and then do a "no" motion with my hands, to gesture that I cannot hear to people. Most people instantly understood that...Thankfully, most games have already implemented floating over-head subtitles for single player stories and similar games, but in most "social" VR games with real beings, there

is no such option. For instance, ... only allows messaging if you add someone as a friend and then private-message them. There's no such thing as floating chat text. Which needs to exist!"

Ability to wear a headset/Holding/Gripping Objects

"My cerebral palsy makes it impossible for me to take my device out of the case and put in in the virtual reality goggles. Therefore, I can't participate in VR without assistance. I would like to be able to set it up by myself, because I often have episodes of anxiety, depression, and pain while I am alone. I use VR to treat those things."

"I'm incapable of fully experiencing VR due to a lack of left hand, which prevents me from gripping both controls."

"Difficulty to put on and take off vr headsets and fitting vr headsets due to the use of glasses."

Spatial Awareness

"I have difficulties with fine motor skills and judging the distance of my body to other things close to it. I have to be really careful not to bump into things when using a motion controller. It can also be slightly difficult to really gently place a HMD or VR motion controller on a hard surface."

Adaptations / Hacks by People with Disabilities

The survey asked an open-ended question about other adaptive hardware/software/accessories that participants use with VR. Participants mentioned the following:

- A tumble mat (to prevent falls)

- Steering wheel for drive games

- Voicemeeter (software to force mono sound)

- Mono headphones

- Prescription lenses for HMD

- Customized foot pedals

- DragonDictate (voice recognition software)

- Videophone and AVA applications

- Arcade joysticks

- MMO mouse (ie high button-count mice)

- Input Remapping software

Here are some quotes from participants about how they make VR accessible to them with their adaptations. Some of these are low-tech while others utilize software, 3-D printing, and other accessories to facilitate access:

Software

"When possible, I'll try to force gamepad input for games that do not traditionally support it. I use remapping software such as Joy2Key or attempt to modify the game code (if open source) to support traditional controls."

Low-Tech Adaptations

"I hang the cord up high so I don't trip on it since I can lose track of it quickly"

"I will often walk to the edge of the tracking space and open a menu so I can walk closer to it than if I was in the center of the space."

"If allowed, I can increase the sensitivity of the head tracking to make me not have to tilt my head forward/back to painful distances. games rarely allow this, preferring a 1:1 mapping. TrackIR does this very well, but VR headsets don't."

"One area I struggle with is when I open a menu and it opens too far away for me to see clearly. To resolve this I will walk to one corner of my play area then open the menu, and walk closer to it using the additional distance to make sure it's large enough to read."

Hardware/Accessories

"I use the Stinky Board and a MMO mouse to augment my gaming"

"I sometimes use a gamepad which allows me to remap the buttons. That way games more accessible for me."

"I use prescription inserts (lenses from zenni optical & a 3D printed lens holder) as glasses can be a pain."

"I'm trying to find a way to adapt the use of a mouthstick for hands, but need a light option."

Recommendations to VR Designers/Developers

Alternatives to Motion Controls

"There's so many motion controllers coming out for VR and an emphasis on using your body to control the game. I've seen traditional games with VR components lock out traditional control methods when a VR headset is being used. This isn't right! I should always be able to use a gamepad coupled with a VR headset to play games, especially games that'd normally support a VR headset. There are very few games that I would say absolutely require motion controls to be fun. I was excluded from playing some Wii games due to motion controls, but VR seems to be excluding me from many games because of them."

Inclusion of Disabled People's Perspectives at the Outset

"I want VR experiences to be conscious of designing for people with disabilities in mind as well as including them in the stories that are being designed."

"Ultimately, get people with disabilities to help create and test your experiences before you ship them! Surveys are helpful to the cause, but until you get people with disabilities creating and testing VR experiences, there's only so much data can do to help."

Settings / Menus

"Setting options within a VR experience is also difficult, if not impossible sometimes. This is largely due to text distance and size. I'd love to see a VR standard that allowed options to be adjusted prior to launching a VR app. this way I could see to configure everything on my monitor and not struggle to set things up once in VR. This would also be helpful for other disabilities like motor impairments as well. Having a settings screen outside an app is especially important for headsets like the Gear VR, where VR content isn't mirrored to another display. If you can't see it in your phone, you can't see it.

