Psychophysical scale of optical distortions of multifocal spectacle lenses

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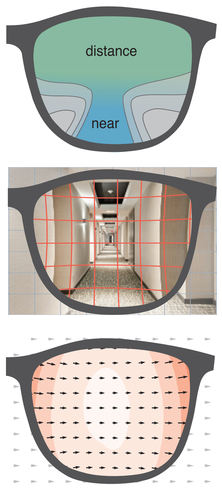
Purpose

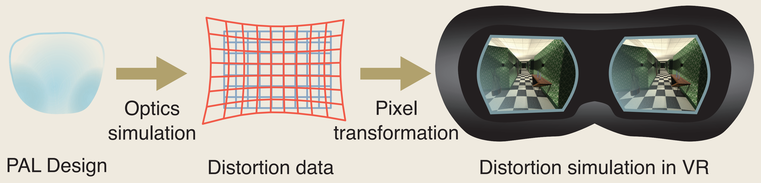
- With increasing age the accomodative capabilities of our eyes decrease (presbyopia) making it progressively harder to focus close objects.
- Progressive Addition Lenses (PALs) are the generally used spectacle solution for presbyopia.
- In one lens, different zones with different optical power correct distance and near vision.
- Gradient of optical power inevitably leads to optical distortions.
- Especially during motion, perception seems unnatural; the environment is perceived as unstable.
- Correction power in the near zone (*Sph*) and far zone (*Add*) both influence shape and strength of optical distortions.



How do perceived distortions scale with the far and near correction of the lens?

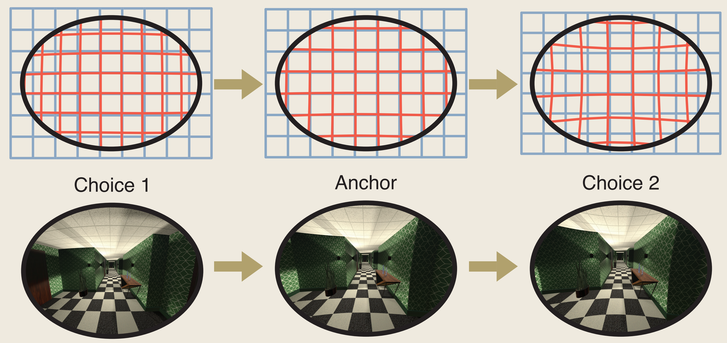
Methods

VR simulation of spectacle lens distortions



Psychophysical experiment

- Subjects (n=13) could move freely in virtual indoor environment
- 10 different distortion stimuli were presented during the experiment
- Varying far and near correction between distortions:
  - *Sph* (correction for distance): -5 dpt to 5 dpt
  - *Add* (additional power for near vision): 1 dpt and 3 dpt
- Presentation of three distortions each trial; 2 sec per distortion



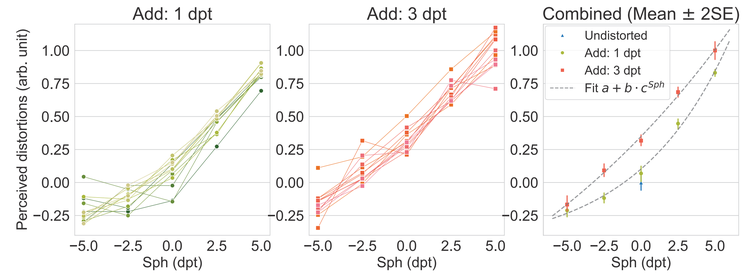
Task: Triplet question
"Which distortion–Choice 1 or Choice 2–is more similar to anchor?"

For three distortions (1,A,2) the answer gives information about perceived dissimilarity δ:

Choice 1: $\delta(1,A) < \delta(A,2)$
Choice 2: $\delta(1,A) > \delta(A,2)$

Results

- Psychophysical scaling function is estimated using ordinal embedding [2]: "perceived distortion" is determined for each stimulus, so that the distance between stimuli maximally agrees with the given dissimilarity data δ
- Embedding accuracy did not increase with more than one dimension
- Individual scaling functions are aligned using procrustes analysis
- Undistorted is set as zero point



Results show a similar scaling for all observers:
- Perceived distortions increase with *Sph* and *Add*
- The scaling flattens for negative *Sph*
- *Add* seems to compensate perceived distortions partly for negative *Sph*

Conclusion

Perceived distortions of PALs depending on near and far correction can be quantified with a 1D scaling function estimated from comparison answers.

Ordinal embedding can be used to measure the psychophysical scaling of PAL distortions. The scaling function is determined from answers to a comparison task in a VR simulation of optical distortions. Both near and far correction increase the perceived distortions. Short-sighted people (negative *Sph*) seem to have an advantage of generally lower percieved distortions and partial compensation of distortions by the positive power in the near zone.

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References

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[2] Haghiri, S., Wichmann, F. A., & von Luxburg, U. (2020). Estimation of perceptual scales using ordinal embedding. Journal of vision, 20(9), 14-14.

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