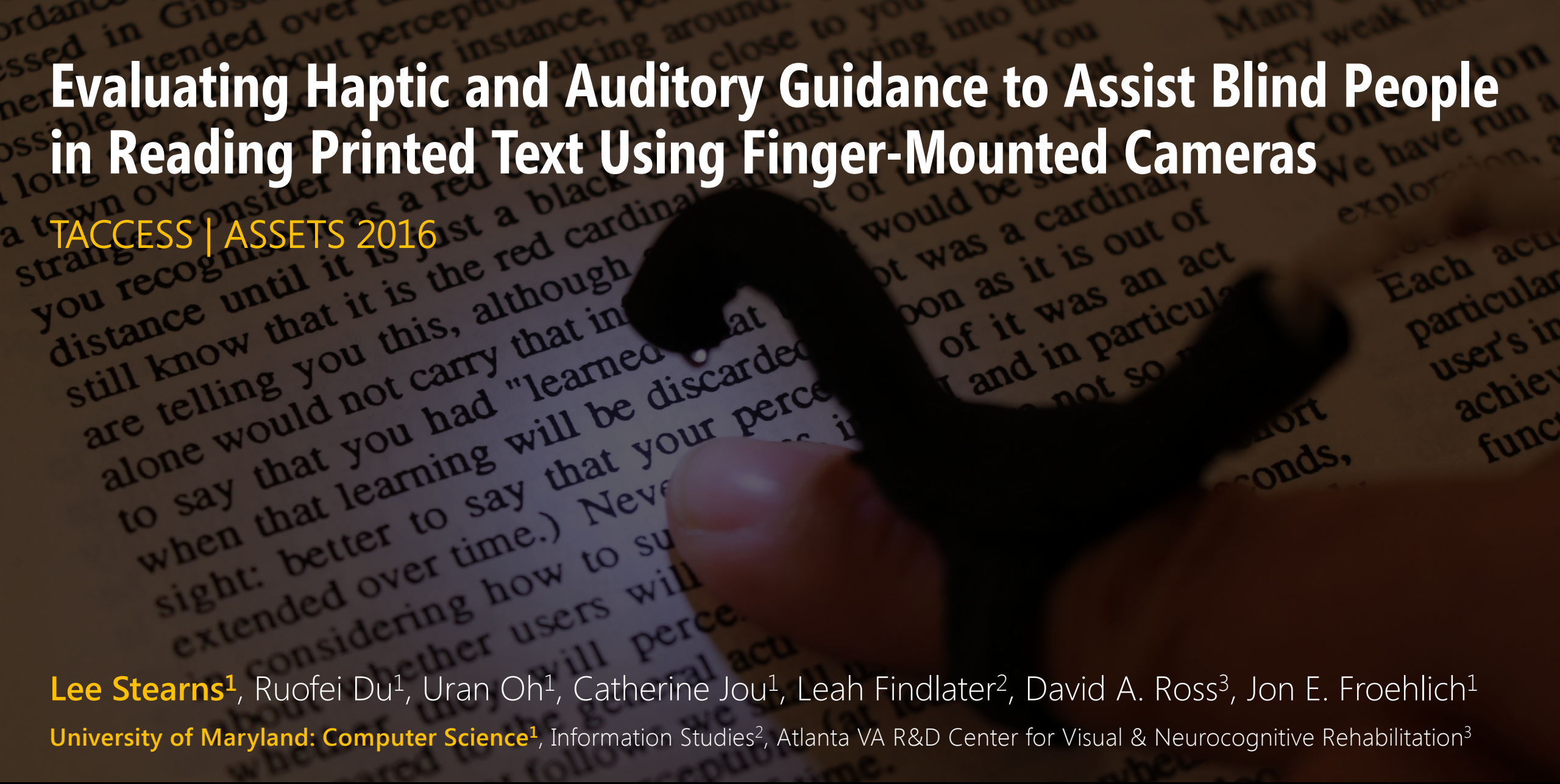
Evaluating Haptic and Auditory Guidance to Assist Blind People in Reading Printed Text Using Finger-Mounted Cameras

TACCESS | ASSETS 2016



Lee Stearns[1], Ruofei Du[1], Uran Oh[1], Catherine Jou[1], Leah Findlater[2], David A. Ross[3], Jon E. Froehlich[1]

University of Maryland: Computer Science[1], Information Studies[2], Atlanta VA R&D Center for Visual & Neurocognitive Rehabilitation[3]

makeability lab

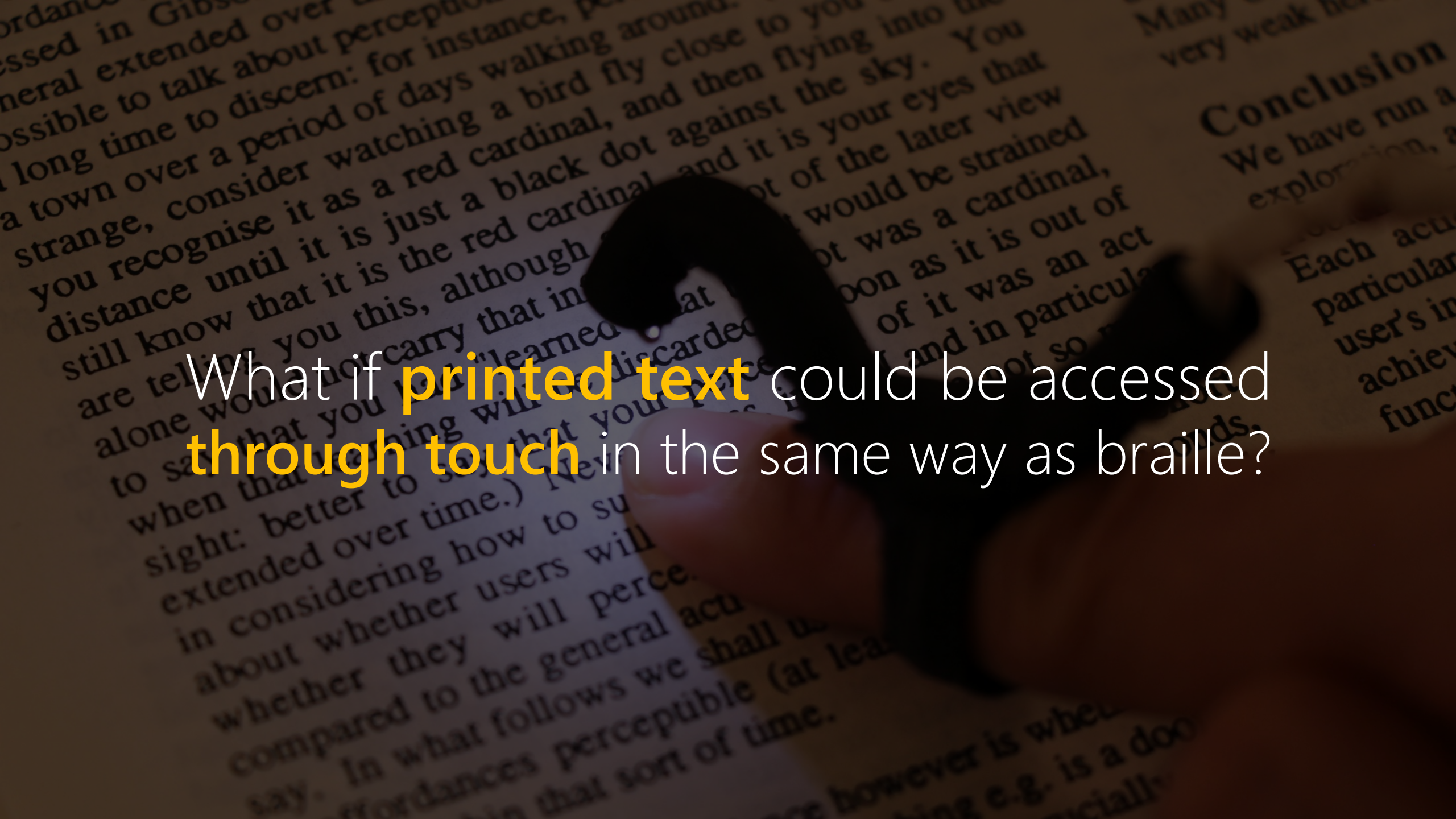
inclusive design lab

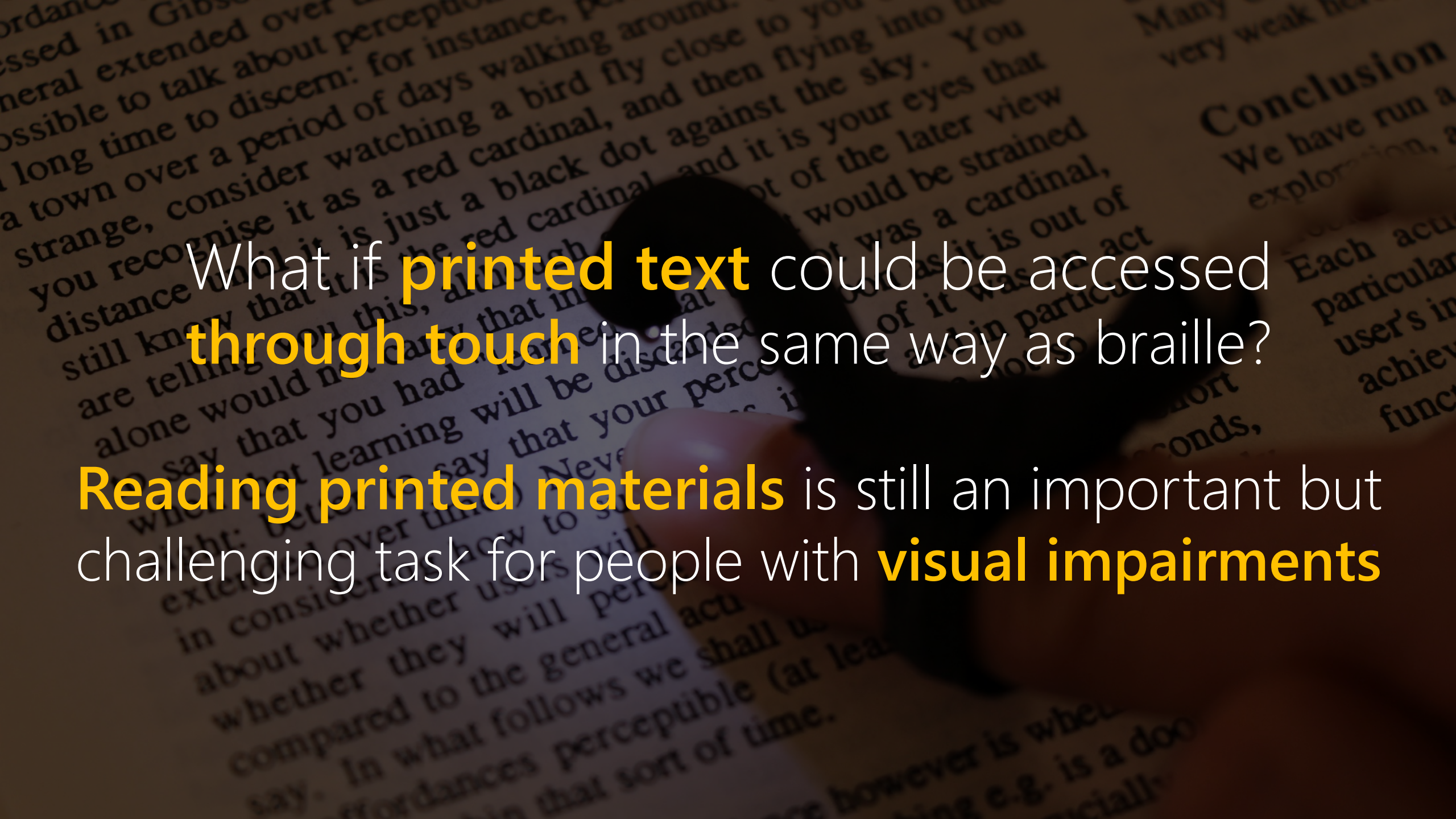
HCIL Human Computer Interaction Laboratory

COMPUTER SCIENCE UNIVERSITY OF MARYLAND

UNIVERSITY OF MARYLAND

*Video Credit: YouTube—Ginny Owens—How I See It (Reading Braille)

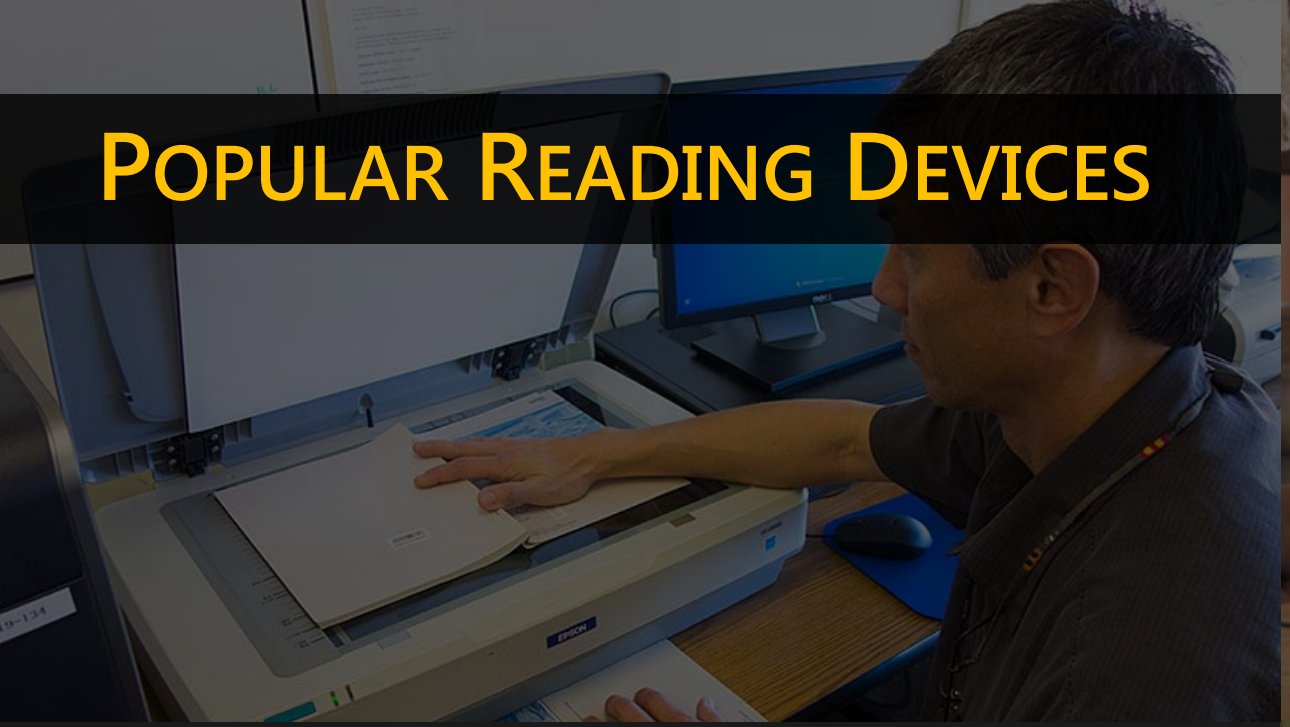

What if **printed text** could be accessed **through touch** in the same way as braille?



What if **printed text** could be accessed **through touch** in the same way as braille?

Reading printed materials is still an important but challenging task for people with **visual impairments**

Popular Reading Devices



Popular Reading Devices

Scanner | OCR | Screen Reader

Popular Reading Devices

Dedicated devices (*e.g.*, video magnifiers)

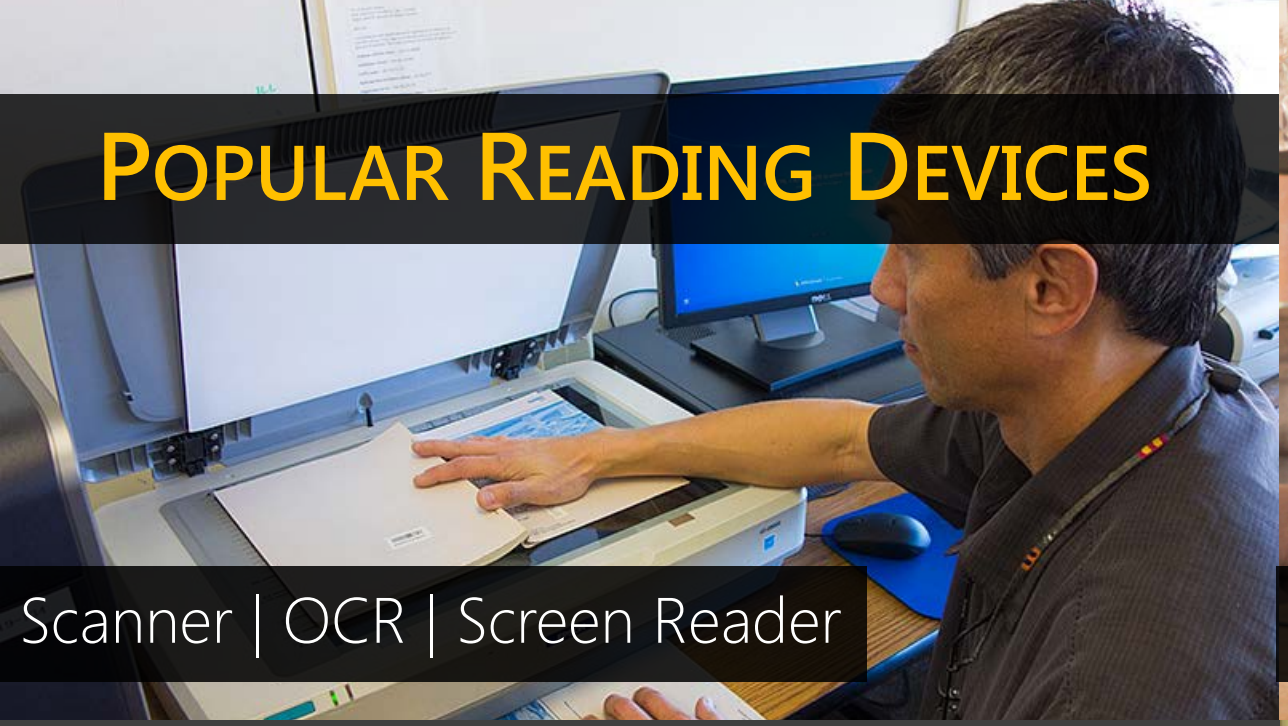
Popular Reading Devices

Smartphone apps (*e.g.,* KNFB Reader iOS)

Popular Reading Devices

Wearable Cameras (*e.g.*, OrCam)

Popular Reading Devices



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Dedicated Devices (*e.g.*, video magifiers)

