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Enhancing the Reading Experience on AR HMDs by Using Smartphones as Assistive Displays

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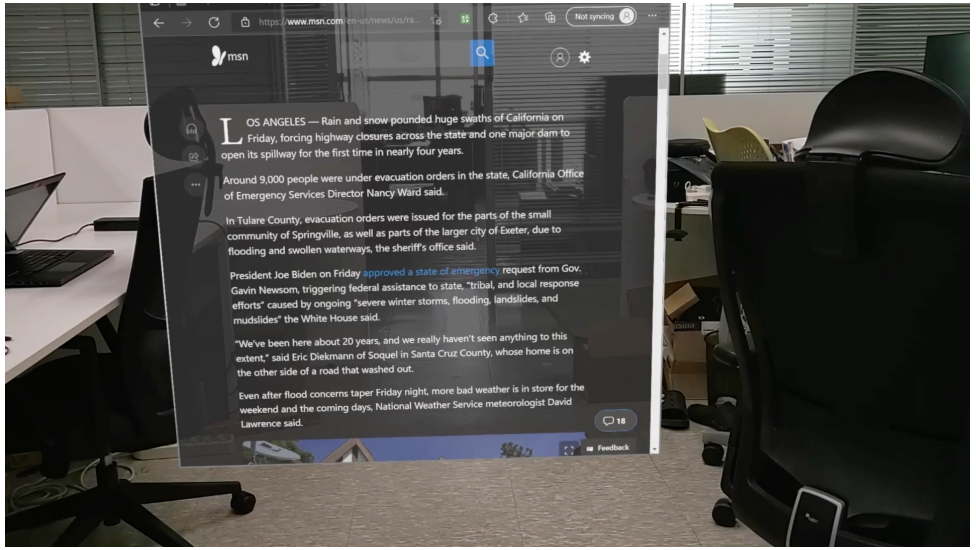
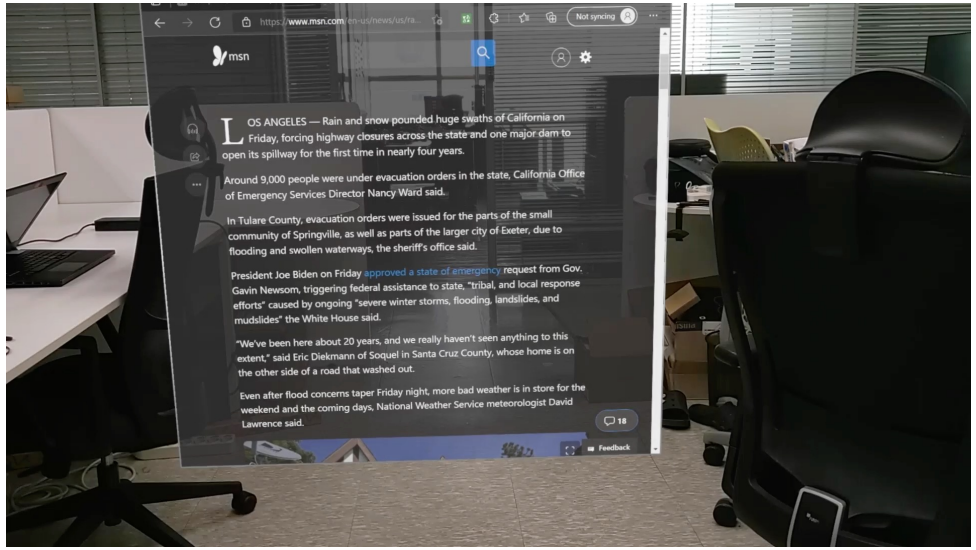
Motivation

Limited readability on AR HMDs



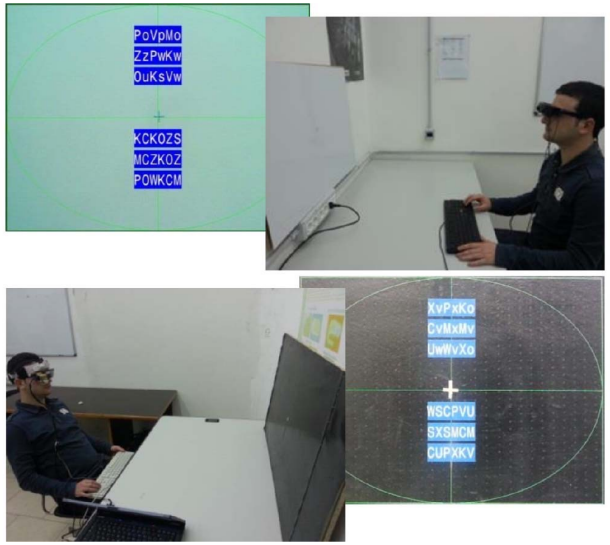
Translucency of display



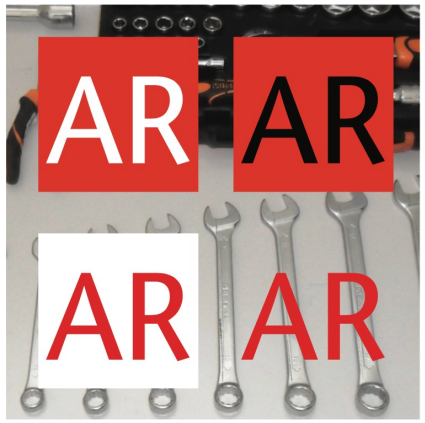
Clipping of the content or
increased interactions due to the small FoV

