

# DESIGN OF AN AUGMENTED REALITY MAGNIFICATION AID FOR LOW VISION USERS

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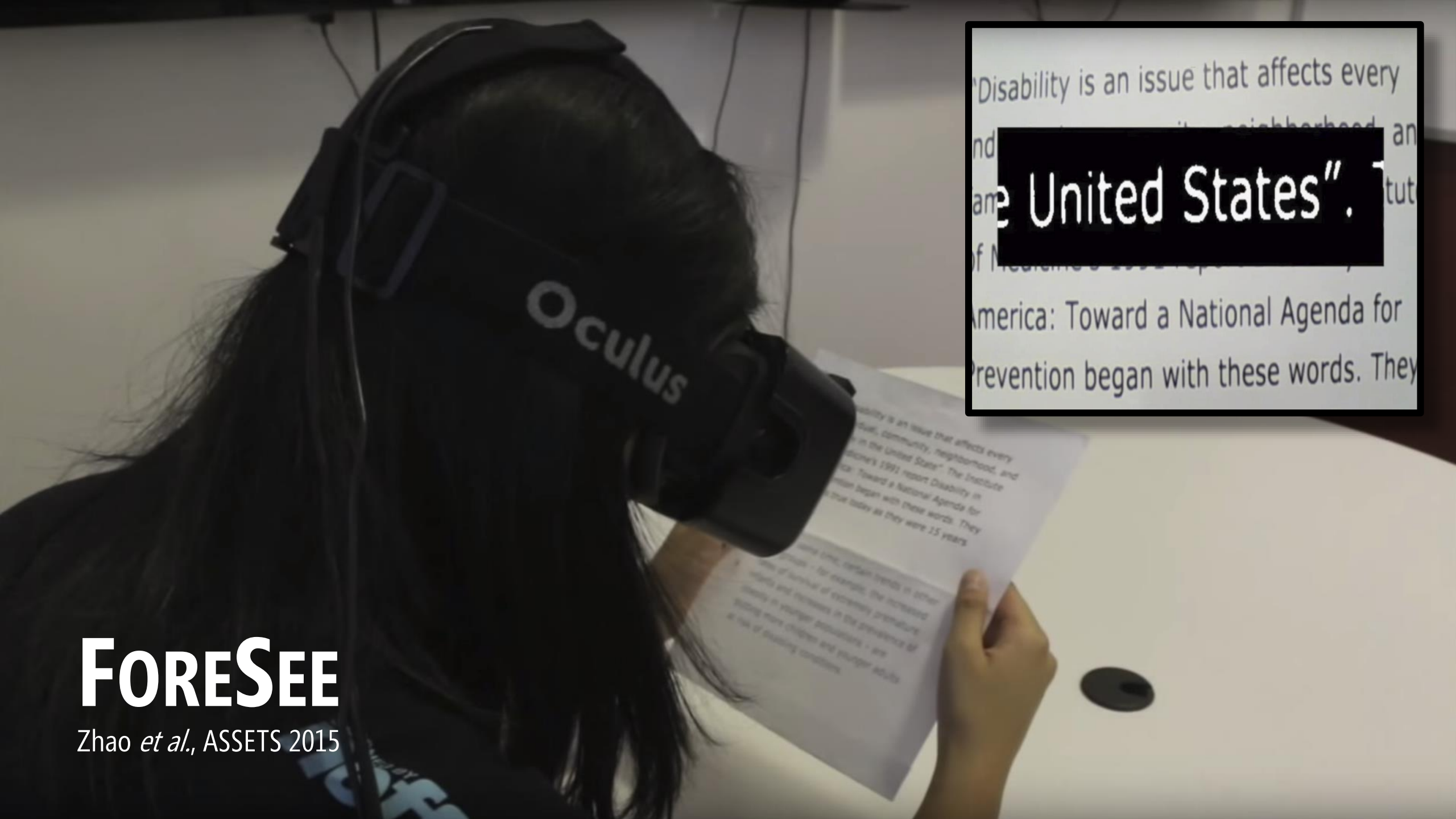


Common reading aids for low vision users include closed circuit television (**CCTV**), **handheld** magnifiers, and **smartphone** apps



A man with a beard and balding head is wearing a pair of white and black AR glasses. He is looking down at a magazine he is holding in his hands. The magazine cover features the text "Seattle Business" in red and "BEST COMPANIES TO WORK FOR" in black. The background is a blurred indoor setting with a bookshelf.