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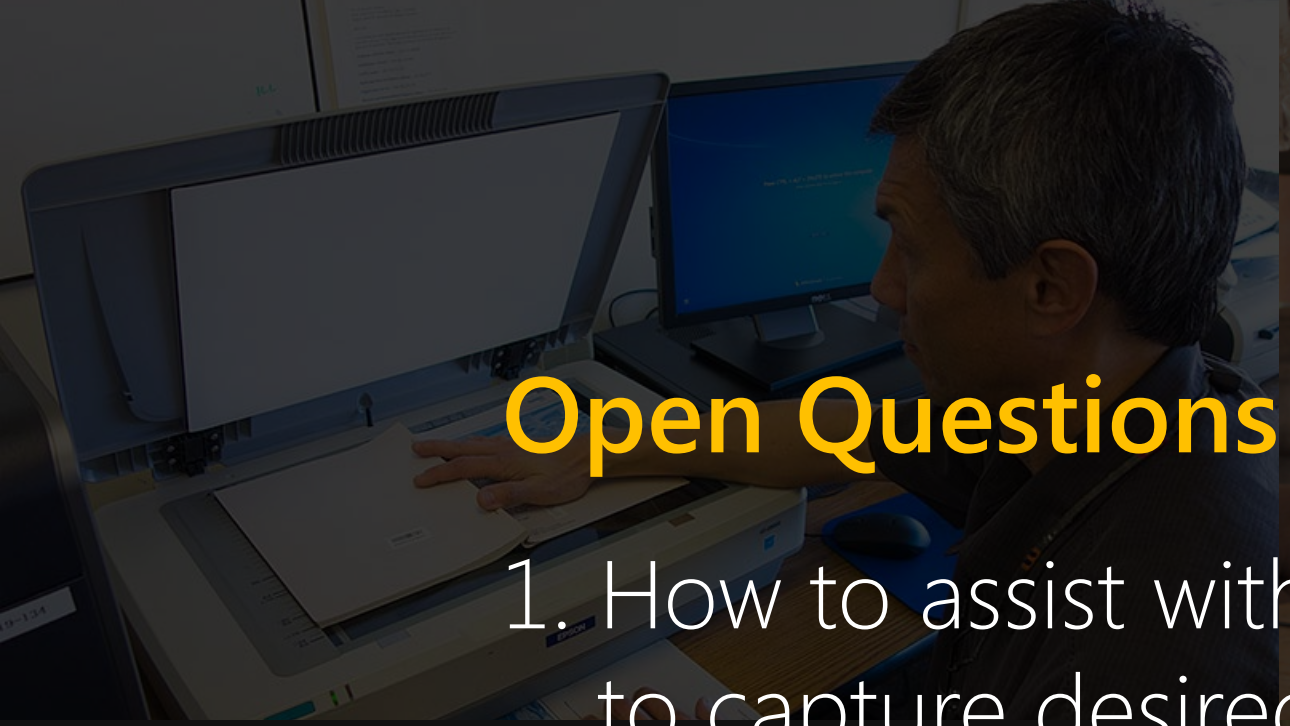
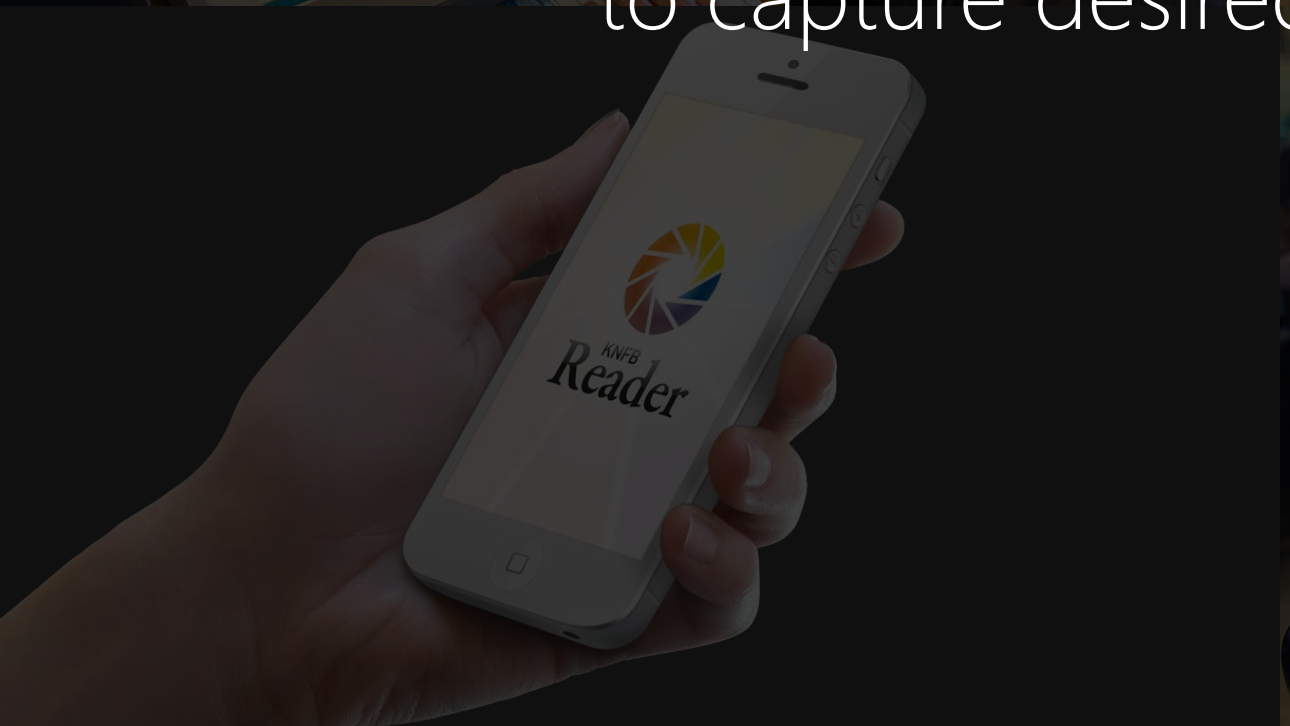
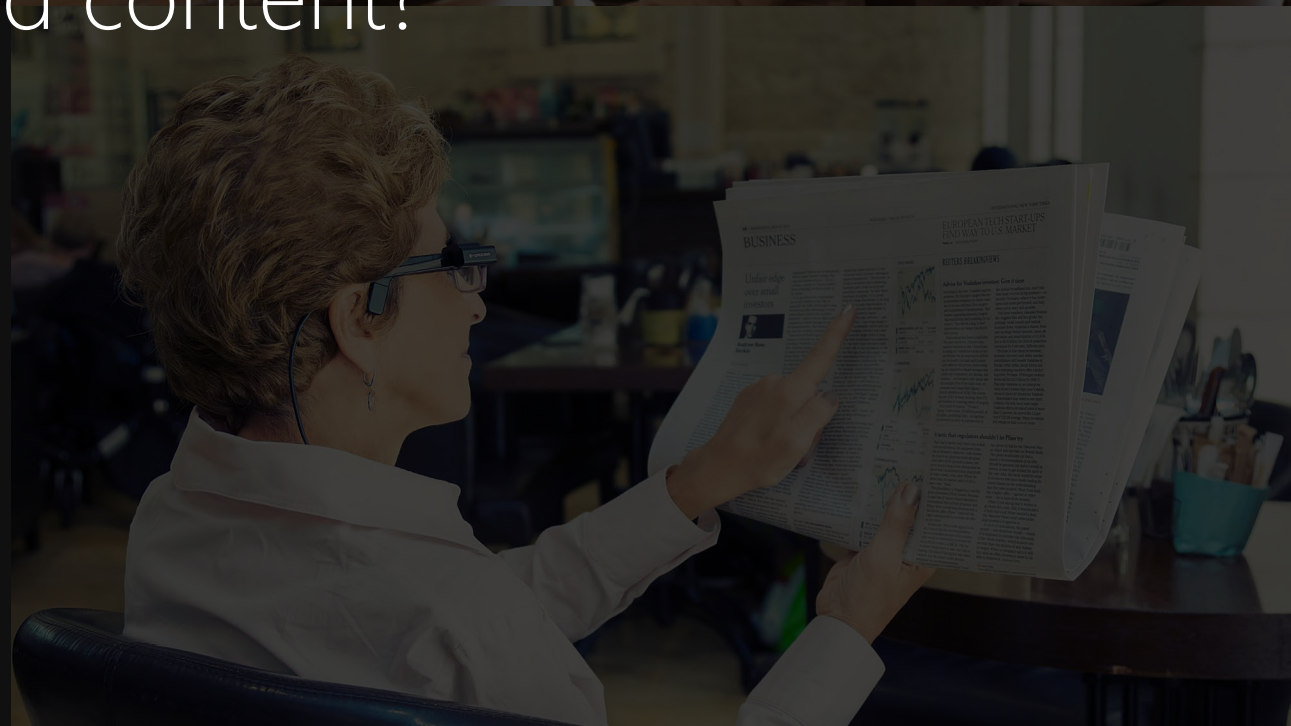
Wearable Cameras (*e.g.*, OrCam)

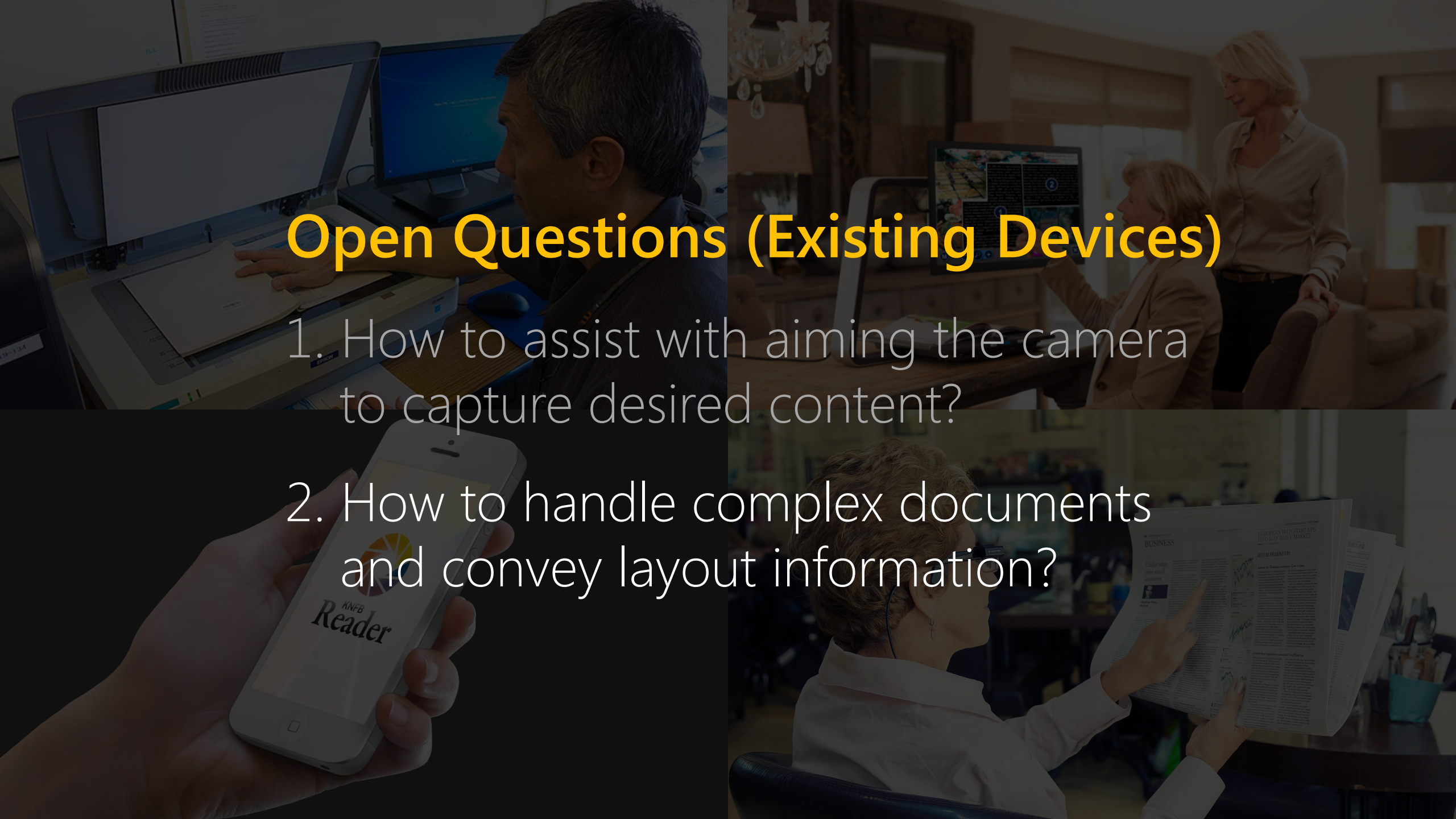
Open Questions (Existing Devices)

1. How to assist with aiming the camera to capture desired content?









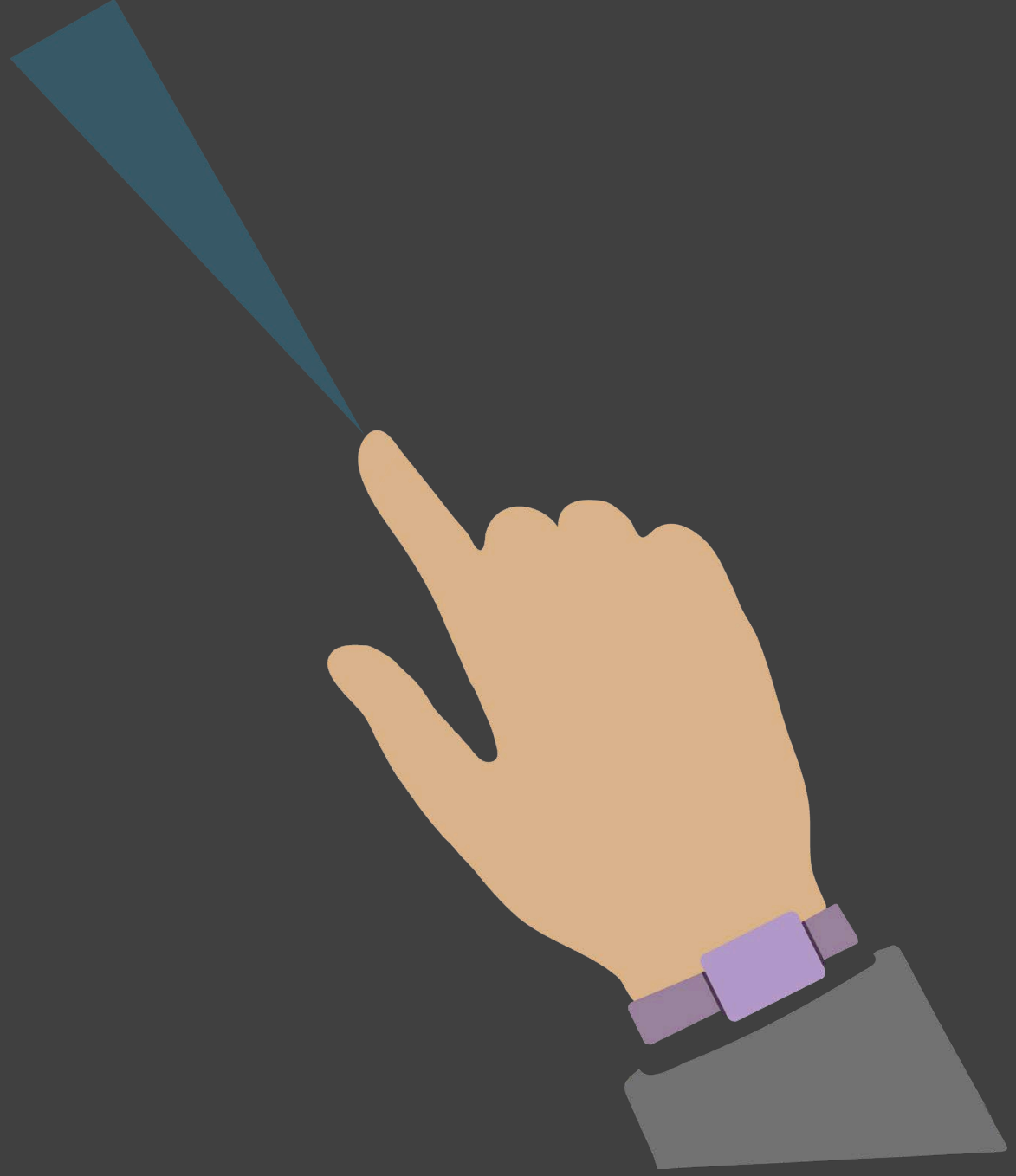
Open Questions (Existing Devices)

1. How to assist with aiming the camera to capture desired content?

2. How to handle complex documents and convey layout information?

HandSight

A vision-augmented touch system



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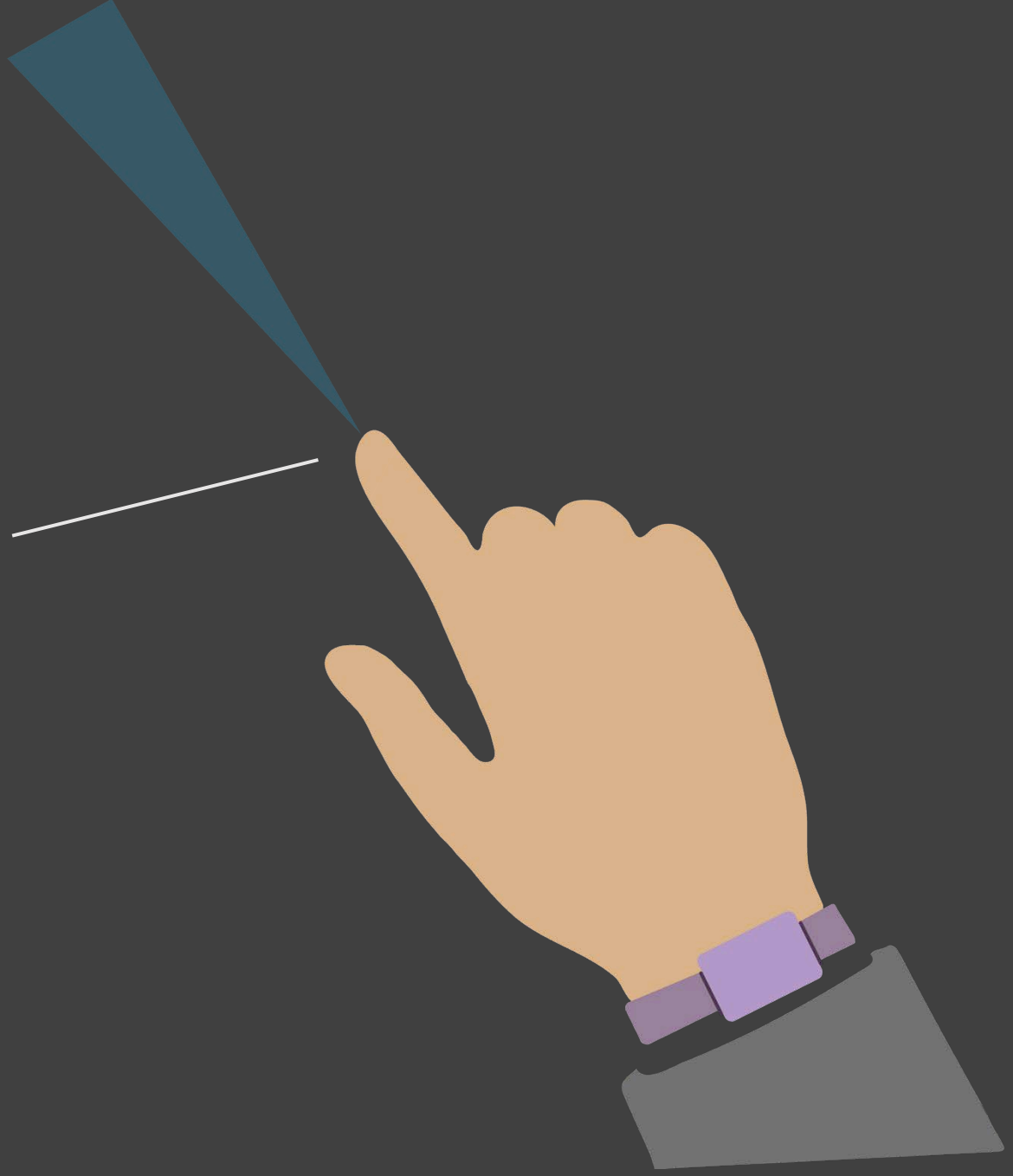
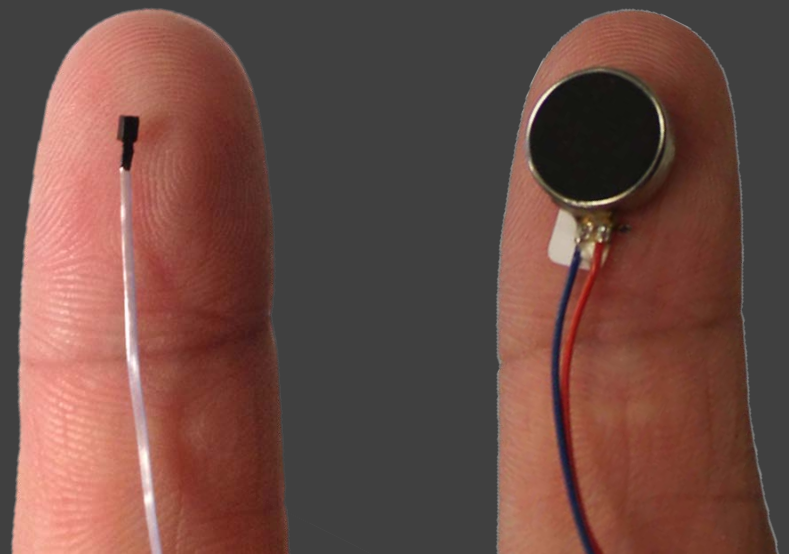