Readability of Information on AR HMDs

Text & billboard styles



Debernardis et al. ‘13



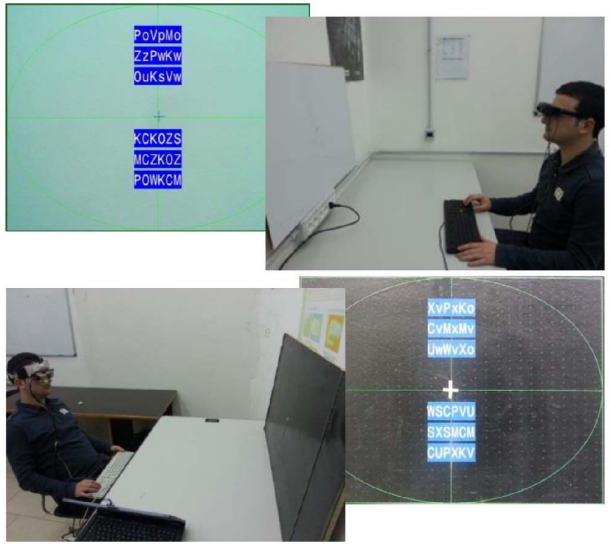
Gattullo et al. ‘15

Dynamic text

Rzayev et al. ‘18

Readability of Information on AR HMDs

Text & billboard styles



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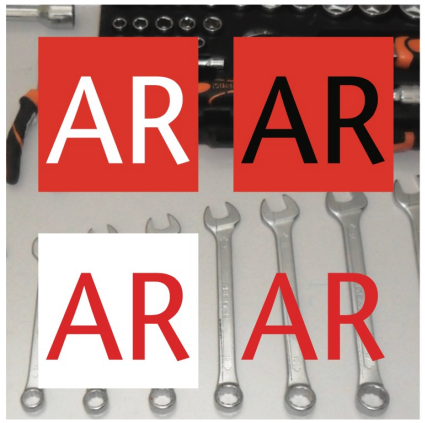

Gattullo et al. ‘15

Dynamic text

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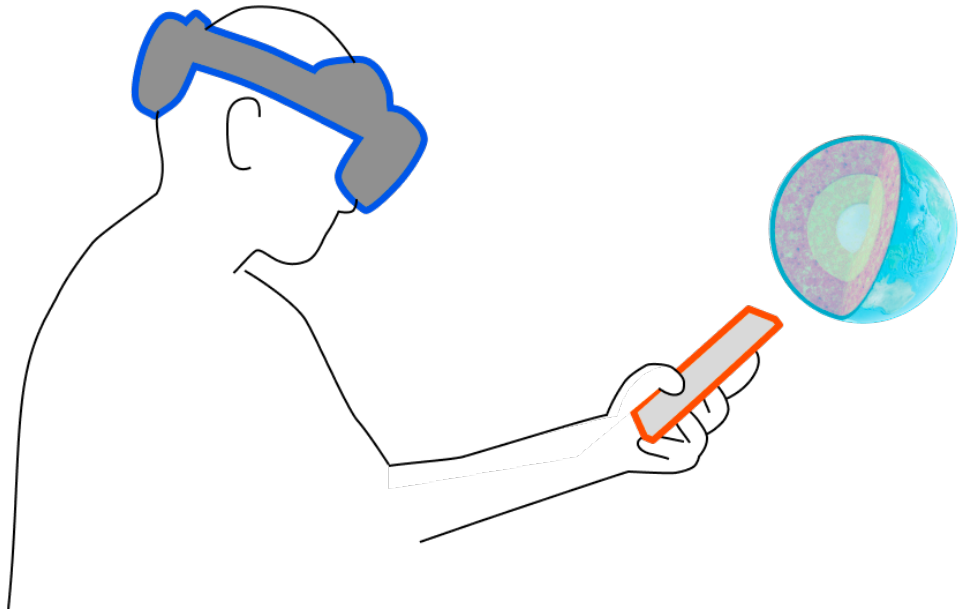
➔ limited readability compared to more traditional displays

Research Goal

To investigate the use of smartphones as assistive displays to AR HMDs to enhance reading in AR



