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Legibility and Readability in Augmented Reality

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Introduction

- Many people suffer from hearing impairments
  - About 6% according to World Health Organization (WHO)[1]
  - Many aids exists with various advantages and disadvantages
  - Speech-to-text interpretation and presentation in Augmented Reality (AR) can be a complement

[1]Kawas et al. 2016; Yu and Deng 2015, s. 1 - 3.

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Are you gonna go out this weekend?

Ska du gå ut i helgen?

Introduction

- Main research question
  - How is the legibility and readability in AR-glasses affected by typographical and perceptual factors?

- Hypotheses
  - Affects legibility in AR-glasses
    1. Polarity of the text presentation
    2. Opacity of a billboard
    3. Ambient illumination
    4. Background
  - Affects readability in AR-glasses
    1. Text size
    2. Number of lines

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Method

- Two sessions A and B

- Session A
  - Visual search task – How many N?

- Session B
  - Reading speed and reading comprehension

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Method

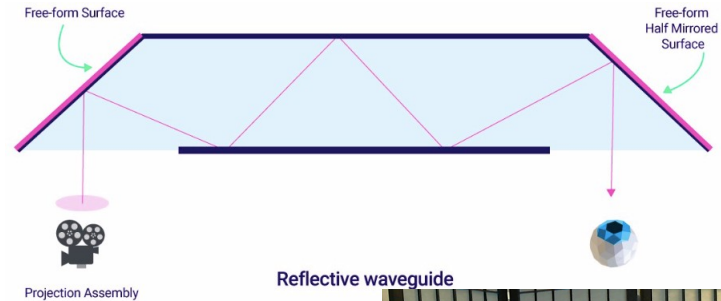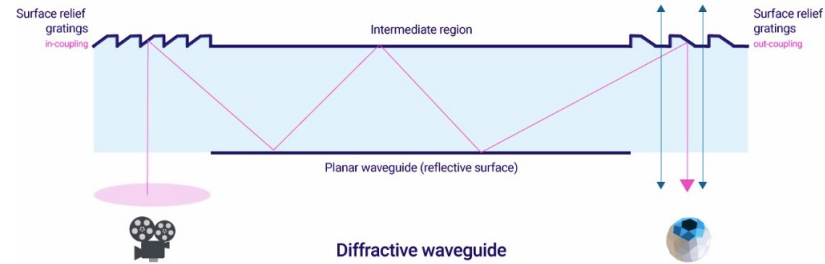- Two AR-glasses
  - Vuzix Blade
    - Monocular
    - 480x480 pixels
    - diffractive waveguide
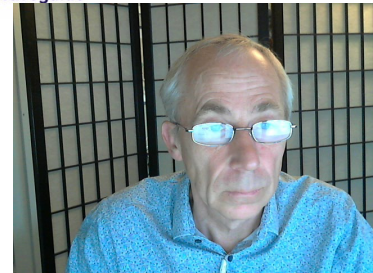 - Epson Moviero BT-300
    - Binocular
    - 1280x720 pixels
    - reflective waveguide
- Half of the test persons were assigned one of them