AR has the potential to be **more portable**, **multi-tasking**, and **better integrated** into a person's everyday life. **low vision users**, **head mounted video displays** and **enhance visual capabilities** are particularly promising.



Disability is an issue that affects every individual, community, neighborhood, and nation in the United States". The Institute of Medicine's 1991 report "Disability in America: Toward a National Agenda for Prevention" began with these words. They

United States".

# FORESEE

Zhao *et al.*, ASSETS 2015



# GOOGLE GLASS



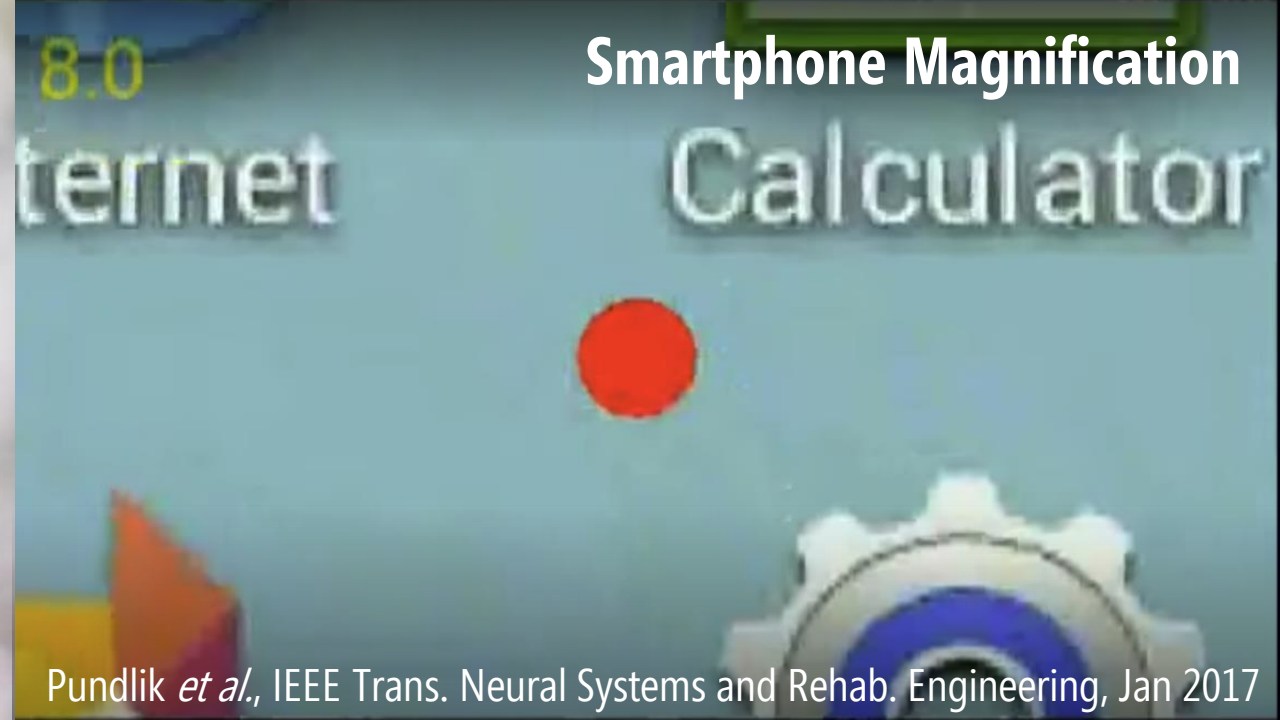
Photo from Wikimedia Commons

## Edge Enhancement



Hwang and Peli, Optometry and Vision Science, Aug 2014

## Smartphone Magnification



Pundlik *et al.*, IEEE Trans. Neural Systems and Rehab. Engineering, Jan 2017



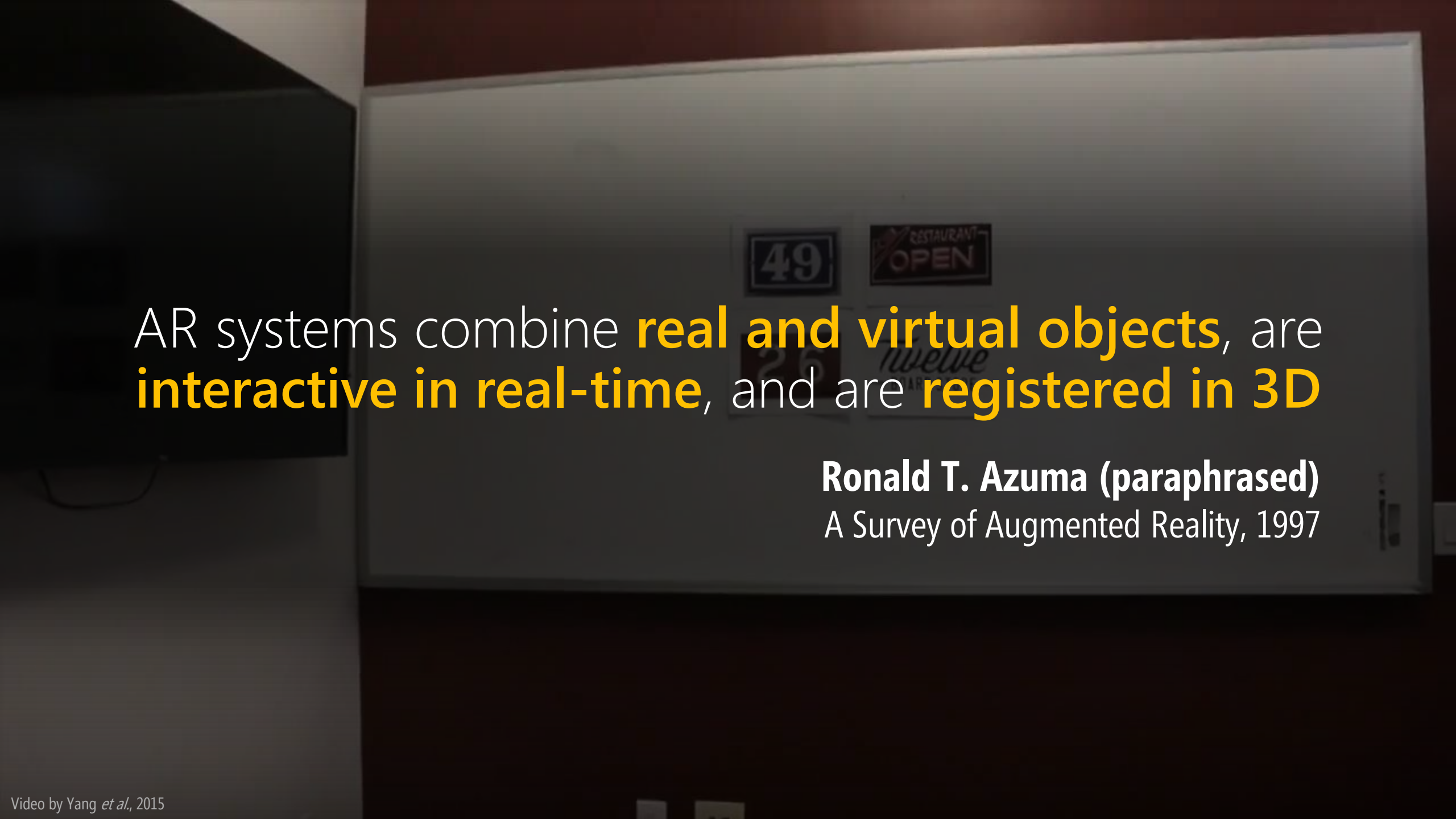
# COMMERCIAL HEAD-WORN VISION ENHANCEMENT SYSTEMS

**Zolyomi et al., ASSETS 2017**—a recent study with eSight that showed the impact a head-worn vision enhancement system can make in users' lives.

