Controlling the readability of Head-Mounted Displays

Aeolus Human Performance Innovation

TNO BRINGING SCIENCE & INNOVATION TO THE FRONTLINE

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Introduction

Information displayed on Head-Mounted Displays (HMDs) can only be read by making eye movements, since head movements have no effect on the ocular image position.

Hypotheses :

1. Opposite target-flanker polarity significantly increases reading speed (symbol legibility) by reducing crowding (clutter).

2. Aniseikonia (asymmetric image magnification in both eyes: a common visual deficit) significantly limits the readability of large field-of-view (FoV) binocular HMDs and causes eye strain.

Methods

Procedure

To investigate the dynamics of information uptake from HMDs as a function of eccentricity and 'clutter' level, we measured

- the ability to quickly determine the orientation of target Ts (T vs ⊥) surrounded by 4 randomly oriented (⊤, ⊥, ⊢, ⊣) flanker T's,
- quantified through reaction time and percentage correct,
- as a function of target-flanker spacing and eccentricity,
- for the same and opposite target and flanker luminance polarity,
- with and without a 2½% aniseikonic lens.

In addition we measured the subjective eye strain.

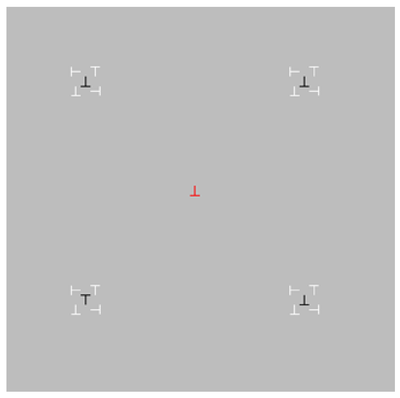
The additional delay caused by the four flankers is adopted as the 'Crowding-Time' (= part of the overall reaction time).
In the aniseikonic condition, a lens placed in front of one eye optically enlarged the image by 2½%, simulating a common optometric condition.

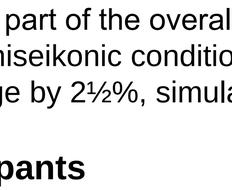
Participants

N= 12, all scored normal on relevant optometric tests (stereopsis, visual acuity, Awaya aniseikonia test, phoria).

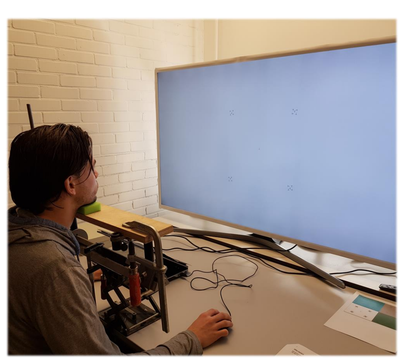
Stimuli

Participants fixated the ⊥ in the middle of the screen. After pressing the space bar to start a trial, they successively looked at the target T's in the four corners and remembered which ones were standing upright, and subsequently pressed the space bar again to stop the trial.

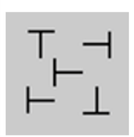




In the aniseikonia condition a 2½% enlarging lens was placed before the left eye.