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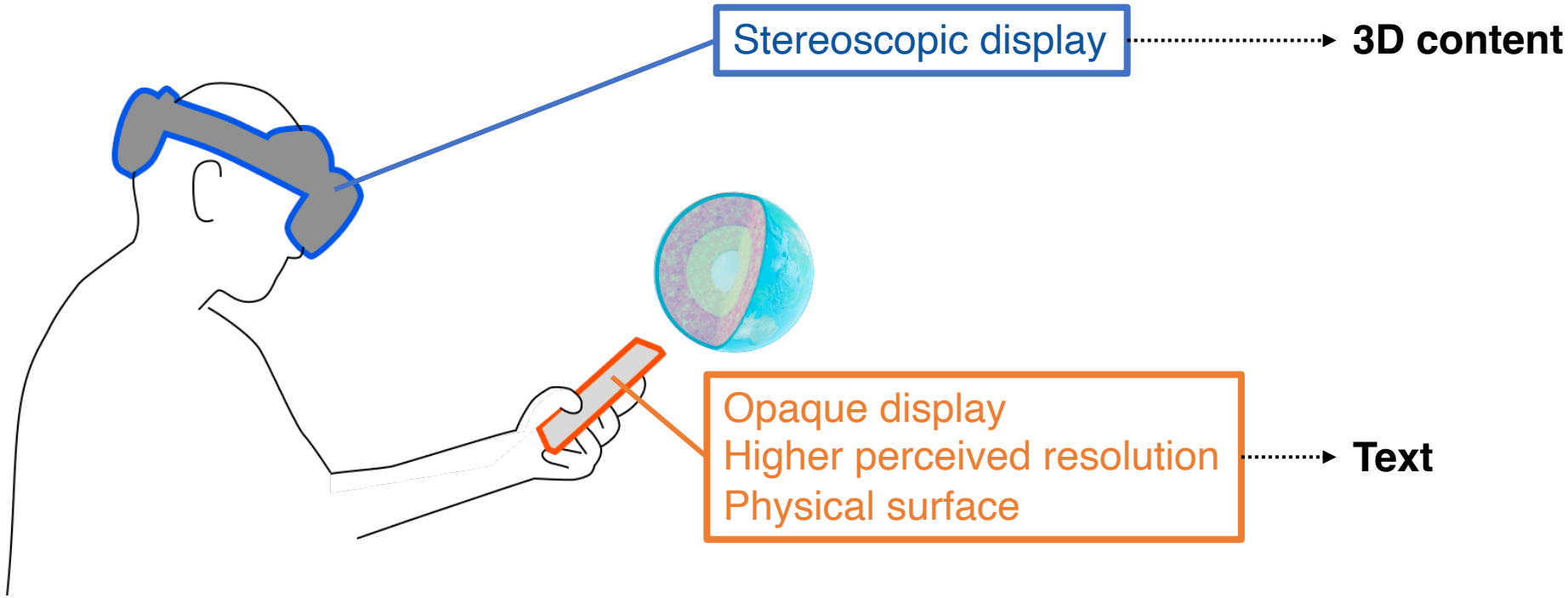
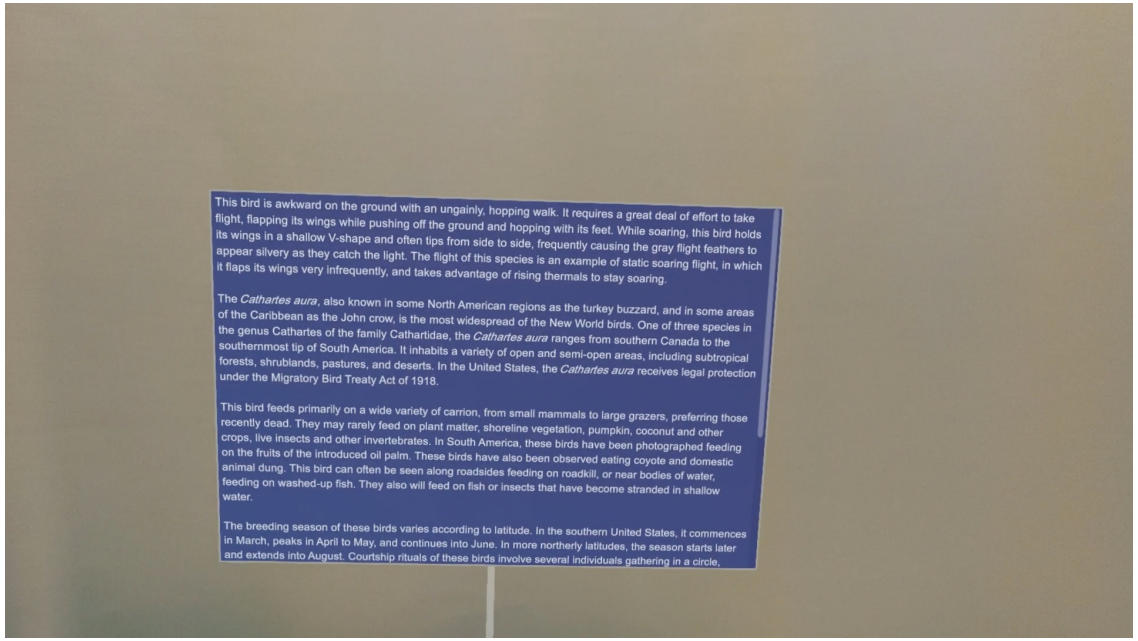
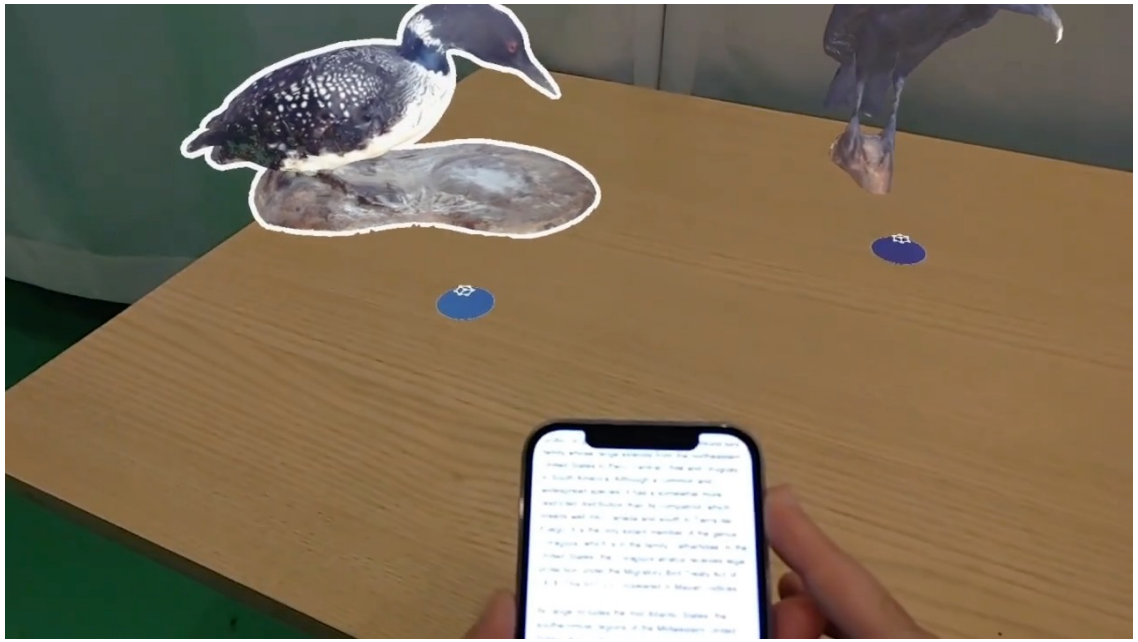