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7

Lamps for ambient illumination
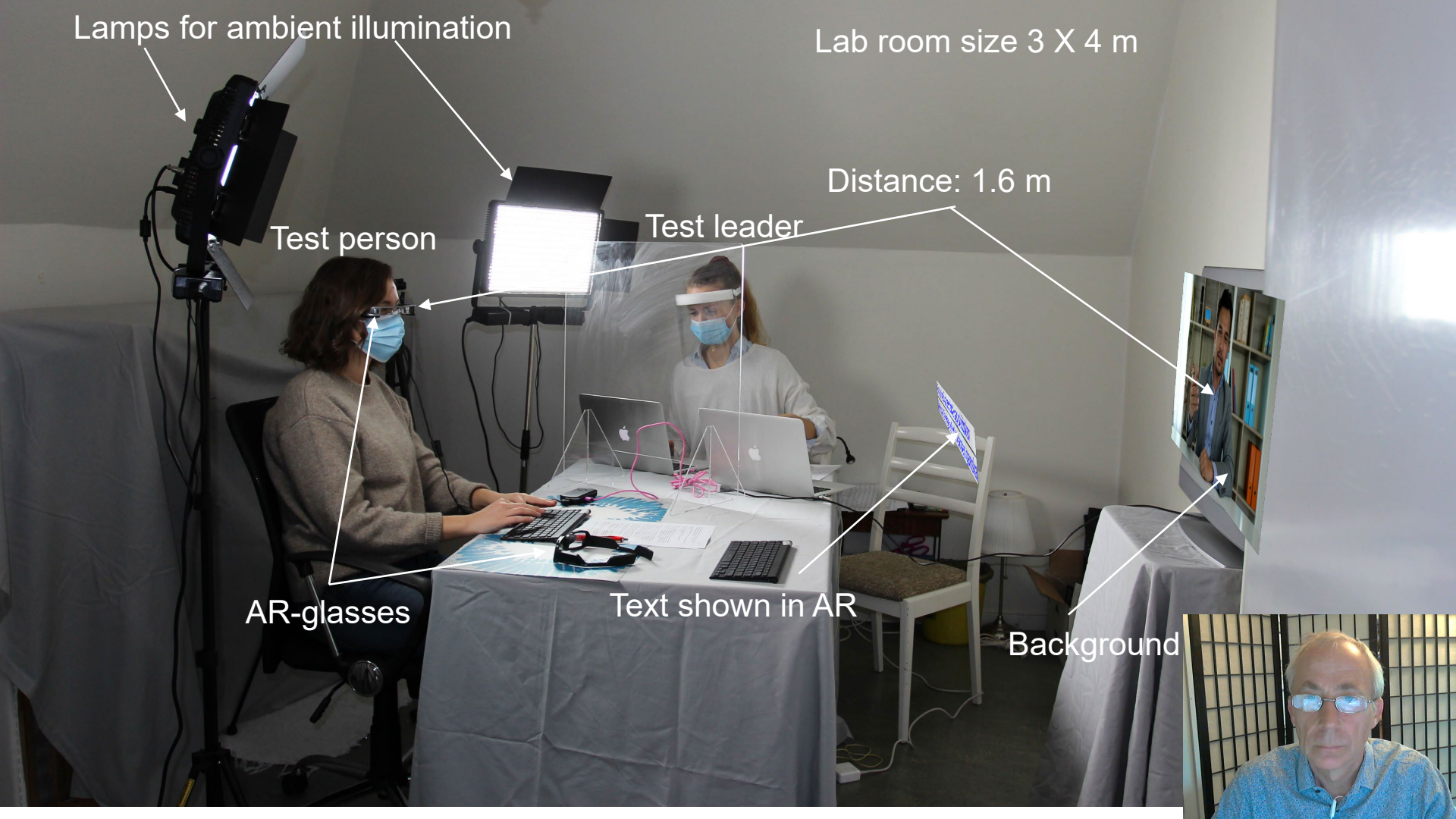
Lab room size 3 X 4 m

Test person

Test leader

Distance: 1.6 m

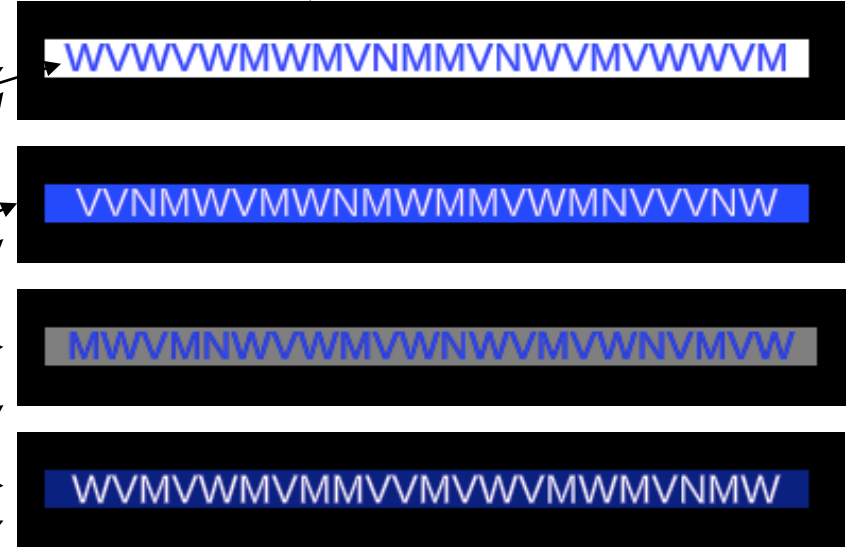AR-glasses

Text shown in AR

Background

Session A

- Visual search task – How many N?

