Extended Reality (XR) Hardware: One Size Doesn't Fit All, Yet.

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Introduction

- **Extended reality (XR)** is an umbrella term to describe virtual reality (VR), augmented reality (AR), and mixed reality (MR) (Stanney, 2021).

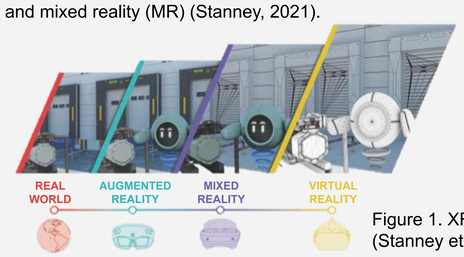

Figure 1. XR Continuum (Stanney et al., 2021)

- **Accessible design** - designs for the capabilities of those who are living with disabilities
- **Inclusive design** - Accessible design + designs for users of different anthropometrics, cultures, and preferences
- If an employer is deploying an XR device to their workforce, they need to consider the employees who will be using the devices.
  - Are they a homogeneous group?
  - How much do individual differences related to face shape, hair style and texture, eyeglasses, different body size and shape impact the user experience with the device?
  - What about cognitive, physical disabilities, or limited mobility due to a temporary injury?

Method

- Assessed XR devices: three head-mounted displays (HMDs) (the Microsoft HoloLens 2, the Magic Leap 1, and the Meta Quest Pro), a mobile phone, and smart glasses (Epson Moverio)
- Referred to standards and best practices for evaluation (Meta, 2019; O'Connor, 2021; Magic Leap, 2018; Apple, n.d.-a; Apple, n.d.-b)
- Created "strengths" and "needs improvement" lists for each device according to accessibility and inclusivity standards through case studies

Case Study 1: HMD

Three HMDs were examined; Meta Quest Pro (MQP), the HoloLens 2 (HL2), and the Magic Leap 1(ML).

- Strengths:
  - ML and HL 2 can be used with either hand, accommodating users with limited mobility
  - Voice control options are available for all devices
  - ML, HL2, and MQP can be adjusted in length to accommodate different head shapes
  - MQP has customizable IPD, while ML and HL 2 uses eye-tracking to calibration
  - HL 2 and MQP accommodate glasses
  - ML utilizes an external "puck" to house necessary hardware to decrease weight
- Areas of Improvement:
  - HL 2: implement customizable/less restricting controls (utilizes 'pinching' currently)
  - ML: create a form fitting control
  - ML: create space for users to wear their own glasses instead of buying lens inserts

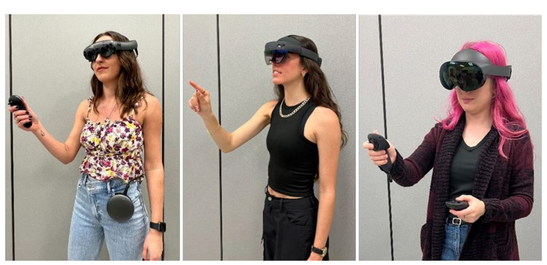

Figure 2. The three HMDs. From left to right: Magic Leap 1 (ML), HoloLens 2 (HL2), and Meta Quest Pro (MQP)

Takeaways

Users with diverse abilities, skills, cultures, preferences, and physical differences **will** be using XR products.

Some XR devices are customizable to these diverse users, while others are unusable. Hardware design should be updated to make XR more inclusive.

Device		HMDs	Mobile	Epson Moverio
Case Study		1	2	3
Fit	Weight	Can be lightweight, depending on device	Can be heavy to hold over long periods of time	Lightweight
	Inclusivity	Customizable for: glasses, different IPDs, different head shapes/sizes Many do not accommodate for diverse hair styles & head coverings	Customizable for: glasses, different hand shapes AR face filters can be inaccurate with users who have diverse hair, skin types, and glasses	Customizable for: nose bridge sizes, and possible to use with prescription lenses (but can be uncomfortable)
	Mobility	May be tethered with a cord, could be a hazard depending on device	Difficult to hold if user has mobility limitations	Tethered with a cord, could be a hazard
Controls	Flexibility of Interactions	Gesture (ambidextrous hands), voice, or controller depending on device	Buttons, screen tap, voice	Controller is required Headphones required for audio or voice input
	Use of Native Accessibility Features	Brightness settings, some allow customizable voice assistant settings	Yes, but not always utilized in XR apps	No
Aborting Virtual Content	———	Quick path (lift visor up or button press)	Quick path (put down mobile device)	No

Case Study 2: Mobile Devices

Mobile devices as a tool to access AR social media filters.

- Strengths:
  - Native accessibility features (screen reader, subtitles/captions, etc) available on device
  - Multiple forms of interaction available (button press or screen press) (Apple, n.d.-b; Meta, 2018)
- Areas of Improvement:
  - Utilize native phone accessibility features in AR apps
  - Allow flexible forms of interaction when creating face filter interactions
    - Users with mobility issues may have difficulties interacting with buttons and tapping on screens.
  - "Beauty filters" can change a user's appearance but may exclude those whose bodies do not fit the "ideal" mirrored by the filter (Siddiqui, 2021)
    - Keep this in mind when designing AR filters
  - Support screen reader functionality with AR apps

Case Study 3: Smart Glasses

Smart glasses examined: Epson Moverio BT-300

- Strengths:
  - Lightweight
    - Comes with shade and frames for a prescription lense, headphones, and nose inserts
  - Customizable for nose bridge sizes and possibility to use prescription lenses and a shaded lens
- Areas of Improvement:
  - Implement customizable size/shape of the device and IPD for different users' anatomy
  - Eliminate the tether by implementing the battery into the headset
    - Can get in the way, caught, and tangled in other things such as accessories, chair arms, and medical wearables
  - Implement speakers into the headset to eliminate the need for external headphone attachment

Figure 3. Epson Moverio BT-300 with Teather, Shade and Prescription Lense, Headphones, and Nose Inserts.

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