Using Windows Magnifier, as described above, is a hack I often use. I'd LOVE to see … platforms integrate some level of accessibility and standards for their platforms. Ideally I'd love to have some support for text to speech or head tracking zoom…Crystal Rift is one game where head tracking is supported on the main menu, and it helps immensely."

Hardware Flexibility

"Games and hardware being locked to certain manufacturers. What makes solving problems with virtual reality accessibility difficult is the fact that there's multiple kinds of headsets in production,

each with their own games and hardware. Most suggestions I make for accessibility might work fine for one kind of headset but be impossible on another. I'm still fighting for consoles to allow for full button remapping on standard game controllers, but the fight for all the input types for VR hardware to be accessible is a different beast. I appreciate software creators making their software accessible but the hardware also has to be accessible."

"Include the option to have key mapping a fundamental feature included in the VR game, it will make it so much easier for the disabled gamer to choose the option of which button is suitable for them to play that particular game, for example Eve Valkyrie, unable to play the game because the buttons are default with very little option to change them, whereas Drive Club VR it can be played with either right or left arm, still won't affect how the game is played, because the option is there to change the buttons in the options link - more gamers are needed to go the latter route then the standard default option."

UI

"The only issues is that there has not been any flexibility in the UI end of things so that people with low vision can accommodate it to their needs. So there are 3 ways that this could be achieved. 1. Have the engine makers such as Unity or Unreal to build this flexibility into their UI 2. Have the developers use an API to add this functionality into their games. 3. Use something called a driver injector such as VorpX or Vireio Perception. Their purpose is to add VR functionality to non-VR games. For DX11 games these driver injectors and manipulate the geometry of the games so it might be possible to target the UI layer of a VR application and change its size and / or distance from the user. There might even be a possibility to change the color scheme of of the UI with some other applications. But this could be enough of a use case to develop an app that does both of the engine makers don't add it in themselves."

"VR should allow for interaction with the environment. Many apps and games provide a simplistic experience without taking into account how the user will be incorporated into the world. Interaction is a key part of the experience. The user should no longer be passive but be able to engage with the world. As disabled users, there is scope to experience different worlds using a multitude of different interaction techniques."

Headsets

"...it would be great if the visual field of the headset was continuous all the way across the visual field to where there is no gap between the eyes. Something like Cyclops from X-Men's headset is."

"VR headsets requiring the user to be in a certain position to play. There are some VR games I could play with motion controls, but because they require the user to be standing, I can't play at all... I seldom use VR because I don't want to be tethered into my computer unable to escape without help...For me to use VR by myself often, headsets would have to be wireless and also have a way for me to see through the headset to navigate the real world. I also would like to see VR headsets handle exceptions better and not hang on bright static images when they freeze. An on-board way to reboot the headset automatically would stop me from worrying about this issue."

"Including eye tracking technology in a next generation headset would let those with physical disabilities enjoy controlling VR, but it would also allow for FOVeated Rendering. Increasing the customizability of VR games would help those with light and sound sensitivity, but they would let those without sensitivities fine tune a game to sound exactly the way they'd like. Even from a completely profit focused perspective, developing technologies to make VR more accessible is a good idea."

Text/Captions

"Instead of closed captions, make create use of open captions a new reality. It will enhance literacy for everyone, deaf and hearing."

"When it comes to text, please try to take into consideration where it's located, how large the text is, and if it can be moved around or positioned for the player to easily read. Tactile objects like clipboards, whiteboards, posters that can be positioned, moved are great because we're able to find the right place to stand and look at it. If a text box floats right in front of us wherever we look, forcing us to cross our eyes, and can't move closer, we won't be able to read it. (I'm looking at you, Survios)"

"Please offer in game subtitles, and take a cue from games like assassin's creed, where I get options in how much subtitles to see. (Cutscenes only, important dialogue only, or all dialogue including banter) I'd also like blu Ray style options to change font, color, and font size."