- Text strings were placed on a background behind the text, that we call a "Billboard"

- Polarity:
  - Positive
  - Negative

- Billboard opacity
  - Completely solid
  - 50% transparent

Transparent

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Session A

- Backgrounds behind the text on the TV-screen
    - Solid white
    - Solid black
    - Abstract
- Illuminance
    - High (about 1300 lux)
        - measured vertically at eye location
    - Medium (about 580 lux)
    - Low (about 20 lux)

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Session B

- Number of lines
    - One, two or three

- Text size
    - 20, 30 and 40 Unity units
    - Unity units (scaled based on number of pixels on the screen)
    - E.g. height 480 pixels, then 20 Unity units = 20*(height of display)/480

- Line width: 480 pixels (max width Vuzix)

- Background: video of a talking person

För sex veckor sen åkte jag skridskor hemma i Sverige och det kändes ganska

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Session B

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Session B

- Silent reading

- Each paragraph was **divided into segments** depending on number of lines and text size.

- When the test persons had read one segment, they pressed **space** to show next segment.

- Time was taken between the start of the **first** segment and the end of the **last** segment.

- After each paragraph **three** questions were asked about the content

För sex veckor sen åkte jag skridskor hemma i Sverige och det kändes ganska

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Procedure

- Washed and disinfected the hands and to put on a face mask.

- Signing consent form (data was to be anonymized and free to stop at any point)

- Height of the chair adjusted

- Acuity test and demographic question (e.g. age, gender, occupation)

- Questions on motion sickness and if they currently experiencing any headache, eyestrain, or nausea.

- Instructions for the experiment was given on paper

- Assigned either Vuzix or Moviero AR-glasses

- Short training for each session (if anything unclear Q&A)

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Covid-19 precaution
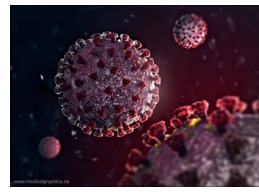
- Test persons washed their hands before and after the test

