Design of an Augmented Reality Magnification Aid for Low Vision Users

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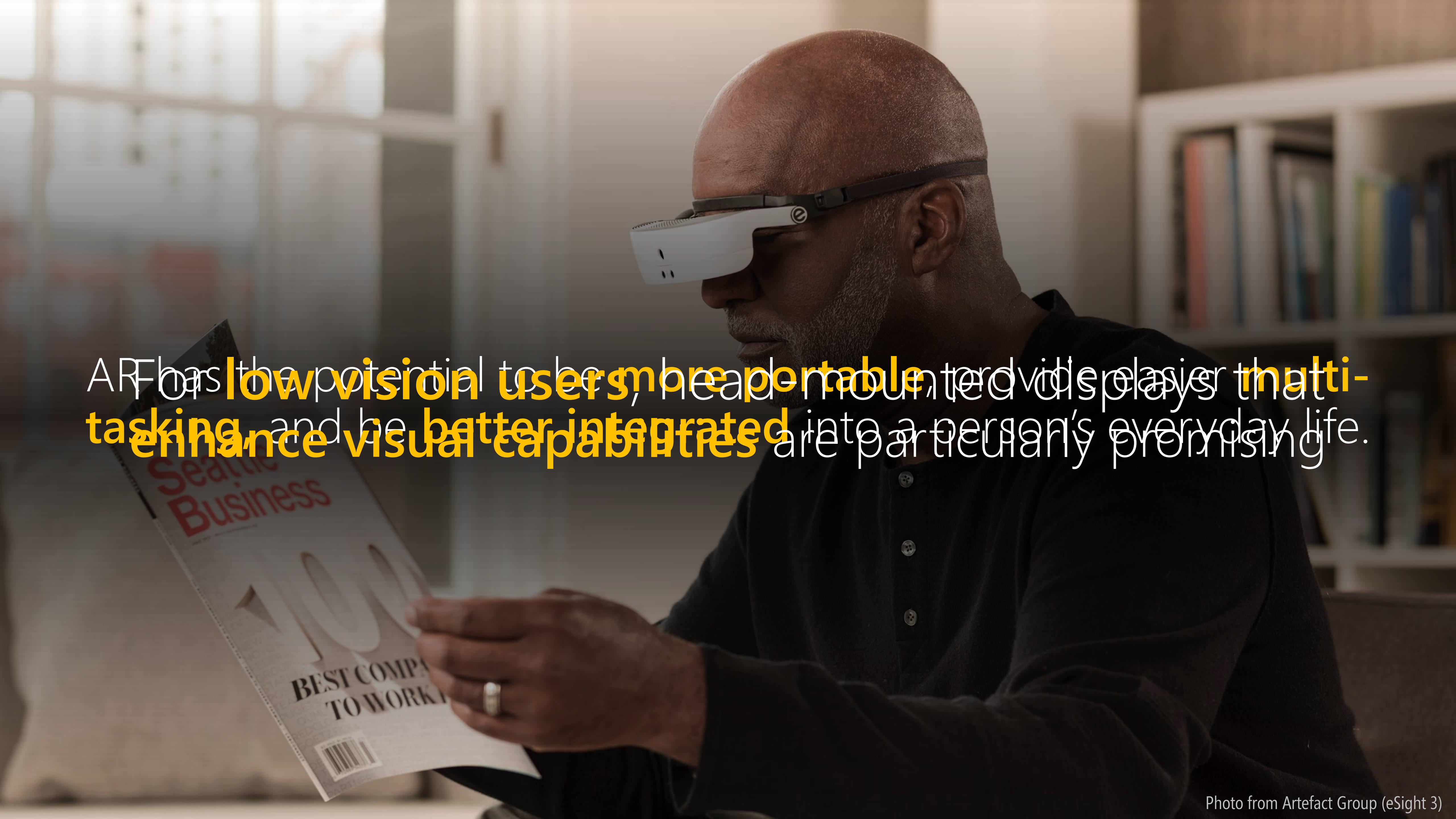
Common reading aids for low vision users include closed circuit television (**CCTV**), **handheld** magnifiers, and **smartphone** apps