**eSight**

**NuEyes**

**IrisVision**



AR systems combine **real and virtual objects**, are **interactive in real-time**, and are **registered in 3D**

**Ronald T. Azuma (paraphrased)**  
A Survey of Augmented Reality, 1997



# MICROSOFT HOLOLENS

TRANSPARENT AR DISPLAY  
PERSISTENT 3D CONTENT





# 3D AUGMENTED REALITY



Chesapeake Bay, predicti  
factors are contributing: geolog  
ice caps are melting; warming seaw  
weakening and carrying less water a  
The average elevation of the Deal Is  
Famine, drought, sickness and extir  
thly life if carbon emissions aren't  
ntually halted. But for Katherine



OUR APPROACH



# DESIGN SPACE **GOALS**

**Augment** rather than **replace** existing vision capabilities

# DESIGN SPACE

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**Augment** rather than **replace** existing vision capabilities

Leverage **augmented reality** and persistent 3D content



# DESIGN SPACE

# GOALS

**Augment** rather than **replace** existing vision capabilities

Leverage **augmented reality** and persistent 3D content

Prioritize **customization** and **flexibility**

# ITERATIVE DESIGN METHOD

Nine design sessions  
Seven VI participants





# ITERATIVE DESIGN METHOD

Nine design sessions  
Seven VI participants

## Three basic prototype designs

HoloLens Only

HoloLens and Finger-Camera

HoloLens and Smartphone



# INITIAL INVESTIGATION: HOLOLENS DESIGN



**Built-in camera** to capture images



**Two display modes:**

Fixed 2D & Fixed 3D



**Voice Commands** to select mode



**Image Enhancements:**

Binary threshold & Invert colors





# INITIAL INVESTIGATION: HOLOLENS **OBSERVATIONS**

**Camera resolution** too low

**Turning head** to look at desired content was uncomfortable

**Voice commands** cumbersome, imprecise, limited customization





# **PROTOTYPE 1**

HoloLens and Finger-Camera

A person is shown in profile, wearing a dark grey HoloLens headset. They are looking down at a document on a wooden table. The document has a large landscape photograph on the left and a smaller image on the right. The person's right hand is holding a thin, black, finger-mounted camera device. The background is a plain, light-colored wall.

**HoloLens**

**Camera**

**PHYSICAL DESIGN**

PROTOTYPE 1: HOLOLENS AND FINGER-CAMERA



Camera

LED

Custom Mount

# PHYSICAL DESIGN

PROTOTYPE 1: HOLOLENS AND FINGER-CAMERA



# Virtual Display Design 1: Fixed 2D

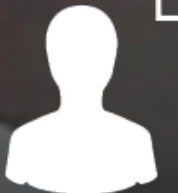
Acts as a heads-up display, stays in the user's view at all times



## VIRTUAL DISPLAYS

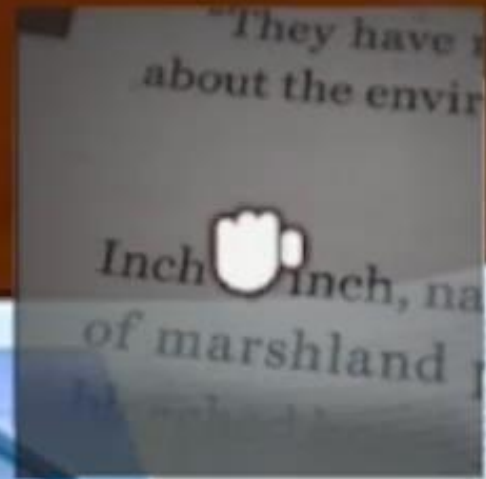
PROTOTYPE 1: HOLOLENS AND FINGER-CAMERA

Aa Bb





Users customize the position and size of the display for each design using midair tap and drag gestures