Locomotion / Movements

"It's understandable that not every VR experience is going to be suited for those of use with disabilities, but there are simple options like adding the ability to rotate and reach objects without having to walk towards them would be a big step in making most of the experiences accessible."

"Please consider VR projects that focus less on human body movement and instead on the mind, something playable with a typical modern game joypad (alongside of motion controls as an

option). Sony might have comfort-level VR design guidelines for PSVR to recommend looking into."

Orientation/Spatial Awareness

"With someone who has balance issues I find the complete lack of feedback about my real world space to be an issue, this has been largely resolved in recent version of the Rift with the play space grid. I would still like to access a small camera to see the real world while in VR."

"I would like for the phone or device to be automatically centred. I have difficulties with lining up the phone with the marker line on the VR goggles."

Game Mechanics

"Inaccessibility in virtual reality is partially due to the fact that many VR games are forcing game mechanics on their users. Like Trials of Tatooine, for example. Why should I be forced to play games in Tatooine? I'd like the option to be able to put on my headset and just experience the planet without the requirement of playing minigames. I don't believe all virtual reality experiences need to provide challenge to be fun or immersive. One trapping we have in accessibility in games is that games need to have some sort of challenge to remain fun. Games with multiplayer or leaderboard components also need to be fair for all players so you need to keep balance in mind. Virtual reality experiences shouldn't feel the need to adhere to this requirement. Also, if Virtual Reality dropped the need for traditional game mechanics, I think they could be a lot more immersive than they are now."

Haptics

"Touch support is a must with all titles as it can remove vr sickness and provides more immersion and can make you feel more part of the experience locomotion options need to be left up to the user not having multiple options limits the way the disabled can interact with your game."

Audio/Sound Options

"Windows and Oculus need mono sound…"

"This doesn't apply to the VR Star Wars games much because Skywalker Sound does incredible work, but Virtual Reality experiences need better audio than they currently have…if Virtual Reality is to provide the most immersive experiences out there, the audio has to have at least as much

care as the graphics. Many VR experiences I see on Steam have terrible audio that isn't fit for the medium. Great audio could also help people hard of seeing be included."

Accommodate People with Glasses

"Must cater for glasses."

Accommodate People who Sit

"Creation of a chair that can rotate without wrapping my vive wire around me would open up vr for me"

"Remember that we exist -- we share this space with able bodied people and as it stands it's very difficult for us to use this new experience without a lot of pain or even at all."

"Make height adjustments available and movements such as bending and crouching optional. Right now I have to take off my headset and put it to the ground to bend down and watch a screen to see what I'm doing."

"Games are VERY hostile to people with any kind of motor disability. However I am not asking for games to be tailored for me or people like me. Get the market as wide as you can as fast as you can and someone will make products I can use without damaging the potential of VR. Having said that, I would not be opposed to a disabled setting that allowed people to play from a more limited field of view and sitting."

"An easy way to adjust game camera height would be good so someone who lacks mobility could still have a full experience within their range of motion.

For instance, I'm 5'11 standing. When in my wheelchair, understandably shorter. It would be nice to be able to adjust camera height, so scale stays appropriate, and maybe even range of motion calibration."

Options that Don't Require 2 Hands or Legs: Hand/Foot Controllers

"A fully featured professionally produced variant would make it better, inside and outside of VR. A further evolved foot-pedal input method could do more than just button pushed-not pushed inputs, enabling those with only one functional hand to take part in software that only require a single hand tracking unit."

"I would like to see more options and accessibility for one-handed control schemes where it would be considered doable and/or appropriate. Just be careful not to butcher your vision to accommodate us."

Testing/Usability

"Test your experiences with people of all sizes/ages/ability levels at the prototype phase. Don't wait until you're in the QA phase to do your usability testing."

"...test with players whose disabilities may be non-obvious or invisible and follow up with those players (I often feel the worst pain days after a physical experience such as a motion controlled game)."

Intersectionality / Diversity in VR Representation

"Also as a trans person, *different secondary sexual characteristics is surprisingly important*, giving me a body that looks like a man's is instant trip to physical nausea these days in VR... this was most exemplified in Elite Dangerous where in alpha you only had a man's body. The gender option just gave small breasts in the edge of field of view, but that removed a lot of on-edgeness the game was constantly subconsciously giving me before."