HandSight

A vision-augmented touch system

Tiny CMOS cameras,
haptic actuators mounted
on one or more fingers



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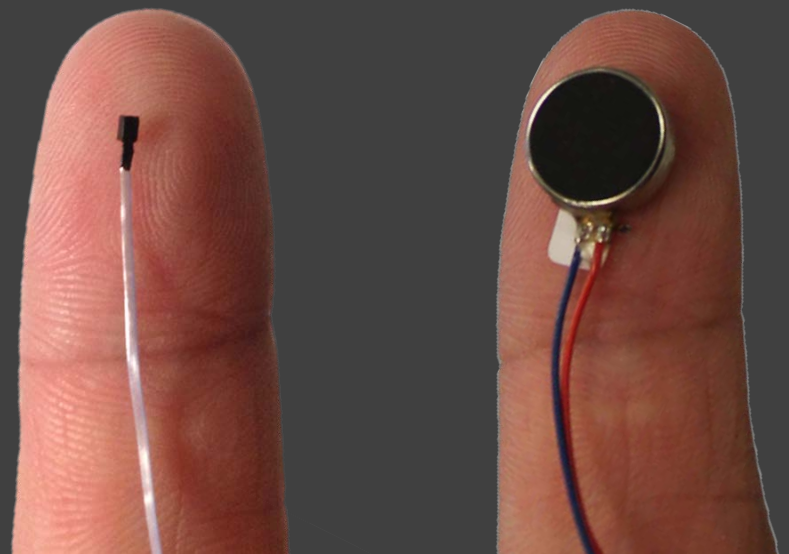
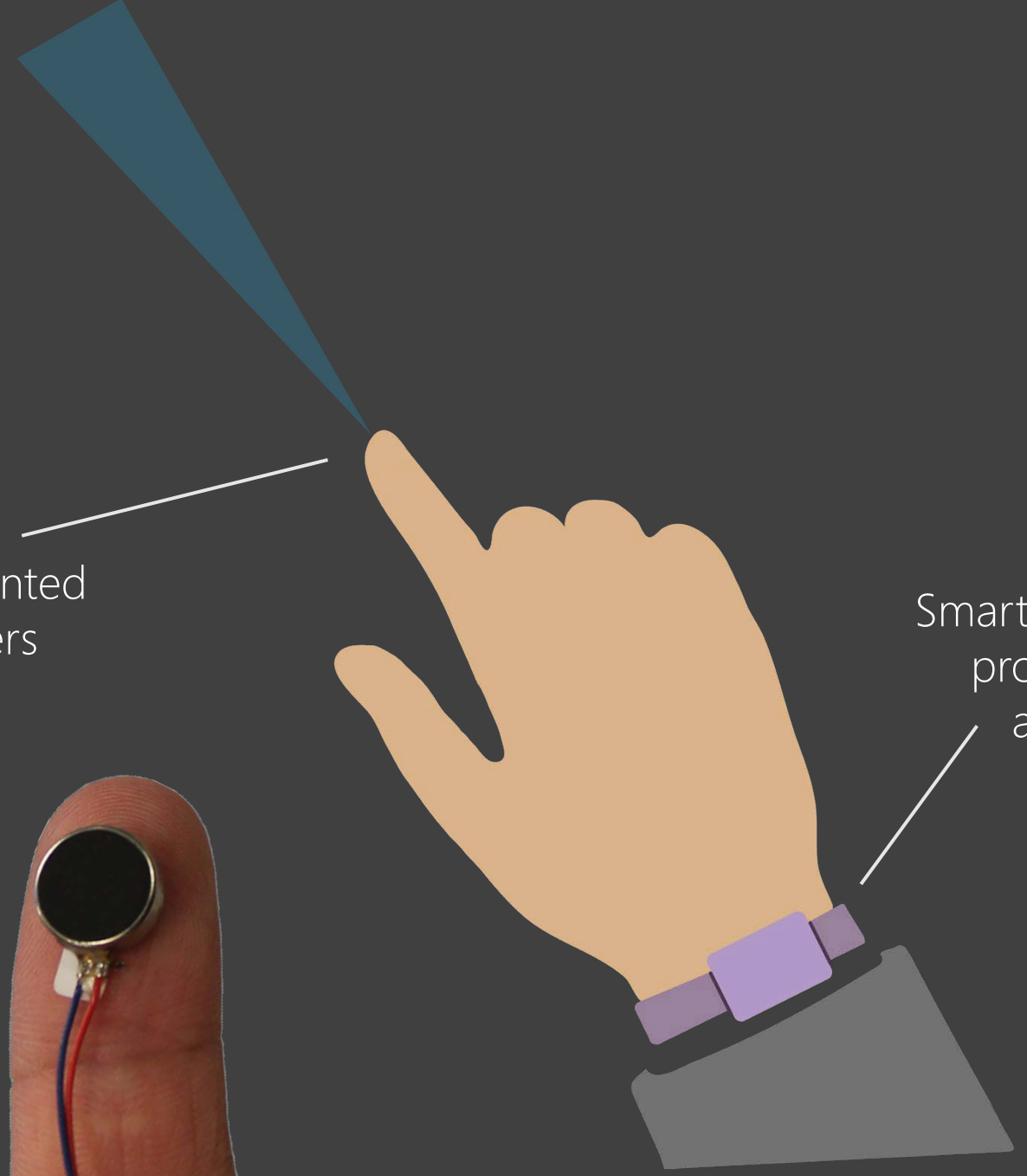




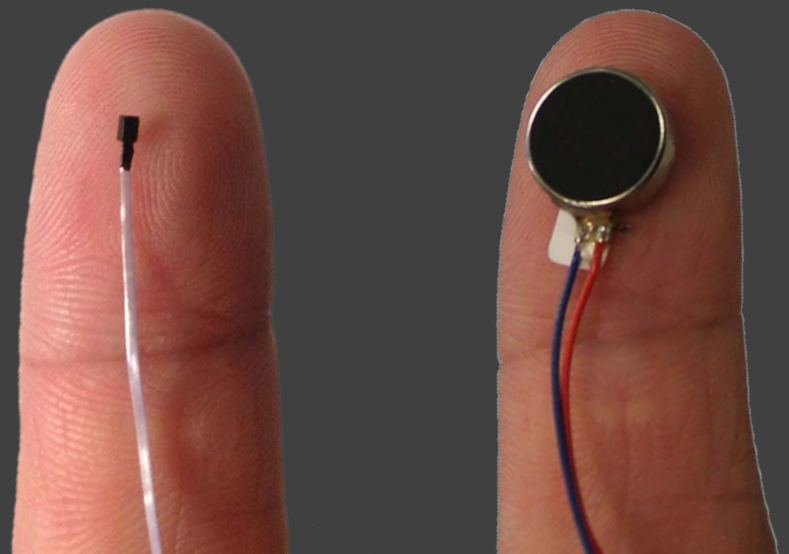
Smartwatch for power,
processing, speech
and audio output

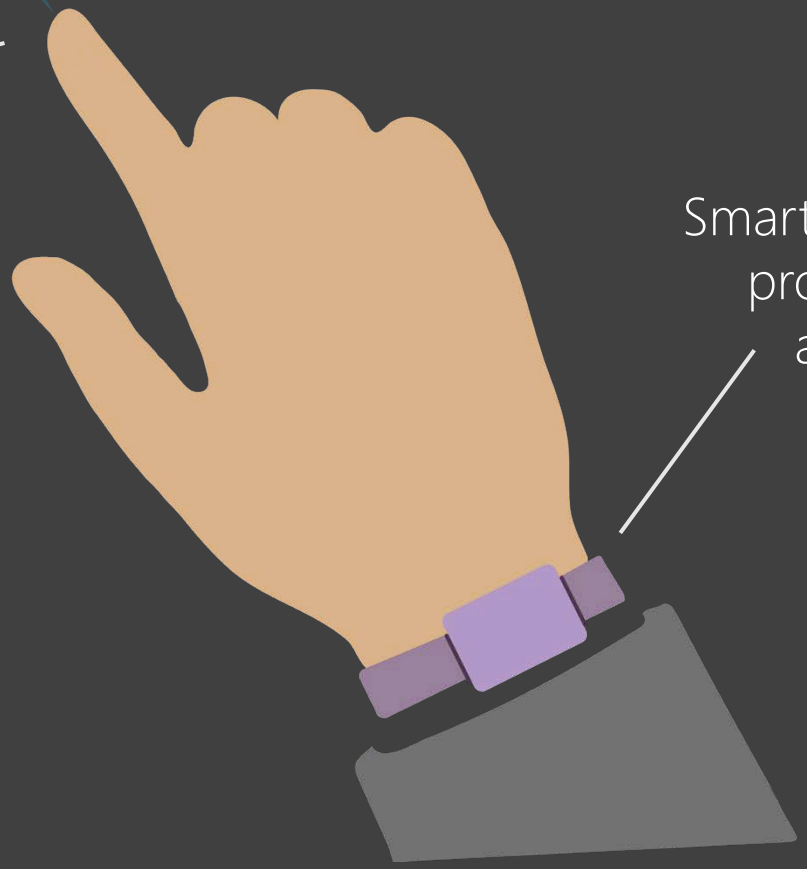
HandSight

A vision-augmented touch system

* Originally proposed in Stearns *et al.* 2014

Tiny CMOS cameras, haptic actuators mounted on one or more fingers

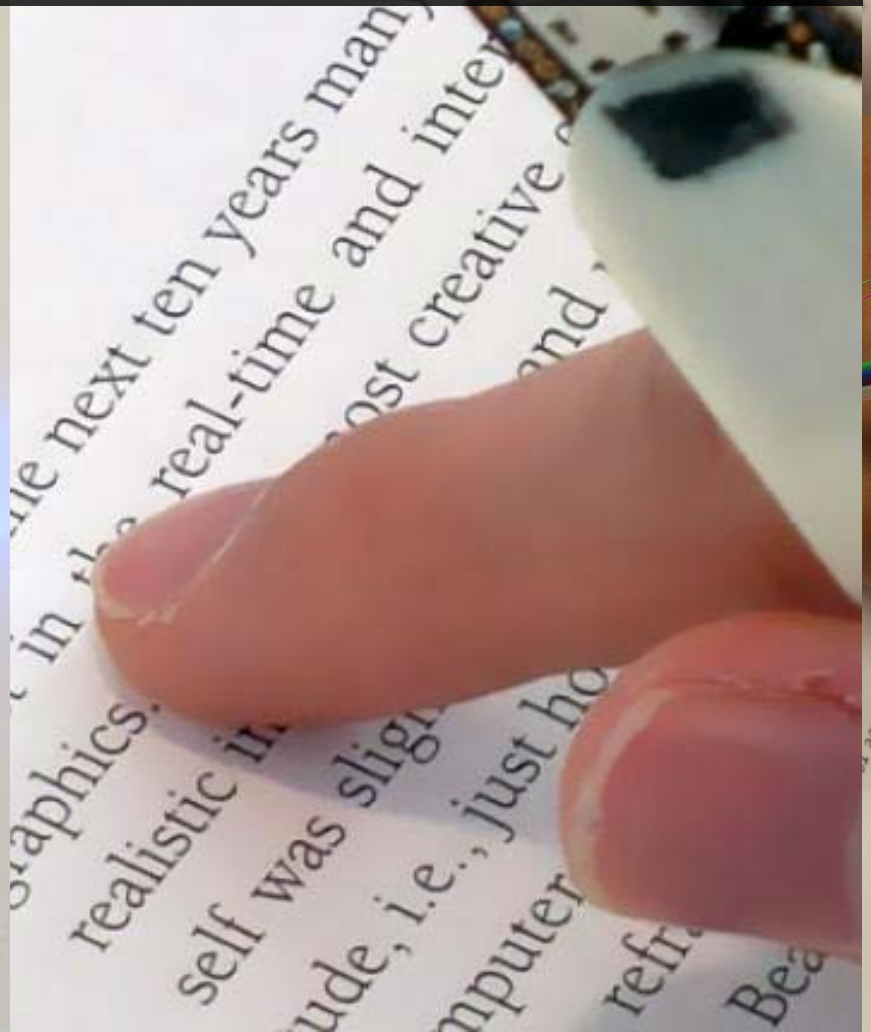


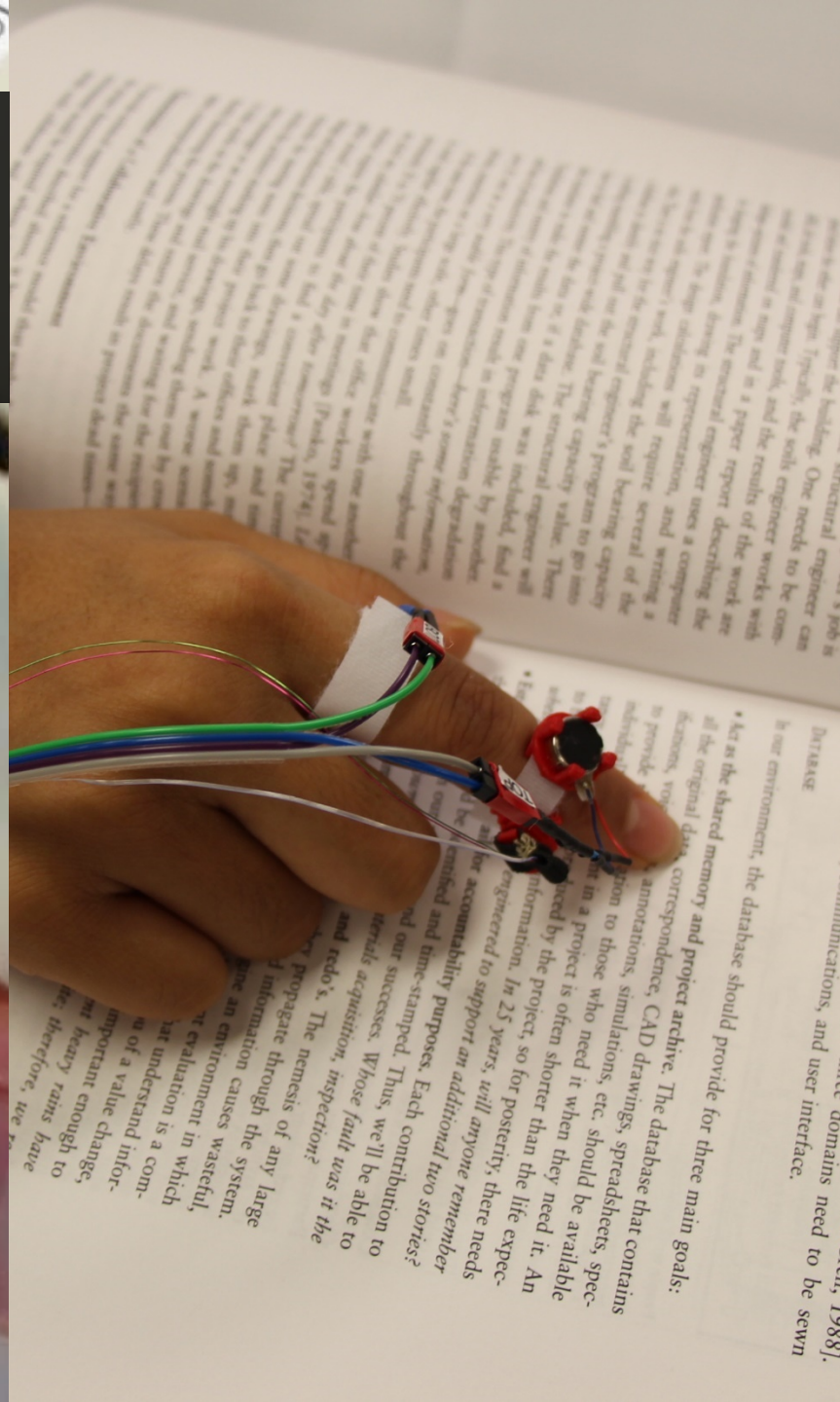


Smartwatch for power, processing, speech and audio output

Augmenting the User's Finger

Survey: Digital Digits (Shilkrot *et al.* 2015)





Augmenting the User's Finger

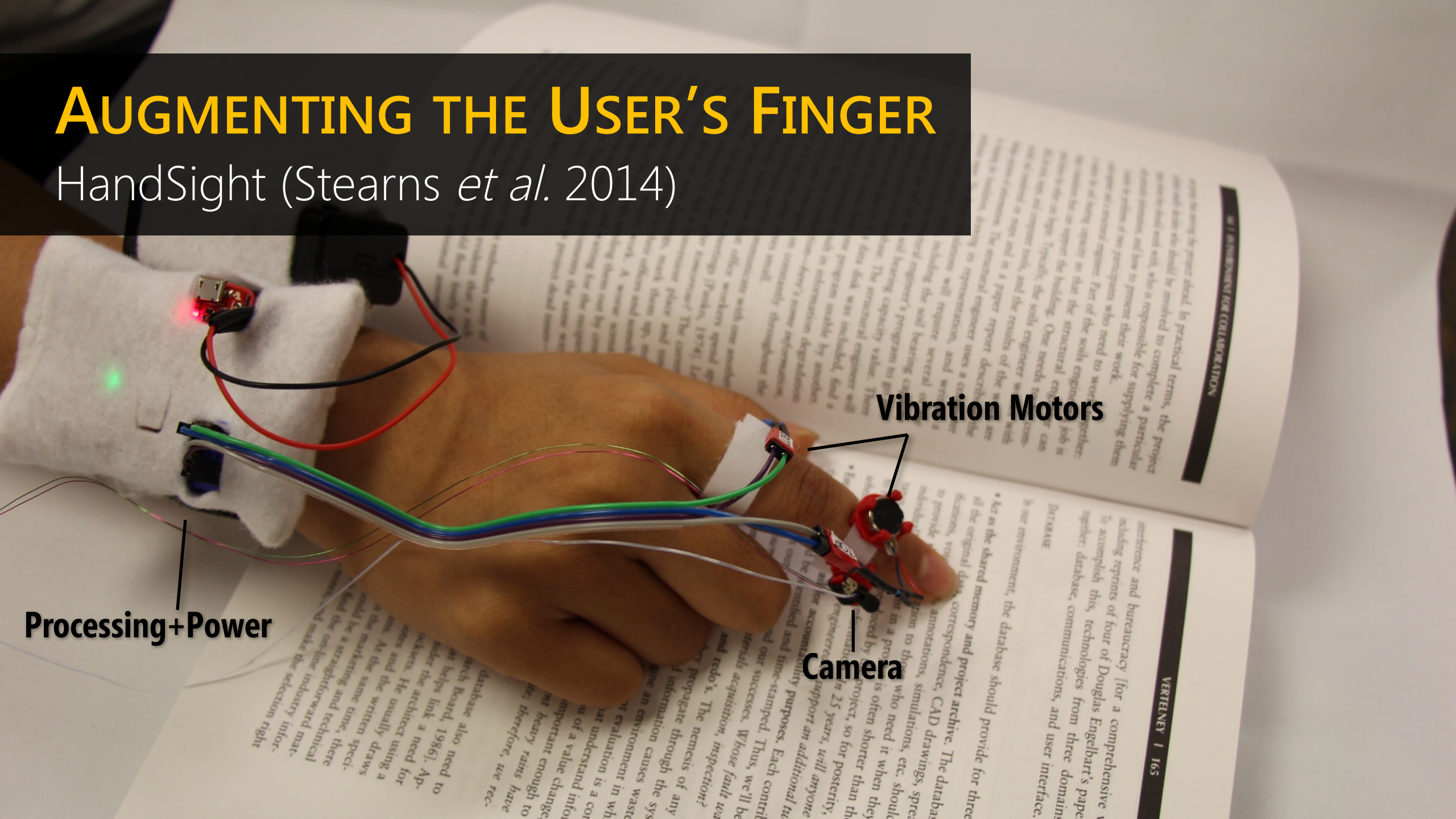
Magic Finger (Yang *et al.* 2012)