# USER INTERACTIONS

PROTOTYPE 1: HOLOLENS AND FINGER-CAMERA





# PROTOTYPE 1: HOLOLENS AND FINGER-CAMERA

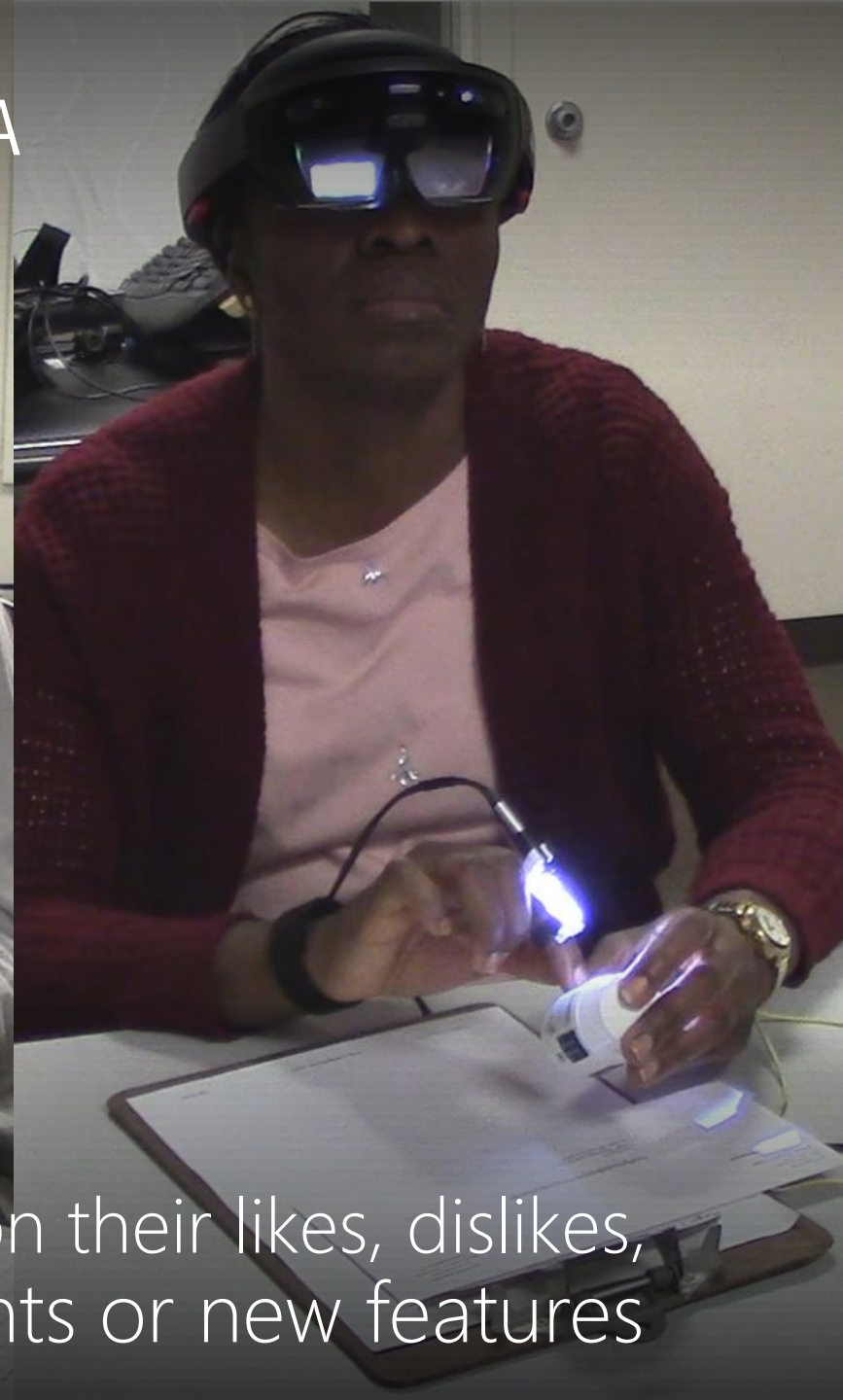
## METHOD



3 **Low Vision Participants** (1 Female, 2 Male, Ages 28-54)  
Each participant used **four virtual display designs** to read  
**documents and other text** (e.g., mail, pill bottle, cereal box)