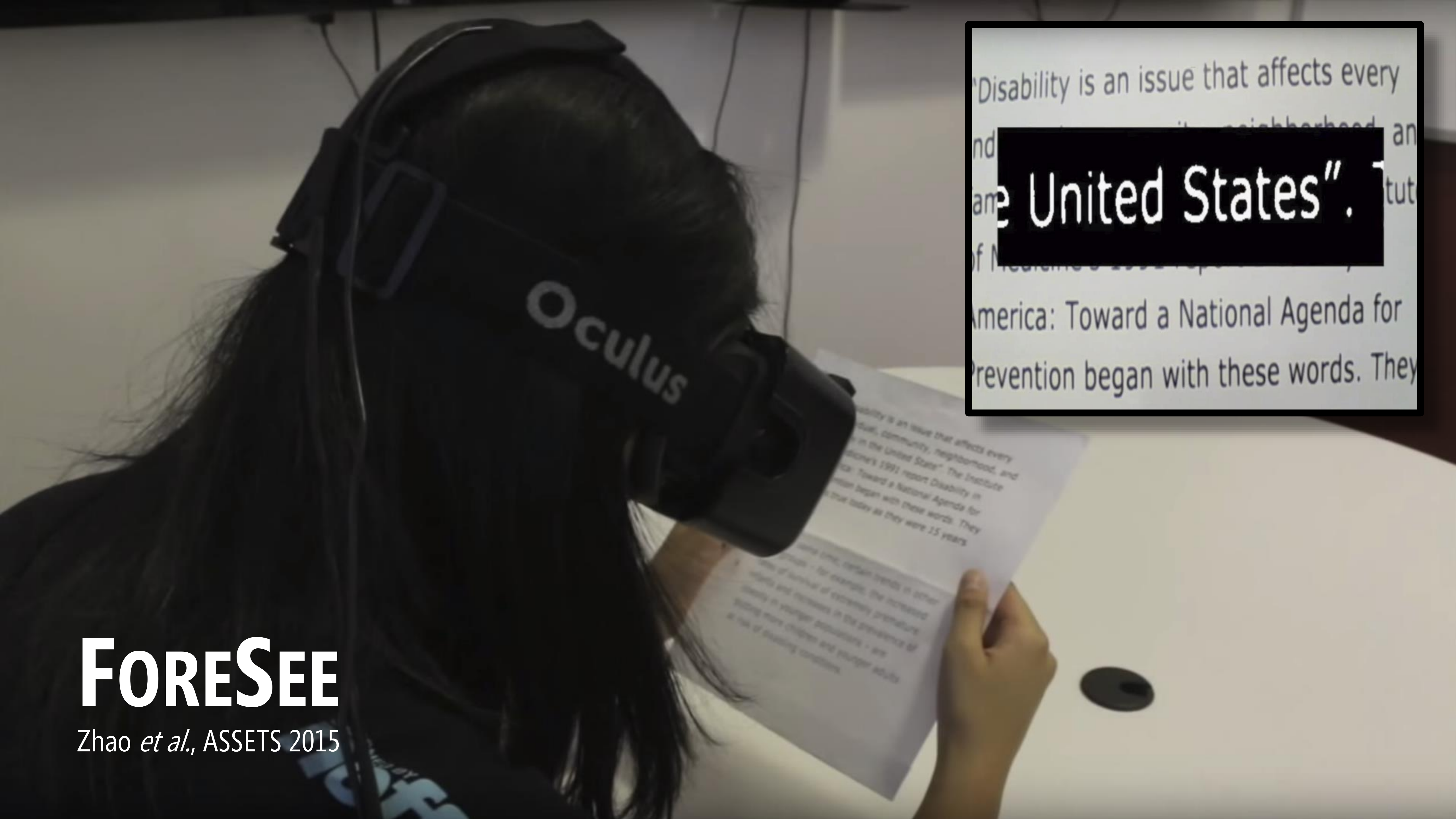
Photo from Vision Dynamics (Opaltec Clearview C Flex)



AR has the potential to be **more portable**, provide easier **multi-tasking**, and be **better integrated** into a person's everyday life.

For **low vision users**, head-mounted displays that **enhance visual capabilities** are particularly promising

Photo from Artefact Group (eSight 3)