"...pay attention to intersection. there are trans disabled folk, disabled people of color, non-binary disabled folk, and they are all gonna have different wants and needs. a black adhd trans woman isn't going to have the same needs as a genderqueer lebanese autistic person and all of those facets make up those reasons"

Feedback Specific to Trials on Tatooine

One-fourth of all survey participants reported trying "Trials on Tatooine" with the remaining 75% reporting either "No" or left the question unanswered. We present direct quotes from participants sharing their experience with Trials on Tatooine.

Menus

"I had no issues with Trials on Tatooine from a low vision perspective. I could walk right up to the menu buttons to easily read them and the scrolling text in the opening scene was easy to read."

"Menu at the beginning of the experience were big enough that I could tell what each button was."

"While the experience is short, I'd appreciate the ability to jump to different sections of the game. As stated previously, I might be able to play the lightsaber section without modification, but I would need some way to jump to that section... As an alternative... auto completion of sections if I look at a certain part of the screen or nod my head. An option for the entire game to play itself would be appreciated, though if there's sections I can do myself, I'd like to play those for myself."

Buttons

"The different buttons Han asks you to press were not very distinct, not could I get to them in my play area. The lack of teleportation also would mean those with mobility issues may struggle."

"buttons on millennium falcon more accessible"

"...it would be so much cooler if the lightsaber was ignited by a button press instead of automatically."

Controller Options

"Include the ability to rotate using the joystick/thumbpad on the Vive Wands / Touch Controllers, allow an 'extend' option on the controllers so that menu buttons and interactive elements can be interacted with, without having to physically move towards them."

"It's possible that the handle on the millennium falcon might be too far up for wheelchair users (I haven't played the game in a while so I can't remember how high up it is). Also, I'd recommend an option that enables "auto-aim" and corrects the trajectory of the reflected blaster bolts so it is easier to hit stormtroopers. I don't feel like this should be the default mode, but rather an option for visually (or otherwise) impaired players. It is very frustrating to be wielding Luke's lightsaber and fighting stormtroopers to the Star Wars battle music, only to be unable to accurately deflect a single shot."

"Ability to turn without turning body"

"Voice commands. This would need some work to get implemented but an alternative to fixing the falcon could be I tell R2D2 to do it. If I can interact with characters through my voice in order to beat the game, I could get by with only using the headset to be immersed in the world."

Difficulty from seated position

"...having it be a one controller experience is good in that handedness is not an issue, nor is having only one usable hand. However, from a seated perspective reaching up to press the button to fix the Millennium Falcon was difficult for me."

Sound / Visuals

"I could see everything so I'm happy."

"Add the option for subtitles for hearing impaired."

"The sound balance is pretty good, I could differentiate between the voices, music and background noises. Having the voice/script complete before we get to play with the light sabre (and that wonderful noise) is a good idea."

"Trials on Tatooine is reasonably accessible to me because it's largely not interactive, but the part where you deflect blaster bolts is almost impossible for me because I have extreme difficulty telling how close they are to me. Frankly, I don't believe there is a way to make this section more accessible to stereoblind people without compromising the way it accurately recreates the Star Wars Universe."

"For interactive portions of the experience provide some visual and or auditory feedback so that they user know that they have successfully performed an interaction. Such as pulling down the inverter lifter on the Millennium Falcon and later pressing the buttons to on the device. Perhaps having a highlighted outline on the tip of the controller and surrounding each button to show that they are intractable with the controller as well as the panel to pull down the inverter."

"Portal 2 esque markers denoting what you're meant to press if it takes you some time to locate it, rather than Han getting mad at you."

Audio / Visual Settings

"As always I am keen to have separate controls for music, sfx and voice. I always turn voice up, music lower, and sfx in the middle."

Room / Scale

"My only issue isn't accessibility it was the room scale size. I have 2m x 1.5m and was just about out of reach for the section where you need to push the buttons."

"Take multiple head heights into consideration when designing space, make it easier to reflect blaster bolts with lightsaber."