- Both test leaders and test person wore mouth protection

- Test leader wore also a visor

- Test person and test leader were separated with a plexiglass shield

- AR-glasses and keyboards were disinfected using a UV-C lamp

- Other equipments were disinfected too
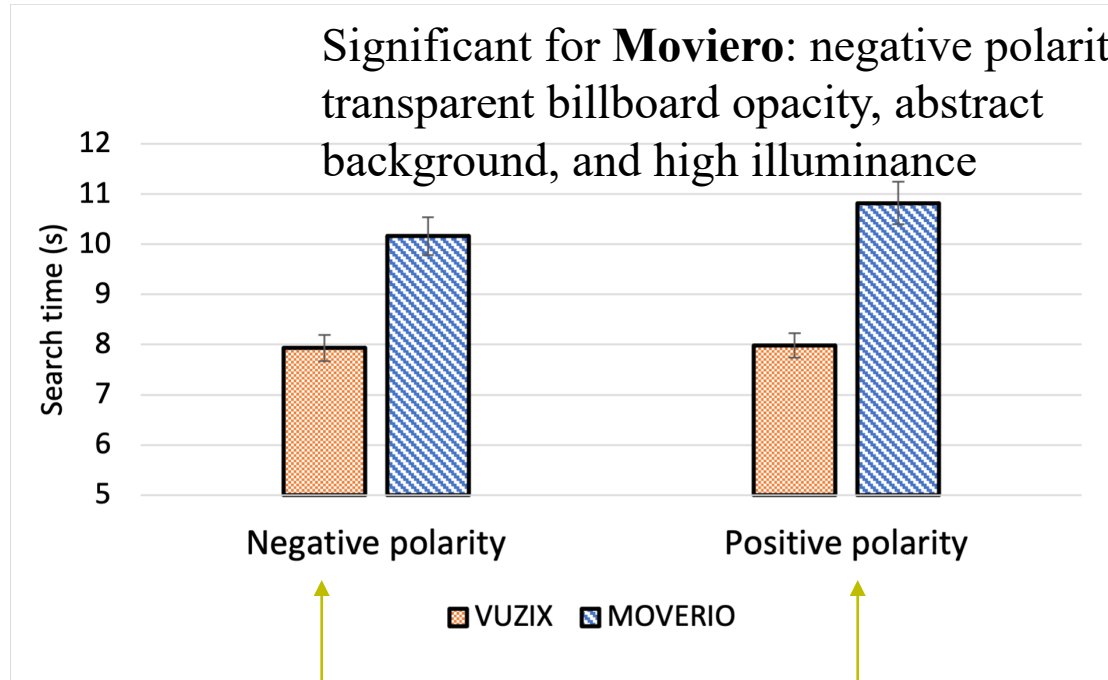
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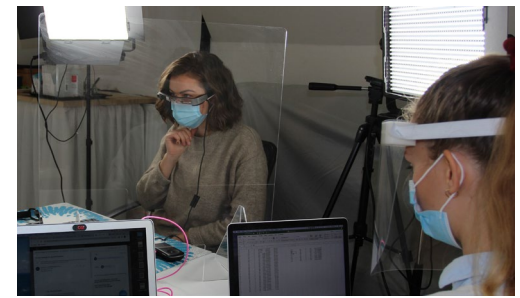
Results

- 23 test persons, 13 men and 10 women. Age: 20 – 27 (mean 25)

- Visual acuity: min: 0.75 on one eye

- Statistical analysis:

  - non parametric Friedman test (two way layout design)

  - Post-hoc: Wilcoxon, Nemenyi and, McDondald-Thompson test

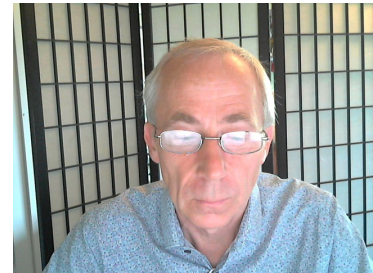 - Significance level: 95%

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Results

Significant for **Vuzix**: negative polarity with solid billboard opacity, abstract background, and medium illuminance

Significant for **Moviero**: negative polarity with transparent billboard opacity, abstract background, and high illuminance
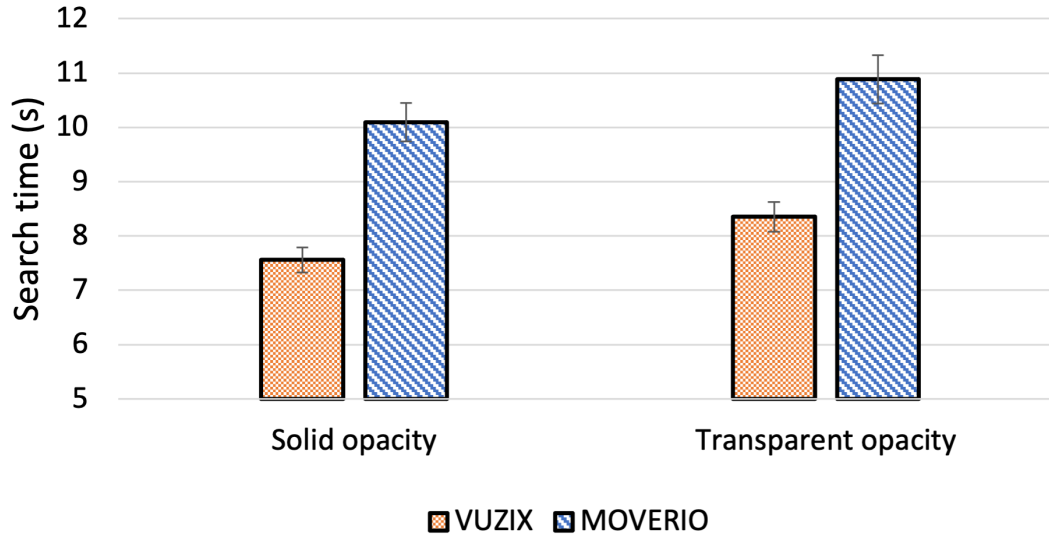

Difference not significant

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Results

Solid billboard opacity had a significantly shorter search time than transparent opacity under negative polarity, medium illuminance, and abstract background for both glasses

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Results

For **Vuzix** high illuminance had a significantly shorter search time compared to low illuminance.