Research Goal





HMD only

***Hybrid** (HMD + smartphone)*

Benefits > Attention switch costs?

Research Questions

Q1. Does the ***hybrid*** interface benefit the user in terms of **task performance** and **perceived task load** in an AR reading task?

Q2. Are the advantages of the ***hybrid*** interface **measurably bigger for longer text** that requires scrolling on the HMD?

Hypotheses

H1. **Task performance** will be higher when using the ***hybrid*** *interface* compared to using ***HMD only*** for both *short* and *long* texts.

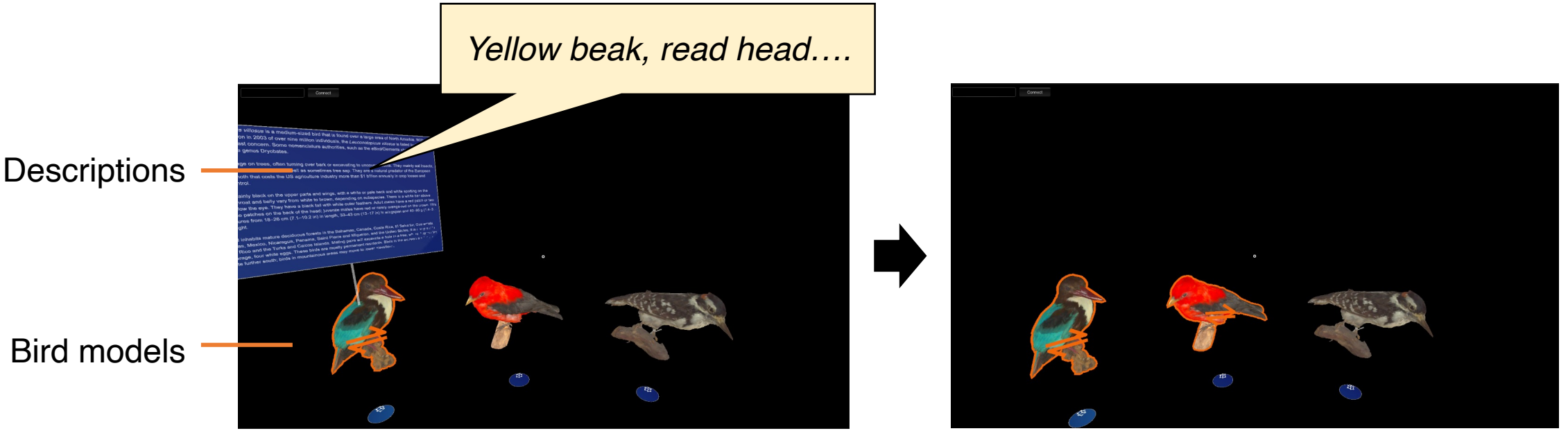
H2. **Perceived task load** will be lower when using the ***hybrid*** *interface* compared to using ***HMD only*** for both *short* and *long* texts.

H3. For both **task performance** and **perceived task load**, there will be an **interaction effect** between the INTERFACE and TEXT LENGTH.

Study Design

- 24 participants aged 20 ~ 32 (10 female, M = 23.21, SD = 2.84)
- 2 x 2 within-subjects design
- **Independent Variables**
  - Interface *(HMD only, Hybrid)*
  - Text Length *(Short, Long)*
- **Dependent Variables**
  - Task completion time and accuracy
  - Perceived task load (RTLX)
  - Subjective ratings: comfort, visual fatigue, perceived readability, ease-of-use, learnability, confidence, system understanding on a 7pt-Likert scale
  - Preference

