Visual processing of Head-Mounted Display symbology

Aeolus Human Performance Innovation

TNO BRINGING SCIENCE & INNOVATION TO THE FRONTLINE

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Introduction

A Head Mounted Display (HMD) is fixed to the head, making eye movements the sole option to scan the display. Large-FoV HMDs require saccades significantly exceeding the typical natural limit of 15deg (Adler & Stark,1975), thereby causing eye-strain (Kooi,1997).In addition, the rate of information uptake is expected to decrease towards the edges.

Methods

Procedure

We measured the dynamics of information uptake from a simulated HMD as a function of eccentricity and 'clutter' level. 12 Participants quickly determined the orientation (T vs ⊥) of a target T surrounded by 4 randomly oriented (T ⊥ ⊢ ⊣) flanker T's as a function of:

1. target-flanker spacing (small / medium / large)
2. eccentricity (15 / 30 / 45 deg)
3. flanker polarity (same / opposite)

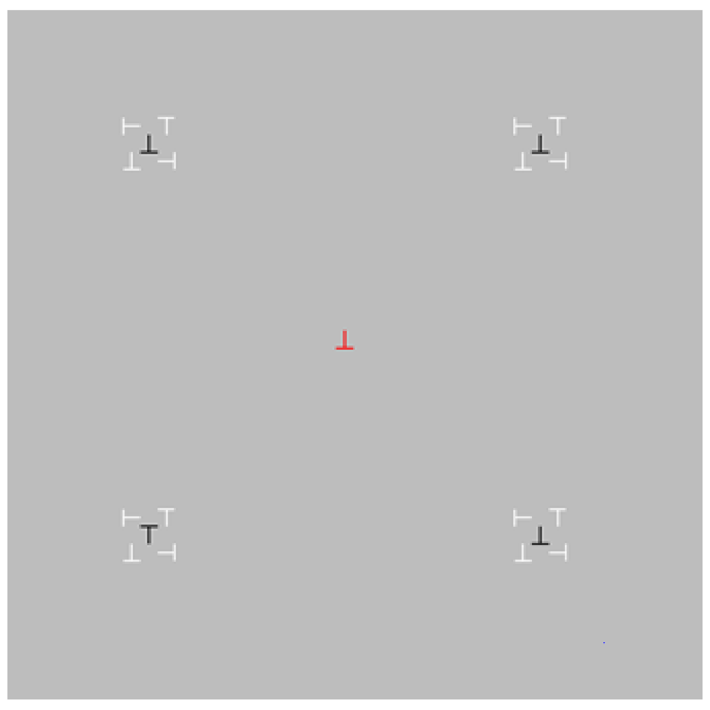
The one-hour test was repeated in reverse order after a 15 min break.
Visual comfort was assessed with questionnaires.

On each trial participants performed the following steps:

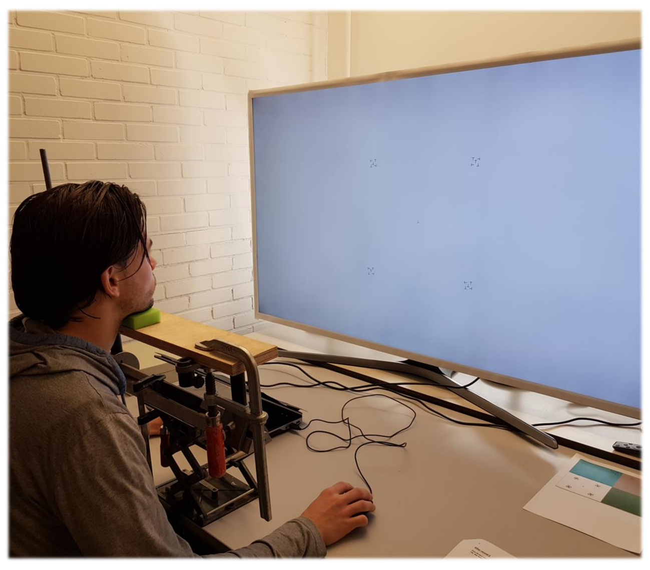
1. Fixate the ⊥ in the middle of the screen
2. Press the space bar to start a trial by flipping the fixation T
3. Look at the target T's in the four corners remembering the upright ones (T)
4. Press the space bar again to stop the trial
5. The participants entered the responses at their own pace.