For **Moviero high** illuminance had a significantly shorter search time compared to **low** illuminance for **positive** polarity, **solid** opacity and **abstract** background and **medium** illuminance had a significantly shorter search time compared to **high** illuminance for **negative** polarity, **solid** opacity and **black** background.

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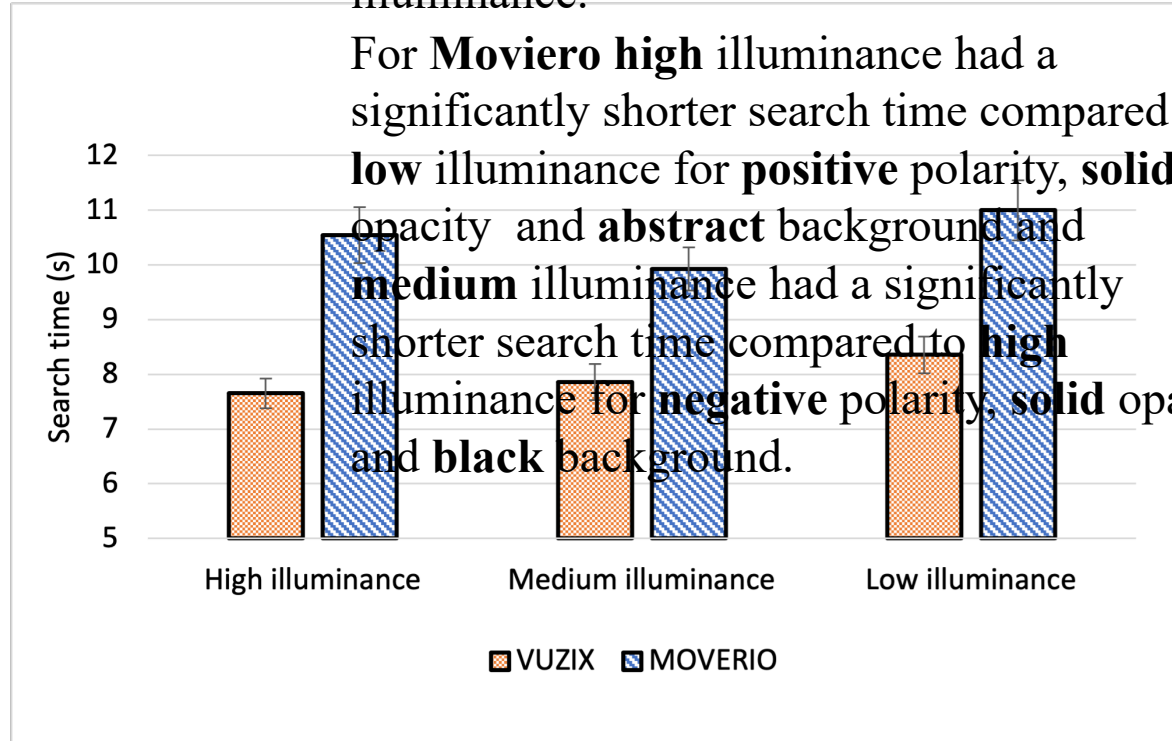
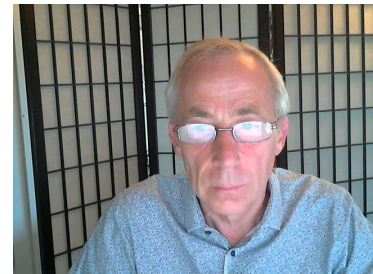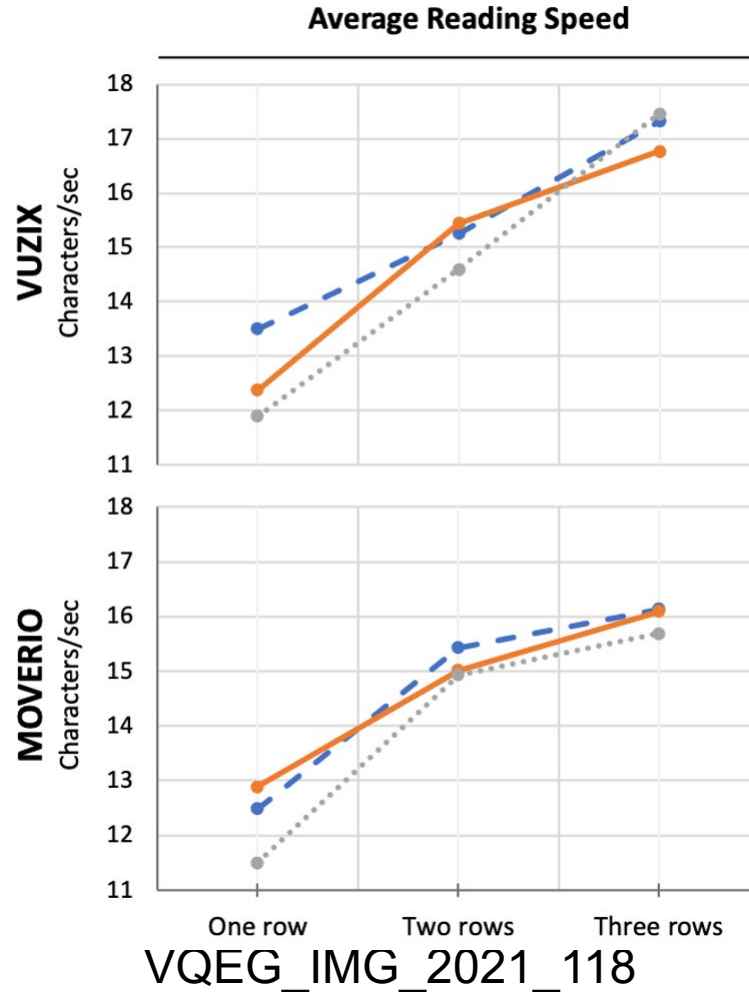# Results – Session B