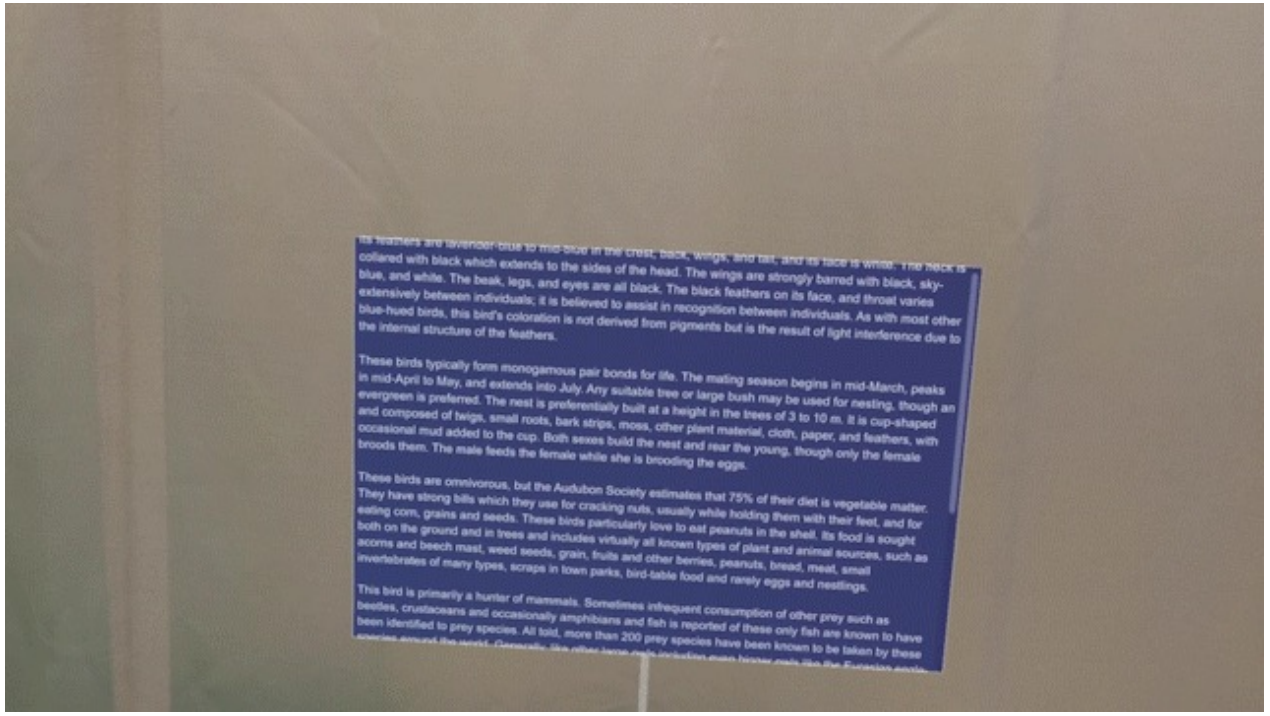
Experimental Task



Label assigning task

to assign the descriptions to the correct 3D bird models

Experimental Task



Label assigning task

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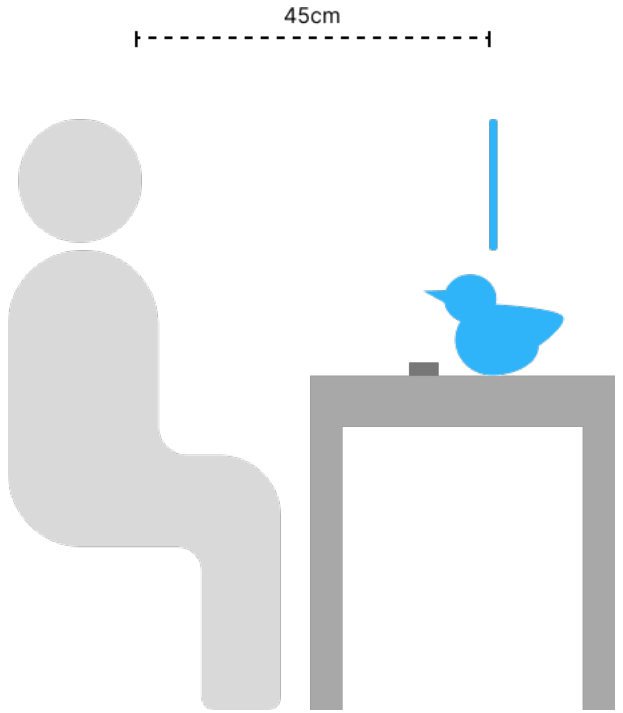
Apparatus

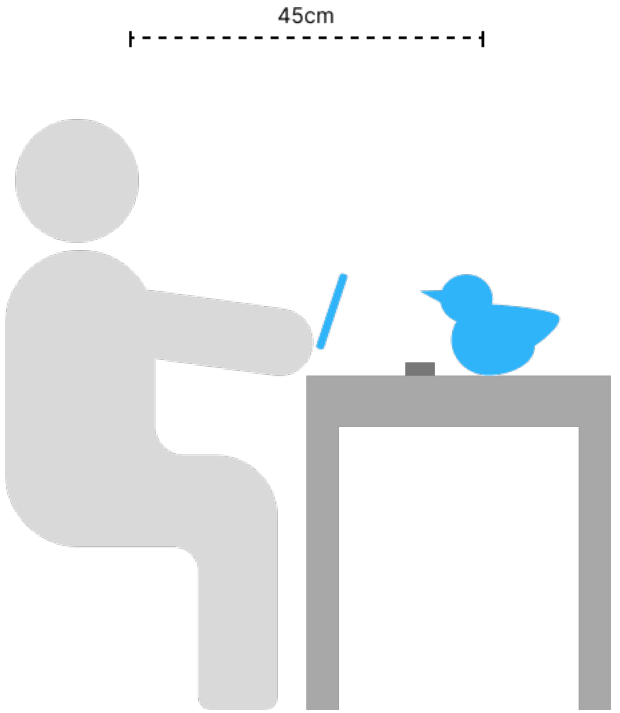
HMD only

(HoloLens 2)