# PROTOTYPE 1: HOLOLENS AND FINGER-CAMERA METHOD



They provided **feedback and suggestions** on their likes, dislikes, design preferences, ideas for improvements or new features



# PROTOTYPE 1: HOLOLENS AND FINGER-CAMERA

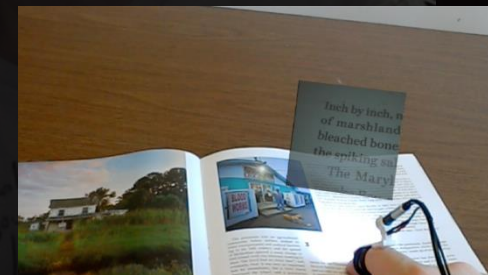
## FINDINGS

### Virtual Display Designs



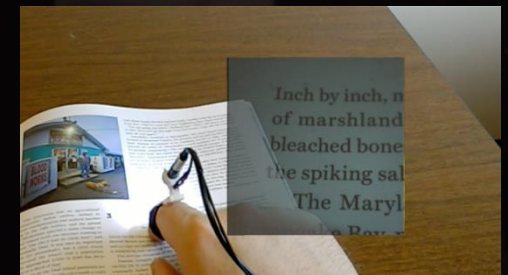
#### Fixed 3D (Vertical or Horizontal)

Reading experience similar to using a CCTV or handheld magnifier.



#### Finger Tracking

Can help to quickly search a document.



#### Fixed 2D

Always visible, required least concentration.

Aa Bb





# PROTOTYPE 1: HOLOLENS AND FINGER-CAMERA

## FINDINGS

### Finger-Worn Camera

- [+] Flexible, allows hands-free use
- [-] Requires moving finger to read
- [-] Small field of view (~3-4 lines)



# PROTOTYPE 1: HOLOLENS AND FINGER-CAMERA

## FINDINGS

### HoloLens Display

- [-] Low contrast due to transparency
- [-] Narrow view, center of vision  
(problem for one participant)





# PROTOTYPE 1: HOLOLENS AND FINGER-CAMERA

# FINDINGS

## User Input

- [-] Midair gestures difficult to use
- [-] Unable to make quick adjustments



# **PROTOTYPE 2**

HoloLens and Smartphone



A person is wearing a dark grey HoloLens headset. They are holding an iPhone in their right hand, which is positioned over an open magazine. The magazine features a photograph of a house in a field and some text. The background is a wooden table. The text 'HoloLens' is written in large white font at the top, with a white line and a dot pointing to the headset. The text 'iPhone' is written in large white font to the right, with a white line and a dot pointing to the phone. At the bottom, the text 'PHYSICAL DESIGN' is written in large white font, followed by 'PROTOTYPE 2: HOLOLENS AND SMARTPHONE' in a smaller white font.

# HoloLens

# iPhone

# PHYSICAL DESIGN

## PROTOTYPE 2: HOLOLENS AND SMARTPHONE



# PROTOTYPE 2: HOLOLENS AND SMARTPHONE

# PHYSICAL DESIGN



## Smartphone app features:

- Wireless streaming to HoloLens
- Standard touchscreen gestures
- Motion to position virtual display



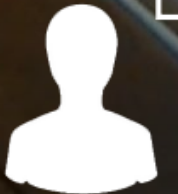
# Virtual Display Design 1: Attached to Headset

Maintains fixed position relative to the user at all times

## VIRTUAL DISPLAYS

PROTOTYPE 2: HOLOLENS AND SMARTPHONE

Aa Bb



# Virtual Display Design 1: Attached to Headset

Maintains fixed position relative to the user at all times

## VIRTUAL DISPLAYS

PROTOTYPE 2: HOLOLENS AND SMARTPHONE

Aa Bb





Each design included several options for customization, including the position, size, and contrast/colors

