Internat. Marit. Health, 2008, 59, 1 - 4

TIME FOR REVISION OF SEAFARERS VISION TESTING? ARTICLE FOR DISCUSSION

NILS BULL [1]

VISION RELATED ACCIDENTS

The maritime sector has a high incidence of serious and fatal injuries because of frequent accidents and maritime catastrophes (1). The Marine Accident Investigation Branch (2) in the United Kingdom claims that, after the positive trends in technological navigation instruments in the past 20 years, one factor is the predominant cause of accidents: human error. This hypothesis is supported by an overview from Rothblum (3) of the United States Coast Guard Research & Development Center showing that 75–96% of maritime accidents result from human error at least in part. Statistics on maritime accidents in New Zealand (4) in 1995–1996 showed that 49 % resulted from human error, 35% from technical factors and 16% environmental factors. The two most common human factors were improper watchkeeping or lookout and error of judgement.

A study of 177 maritime accidents in eight countries (5) related 71% of human error to situation awareness. This was defined at three levels: 1) failure to correctly perceive information, 2) failure to correctly integrate or comprehend information and 3) failure to project future actions or the state of the system (a combination of levels 1 and 2). It was

[1] Haukeland University Hospital, Bergen, Norway
Address for Correspondence: Dr Nils Bull, MD, PhD, Specialist in Occupational Medicine, Specialist in Ophtalmology, Director of Department of Ophtalmology, Hordnesveien 136, Fana 5244, Norway, Tel.+47 55 97 4099,
E-mail:nils.bull@uib.no

shown that 59% of the situation awareness failures were at level 1, 33% at level 2 and 9% at level 3. Thus, the most common human error is that seafarers cannot or do not see what is happening, but we do not know how much of this which is caused by reduced vision. Wood and Owens studied vision in car drivers and found that standard measures of visual acuity do not predict driver's recognition performance under day or night conditions (6). The paper concludes that the performance of a driving test with real-world recognition of objects under various light conditions was better predicted by a standard test of contrast sensitivity than by visual acuity. But interestingly contrast sensitivity was highly correlated with visual acuity measured under low-luminance conditions. The results also showed that older drivers have greater problems with visibility during night driving. The conclusion strengthens the hypothesis of this paper that testing of visual acuity in daylight might not be sufficient as vision testing for recognition of objects under various light and weather conditions at sea and that new tests are needed.

Maritime vision

Vision is the most important sense used in maritime navigation. The bridge crew navigates ships with tremendous weight travelling at high speeds in narrow waters with other vessels in the dark and in poor weather. The bridge crew may encounter the wreck of a small boat without lights or radar reflectors drifting in the path of their ship. The bridge crew must simultaneously watch the path of the ship and monitor radar, map plotters and an instrument panel, which adversely affects their night vision. If the technical aids fail, the crew members are extremely dependent on good night vision, but they must continue to use light to see the maritime maps. In bright sunlight and especially when the sun is low on the horizon and in directly in their field of vision in the direction the ship is moving, crew members are blinded and the monitors on the bridge may be difficult to see because of reflections and poor contrast.

Seafarers' vision is tested for distance, colour and field of vision. Distance vision is tested using a Snellen vision test from 1862. Snellen defined standard vision as the ability to discern details of one minute of arc (1/60 of a degree), or details 1.5 mm large from 5 metres away. This is the current Norwegian requirement for bridge crew with both eyes simultaneously. This vision test has disadvantages, such as some letters being easier to recognize, fewer letters for weak vision abilities, identical distance between the letters regardless of their size and nonlogarithmic changes in letter size, such that the precision varies in different parts of the chart. The test is performed in normal daylight and uses black letters on a white background, providing 100% contrast. These are optimum contrast conditions, which are in blatant contradiction to the actual visual conditions at sea, where there may be extremely bright sunlight, fog, heavy rain, snow and especially darkness, often with minimal contrast in the field of vision. Bridge crew also need depth perception (stereopsis), which is needed for instance to assess whether a large ship ahead has slowed down, but depth perception is not tested.