ForeSee

Zhao *et al.*, ASSETS 2015

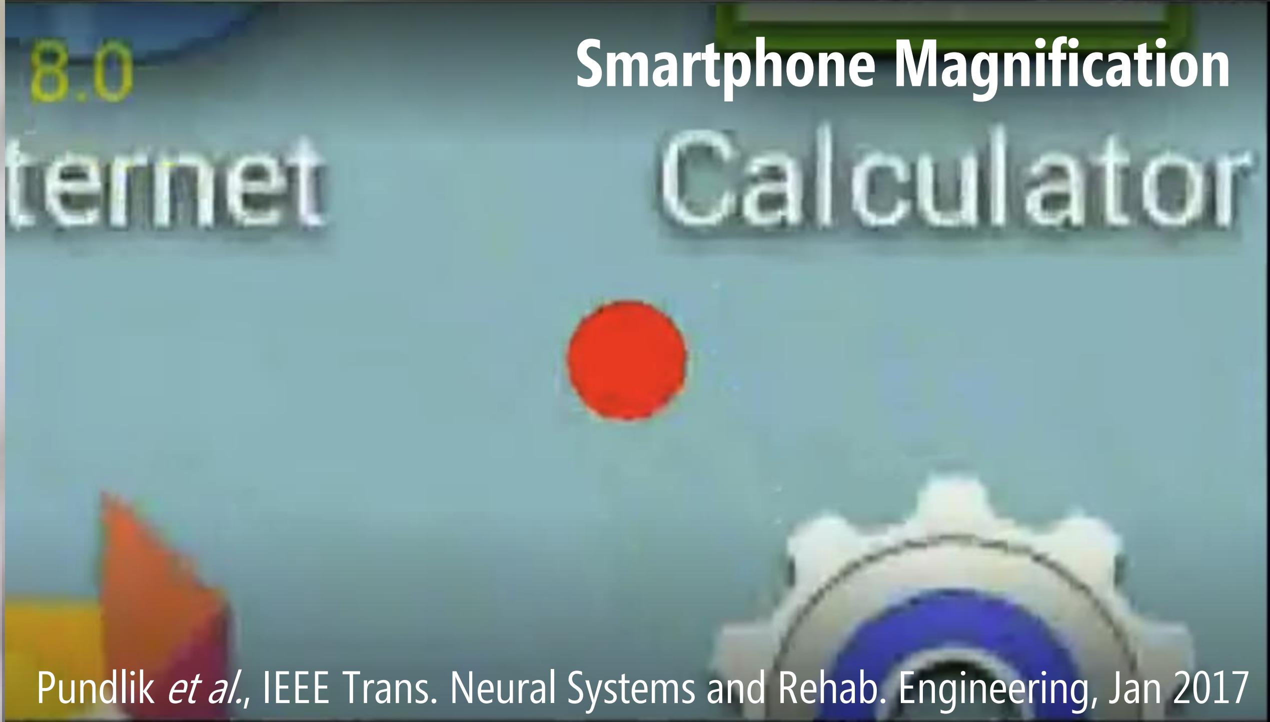
Google Glass

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

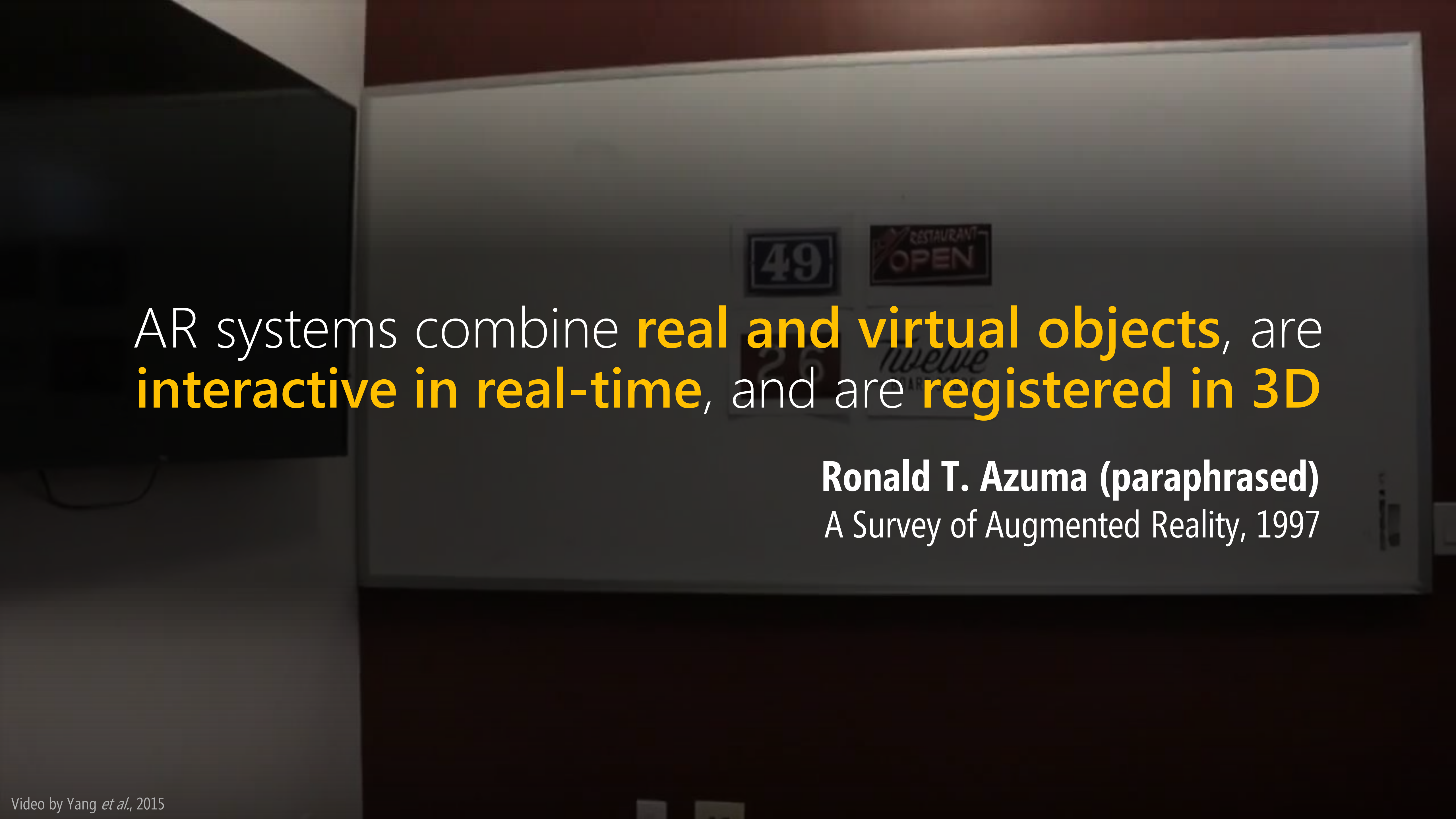
Commercial Head-Worn Vision Enhancement Systems

