User Fatigue Detection in Augmented Reality using Eye Tracking

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Background

Motivation:
- Workers in many industries suffer fatigue at the workplace, impacting productivity, well-being, and safety.
- As augmented reality (AR) technology advances, its applications will be more widely adopted by these workplaces, presenting the opportunity and challenge of understanding user fatigue in AR.
- This study focused on using eye tracking from a MagicLeap One AR headset and measured performance on a user task to detect user fatigue and its impact on task performance.

Eye-tracking:
- Past studies have shown that eye-tracking is an unobtrusive way to monitor mental fatigue [1-4].
- As users become more fatigued, metrics showed:
  - **Decrease** in Pupil Diameter
  - **Increases** in Blink Rate and Duration

Figure 1. MagicLeap One Augmented Reality Headset

User Study

Pilot user study (n=8):
Each session was conducted in 7 phases:
1. Entry questionnaire
2. First user task
3. Post-task questionnaire
4. Fatiguing activity
5. Post-activity questionnaire
6. Second user task
7. Exit questionnaire

- Each of the four questionnaires asked users to rate their fatigue on a 1 – 10 scale.
- Fatiguing activity consisted of a warehouse safety training video (21 minutes in length). This phase was designed to fatigue the user.
- I developed this experimental design based on similar procedure from past studies [1-3, 5].

Augmented Reality Task

- Users were asked to perform a **simulated warehouse inspection task** with a custom AR app I developed using Unity 3D.
- Task asked users to locate items by serial number from ten AR inventory lists placed around a room.
- The AR app recorded eye tracking metrics at 30 Hz:
  - Blink time, rate, and duration
  - Pupil diameter (left, right, average)
- All list contents were randomized for each session.

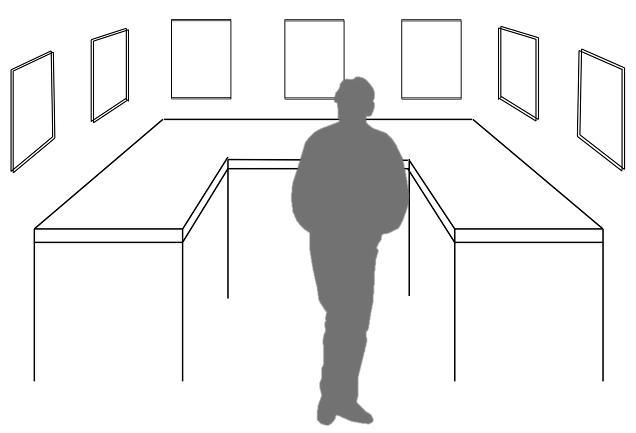

Figure 2. Layout of AR elements in the simulated warehouse inspection task

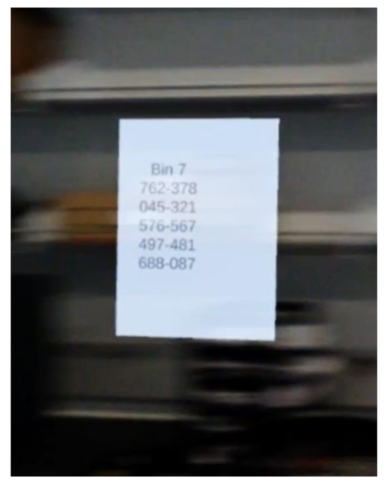

Figure 3. Screen capture of an inventory list from custom AR app

Eye Tracking Metrics

First and Second User Tasks:
When comparing eye tracking data from the second user task with the first user task, the results showed:

Blink Metrics:
- **Decrease** in mean blink rate (Δ -1.35 blinks per minute)
- **Increase** in mean blink duration (Δ +63.16 ms per blink)

Pupil Diameter:
- There was a **decrease** in mean pupil diameter (Δ -0.57 mm)

Fatiguing Task:
Eye tracking metrics exhibited trends consistent with the hypothesis, as shown below (representative sample data).