No one has ever investigated whether the Snellen vision test is sensitive to the vision ability needed for bridge crew members on ships: that is, whether the test excludes people whose vision is inadequate to perform bridge crew duties in anything other than normal daylight. The results of inadequate vision among bridge crew members can be fatal.

Vision requirements for pilots

Civilian commercial pilots in Norway undergo a comprehensive initial examination by an ophthalmologist at the Institute of Aviation Medicine in Oslo. International ophthalmological requirements are complied with (7), but the initial examination in Norway includes more tests that the minimum requirements, including contrast vision testing and the topography of the cornea. In principle, no form of eye disease or disorder, eye surgery or eye injury is acceptable. The use of corrective lenses is accepted up to moderate strength if the candidates do not achieve distance vision of 6/6 (1.0) with both eyes simultaneously. For military pilots in Norway, the use of corrective lenses is not acceptable. The occupation of pilot therefore ends up selecting people with good vision. Similar requirements for seafarers with bridge duty would exclude many current seafarers, be very expensive, take up a great deal of ophthalmological resources and not be based on evidence.

Vision requirements for seafarers

Minimum in-service eyesight standards in section B of the Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Code requires bridge crew to have uncorrected distant vision of 0.1 and corrected vision of 0.5 in both eyes. The requirement for night vision is “to perform all necessary functions in darkness without compromise”. Visual fields should be normal and no significant double vision evident. There is no specification of how to perform testing to meet these requirements. A requirement of 0.5 (50%) distance vision for outlook duties is obviously not sufficient and for this reason the vision requirements vary throughout the world.

The current vision requirements for bridge crew in Norway are laid down in the Circular on Health Examination of Employees on Ships of 1 January 2002:

- uncorrected vision in the best eye: 5/20 (0.25) and in the other eye, 5/30 (0.17);
- corrected vision with both eyes: 5/5 (1.0);
- normal field of vision in both eyes; and

- normal colour vision in the Ishihara test, and if this is not passed, then referral to an ophthalmologist for a lantern test.

Work is being carried out in several countries to achieve uniform requirements for examining seafarers (8-9). The requirements should be evidence based. The current tests risk passing seafarers who have inadequate vision for bridge duty. A high-quality vision test or set of tests, is clearly needed that passes people with satisfactory vision and fails people with inadequate vision.

CRITICAL UNANSWERED QUESTIONS

Question 1

Will people with mild cataracts or corneal scarring have problems with blinding in bright light such that they would have inadequate vision for bridge duty if they were tested under such conditions? This would result from refraction in the imperfection in the lens or cornea (this blinding is similar to that experienced in driving into the evening sun with a dirty windshield).

Question 2

Will people who have had laser surgery to correct vision have inadequate vision in the dark even though they meet the current vision requirements for bridge duty, which is tested in daylight? Many seafarers have had laser surgery on their cornea to be able to meet the vision requirements for bridge duty or to avoid using corrective lenses. Laser surgery is carried out on the central part of the cornea, and people end up with a transitional zone towards the untreated periphery in which light is not blocked such that it falls on the retina. In bright light with a constricted pupil, vision is optimal, but when the pupil dilates in the dark some light waves can enter through the transitional zone where the cornea has not been treated. The transitional zone in the periphery would be able to produce refraction that makes vision worse, and when the person is facing the source of light he or she will see disturbing rings or star-like formations around these sources of light. In the first few years in which laser surgery was carried out, the diameter of the treatment zone was smaller than it is today, and these problems with night vision are therefore more common and more pronounced among people operated before 2000. Similarly, astigmatism and peripheral scarring in the cornea will produce refraction with dilated pupils. O'Brart showed that refractive laseroperations resulted in visual problems in darkness, where 38 % were classified as mild, while 5 % were so serious that patients were unable to drive in darkness (10). Villa et al. describes a 2.15

increase of halo after “successful” refractive surgery in a study from 2007, which indicates that nightvision problems associated with these operations is a serious problem (11).