"Have the mechanical unit you have to repair be closer to where you start the experience. I kept triggering the chaperone when I reached out for it and a person with difficulty of walking might have trouble getting to it."

Movement / Action / Gameplay

"On-rails movement. I love games like Rez Infinite or more traditionally, Time Crisis, because movement is automatic, letting me focus on the action. A good example in this instance would be the arcade game, Star Wars Trilogy, created by SEGA in the late 90s. In that game, there were sequences where you just had to use the joystick to move and deflect incoming fire with your lightsaber. With just that one joystick, you could actually fly with the X-Wing, shoot with blasters, use a lightsaber, pilot a speeder bike, and many other things. This kind of on-rails movement would work very well for VR, specifically the ToT experience. Thinking about it, the original Star Wars arcade game and Trilogy would work well for VR!"

"Infinite health during action scenes. I'm not sure if you can lose at ToT as I never got past repairing the ship, however if you can lose, an option to not fall in battle would help others completely experience the game. This is such a simple feature to program I always recommend it for any game."

Difficulties with Hand / Body Movements

"Some body & hand movement required but otherwise visually stunning experience"

"Because Trials of Tatooine requires motion controllers and movement to play, I cannot progress through the game because I cannot use my hands or walk. I'm unable to even repair the millennium falcon at the beginning of the game so that's where my adventure ended. Watching a friend play, the only part that might be accessible to me is the lightsaber sequence as I could remain stationary and use my feet to deflect lasers with the motion controller."

"It's pretty accessible can be partially used sitting but would help to have different locomotion options"

"Allow for traditional input methods. I could easily experience ToT if the game had gamepad / m&k support. The lightsaber could be mapped to the right stick/mouse like most Star Wars games I've beaten on PC such as the Jedi Knight series."

Potential of VR and What People with Disabilities Want

The survey participants expressed optimism and excitement about the potential of VR despite accessibility and design issues. As VR becomes more popular and affordable, participants would like to see a parallel increase in accessible features in VR.

People with disabilities, for a variety of physical, economic, and cultural reasons, have been isolated from one another and with non-disabled people. Only within the last 50 years (in the

United States) have people with disabilities been fully integrated into society and out of institutions. Social participation requires access to the same goods and services to everyone else. Technology needs to address these needs and be responsive to the lived experiences of people with disabilities.

Survey participants mentioned the following when asked about the potential of VR on their lives and others:

- Experience new worlds and environments that one may not be able to in the 'real world' due to disability

- Sense of complete immersion and inclusion, losing yourself

- Entertainment, recreation, and leisure opportunities

- Educational and professional opportunities, training and simulations

- Communicate with different people in different ways

- Forming new relationships in online communities

- Giving people extra-abilities beyond their minds and bodies

- Giving people with disabilities an equal playing field with non-disabled people

- Reduce social isolation, anxiety, PTSD, pain

- Increase empathy for other people

Many of these sentiments are no different than non-disabled VR users. Below are a few quotes from participants that provide greater detail on their thoughts about VR.

Enriches Personal Life and Increases Access to Information

"I've always been into the idea of VR, and now that it's finally here, I love it. I see many great possibilities for VR both in gaming, and other areas. Just being more immersed into an environment is really cool, and then adding touch controllers adds even more. Shooting games are fun, but I'm just as interested in non-shooting games and experiences. VR horror could be amazing because you can't look away from the screen without taking off the headset. I'm also interested in non-gaming apps. The idea of Google Earth seems amazing, and a good accessibility tool, especially when they add the ability to search for an address. This would make virtual trip planning easier because I could fly through my route in VR and see landmarks I'm looking for ahead of time. I've done this with Google Street View already. I'm also interested in

educational content, like virtual field trips, tours, etc. Concerts and events with multiple seat points would also be great. I could actually see the stage or the action happening closer up."

"I think VR for people with disabilities has tremendous potential in almost all areas of life. I think it has incredible educational and recreational potential and I also think it has the ability to provide life simulation activities that could encourage more personal development and growth in a fun way. I think VR experiences of all kinds should be available to people with disabilities and that there are specific things like driving simulators and life simulation experiences that could be of real benefit to the disability community."