# USER INTERACTIONS

PROTOTYPE 2: HOLOLENS AND SMARTPHONE



# PROTOTYPE 2: HOLOLENS AND SMARTPHONE METHOD



6 **Low Vision Participants** (3 Female, 3 Male, Ages 28-68)  
Each participant used **three virtual display designs** to read **documents and other text** (e.g., mail, pill bottle, cereal box)



# PROTOTYPE 2: HOLOLENS AND SMARTPHONE FINDINGS

Participants were **more successful and positive** about their experience using this version of our system.

They were better able to experience the **AR aspects of our approach**, which most participants found promising.

## PROTOTYPE 2: HOLOLENS AND SMARTPHONE

# FINDINGS

That is so much better [than my CCTV], **you can go down the whole page and read it.** Like if I want to read a book or something to my kids, Mommy **doesn't have to go line by line.** I can read it and keep the flow going.”



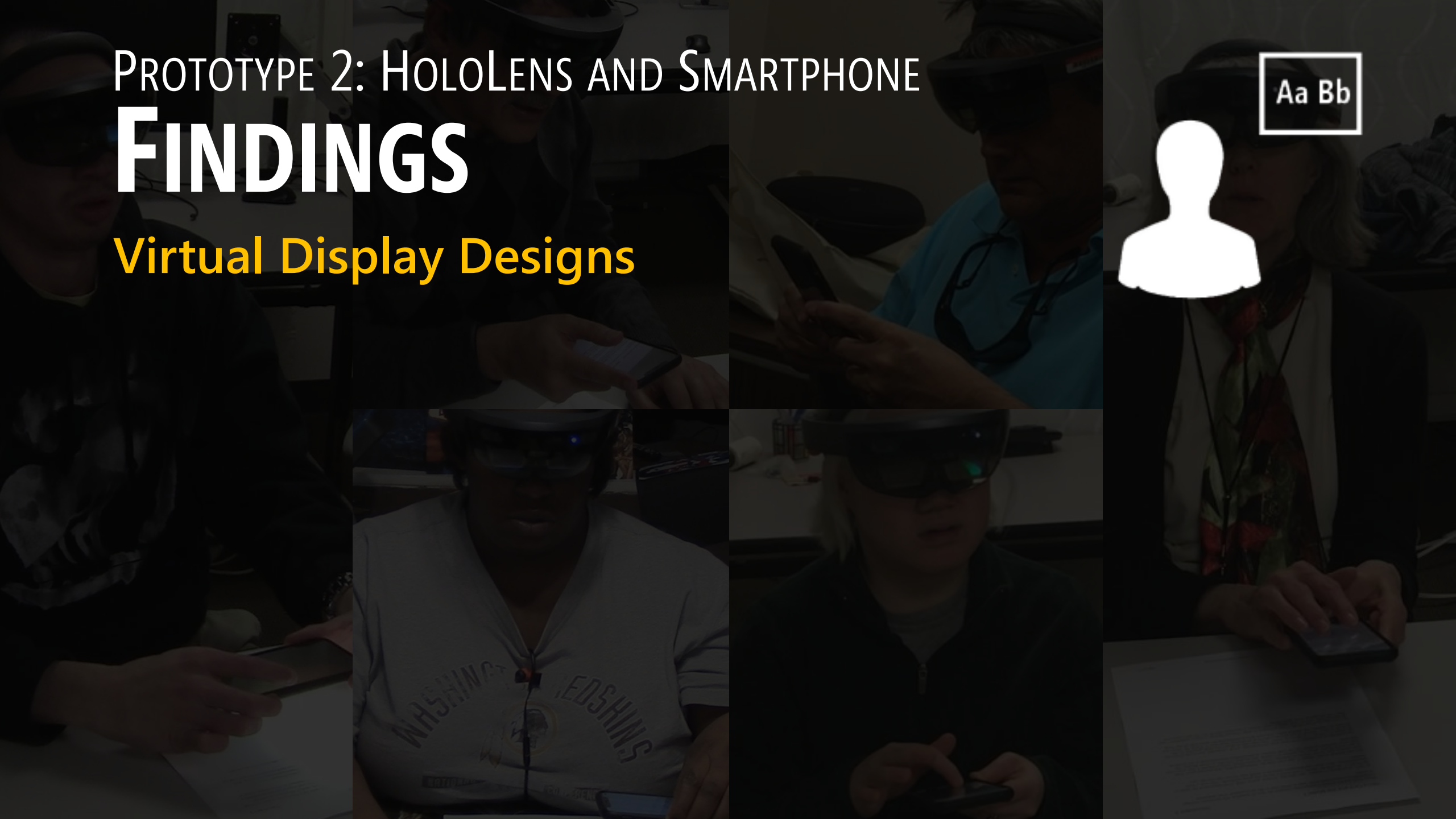
PROTOTYPE 2: HOLOLENS AND SMARTPHONE

# FINDINGS

Virtual Display Designs



Aa Bb

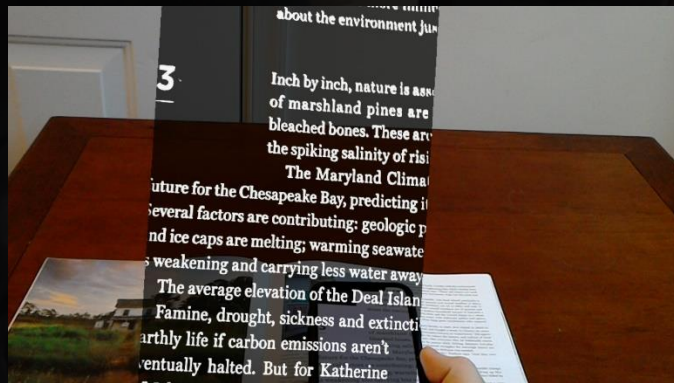


# PROTOTYPE 2: HOLOLENS AND SMARTPHONE

# FINDINGS

## Virtual Display Designs

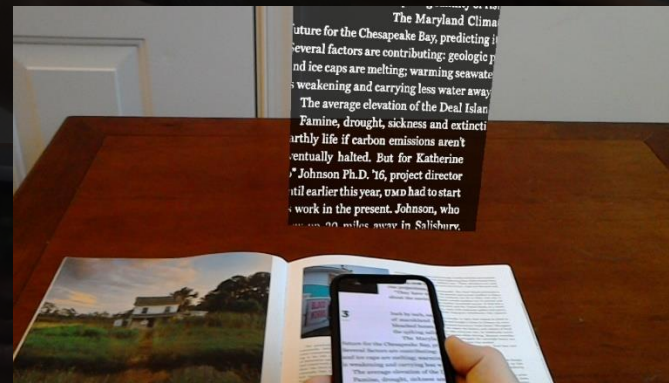
Aa Bb



### Attached to Headset

Easier to focus on the text

Potentially distracting



### Attached to World

Natural reading experience

Easier to multitask



### Attached to Phone

Versatile

Intuitive interactions



# PROTOTYPE 2: HOLOLENS AND SMARTPHONE

# FINDINGS



## Smartphone

- [+] Better camera
- [+] More usable interactions
- [-] No longer hands-free
- [-] Too heavy for extended use



# PROTOTYPE 2: HOLOLENS AND SMARTPHONE FINDINGS



## HoloLens

Issues with contrast, field of view, and physical size and weight still present.

**Emphasizes need for customizability.**





# CONCLUSIONS

## Strengths and Weaknesses of 3D AR for Magnification

- [+] Enables new interactions not possible with other approaches
- [+] Good for multitasking





# CONCLUSIONS

## Strengths and Weaknesses of 3D AR for Magnification

- [+] Enables new interactions not possible with other approaches
- [+] Good for multitasking
- [-] May require more effort to use than fixed 2D display

## Future work

Alternative camera positions and virtual display designs



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