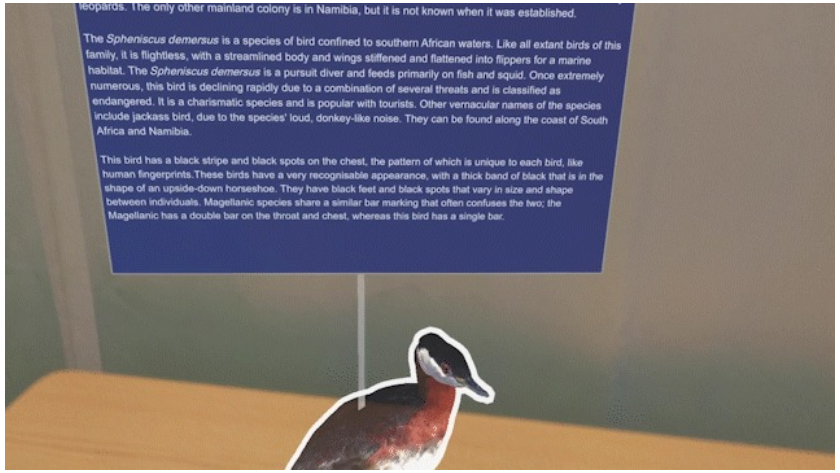
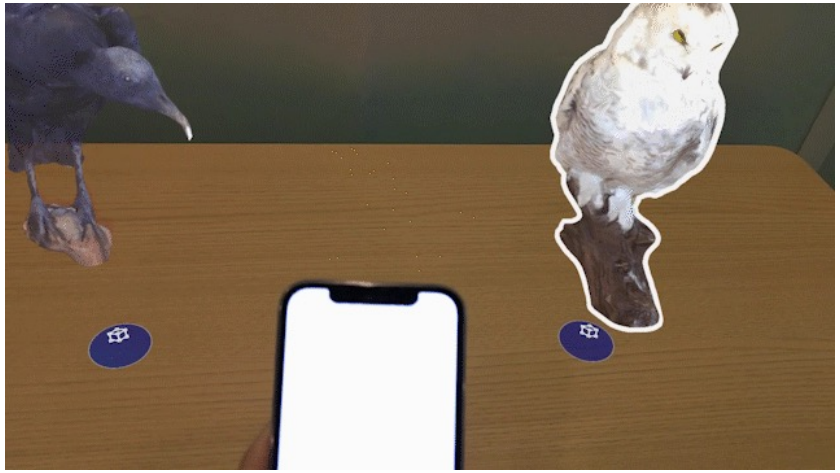
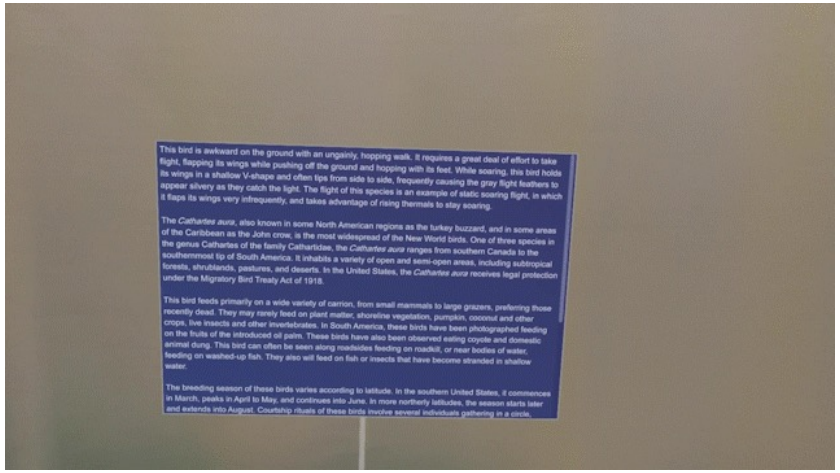
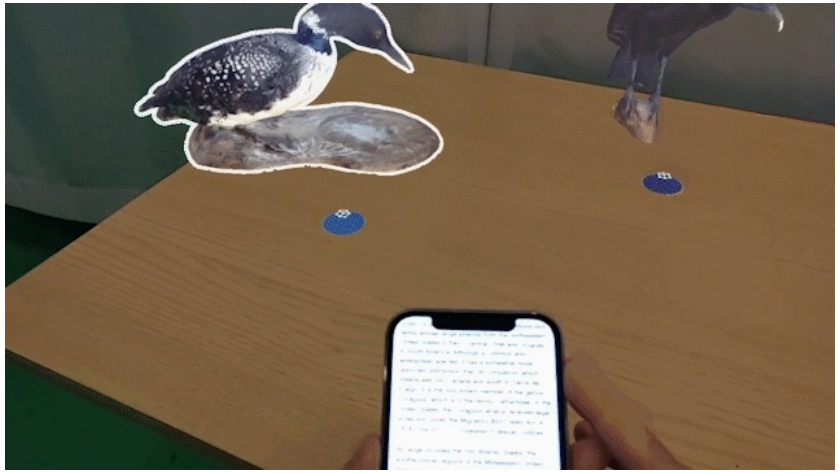


Hybrid

(HoloLens 2 + iPhone 12 Pro)

