Stroboscopic goggles as a countermeasure for dynamic visual acuity and landing sickness after long-duration spaceflight

M.J.F. Rosenberg[1,2], G.A. Kreutzberg[2], B.T. Peters[2], and M.F. Reschke[3]

[1]Baylor College of Medicine, 1 Baylor Plaza, Houston TX 77030 (marissa.j.rosenberg@nasa.gov)
[2]KBRwyle Science, Technology, & Engineering Group, Houston, TX
[3]NASA Johnson Space Center, Neuroscience Laboratory, Houston, TX

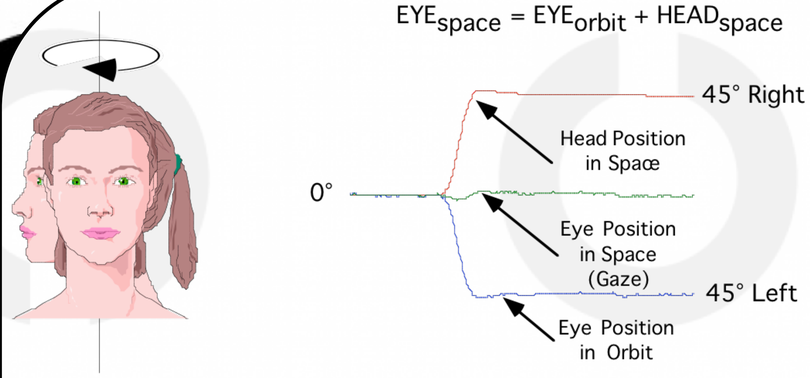


Figure 1. Example of gaze control and the vestibulo-occular reflex.

Gravity transitions cause changes in the vestibulo-occular reflex (VOR), which manifests as poor gaze control, a decrement in dynamic visual acuity (the ability to maintain gaze while in motion), both of which are caused by retinal slip.

Background

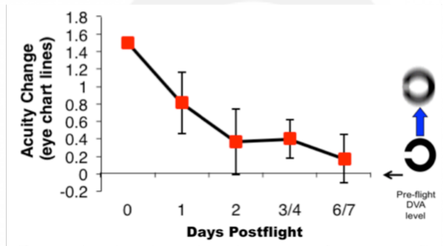


Figure 2. Dynamic visual acuity changes after spaceflight. Adapted from Peters et al. (2011).

Retinal slip, the inability to keep an image focused on the retina, can drive or worsen sensory conflict, resulting in motion sickness (MS). Currently 100% of returning crewmembers report MS symptoms, which might affect their ability to perform mission critical tasks immediately after landing.

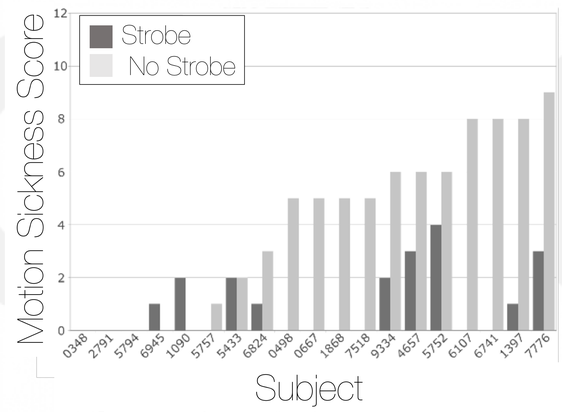
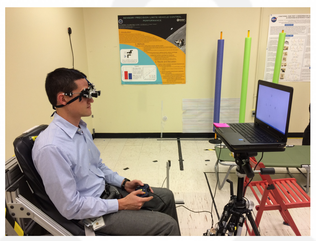


Figure 3. MS scores after reading in a moving car, with and without stroboscopic goggles. Adapted from Reschke et al. (2007).

Reschke et al. (2007) demonstrate that stroboscopic vision goggles improve motion sickness onset and symptom severity in motion sickness driven by retinal slip.

Methods

Dynamic visual acuity (DVA) is assessed using an oscillating chair developed in the Neuroscience Lab at JSC. This chair is motor-driven and oscillates vertically at 2 Hz with a vertical displacement of 5 cm to simulate walking. The subject is asked to discern the direction of Landolt-C optotypes of varying sizes and record its direction using a gamepad. The size of the "C" is determined by a forced-choice best parameter estimation that rapidly converges on the acuity threshold. Visual acuity thresholds were determined both for static (seated) and dynamic (oscillating) conditions, where DVA is the difference between the dynamic and static acuity.



To simulate the adaptive state of the VOR experienced by returning astronauts, subjects wore 0.5x minifying lenses. We tested the following randomized conditions:

A) No lenses, no goggles
B) Minifying lenses
C) Stroboscopic Goggles
D) Lenses & goggles

The presentation of the "C" is reduced to 200ms for the conditions without lenses or goggles, and just the lenses to compensate for the fraction of light available while wearing the stroboscopic goggles. When the goggles are worn, the presentation lasts 1s.

Results

Healthy subjects (n=20) had significantly worse DVA (31.5%, $p<0.05$) while wearing minifying lenses. On average, DVA was improved 8.8% with strobe goggles and was only 6.9% worse with the lenses and the goggles, but neither change was significant compared to no lenses, no goggles.

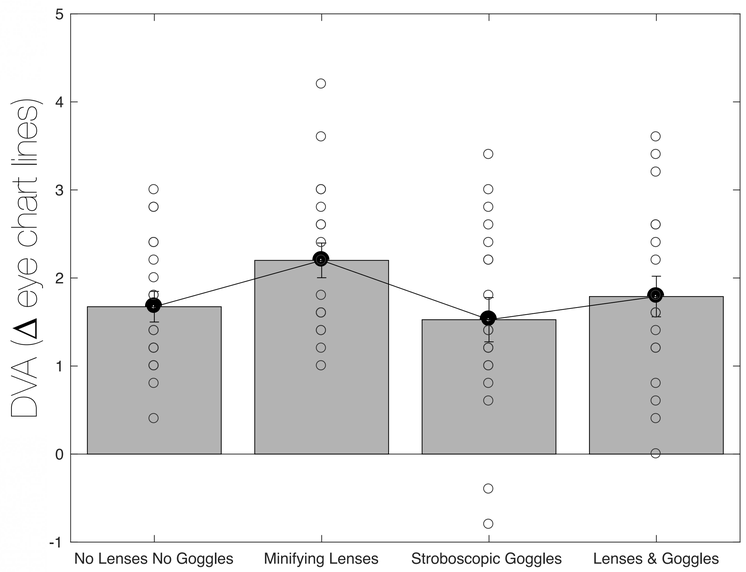


Figure 4. Difference in eye chart lines between dynamic and static acuity in each condition. Minifying lenses had significantly worse acuity..

Conclusions

Stroboscopic goggles do not cause a decrement in DVA while the VOR is undergoing adaptation, and are thus a safe countermeasure for landing sickness symptoms. These goggles might also be used to counter blurred vision experienced during launch where the vehicle vibrations are greatest.

References

Peters BT, Miller CA, Brady RA, Richards JT, Mulavara AP & Bloomberg JJ (2011). Dynamic visual acuity during walking after long-duration spaceflight. Aviation, space, and environmental medicine 82, 463-466

Reschke M, Kmavek J, Somers J, Ford G, Hwang E, Leigh R & Estrada A (2007). Stroboscopic vision as a treatment for retinal slip induced motion sickness in Proceedings of the First International Symposium on Visually Induced Motion Sickness, Fatigue, and Photosensitive Epileptic Seizures (MMS2007), Vol. 1, pp. 55-58

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