Employment and Professional Benefits

"I'm currently developing VR experiences for working at home so it excites me to know that VR can help mobility impaired people get to work."

"It could be used for training and teaching about accessibility, to anyone from teachers to doctors, architects to first responders and elderly care helpers. What does the world or this room you designed look if you're blind or deafblind? Follow this group discussion with 90db hearing loss. here, your task is to visit a doctor, your senses are configured to autistic and you don't speak etc"

Unhindered by Inaccessible Environments or Bodies

"For me, it's being transported to another world, one where I can see sights I normally never would, take part in experiences I can't in real life, and be a part of social spaces my visual impairment would restrict me in. The aspect of independence and freedom has the most impact for me."

"Personally I'm unable to do many things because of my disability. I'm stuck at home unable to go out, unable to enjoy seeing new places and experiencing new things. I'm hoping VR will help with that, and allow me to explore new places. To help relieve some of the cabin fever I experience as a result of my disability."

"The ability to experience things (actions, places, events) that I cannot - either due to my disability or due to other accessibility issues (distance, time, money.)"

"That it's a virtual space where I could be able to make everything big enough to be able to see clearly."

"I am excited about gaming without hands!"

"It has great potential to bring us Deaf people on same leverage as hearing - some are not there with captions"

"I'm excited by the illusion of traveling free of the confinement of my body. This would hold true of anyone, with and without a disability. But VR opens up the possibility of being able to walk in the woods and feel surrounded by trees and the sounds of the forest."

"...I am interested in is how Social VR and multiplayer games might help put more people on a level playing with no discrimination."

"I can do things in VR, like drive a car that I can no longer safely do in real life. And, like healthy people, I can do and see things in VR that I could never do in real life."

Develop Empathy and Understanding of Others

"I think it can truly create magical experiences that could help encourage and help people to understand empathy on a more deeper level."

Exploration, Fun, Adventure, Total Immersion

"I really want collaborative games, where I could have adventures with friends that we couldn't experience together in reality: for me, that could be as simple as going to a theatre—but since we can, I want to try exploring another galaxy."

"I love the idea of new flight sims, and I would love to play a Jedi Knight game in VR. In general, I'm excited about what VR means for disabled people who are less mobile than myself. People can get a strong sense of experiences that they might never be able to experience."

"Something unexpected that really brings that sense of awe and wonder. Large scale environments and being high up on a ledge affect me in the biggest way."

"To feel free of constraint and able to participate fully in the experience."

"Virtual Reality if done correctly, can take people with disabilities to worlds they've never imagined they could ever see. I remember my first experience with VR being on a roller coaster I could never ride in real life due to my disability. VR enables me to pilot an X-Wing, feel fear like never before in horror games, and so many other things. I want to always be included in VR experiences by them not forcing me to use motion to operate them, as I believe it is the future of entertainment."

"The thought of almost everyone being able to live out their fantasies in a virtual world regardless of real-life ability is a humbling and powerful one. If Trials on Tatooine makes me almost tear up

with joy during the lightsaber sequence, I can only imagine how much happiness it brings to people less fortunate than I am."

New Ways of Sensing and Communicating in the World

"I'm interested in the ways that VR might provide extra normal abilities -- being able to see sound. Speech to text with collaborators. Similarly interested in the ways that VR can invoke new mental experiences both for disabled and abled."

"It can allow me to experience acrobatic or superhuman feats my own body is incapable of; more simply, full immersion can be a small escape from pain"

"Convenient and accessible communication between deaf American Sign Language users and hearing people who do not know American sign language"

Conclusion

People with disabilities are assets as consultants and as colleagues/collaborators with the VR industry. This survey is just a small sample of the deep knowledge that people with disabilities have about their bodies, their environments, and the everyday interactions that inform their understanding of the world.

The survey participants want to be seen and heard — they also want to see systemic changes in production and conception of VR so that everyone can benefit from accessible and inclusive technology.

It would serve VR developers and companies well if they tapped into this potential market and workforce by investing and reaching out to this population that makes up 1 billion in the world[5].

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[5] http://www.worldbank.org/en/topic/disability/overview

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