Question 3

Will lack of stereopsis (binocular vision) lead to objects being discovered too late and incorrect assessment of whether an object is approaching or receding? Will lack of stereopsis cause a person to misjudge which of distant objects is closest? There is no current requirement for stereopsis among people with bridge duty.

A PROPOSAL FOR DEVELOPMENT OF EVIDENCE-BASED VISION TESTING WITH PASSIVE STEREO

In the following a vision test is described which will attempt to recreate the visually demanding conditions at sea in the most realistic way possible with video that provides 3D images of objects to be observed in the sea. The method can be used in a project as a standard for validating existing tests, with the purpose to try to find a set of tests which will be sufficient for vision testing of seafarers. This can for instance be LogMar visual acuity testing in daylight and under low luminance conditions, combined with contrast senstitivity testing. If no such set of existing tests will be found, the new video test can be developed as a new standard for vision testing. Passive stereo can be used to make the vision testing as realistic as possible, it provides three-dimensional (3D) visual experiences and has been used in medicine for anatomical instruction (12), in neurosurgery (13) and at the Department of Oncology of Haukeland University Hospital for dosage planning for treating malignancies (14). Passive stereo has not previously been used for vision testing.

A simulator is a similar method for making the test situation realistic and further adds interaction with the test person who is to navigate a ship or pilot an airplane. A bridge simulator is used to teach navigation but has not been used for vision testing. Existing bridge simulators provide a two-dimensional image so that the trainees do not have to use their depth perception. Kruk & Regan (15) studied performance in piloting jet fighters in simulators and how it was associated with the vision testing of these pilots; the results of the vision testing were associated with depth recognition (in-depth eye tracking) and the ability to hit targets with bombs. Piloting performance was not associated with the results of visual acuity, contrast sensitivity and motion detection tests, but this group is already selected for excellent vision. Simulators have also been used in experiments with car drivers, and drivers with a limited field of vision maintained lower speeds in the simulator (16). George (17) showed that people who were tired had reduced driving performance and an increased incidence of collision. The driving simulator at the Norwegian University of Science and Technology in Trondheim is used for testing whether people with a limited field of vision can drive properly.

Recording of stereo video footage

Video footage can be recorded of various objects that are either close or far away in the open sea under various light and weather conditions. The external factors that determine whether an object is visible include size, distance, movement, lighting, contrast, how long the object is presented and the degree to which the surroundings disturb the viewer. These factors can be measured and systematically varied such that the whole spectrum with diverse variation will be presented. The film can be recorded under actual conditions of rain, fog and snow in both darkness and extreme sunlight but can also be manipulated by adjusting the light and contrast effects. Two cameras can be used that are mounted in parallel on a track 6.5 cm apart, corresponding to the distance between people's eyes.

Projection of stereo video

The film can be shown using two projectors in passive video, in which one projector with film from one camera polarizes the light horizontally and the projector with film from the other camera polarizes the light vertically. Similar polarizing will be used in the right and left lenses of the eyeglasses to be worn by the test person during the test, who will experience the film in 3D if binocular vision is present. If the person does not have stereopsis, the picture will appear in two dimensions as the person normally sees. One object can be presented at a time, such as the mainland, small islands, rocks, ships moving, lighthouses, logs and a passenger over board. The test person can point with a laser pen as soon as an object becomes visible, and an observer will register correct and incorrect observations. The objects can be presented with varying contrast and brightness, first in a dark room to simulate night navigation in which the test person adapts to night vision and the film and the test room gradually become lighter and lighter until the strongly blinding light from a lamp simulates the sun on the horizon in the path of the ship. The observer in the room will ask questions about the colour of lanterns, whether objects are approaching or receding and which of five objects is closest. Each test person will receive a graded profile with total points in the categories of night vision, colour vision, depth perception, vision in daylight, fog, rain, snow, waves and sun in the eyes such that the weaknesses of the test person are easy to spot.