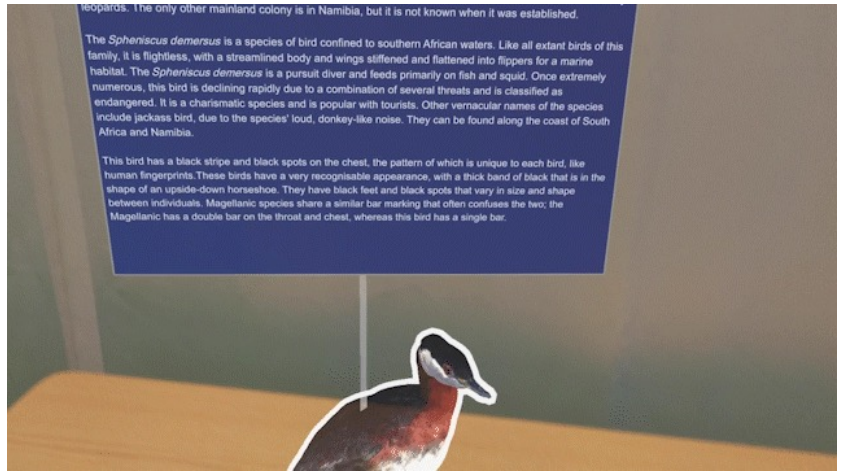


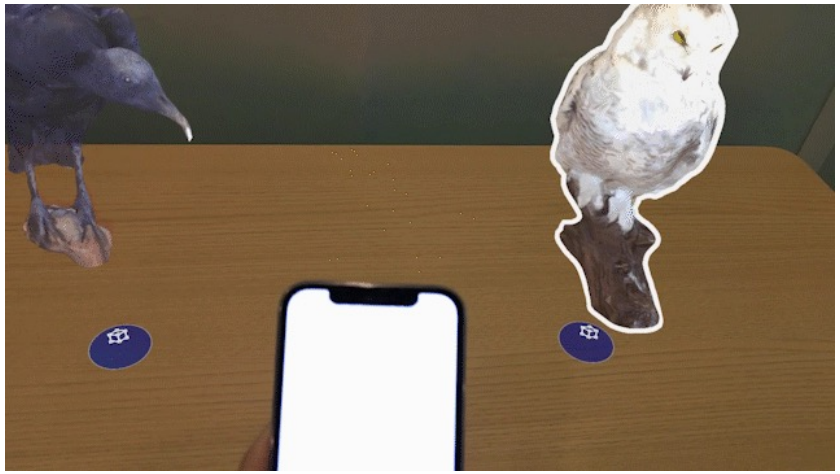
Experimental Conditions

Short *(300 words)*		
Long *(600 words)*		
	HMD only	***Hybrid*** *(HMD + smartphone)*

Text Settings

***Short** (300 words)*

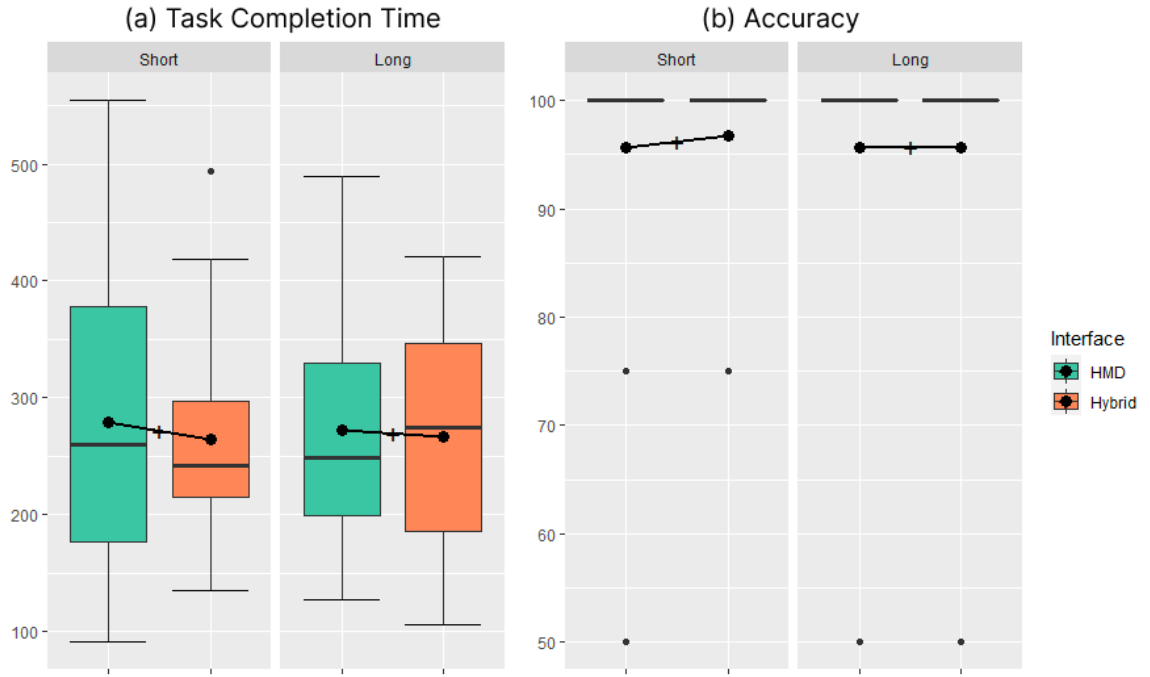




	HMD only	***Hybrid** (HMD + smartphone)*
Text font	Arial	Arial
Text size	0.45º	0.45º
Viewing distance	45cm	≈ 34cm
Text color	White	Black
Background color	Blue	White
Textbox size	32.3º × 21.52º	12º × 24.35º