Augmenting the User's Finger

FingerReader (Shilkrot *et al.* 2014, 2015)

Augmenting the User's Finger

HandSight (Stearns *et al.* 2014)



Advantages of Finger-Based Reading

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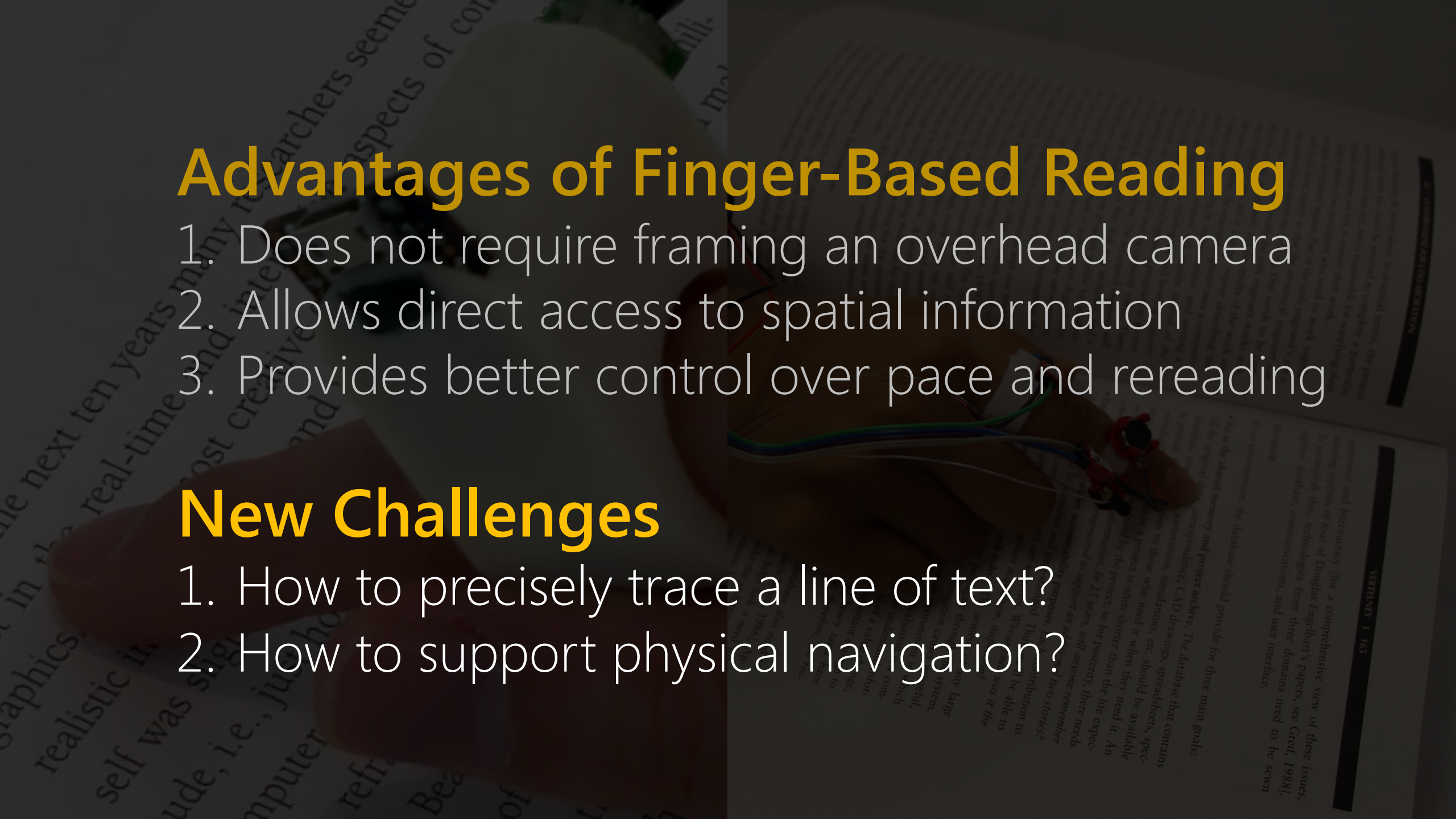

Advantages of Finger-Based Reading

1. Does not require framing an overhead camera
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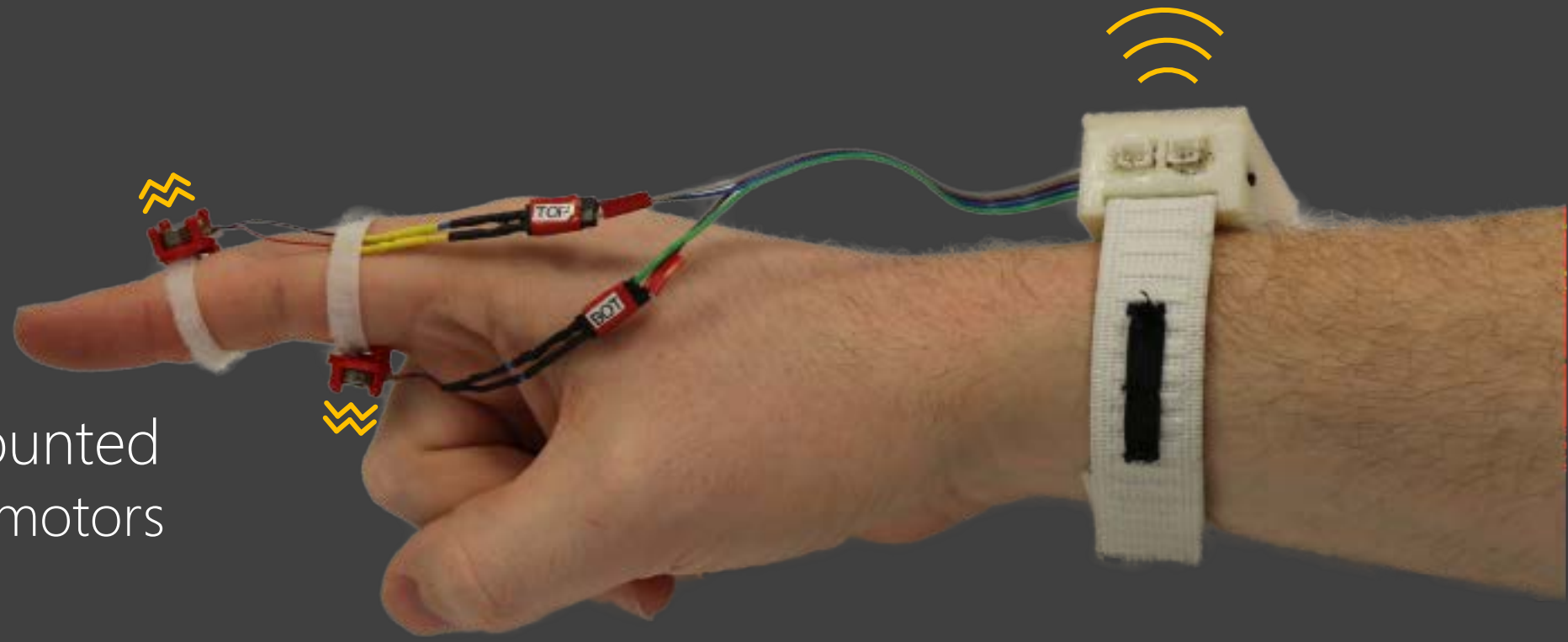
New Challenges

1. How to precisely trace a line of text?
2. How to support physical navigation?

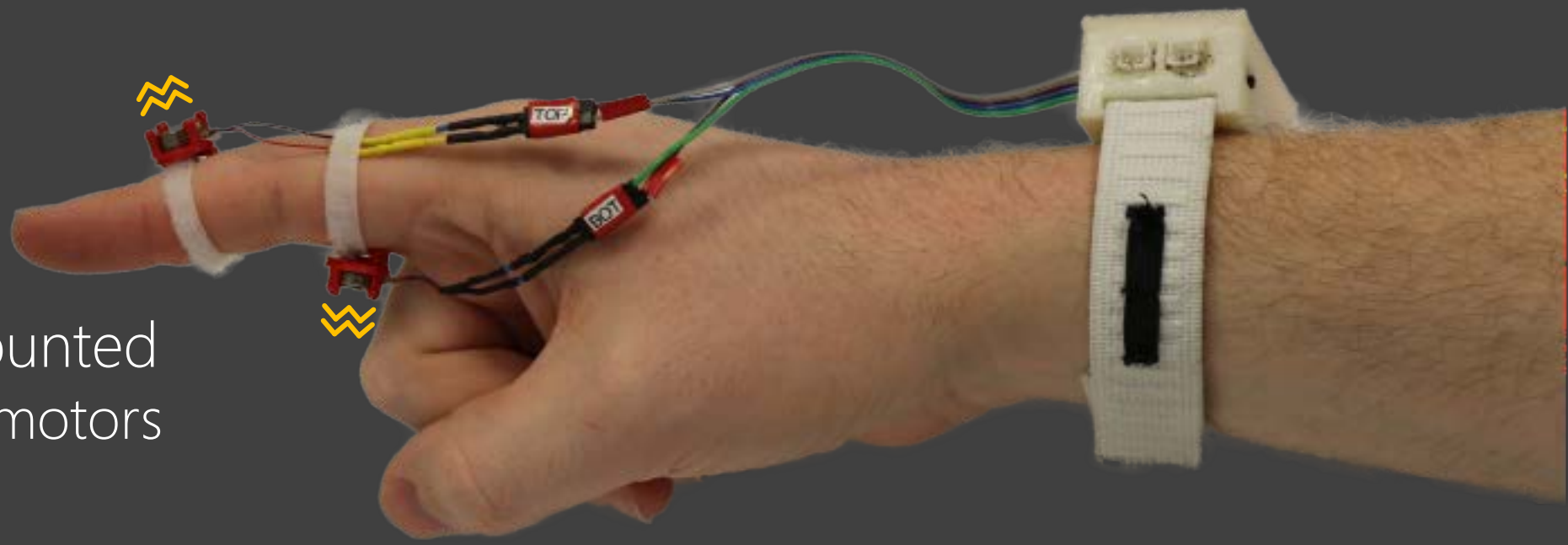
Comparing Two Types of Directional Finger Guidance

2. **Audio** via built-in or external speakers



1. Finger-mounted **vibration** motors

Comparing Two Types of Directional Finger Guidance



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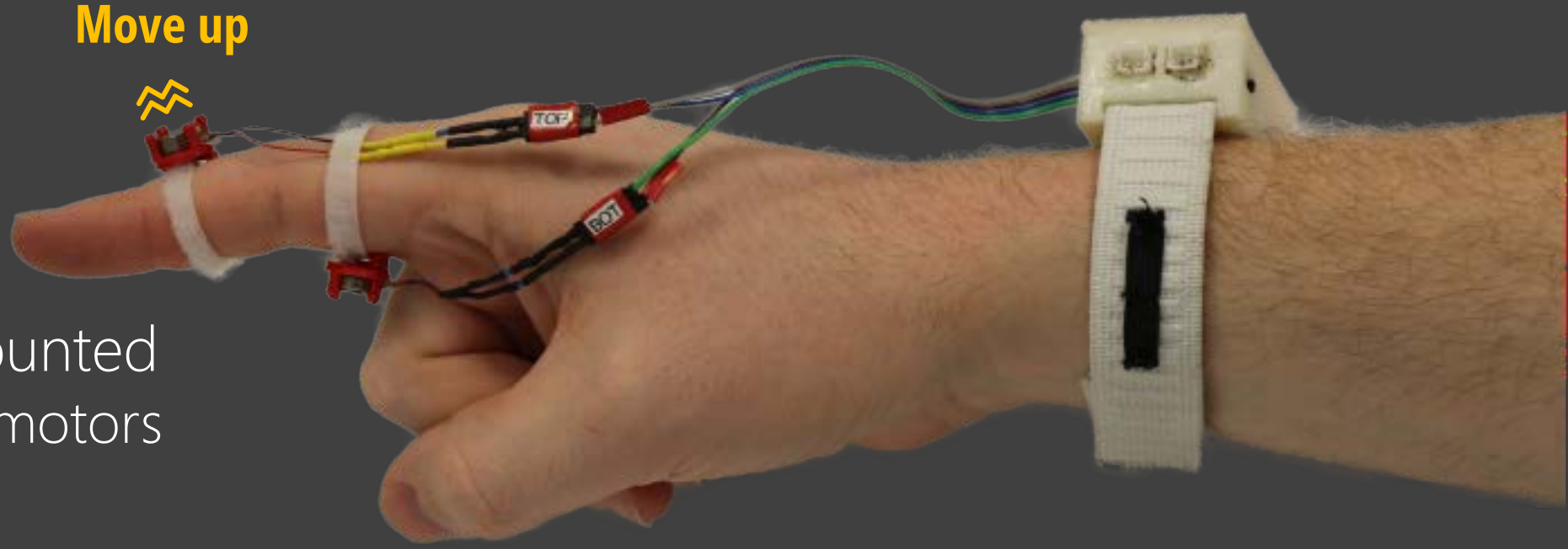

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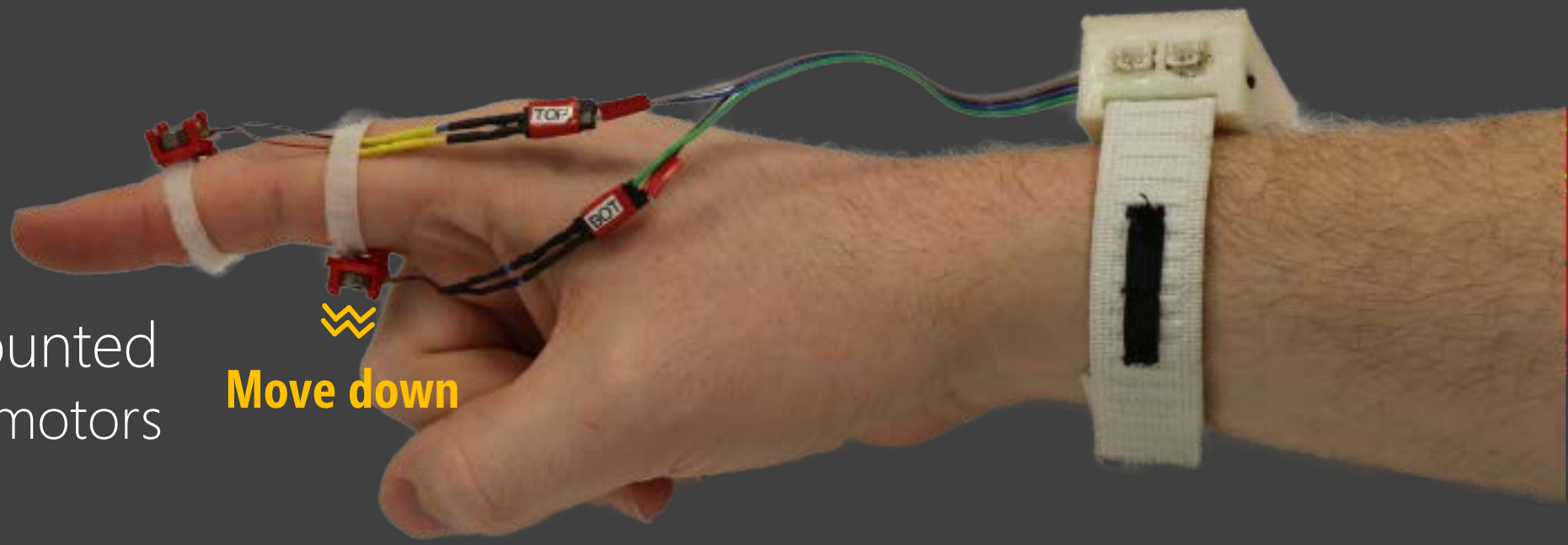

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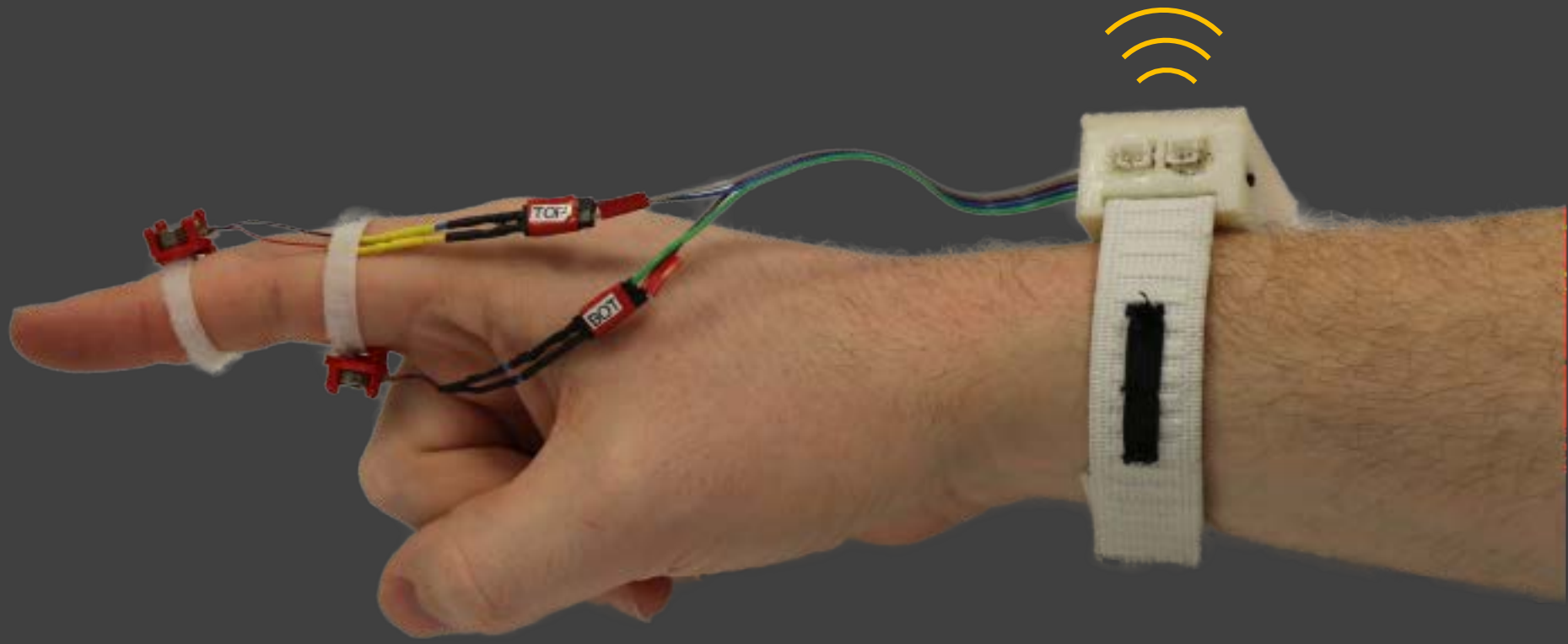
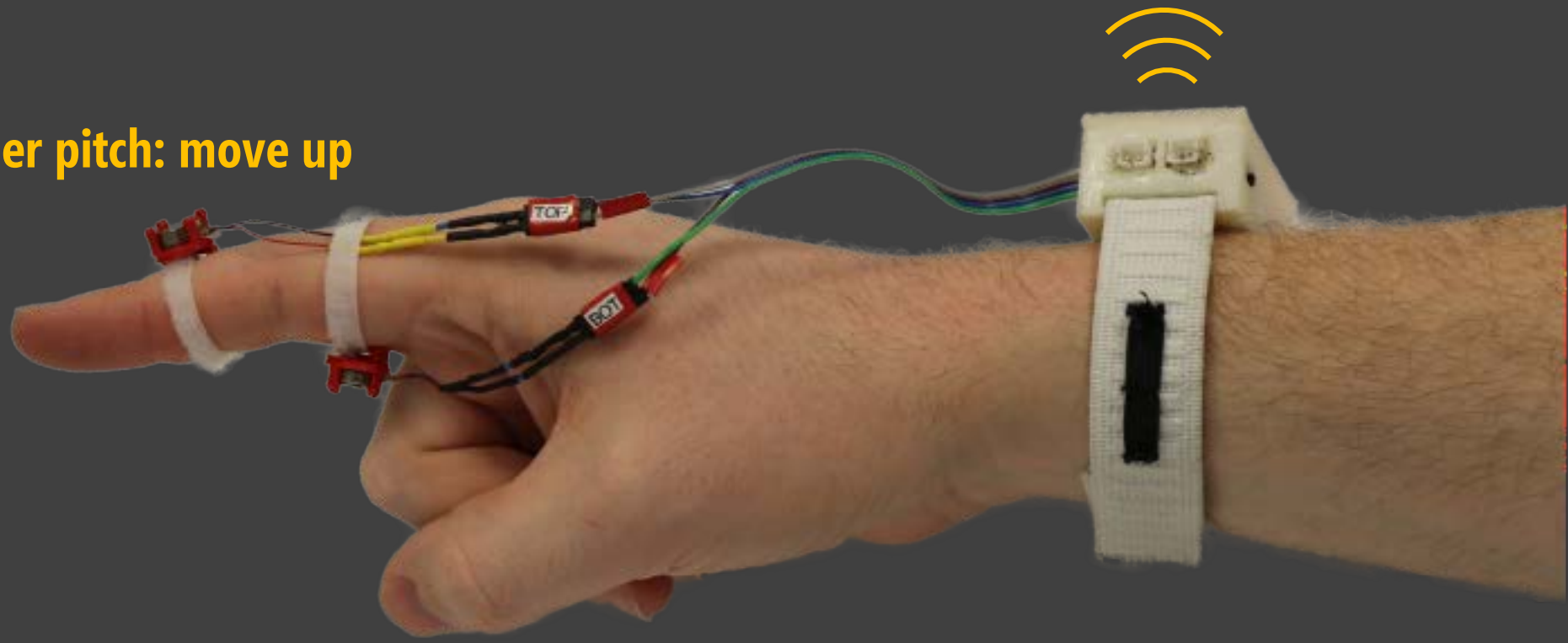