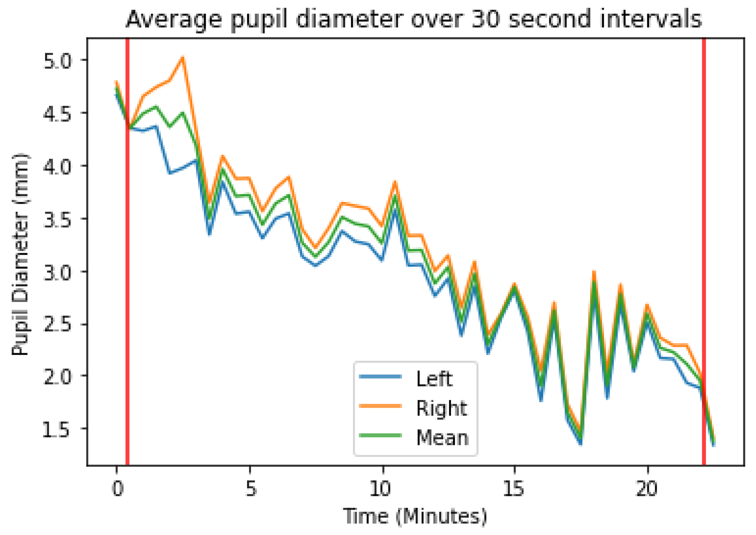

Figure 4. Pupil diameter during fatiguing task.

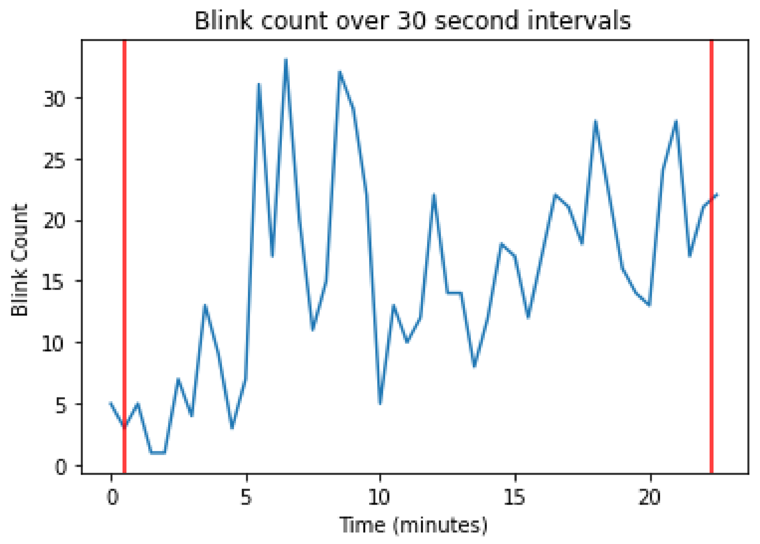

Figure 5. Blink rate during fatiguing task.

Results and Discussion

Reported Fatigue:
- All participants reported an **increase in fatigue** (mean difference of **2.5**) as a result of the fatiguing activity.
- Performing the user task reduced reported user fatigue by a mean difference of **0.125 for the first user task**, and **1.0 for the second user task**.

Task Performance:
- 2 of 8 participants completed the second user task **10% more accurately** than the first user task, while there **was no difference in accuracy** for the other participants.
- Half of the participants completed the second user task an average of **17.75 seconds** faster, while the other half completed the second user task on average **25 seconds** slower.

These results show that:
- **Decrease** in pupil diameter and **increase** in blink time (blink rate x duration) is correlated with increased fatigue, **consistent with the hypothesis**.
- Certain activities (i.e. the user tasks) may **reduce user fatigue**.
- A correlation between task performance and reported fatigue was not found.

Future Work

- Add a **"training" phase** prior to the first user task, to mitigate the effects of familiarity with the task on performance.
- Further investigate **classifiers** and machine learning-based methods to detect fatigue in **real-time**.
- Explore ways to **dynamically** adapt AR content to reduce user fatigue when performing tasks.
- Expand into other cognitive measures that can be detected using eye-tracking, such as cognitive load.

References

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