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

Video by Yang *et al.*, 2015

Transparent AR Display
Persistent 3D Content

Microsoft HoloLens

Photo from Wikimedia Commons

3D Augmented Reality

Photo from Windows Central

OUR APPROACH

Design Space
Goals

Augment rather than **replace** existing vision capabilities

Design Space

Goals

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

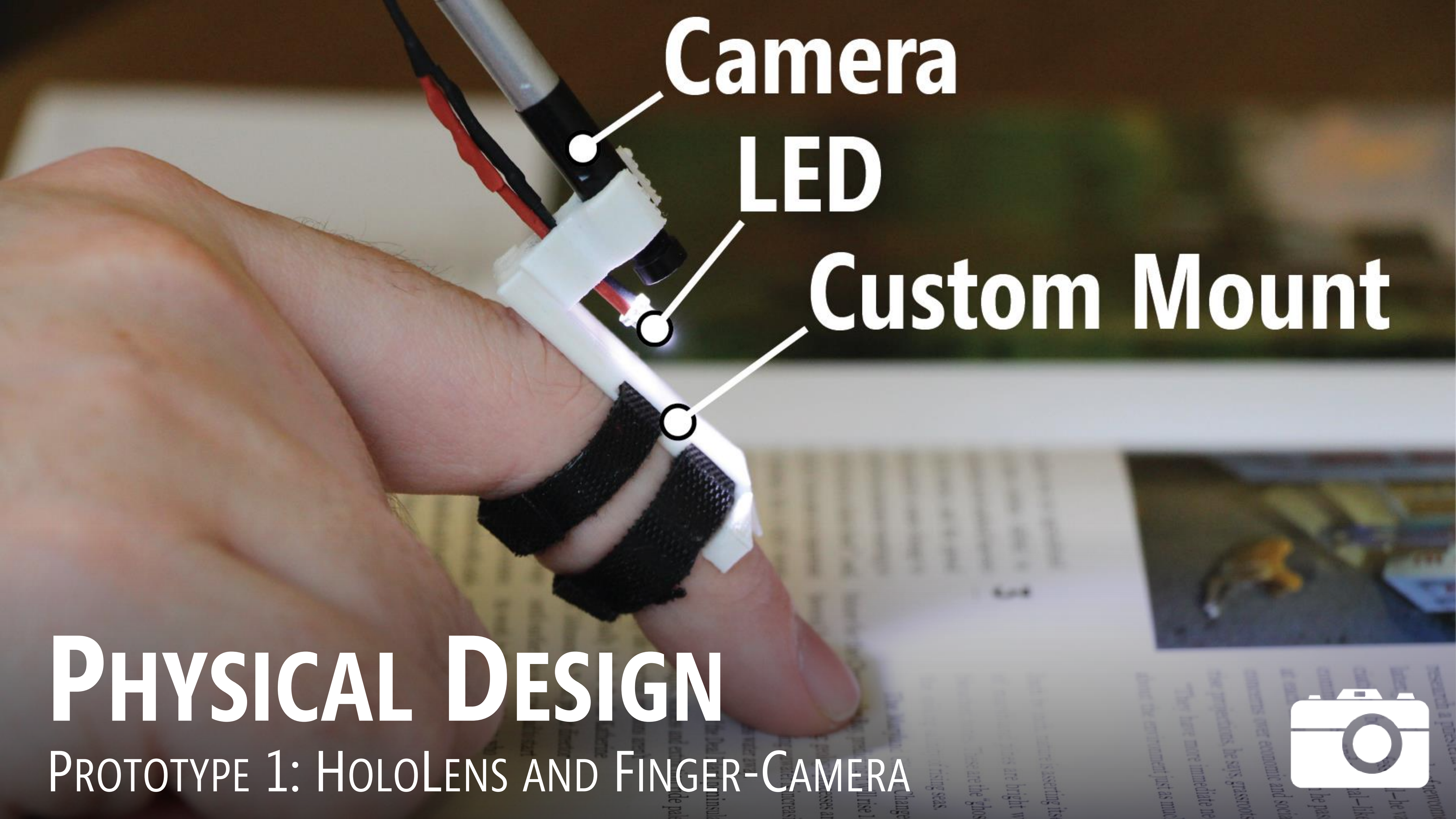
Turning head to look at desired content was uncomfortable