Stimuli

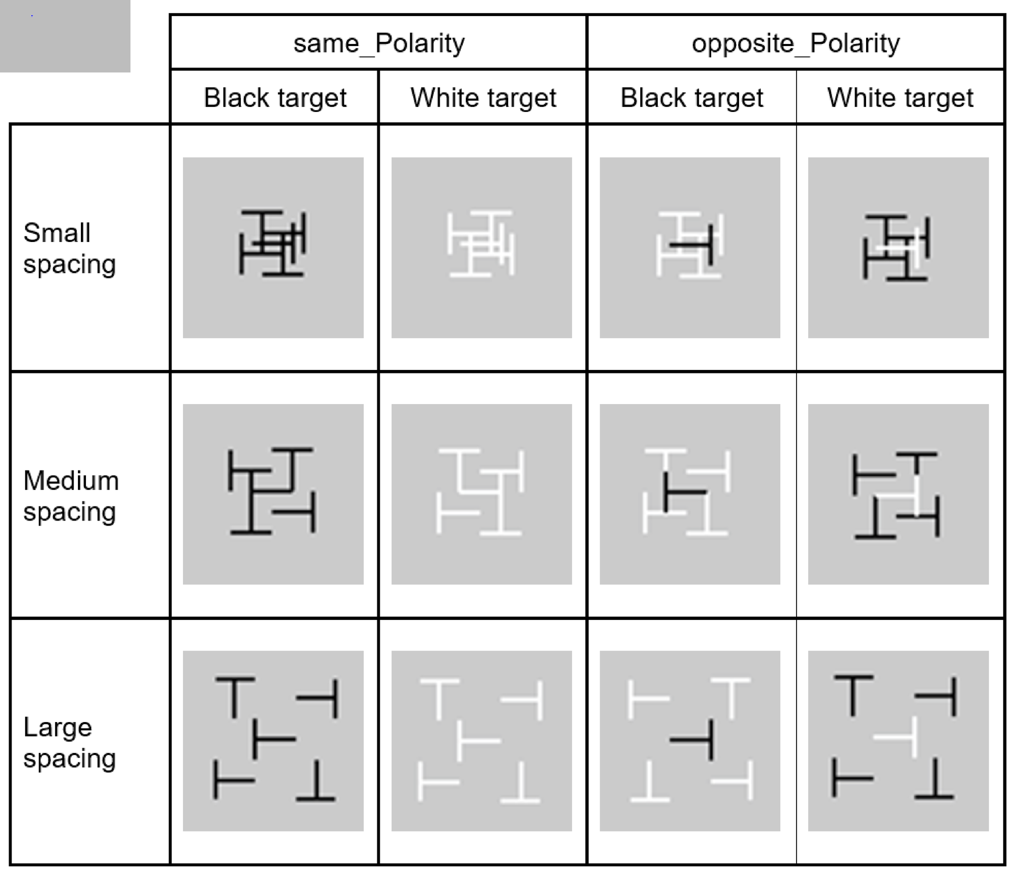
Example stimulus
(4 black target **T**'s, white flankers)