Comparing Two Types of Directional Finger Guidance

2. **Audio** via built-in or external speakers

Higher pitch: move up



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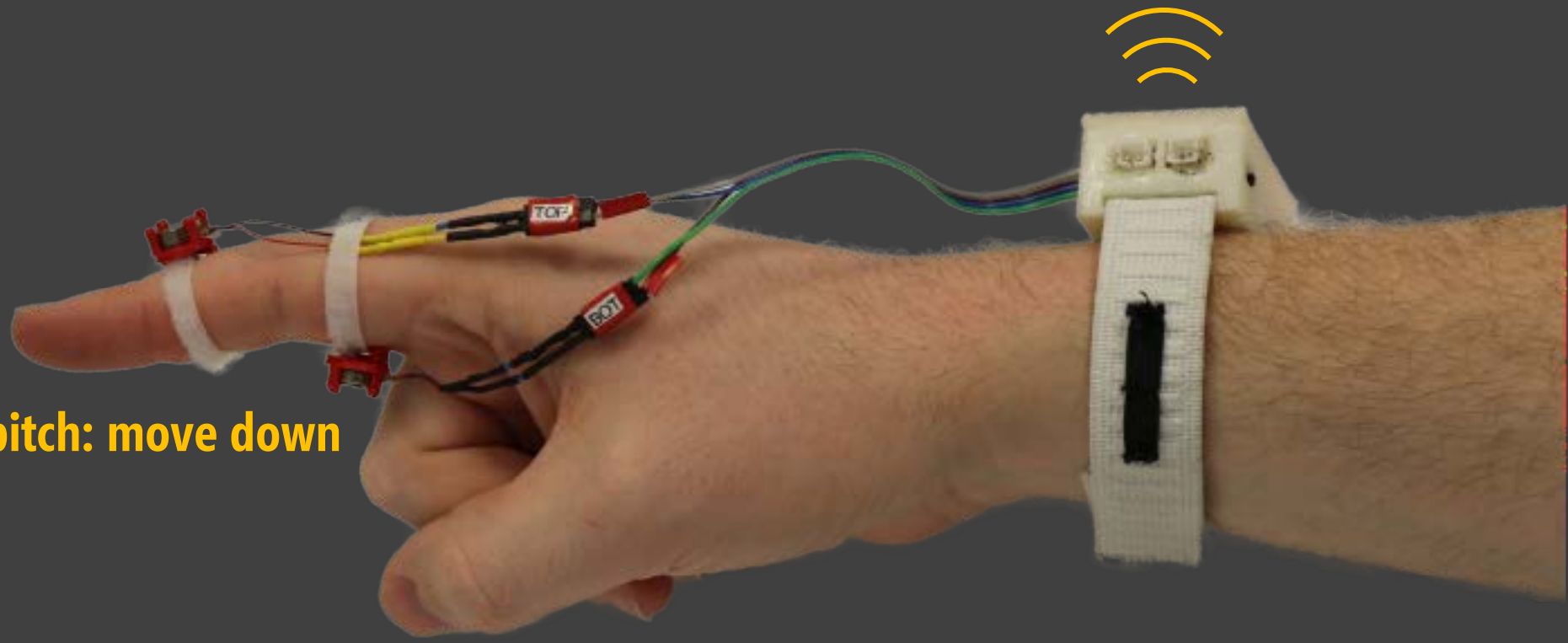
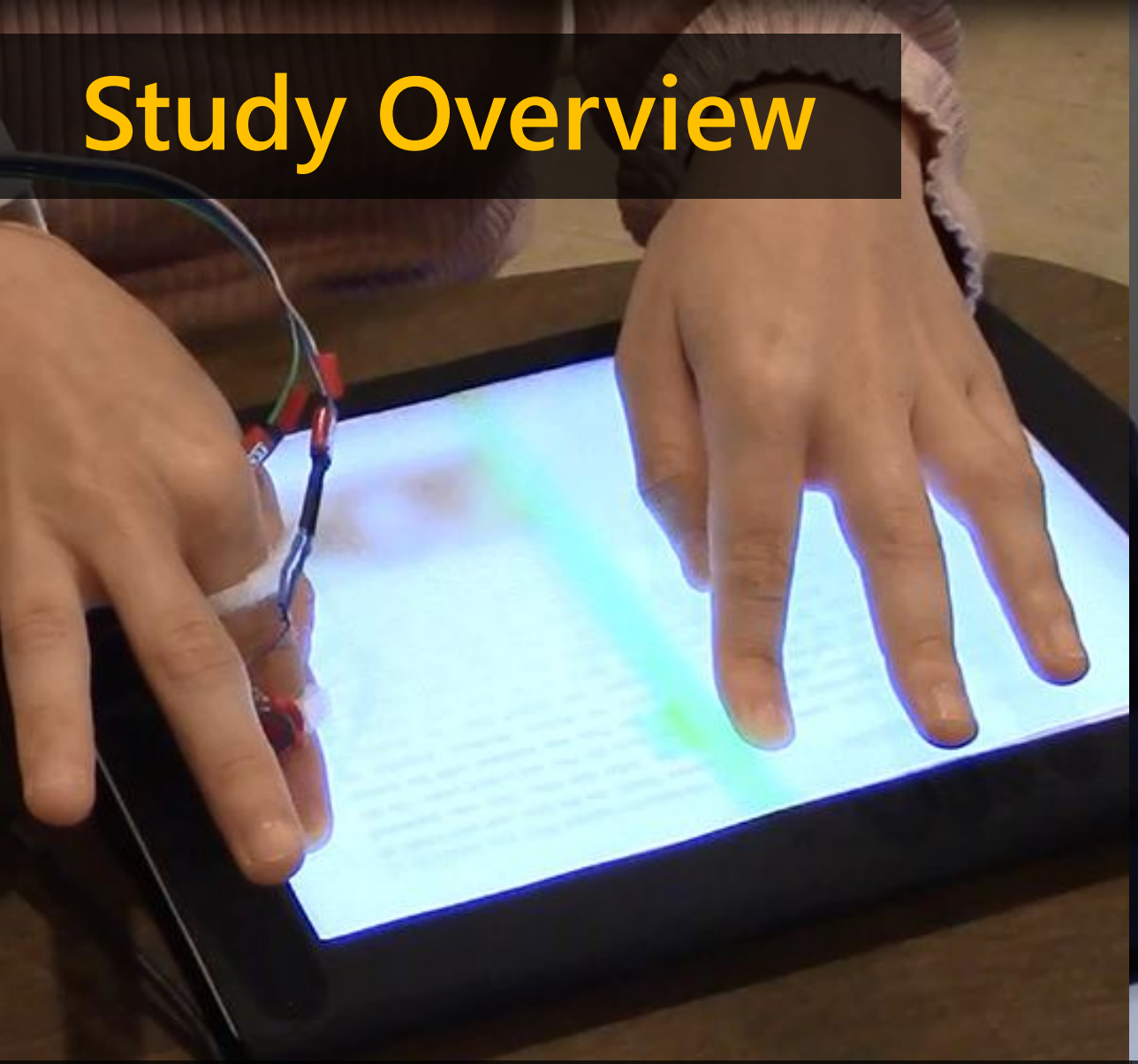


Lower pitch: move down

Research Questions

1. To what extent are finger-based cameras a viable accessibility solution for reading printed text?
2. What design choices can improve this viability?

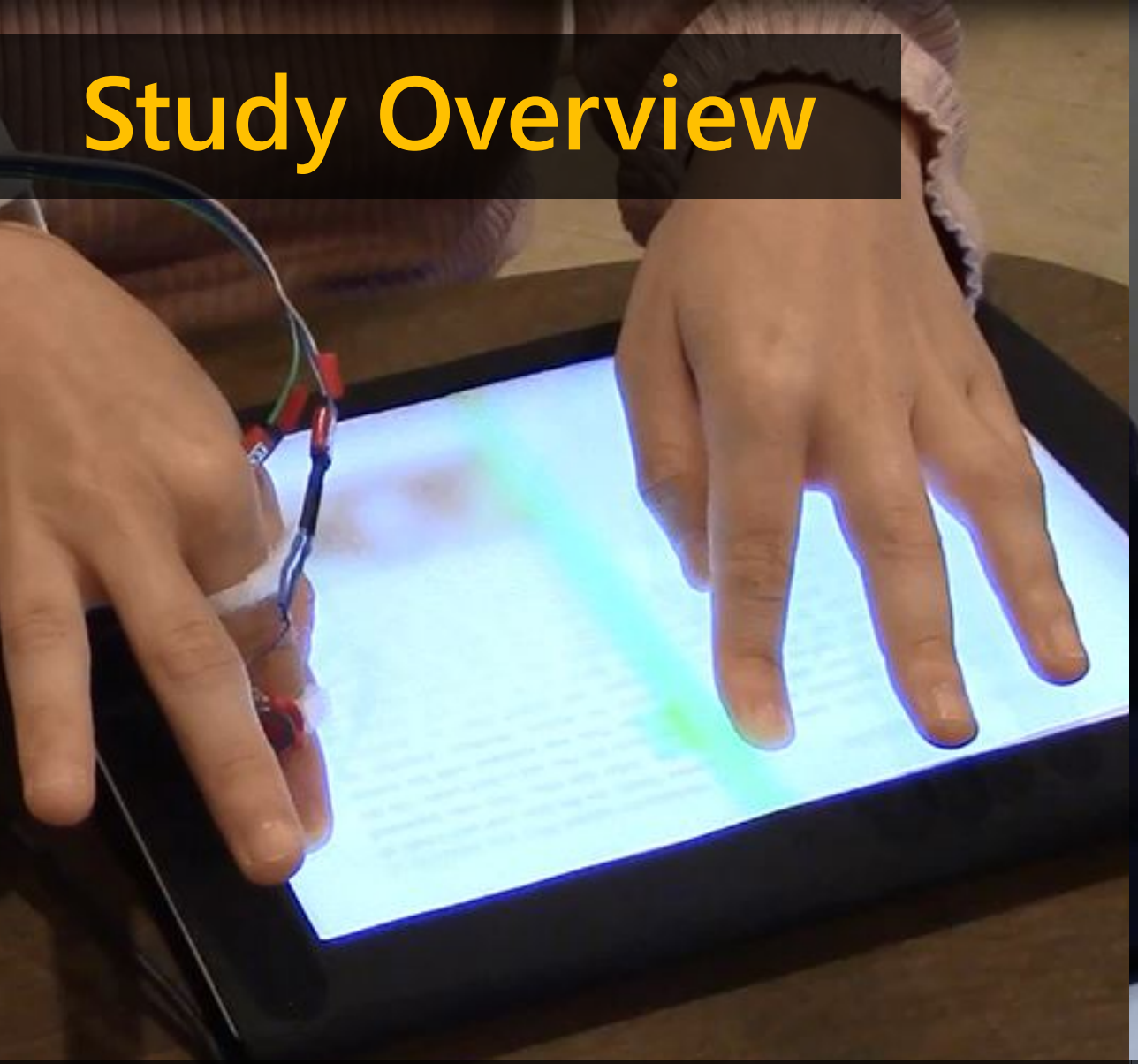
Study Overview



Study I: initial iPad study (19 participants)

Study II: physical prototype study (4 participants)

Study Overview



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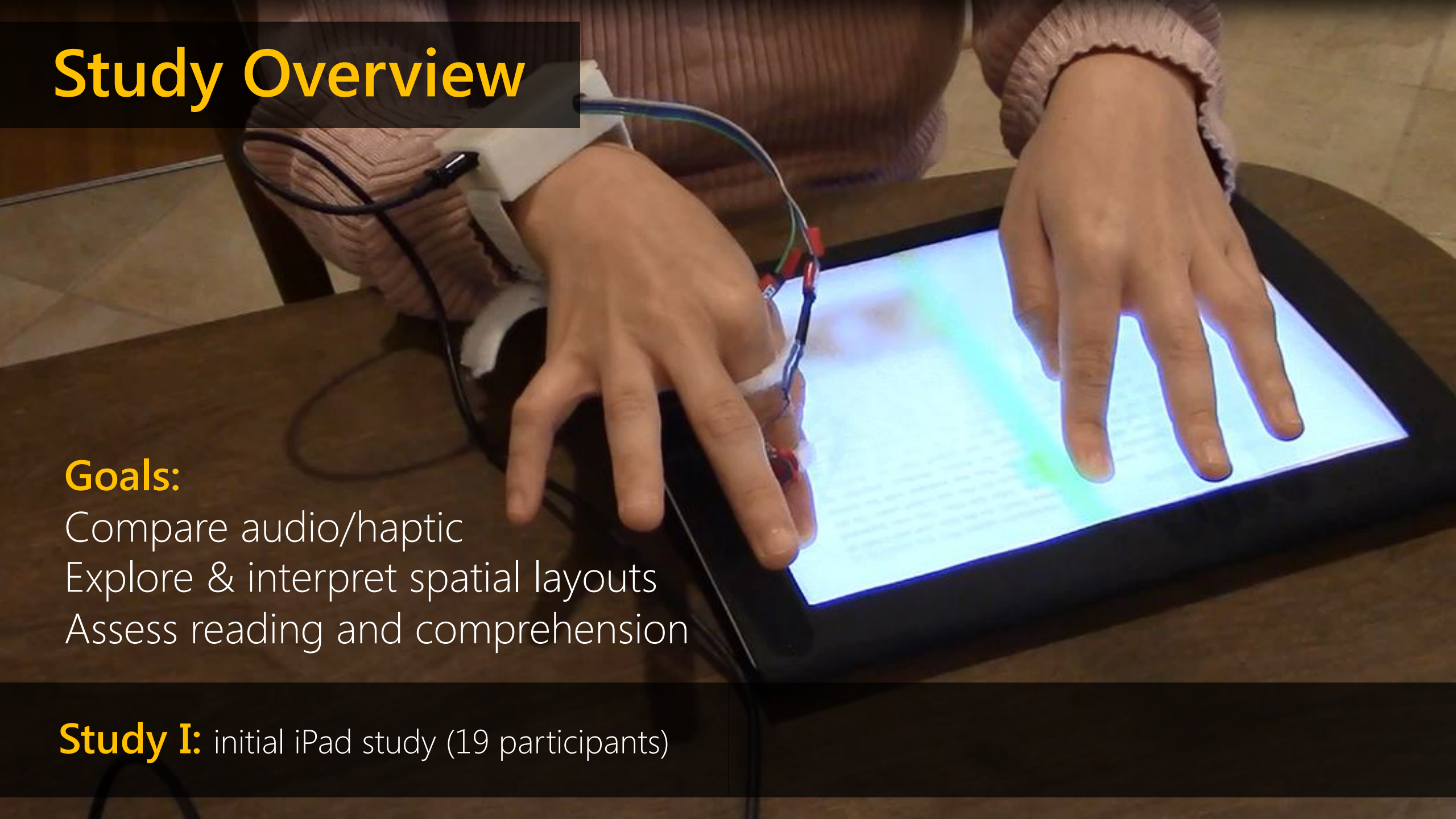


Goals:

Compare audio/haptic

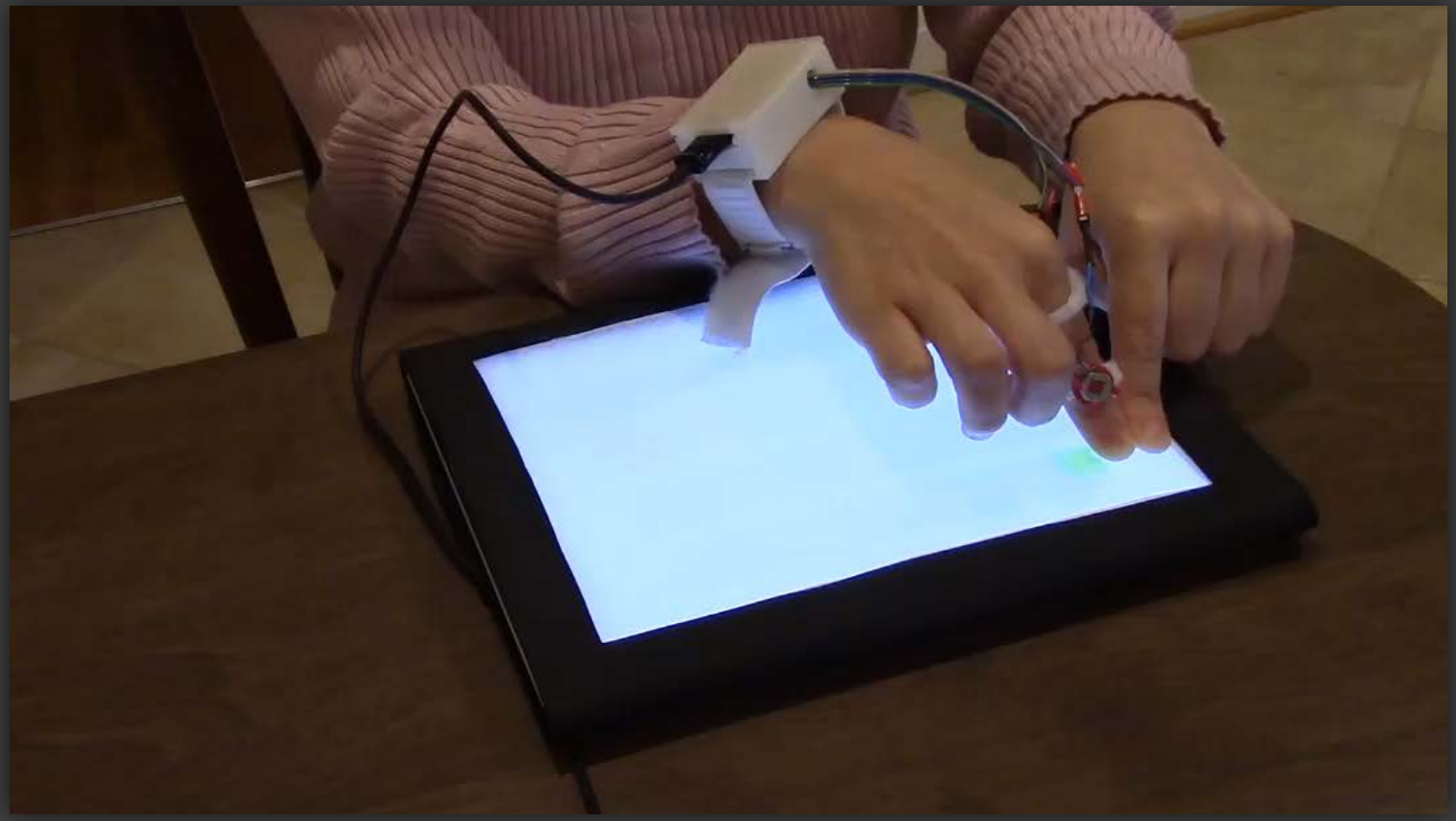
Explore & interpret spatial layouts

Assess reading and comprehension

Study I: initial iPad study (19 participants)

Study I Method

Used an iPad to focus on **user experience**, gather **finger trace** data



Study I Method

Used an iPad to focus on user experience, gather finger trace data

19 participants

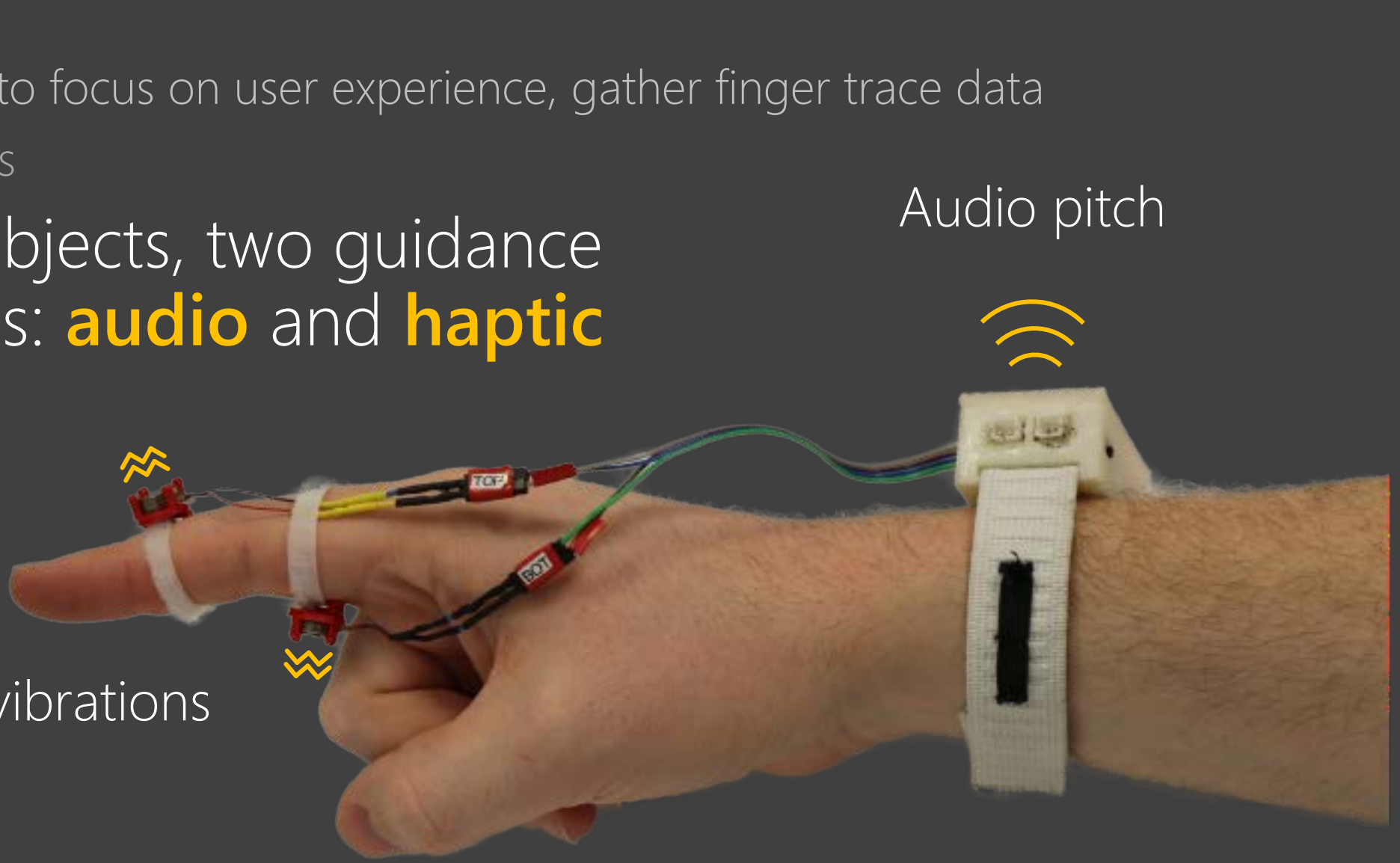
Median Age	48 (*SD*=12, *Range*=26-67)
Gender	11 Male, 8 Female
Vision Level	10 Totally Blind, 9 Light Sensitive

Study I Method

Used an iPad to focus on user experience, gather finger trace data

19 participants

Within-subjects, two guidance conditions: **audio** and **haptic**



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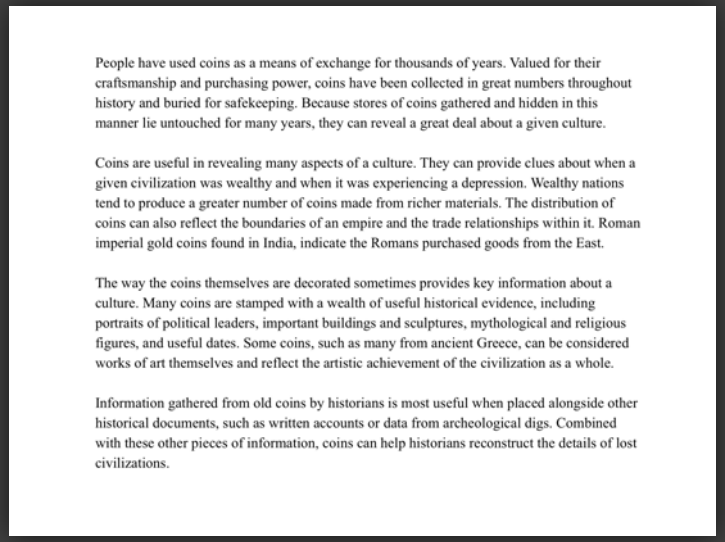
Participants read **two documents** for each condition



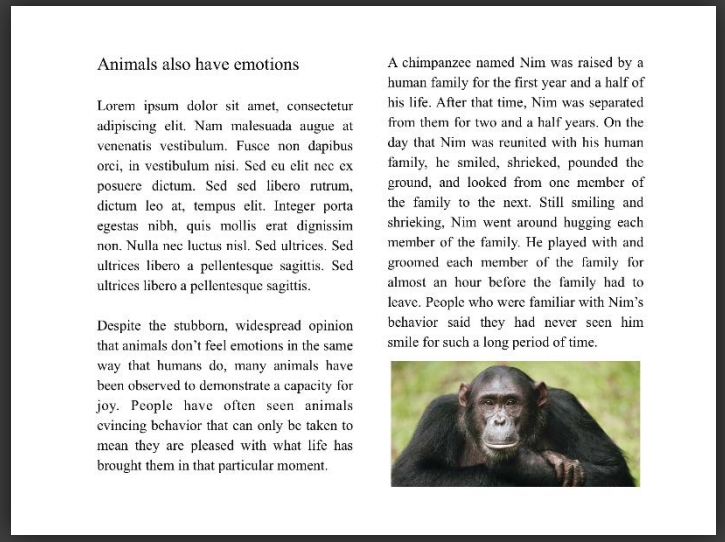
People have used coins as a means of exchange for thousands of years. Valued for their craftsmanship and purchasing power, coins have been collected in great numbers throughout history and buried for safekeeping. Because stores of coins gathered and hidden in this manner lie untouched for many years, they can reveal a great deal about a given culture.

Coins are useful in revealing many aspects of a culture. They can provide clues about when a given civilization was wealthy and when it was experiencing a depression. Wealthy nations tend to produce a greater number of coins made from richer materials. The distribution of coins can also reflect the boundaries of an empire and the trade relationships within it. Roman imperial gold coins found in India, indicate the Romans purchased goods from the East.

The way the coins themselves are decorated sometimes provides key information about a culture. Many coins are stamped with a wealth of useful historical evidence, including portraits of political leaders, important buildings and sculptures, mythological and religious figures, and useful dates. Some coins, such as many from ancient Greece, can be considered works of art themselves and reflect the artistic achievement of the civilization as a whole.

Information gathered from old coins by historians is most useful when placed alongside other historical documents, such as written accounts or data from archeological digs. Combined with these other pieces of information, coins can help historians reconstruct the details of lost civilizations.

plain



Animals also have emotions

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Despite the stubborn, widespread opinion that animals don't feel emotions in the same way that humans do, many animals have been observed to demonstrate a capacity for joy. People have often seen animals evincing behavior that can only be taken to mean they are pleased with what life has brought them in that particular moment.

A chimpanzee named Nim was raised by a human family for the first year and a half of his life. After that time, Nim was separated from them for two and a half years. On the day that Nim was reunited with his human family, he smiled, shrieked, pounded the ground, and looked from one member of the family to the next. Still smiling and shrieking, Nim went around hugging each member of the family. He played with and groomed each member of the family for almost an hour before the family had to leave. People who were familiar with Nim's behavior said they had never seen him smile for such a long period of time.

magazine

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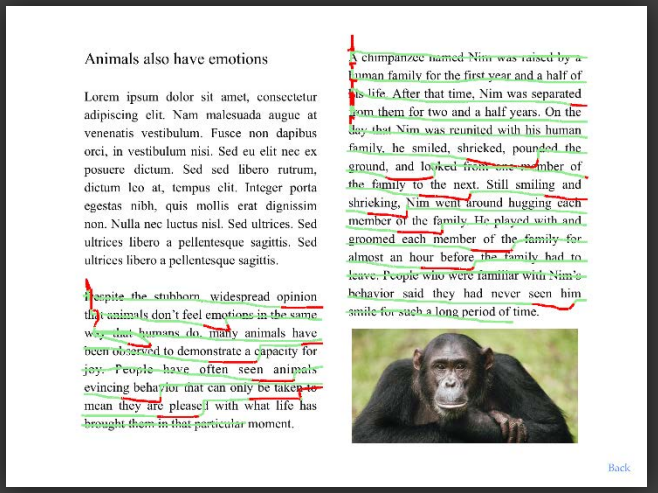
19 participants

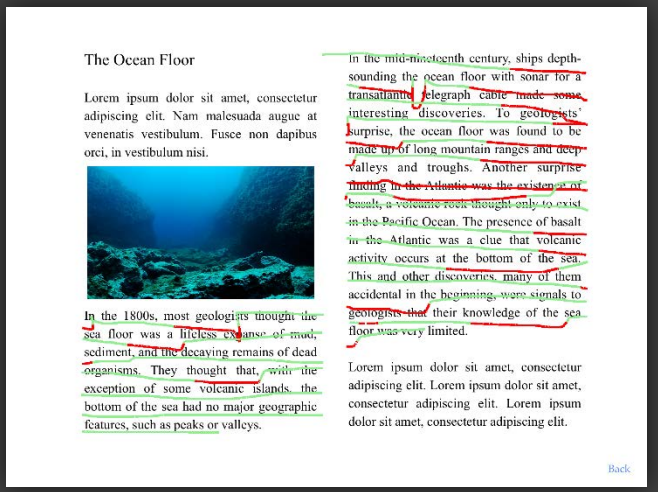
Within-subject, two guidance conditions: audio and haptic

Participants read two documents for each condition

Analysis: reading **speed** and **accuracy**, **comprehension**, subjective **feedback**

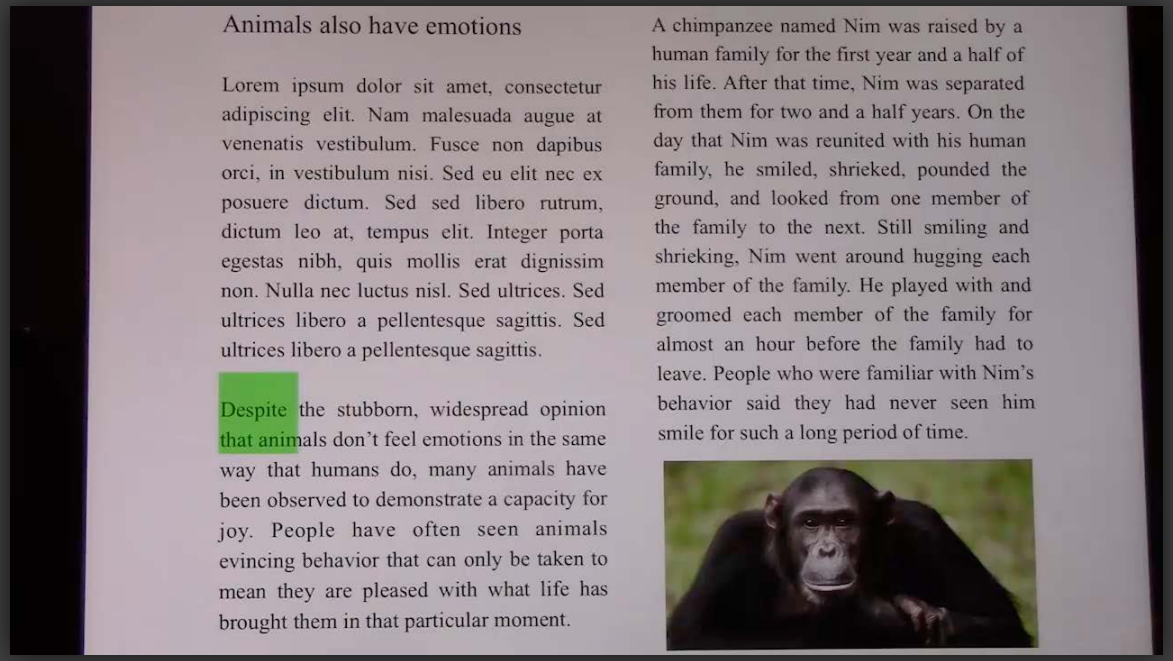


audio



haptic

System Design: Exploration and Reading Modes



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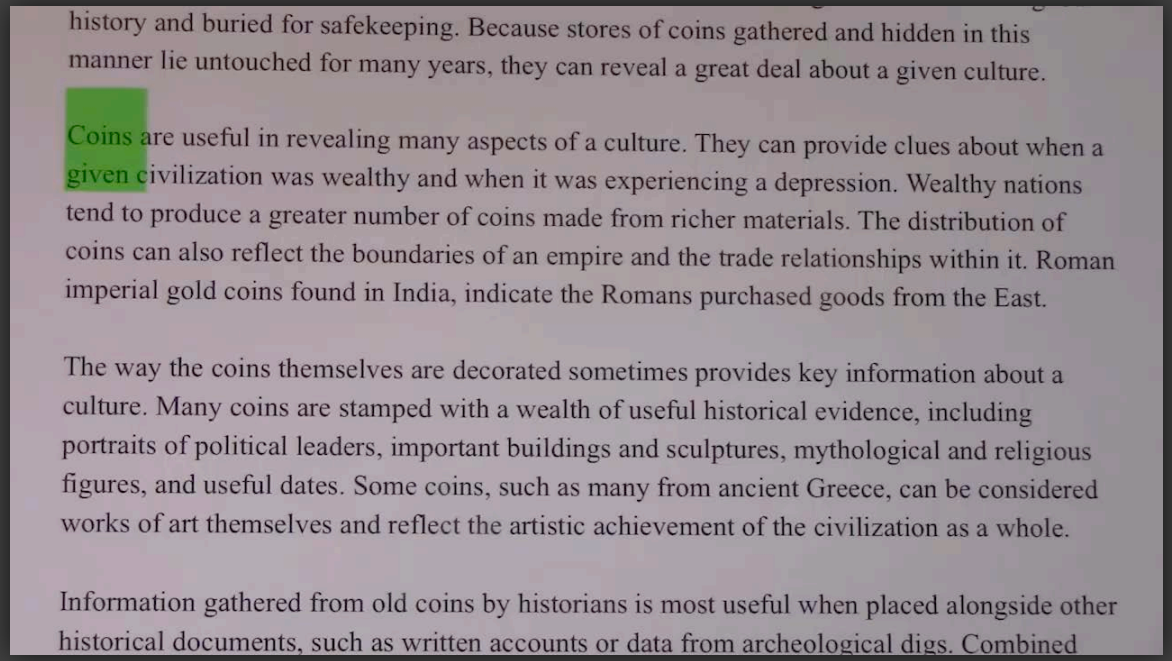
Exploration Mode



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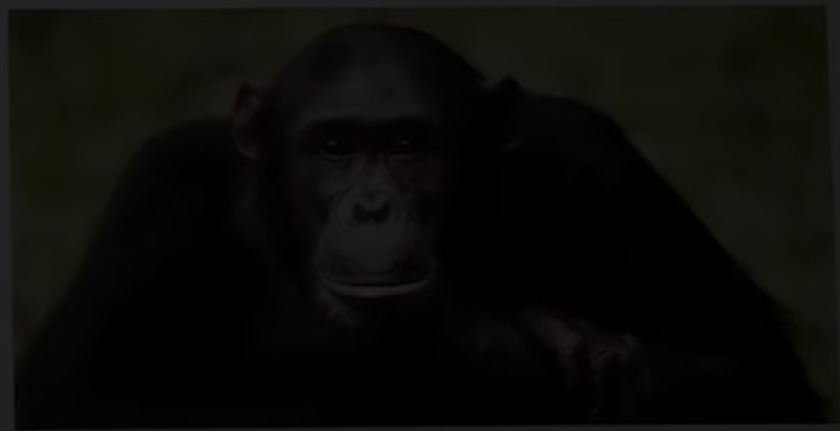
Reading Mode

System Design: Exploration Mode

Continuous audio feedback to identify content beneath finger

- **Flute sound**: text
- **Cello sound**: picture
- **Silence**: empty space

Same across both conditions



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Despite the stubborn, widespread opinion that animals don't feel emotions in the same way that humans do, many animals have been observed to demonstrate a capacity for joy. People have often seen animals evincing behavior that can only be taken to mean they are pleased with what life has brought them in that particular moment.

A chimpanzee named Nim was raised by a human family for the first year and a half of his life. After that time, Nim was separated from them for two and a half years. On the day that Nim was reunited with his human family, he smiled, shrieked, pounded the ground, and looked from one member of the family to the next. Still smiling and shrieking, Nim went around hugging each member of the family. He played with and groomed each member of the family for almost an hour before the family had to leave. People who were familiar with Nim's behavior said they had never seen him smile for such a long period of time.