1. Text size: only marginal effect on reading speed.

2. Number of lines: Reading speed increased with the number of lines

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Results

Average Reading Speed

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Results – Hypothesis support

1. Polarity of the text presentation affects the legibility in AR-glasses.

    - Transparent or solid billboard opacity, with abstract background under medium illuminance.

2. Opacity of a billboard affects the legibility in AR-glasses.

    - Negative polarity, medium illuminance and with abstract background

3. Ambient illumination affects the legibility in AR-glasses

    - Positive polarity, solid opacity and an abstract background

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Results – Hypothesis support

4. Background affects the legibility in AR-glasses.

   - Abstract background in low illumination

5. Text size affects the readability in AR-glasses.

   - only for Vuzix

6. Number of lines of text affects the readability in AR-glasses.

   - For both AR-glasses

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Conclusions

- Positive polarity best for legibility in AR

  - But could be affected by the opacity

- Three lines resulted in best readability

  - But more than three lines was not studied

- Large difference between the AR-glasses

  - Moviero, although better optics, resolution and stereo, not as good as Vuzix

  - Most likely this was caused by the interpupillary distance for stereo that was not adjustable in Moviero

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Thank you

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[1]. Eksvärd, S. and J. Falk. (2021). *Evaluating Speech-to-Text Systems and AR-glasses: A study to develop a potential assistive device for people with hearing impairments* (978-91-89385-16-0 (ISBN)), DOI: 10.23699/yedh-qn68.

[2]. Falk, J., S. Eksvärd, B. Schenkman, B. Andrén, and K. Brunnström. (2021). *Legibility and readability in Augmented Reality*. in *International Conference on Quality of Multimedia Experience, QoMEX 2021*. Montreal, Canada (virtual event): IEEE.