The setup

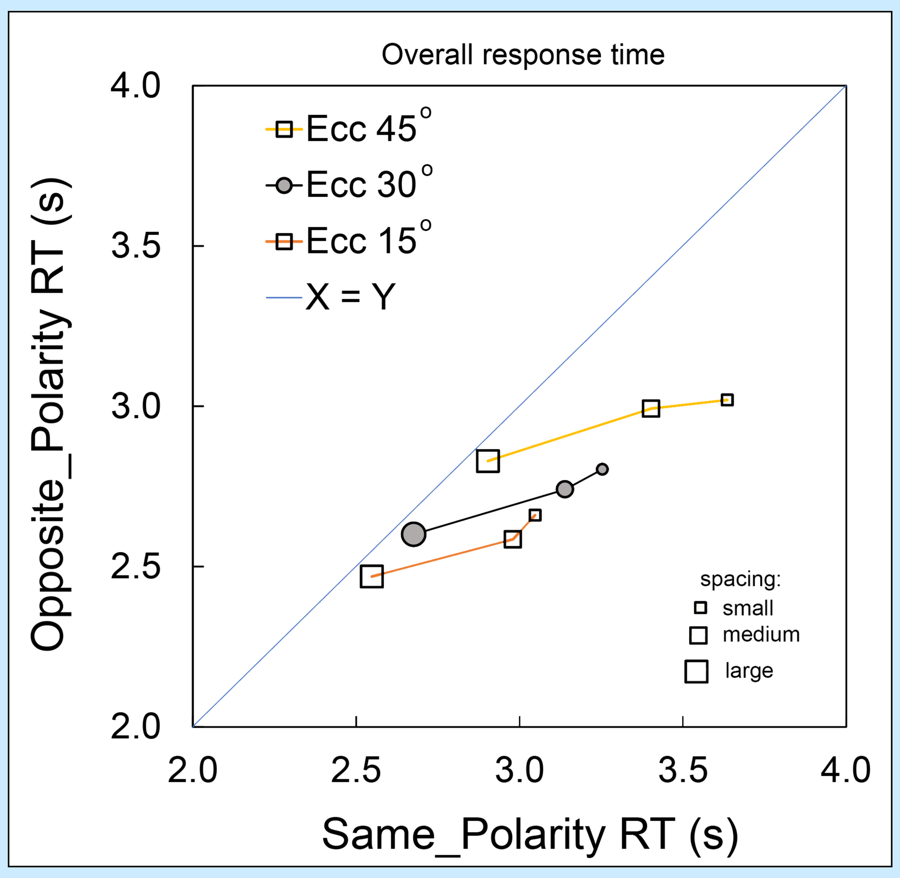


Stimulus Configurations:

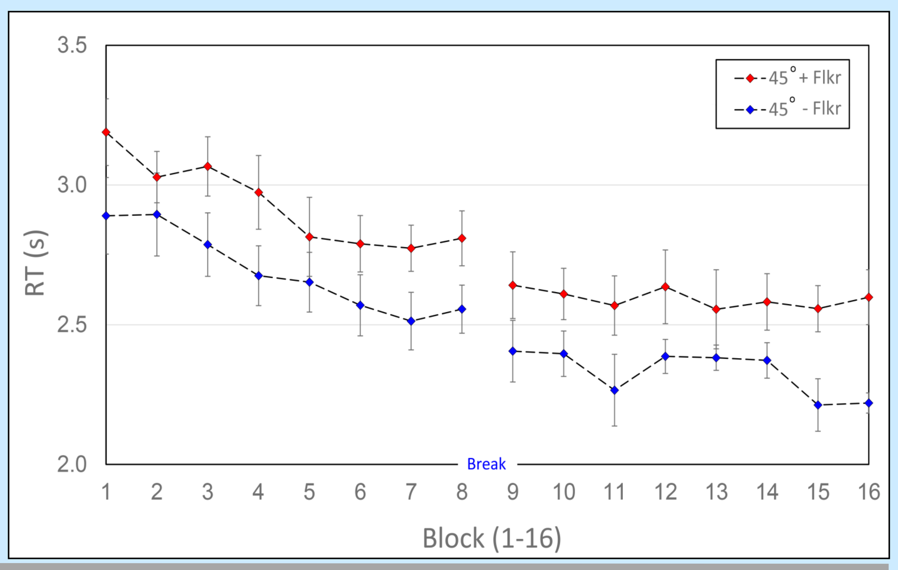


Results

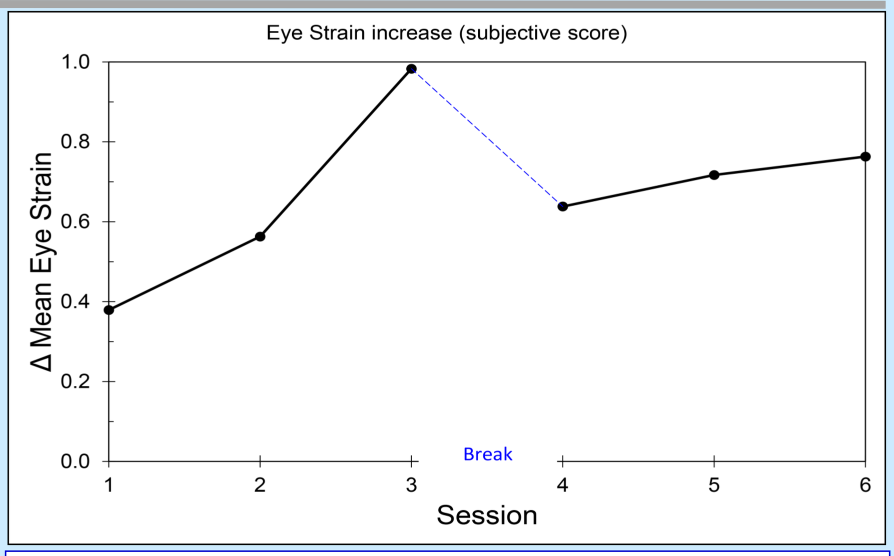
Reaction time increases with crowding, symbol eccentricity, and decreases with opposite target-flanker polarity (p values < 0.001):



Contrary to our expectations, reaction time decreases after the break, suggesting saccadic motility improves over time (Parsons & Ivry, 2018):

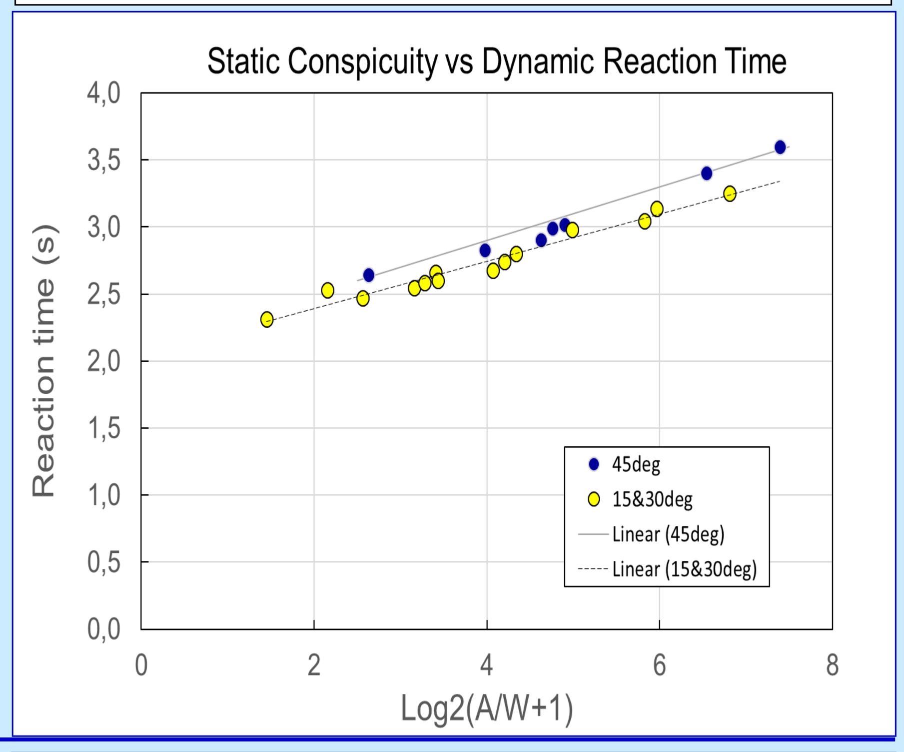


As expected, subjects complain most of eye-strain at large eccentricities (45º: p<0.037):