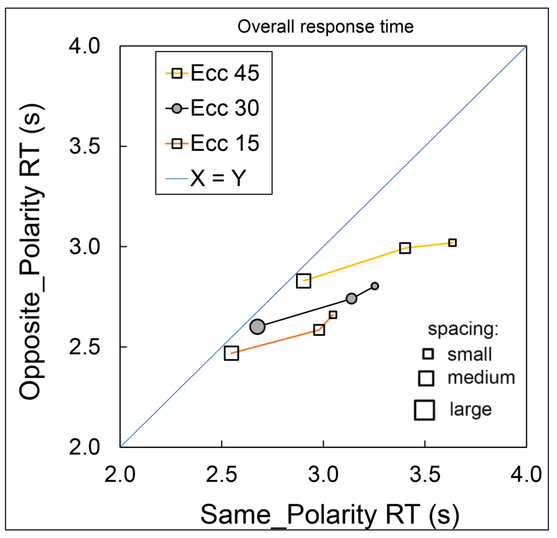


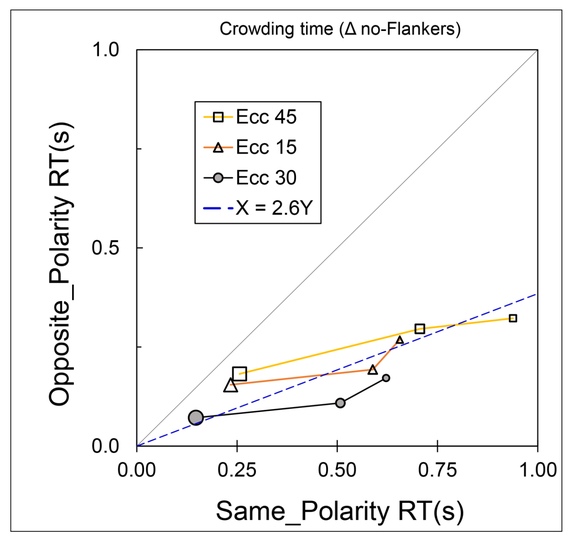
The different stimulus configurations used in this study.

	same_Polarity		opposite_Polarity	
	Black target	White target	Black target	White target
Small spacing				
Medium spacing				
Large spacing				

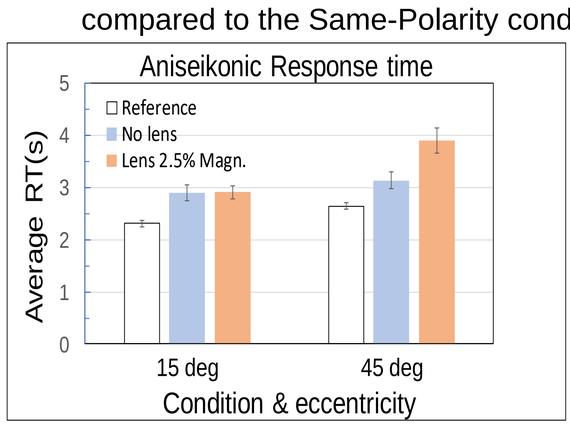
Results

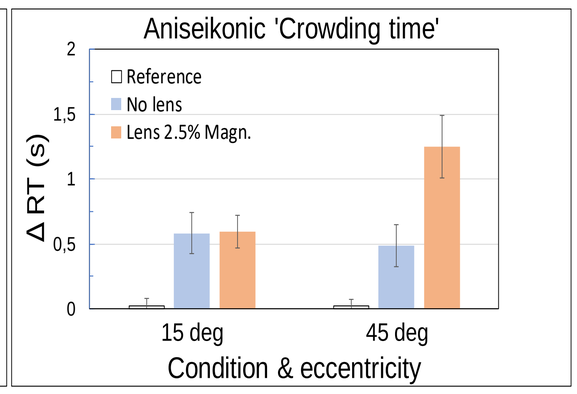
Crowding time is heavily influenced by polarity and aniseikonia:





Opposite-Polarity reduced Crowding-Time by a factor of 2.6 ($p < 0.001$) compared to the Same-Polarity condition.





Unexpectedly, mild aniseikonia:

- doubled Crowding-Time ($p<0.001$), and
- caused the highest level of eye strain ($p< 0.001$).

At large eccentricities, participants also complain of eye-strain.

Conclusions

For all eccentricities and target-flanker spacings, Crowding-Time is :

- reduced more than twofold by opposite polarity,
- doubled by 2½% un-habituated aniseikonia.

Thus, optimal deployment of large FoV HMDs requires:

- decluttering to optimize overall display readability
- screening of common optometric conditions like mild aniseikonia

Practical implications

Even users with mild aniseikonia are likely to experience problems while reading large FoV HMDs.

Currently the F35 HMDS is the only wide FoV symbology HMD in use, but more are bound to follow.

Current screening norms do not exclude mild aniseikonia: Dutch pilots who just pass the norm for anisometropia (<2D) can exhibit 2½% aniseikonia* which doubles Crowding-Time.

Design: A decluttered HMD design significantly increases information uptake.

* corrected by spectacles if Refractive Anisometropia or contact lenses if Axial Anisometropia.

Acknowledgement

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References

Kooi, F.L. (1997) Visual strain: a comparison of monitors and head-mounted displays. Imaging Sciences and Display Technologies, SPIE-2949, pp. 162-171. DOI: 10.1117/12.266346.