Voice commands cumbersome, imprecise, limited customization

Prototype 1

HoloLens and Finger-Camera


HoloLens
Camera
Physical Design
Prototype 1: HoloLens and Finger-Camera



Physical Design

Prototype 1: HoloLens and Finger-Camera

Virtual Displays

Prototype 1: HoloLens and Finger-Camera

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

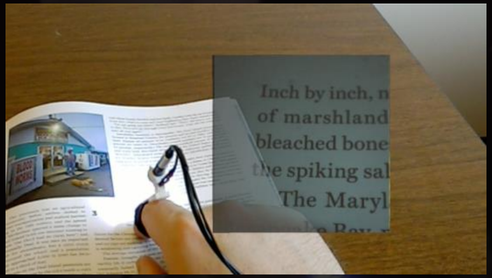
Method

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.

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

Physical Design

Prototype 2: HoloLens and Smartphone

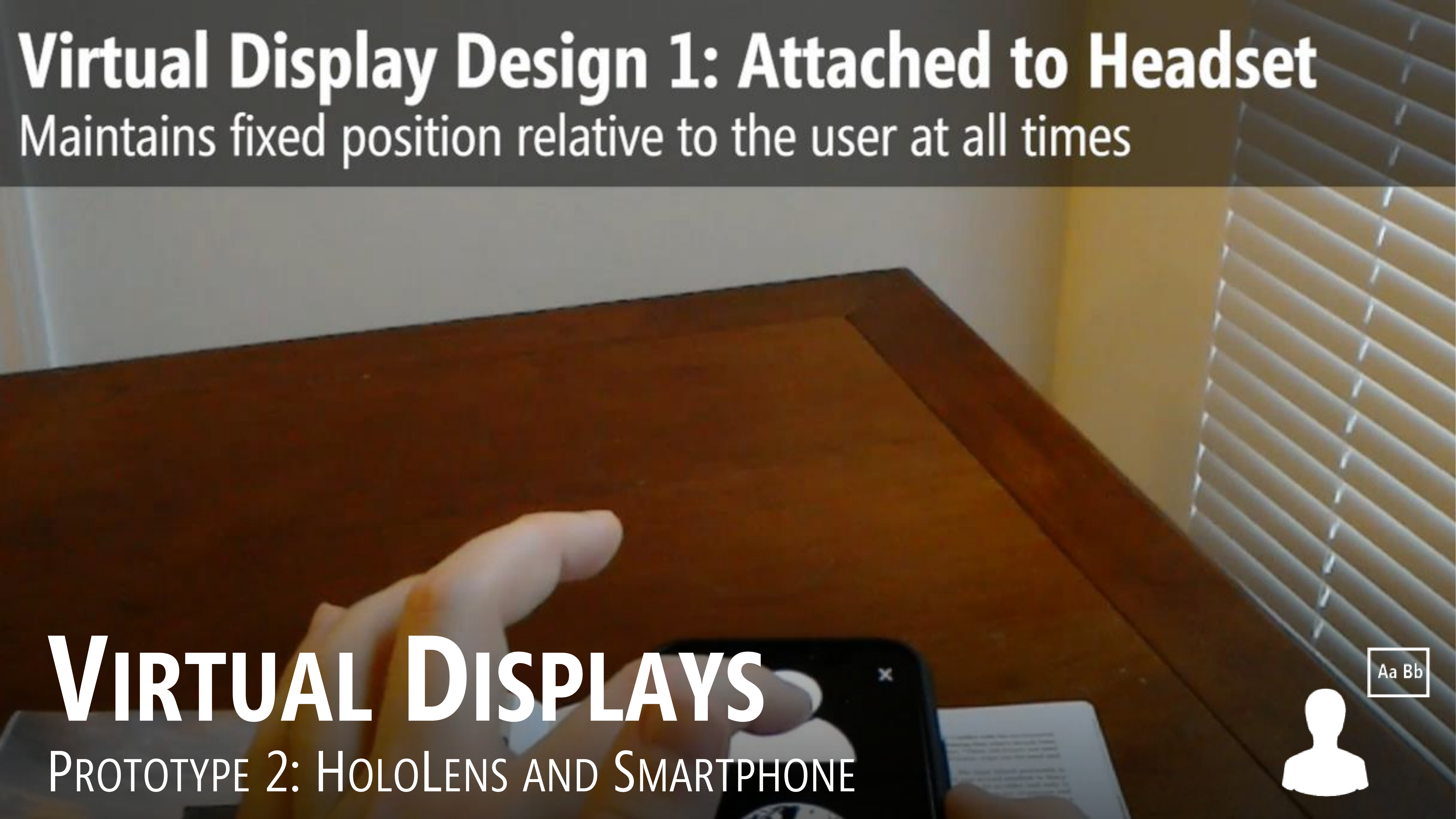
Prototype 2: HoloLens and Smartphone

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 Displays

Prototype 2: HoloLens and Smartphone

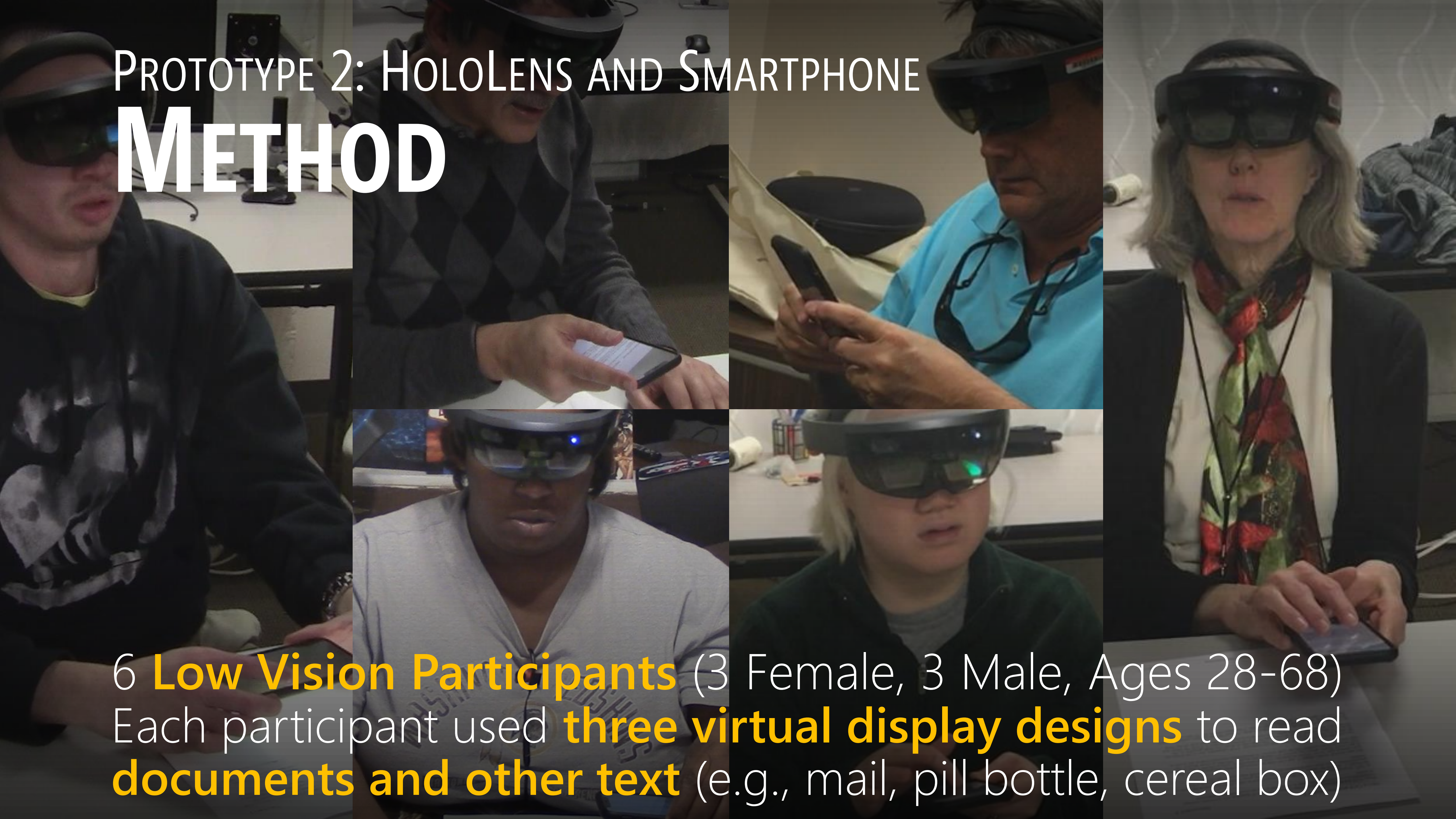
Each design included several options for customization, including the position, size, and contrast/colors