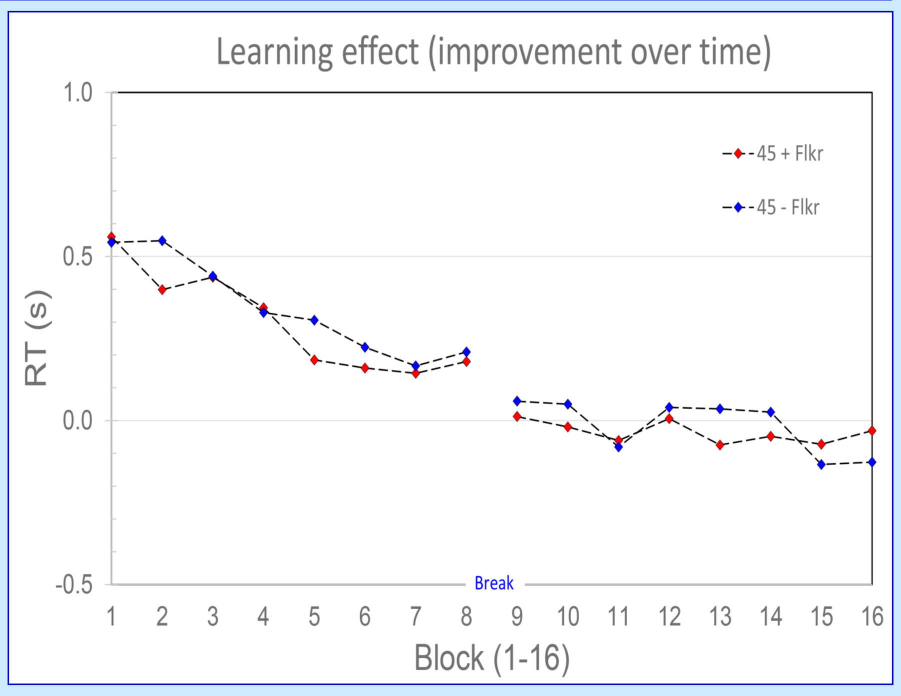


Modelling

The 15 & 30 degree measurements can be linearly modelled with a Fitts' like model: The 45 degrees eccentricity data separately also follow Fitts' law, but require 200ms longer:



The learning curve levels out after one hour intensive training at the large eccentricities:



Conclusions

1) Crowding significantly reduces reading speed
   - Opposite Polarity leads to less, but not zero crowding
2) Ocular motility appears to be trainable
   - Like cycling, the learning effect appears to be persistent
3) The dynamics of HMD information uptake resembles Fitts' law:
   - Suitable as a Design tool for the spatial layout of symbology HMDs

Practical implications

1. Design HMDs with crowding in mind
   - Look for practical 'tricks' to reduce crowding in a HMD
2. Design HMDs with eye-strain in mind
   - e.g. limit the FoV of symbology HMDs to ~30 degrees
3. Train'up' ocular motility first, before applicant-selection

Acknowledgement

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References

Bahill, Adler & Stark (1975). Most naturally occurring human saccades have magnitudes of 158 or less. Invest. Ophthal. & Vis Sci 14, 468-469.

Parsons & Ivry (2018). Rapid alternating saccade training. In *Proc. 2018 ACM Symp. on Eye Tracking Res. & Appl.* (p. 30). ACM.

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