Silence: empty space

Flute sound: text

Cello sound: picture

System Design: Reading Mode

- Bimanual: **right** index finger to read, **left** to anchor start of line
- Directional guidance: **audio** or **haptic** depending on condition
  - Used to stay on the line or find the start of the next line
  - **Audio:** pitch of continuous audio
  - **Haptic:** strength and position of vibration
- Additional **audio cues** (same for both conditions)
  - Start/end of line or paragraph
  - Synthesized speech

history and buried for safekeeping. Be this
manner lie untouched for many years, ulture.

Coins are useful in revealing many aspects of a culture. They can provide clues about when a given civilization was wealthy and when it was experiencing a depression. Wealthy nations tend to produce a greater number of coins made from richer materials. The distribution of coins can also reflect the boundaries of an empire and the trade relationships within it. Roman imperial gold coins found in India, indicate the Romans purchased goods from the East.

The way the coins themselves are decorated sometimes provides key information about a culture. Many coins are stamped with a wealth of useful historical evidence, including portraits of political leaders, important buildings and sculptures, mythological and religious figures, and useful dates. Some coins, such as many from ancient Greece, can be considered works of art themselves and reflect the artistic achievement of the civilization as a whole.

Information gathered from old coins by historians is most useful when placed alongside other historical documents, such as written accounts or data from archeological digs. Combined

Above the line: downward guidance
(low pitch or lower vibration motor)

Below the line: upward guidance
(high pitch or upper vibration motor)

Start/end of line or paragraph
(short but distinctive audio cues)

Study I Findings

Haptic vs. Audio: Quantitative Performance

Study I Findings

Haptic vs. Audio: Quantitative Performance

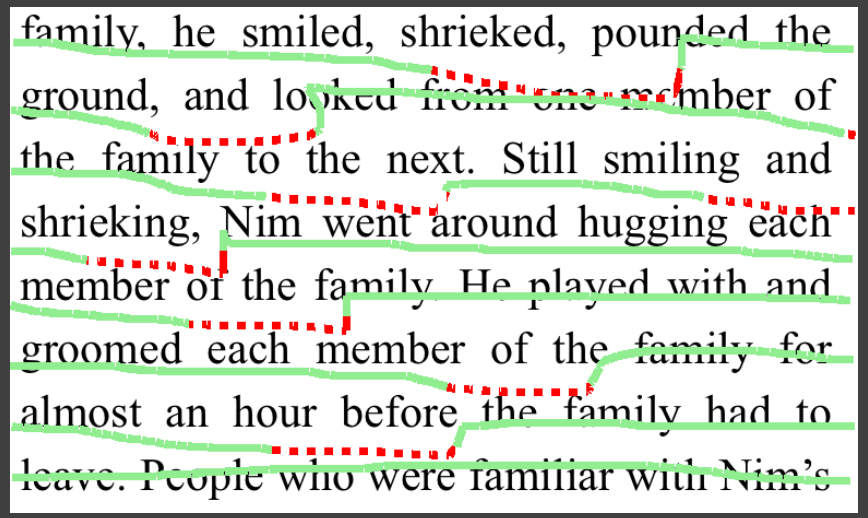
Line tracing / magazine documents: **Audio** significantly more accurate ($p = 0.018$)

Study I Findings

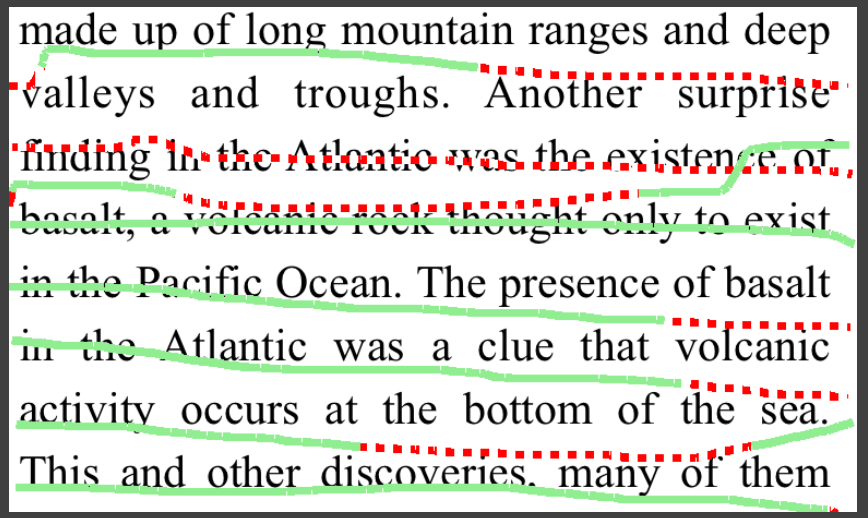
Haptic vs. Audio: Quantitative Performance

Line tracing / magazine documents: **Audio** significantly more accurate (p = 0.018)

audio



haptic



Example finger traces—**Dashed red lines** mark drift off of the line

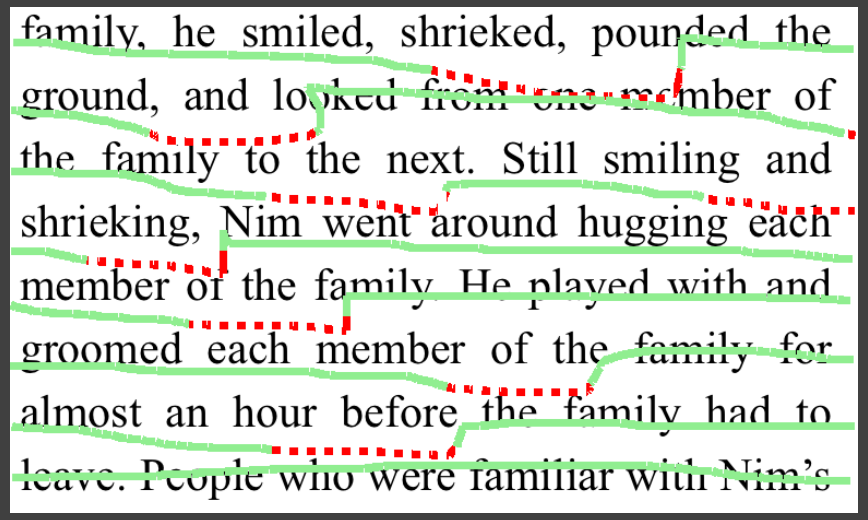
Study I Findings

Haptic vs. Audio: Quantitative Performance

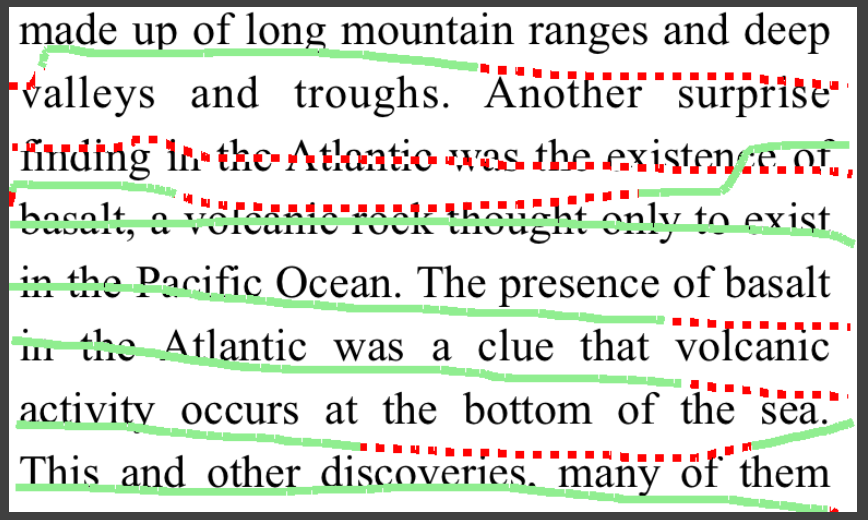
Line tracing / magazine documents: **Audio** significantly more accurate (p = 0.018)

Comprehension high, no significant differences between conditions

audio



haptic



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Study I Findings

Haptic vs. Audio: Subjective Preference

Preferences split (11 haptic, 7 audio, 1 equal preference)

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Preferred Haptic	
More intuitive	
Easier to use	
Faster	
Less distracting	

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Reflects contradictory findings in Stearns *et al.* 2014, Shilkrot *et al.* 2014, 2015

Study I Findings

Overall Reading Experience

Pros	
Low learning curve	
Flexible	
Direct control over speed	

Study I Findings

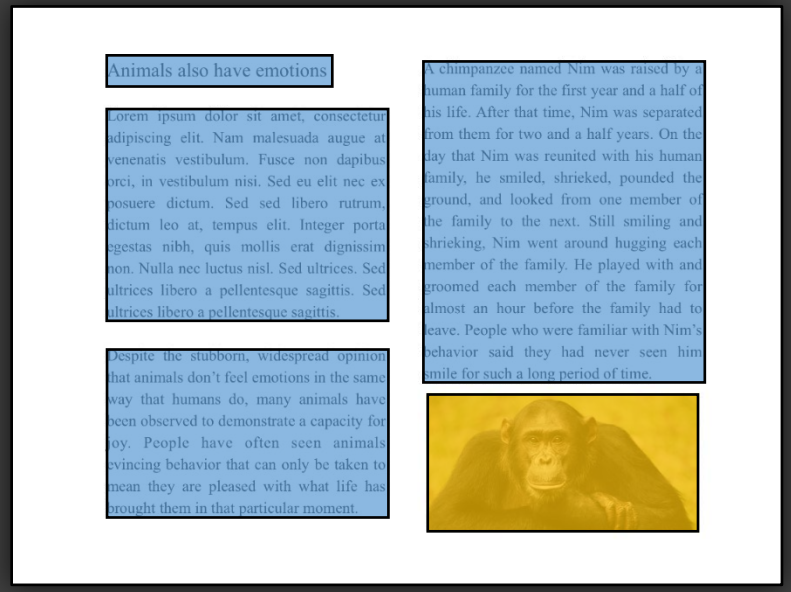
Overall Reading Experience

Pros	Cons
Low learning curve	Hard to use for reading
Flexible	High cognitive load may affect comprehension
Direct control over speed	

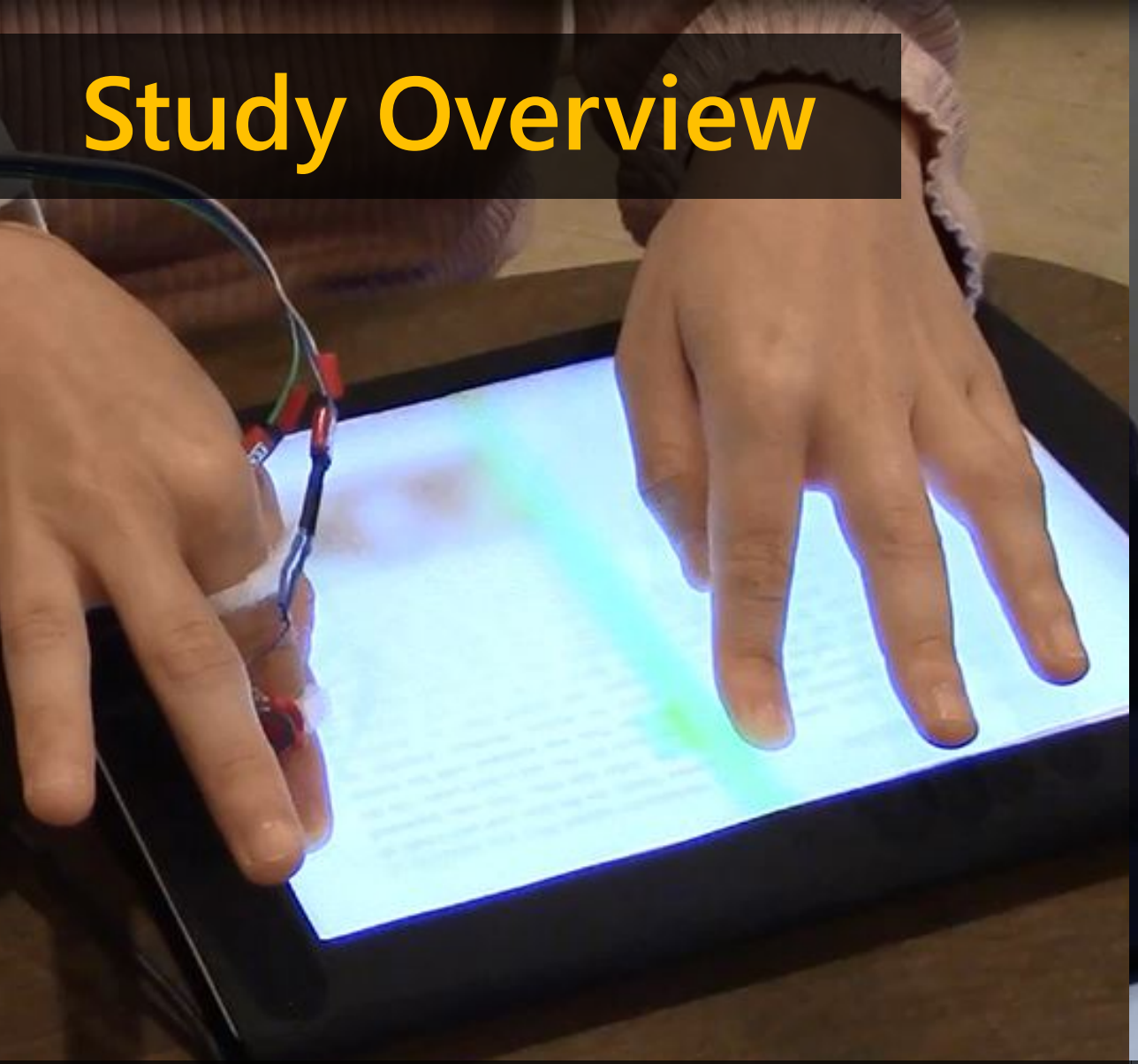
Study I Findings

Exploration Mode

Participants appreciated direct access to spatial information, and nearly all able to locate images and count the number of columns.



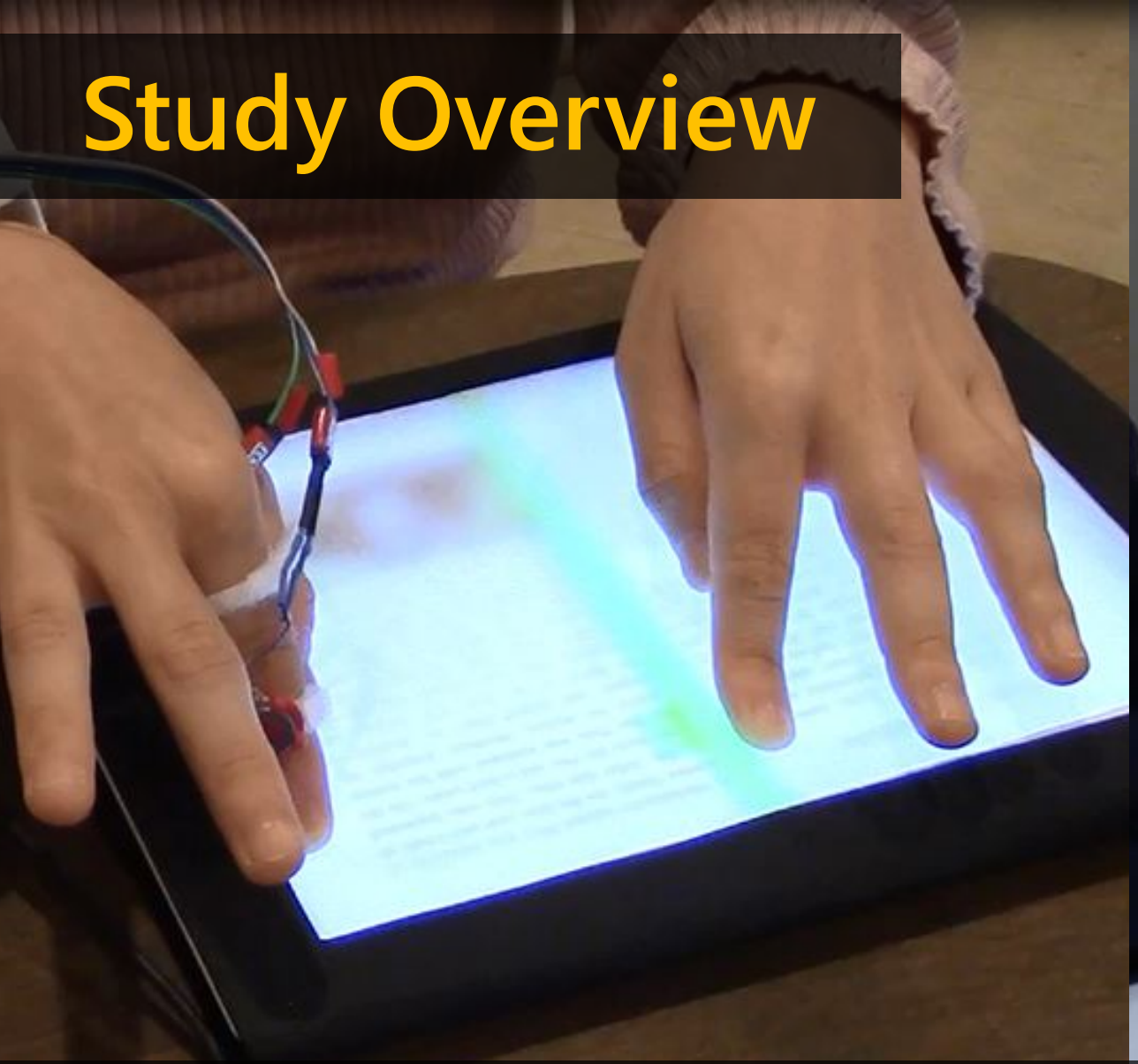
Study Overview



Study I: initial iPad study (19 participants)

Study II: physical prototype study (4 participants)

Study Overview



Study I: initial iPad study (19 participants)

Study II: physical prototype study (4 participants)

Study Overview

Goals:

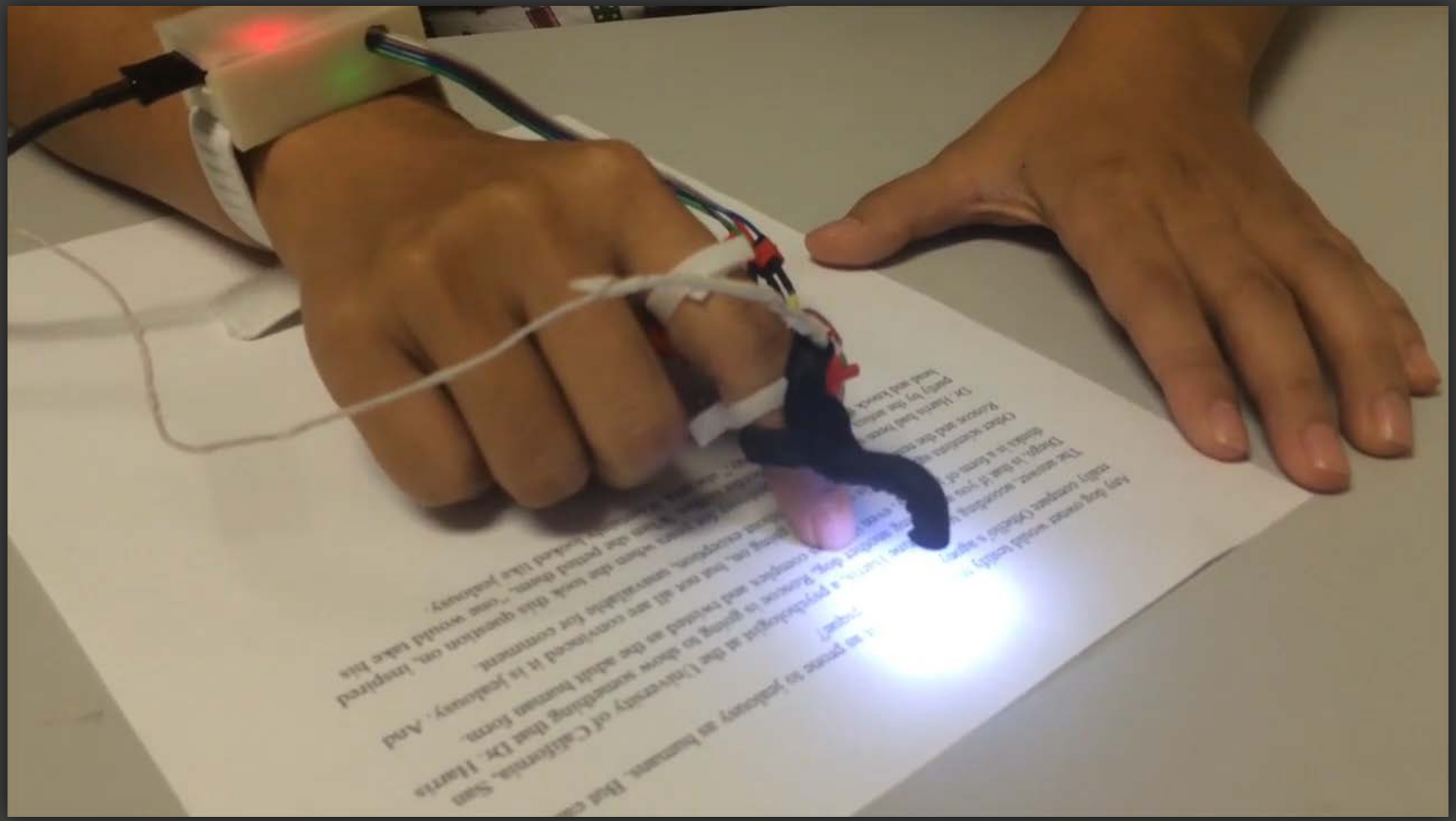
Evaluate HandSight prototype

Gather subjective feedback

Compare with KNFB Reader iOS

Study II: physical prototype study (4 participants)

Study II: HandSight Prototype System

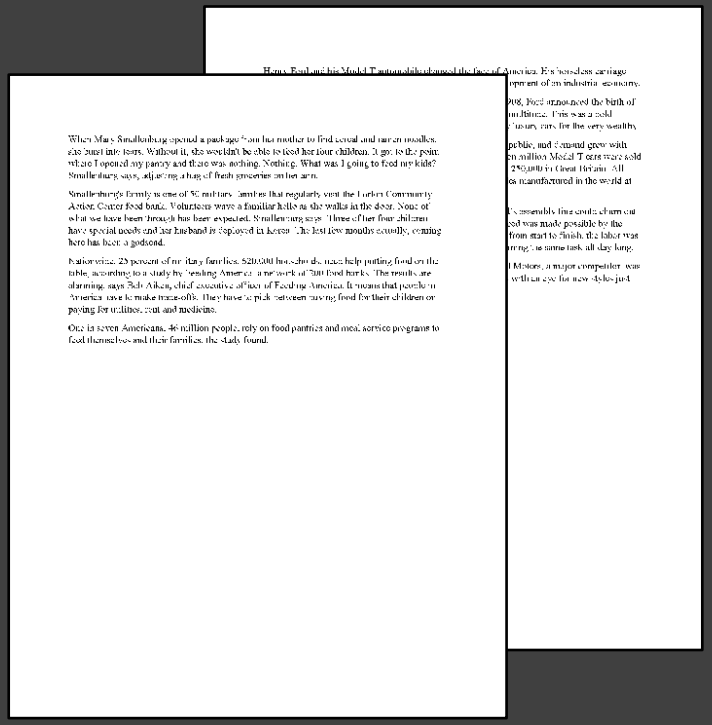


Finger-mounted camera to read physical documents

Study II Method

HandSight:

Each participant used their preferred guidance from Study I to explore and read two documents



When Mary Smallenburg opened a package from her mother to find cereal and macaroni noodles, she burst into tears. Without it, she wouldn't be able to feed her four children. It got to the point where I opened my pantry and there was nothing. Nothing. What was I going to feed my kids? Smallenburg says, adjusting a bag of fresh groceries on her arm.

Smallenburg's family is one of 50 visitors Tuesday that regularly visit the Harlem Community Action Center food bank. Volunteers wave a familiar hello as she walks in the door. None of what we have been through has been expected. Smallenburg says. Three of her four children have special needs and her husband is deployed in Korea. The last few months actually, coming here has been a godsend.

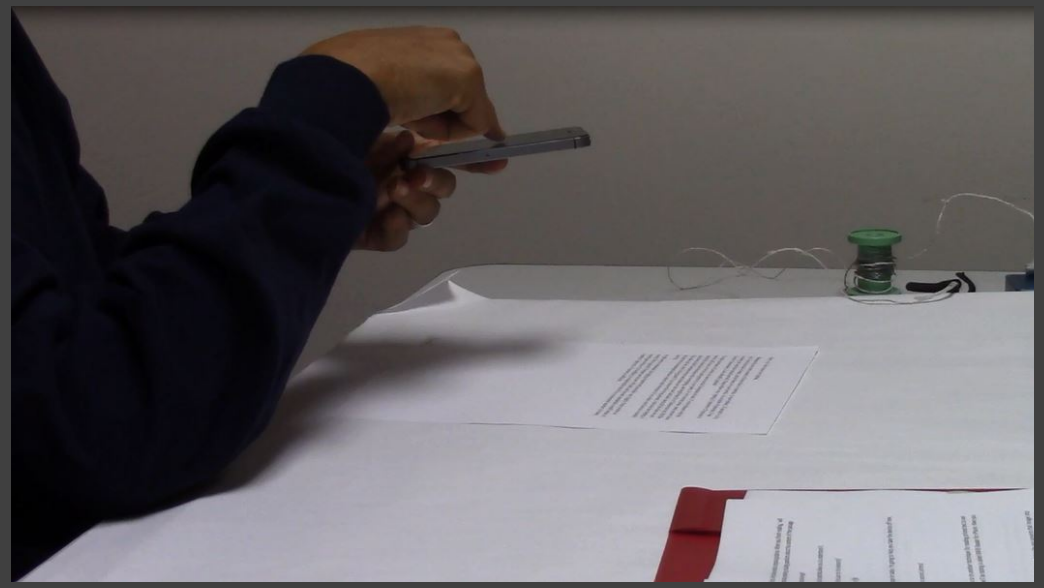
Nationwide, 25 percent of the many families, 820,000 households, need help putting food on the table, according to a study by Feeding America, a network of 200 food banks. The results are alarming, says Bob Aiken, chief executive officer of Feeding America. It means that people in America have to make trade-offs. They have to pick between buying food for their children or paying for utilities, rent and medicine.

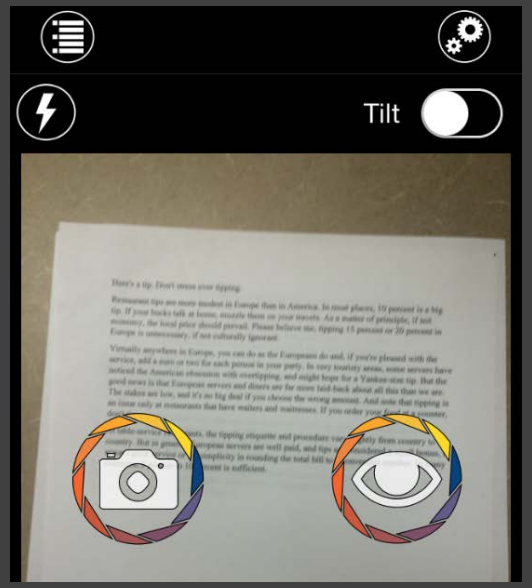
One in seven Americans, 46 million people, rely on food pantries and meal service programs to feed themselves and their families, the study found.

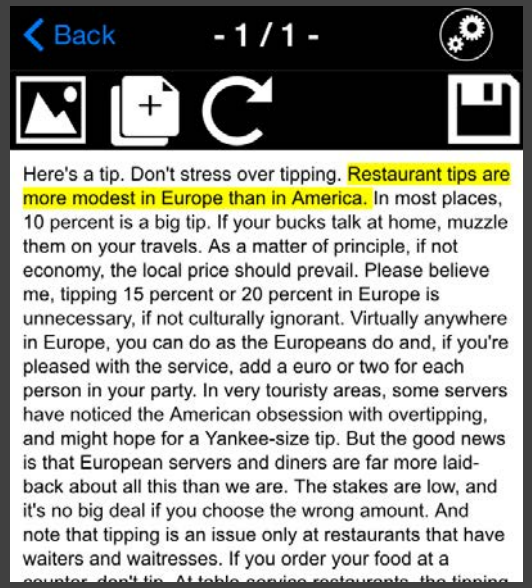
Study II Method

KNFB Reader iOS:

Photograph and read 3 physical documents







Study II Findings

HandSight: Overall Experience

Average reading speed: 45 wpm (*SD*=19, *Range*=18-60)

Rated somewhat easy to use, but slow and required concentration

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HandSight: Overall Experience

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Rated somewhat easy to use, but slow and required concentration

Participant Quotes:

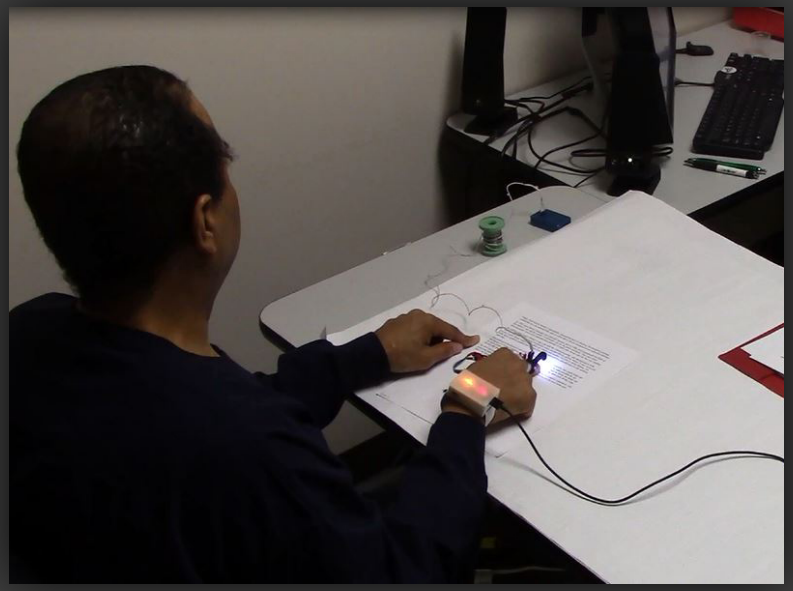
"I'm very pleased and excited about the system. I think it could make a great difference in my life." (P19)

"It seems like a lot of effort for reading text." (P12)

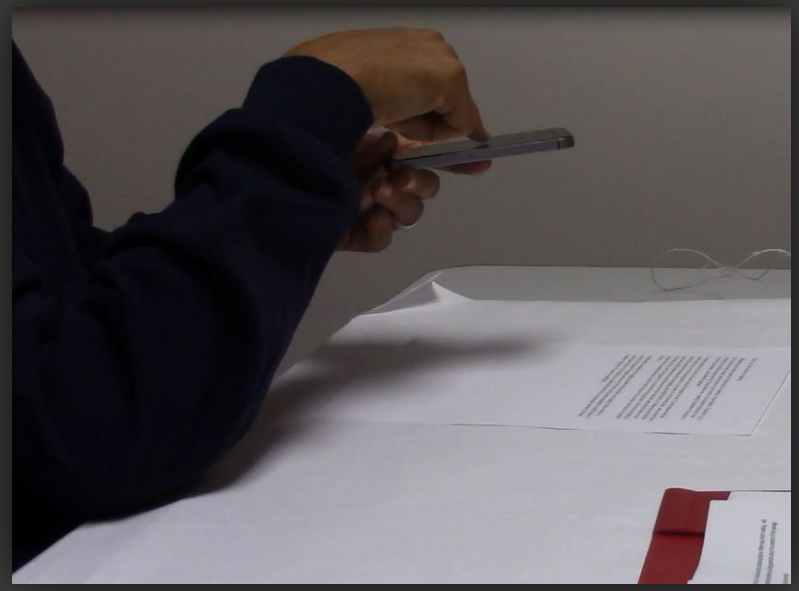
Study II Findings

HandSight *vs.* KNFB Reader iOS

Participants unanimously preferred KNFB Reader iOS



HandSight



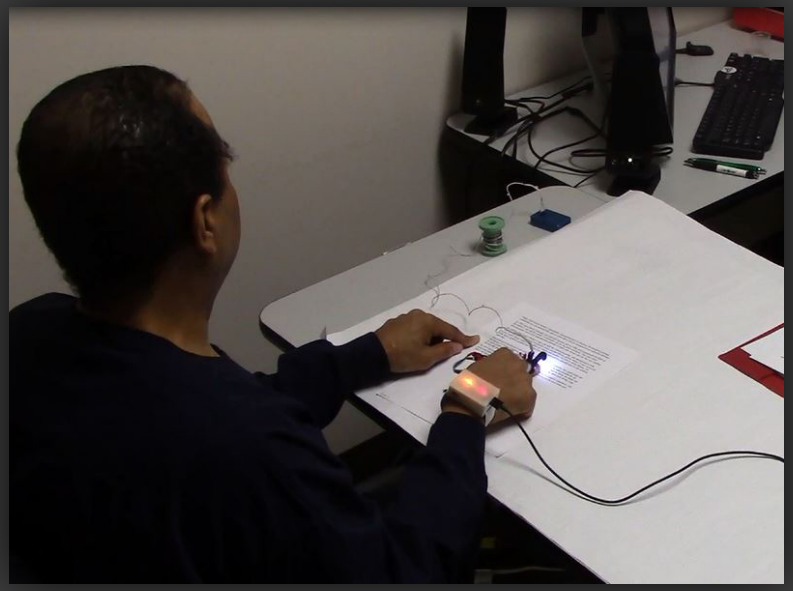
KNFB Reader iOS

Study II Findings

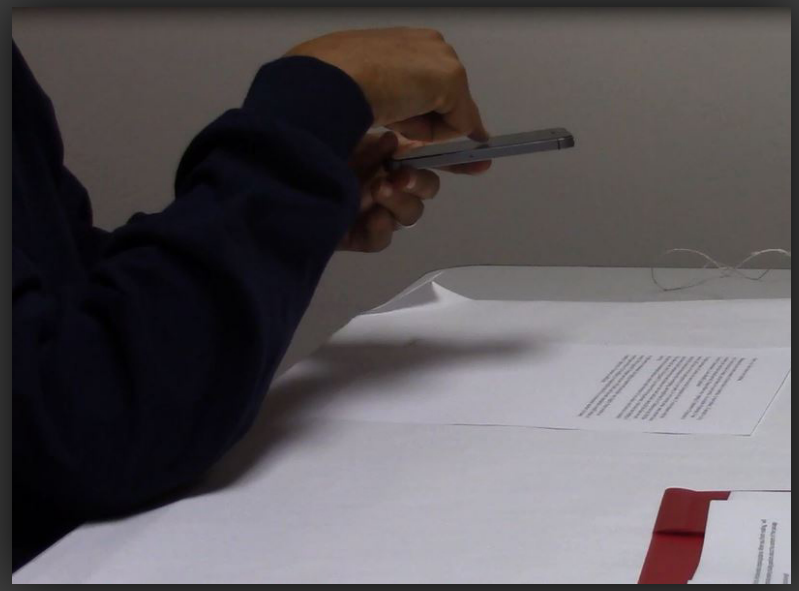
HandSight *vs.* KNFB Reader iOS

Participants unanimously preferred KNFB Reader iOS

Faster, easier to concentrate on the content of the text



HandSight



KNFB Reader iOS

Implications

Feasibility of a Finger-Based Reading Approach

Pros	

Implications

Feasibility of a Finger-Based Reading Approach

Pros	
Spatial layout information	

Implications

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Pros	
Spatial layout information	
Direct control over reading	

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* We observed these in our studies

Implications

Feasibility of a Finger-Based Reading Approach

Pros	Cons
Spatial layout information	**Slower, requires increased concentration and physical dexterity**
Direct control over reading	
Reduced camera framing issues	
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Implications

Feasibility of a Finger-Based Reading Approach

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Spatial layout information	**Slower, requires increased concentration and physical dexterity**
Direct control over reading	* Consistent with Shilkrot *et al.* 2014, 2015
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Feasibility of a Finger-Based Reading Approach

Pros	Cons
Spatial layout information	Slower, requires increased concentration and physical dexterity
Direct control over reading	* Consistent with Shilkrot *et al.* 2014, 2015
Reduced camera framing issues	**Importance of spatial layout information is unclear**
Efficient text detection and recognition	
* We observed these in our studies	

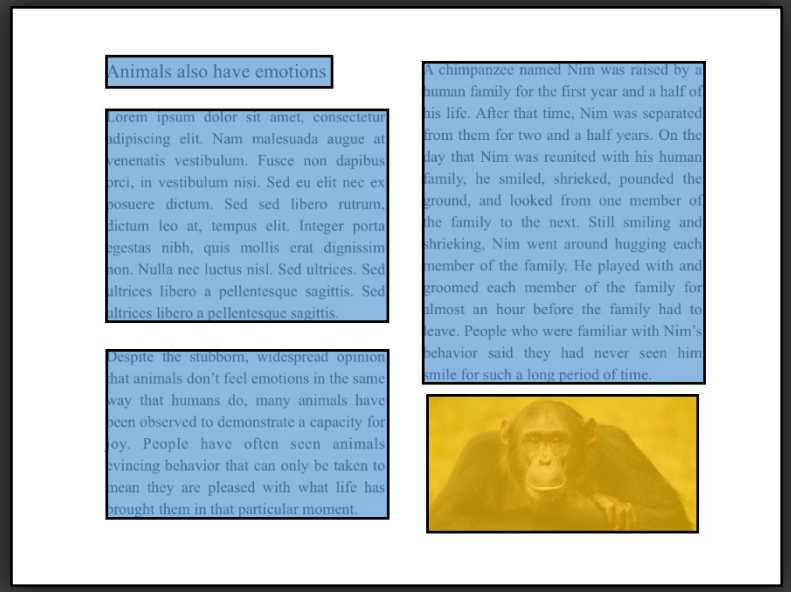
Implications

Feasibility of a Finger-Based Reading Approach

Pros	Cons
Spatial layout information	Slower, requires increased concentration and physical dexterity * Consistent with Shilkrot *et al.* 2014, 2015
Direct control over reading	**Importance of spatial layout information is unclear** * Has yet to be investigated in this context
Reduced camera framing issues	
Efficient text detection and recognition * We observed these in our studies	

Future Work

Study utility of spatial layout information in everyday use



(*e.g.*, newspapers, menus, maps, graphs)

Future Work

Study utility of spatial layout information

Explore possibilities for camera placement

HandSight

a vision augmented touch system

Evaluating Haptic and Auditory Guidance to Assist Blind People in Reading Printed Text Using Finger-Mounted Cameras

TACCESS | ASSETS 2016

Questions?

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University of Maryland: Computer Science[1], Information Studies[2], Atlanta VA R&D Center for Visual & Neurocognitive Rehabilitation[3]

Thank you to our participants and the Maryland State Library for the Blind and Physically Handicapped.

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makeability lab

inclusive design lab

HCIL Human Computer Interaction Laboratory

COMPUTER SCIENCE UNIVERSITY OF MARYLAND

UNIVERSITY OF MARYLAND

Limitations of previous studies*

1. Small sample size (3-4 participants)
2. No quantitative performance metrics
3. Contradictory participant preferences

* Stearns *et al.* 2014, Shilkrot *et al.* 2014, 2015