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

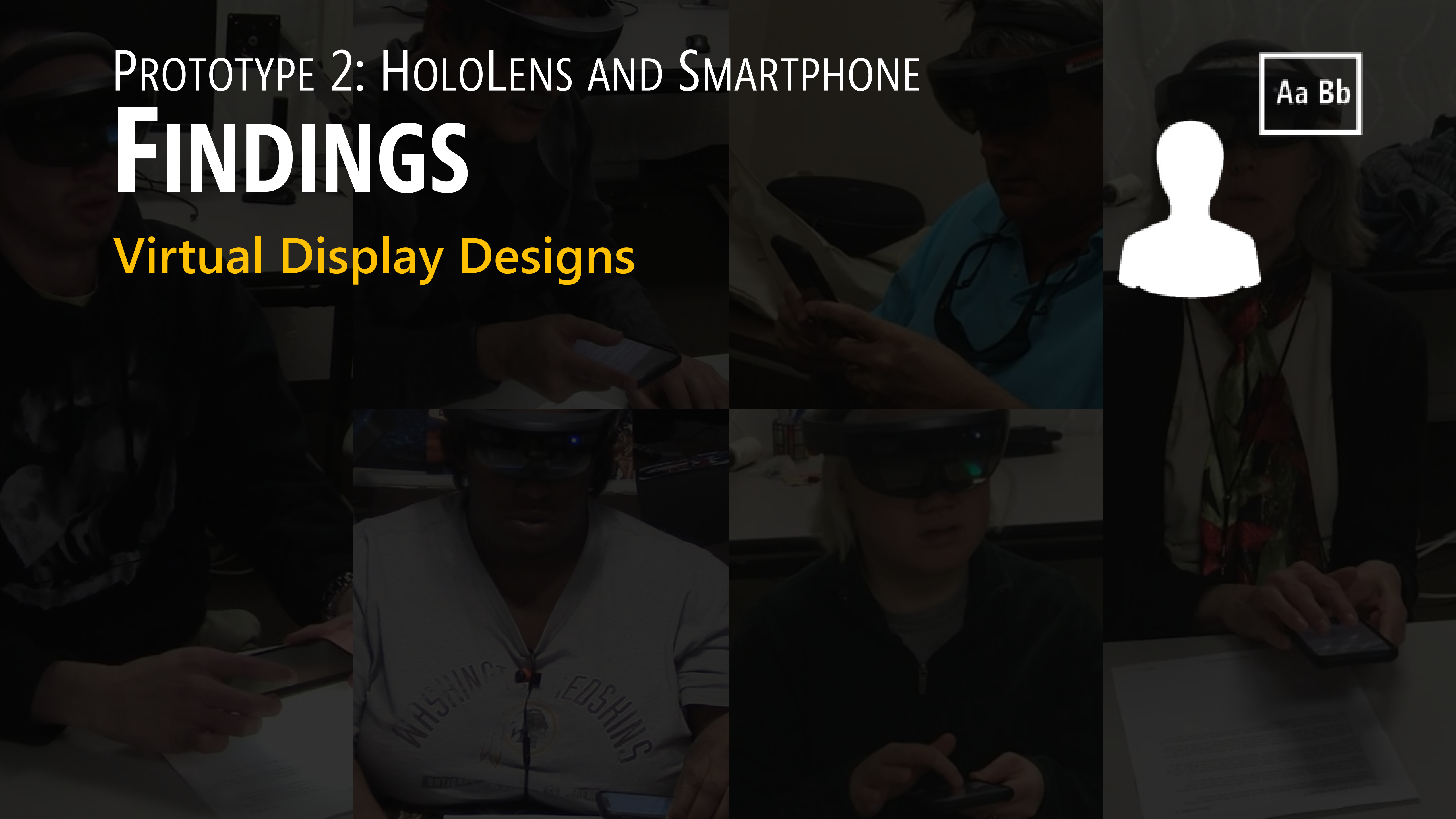
"That is so much better [than my CCTV], **you can go down the whole page and read it**. Like if I want to read a book or something to my kids, Mommy **doesn't have to go line by line**. I can read it and keep the flow going."