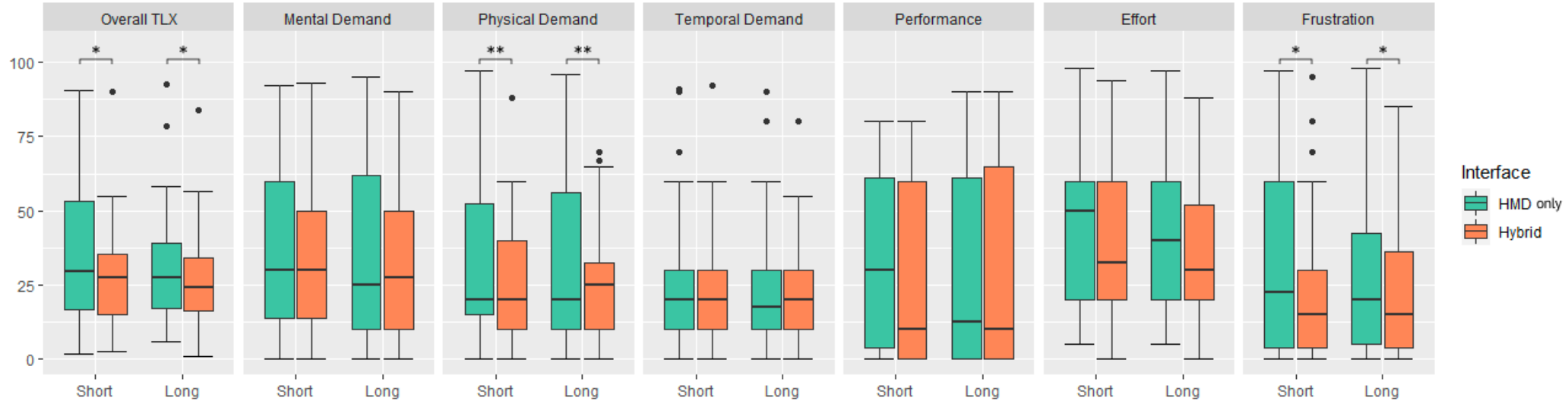
Results: Task Performance

- **No significant difference** between ***HMD only*** and ***hybrid*** ➔ H1 Rejected
- No interaction effect between INTERFACE and TEXT LENGTH ➔ H3 Rejected



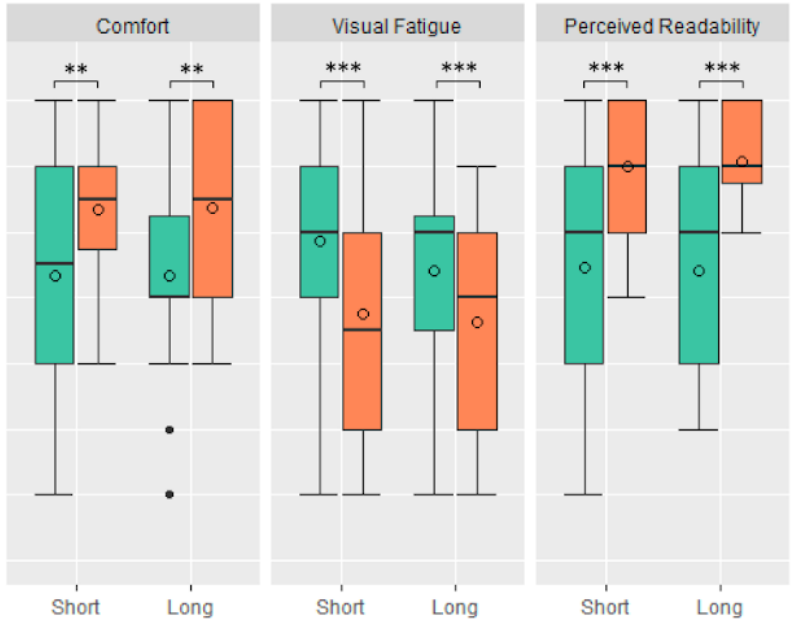
Results: Perceived Task Load

- ***Hybrid*** yields **lower perceived task load** than ***HMD only*** ➔ H2 Accepted
- **Lower physical demand and frustration** for ***hybrid***
- No interaction effect between INTERFACE and TEXT LENGTH ➔ H3 Rejected



Results: Subjective Ratings

- ***Hybrid*** interface provides **lower visual fatigue, and higher comfort and perceived readability** compared to ***HMD only***
- No interaction effect between INTERFACE and TEXT LENGTH



- *"Easier and more comfortable to read text due to the smartphone's higher resolution"*
- *"I could read in a more comfortable posture."*
- *"Scrolling was easier on the phone. Nevertheless, I could quickly get accustomed to scrolling on the HMD."*

Results: Preference

- **19 out of 24 (79.17%)** reported an **overall preference** for using the ***hybrid*** over ***HMD only*** for reading in AR
  - **16 (66.67%)** preferred the ***hybrid*** over ***HMD only*** for ***short*** text
  - **21 (87.5%)** preferred the ***hybrid*** over ***HMD only*** for ***long*** text

Disdvantages of the *hybrid* interface

- *"Less immersive and less entertaining"*
- *"Higher attention switch cost"*

Summary

- **A smartphone-assisted hybrid interface is a viable solution** for enhancing the user's **subjective AR reading experience**
  - Although the *hybrid* interface does not improve task performance, it **reduces the user's perceived task load**, especially the **physical load**.
  - It also increases the **perceived readability** and **user comfort,** while reducing **eye fatigue**.
  - The **benefits of the hybrid interface outweigh the associated costs** regardless of text length.