P4

Prototype 2: HoloLens and Smartphone

Findings

Virtual Display Designs

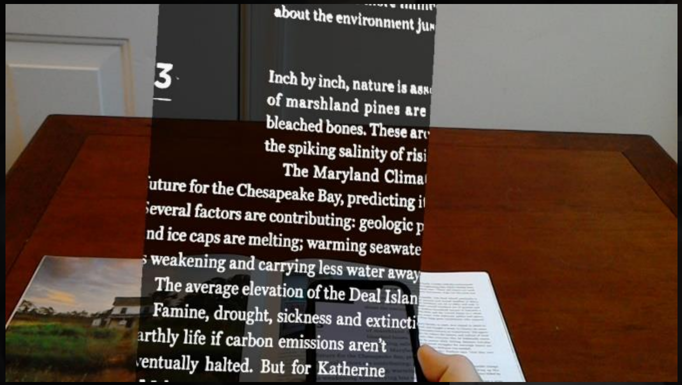


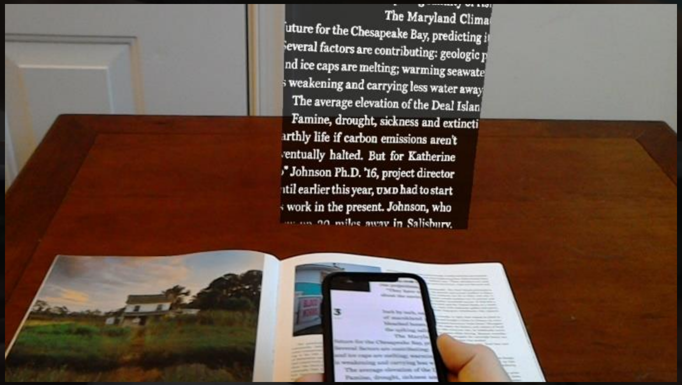
Prototype 2: HoloLens and Smartphone

Findings

Virtual Display Designs

Aa Bb





Attached to Headset	Attached to World	Attached to Phone
Easier to focus on the text	Natural reading experience	Versatile
Potentially distracting	Easier to multitask	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

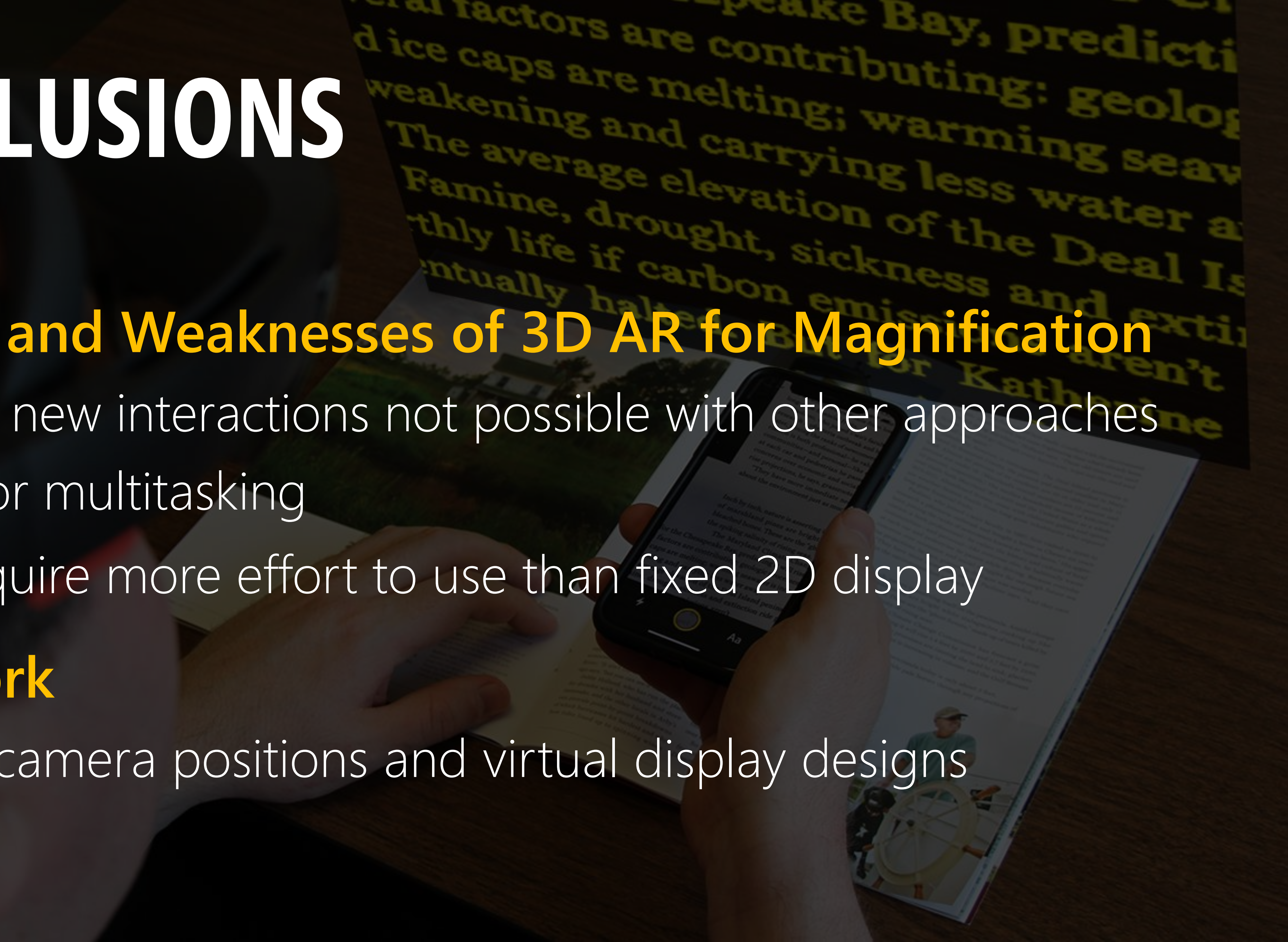
[+] Enables new interactions not possible with other approaches

[+] 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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