Ethical considerations

A better screening might have the result that a number of seafarers that pass the requirements today will be declared unfit for bridge duty with the new test, which can have serious social and economic consequences. An alternative might be to use the new test for a period only in screening of students to maritime schools. The test, if implemented, will require investment in new expensive equipment where the tests are performed, which in turn might exclude seamen that can not afford higher costs.

CONCLUSION

No evidence-based vision test for selecting bridge crew considers the realistic, demanding vision requirements at sea. This may be the cause of serious accidents. A proposal is outlined for development of a test that recreate the visually demanding conditions at sea with video that provides 3D images of objects to be observed.

REFERENCES

1. Hansen HL, Nielsen D, Frydenberg M. Occupational accidents aboard merchant ships. Occup Environ Med 2002 Feb;59(2):85–91.
2. Department of the Environment, Transport and Regions. Marine Accident Investigation Branch. Annual report 1999. London 2000.
3. Rothblum AR. Human error and marine safety. Paper presented at the National Safety Council Congress and Expo, Orlando, FL, USA, October 13–20, 2000.
4. Maritime Safety Authority of New Zealand. Maritime accidents 1995–1996. Auckland 1997.
5. Grech M, Horberry T, Smith A. Human errors in maritime operations: analyses of accidents reports using the Leximancer tool. Presented at the Proceedings of the 4th Annual Meeting of the Human Factors and Ergonomics Society, Baltimore, MD, USA, September 30–October 4, 2002.
6. Wood JM, Owens DA. Standard measures of visual acuity do not predict drivers' recognition performance under day or night conditions. Optom Vis Sci. 2005. Aug;82(8):698-705.
7. Civil Aviation Authority. Joint aviation requirements – flight crew licensing, ophthalmological requirements JAR-CL 3.215. Bodø 2007.
8. Carter T. Fitness standards for the transport industries. J R Soc Med 2001 Oct;94(10):534–5.

9. Carter T. Fit to go to sea? Travel Med Infect Dis 2003 Feb;1(1):15–6.
10. O'Brart DP, Lohmann CP, Fitzke FW, Klonos G, Corbett MC, Kerr-Muir MG, Marshall J. Disturbances in night vision after excimer laser photorefractive keratectomy. Eye. 1994;8 (Pt 1):46-51
11. Villa C, Gutiérrez R, Jiménez JR, González-Méijome JM Night vision disturbances after successful LASIK surgery. Br J Ophthalmol. 2007 Aug;91(8):1031-7.
12. Silverstein JC, Walsh C, Dech F, Olson E, Papka ME, Parsad N, Stevens R. Immersive virtual anatomy course using a cluster of volume visualization machines and passive stereo. Stud Health Technol Inform 2007;125:439–44.
13. Sun H, Lunn KE, Farid H, Wu Z, Roberts DW, Hartov A, Paulsen KD. Stereopsis-guided brain shift compensation. IEEE Trans Med Imaging 2005 Aug;24(8):1039–52.
14. Patel D, Muren LP, Mehus A, Kvinnsland Y, Ulvang DM, Villanger KP. A virtual reality solution for evaluation of radiotherapy plans. Radiother Oncol 2007 Feb;82(2):218–21.
15. Kruk R, Regan D. Visual test results compared with flying performance in telemetry-tracked aircraft. Aviat Space Environ Med 1983 Oct;54(10):906–11.
16. Rogé J, Pébayle T, Campagne A, Muzet A. Useful visual field reduction as a function of age and risk of accident in simulated car driving. Invest Ophthalmol Vis Sci 2005 May;46(5):1774–9.
17. George CF. Driving simulators in clinical practice. Sleep Med Rev 2003 Aug;7(4):311–20.

Editorial note:

This paper addresses a very important maritime issue.

The Author proposes to develop a new method for testing the vision of seafarers.

We invite our Readers to express their views on the subject, during the International Congress on Maritime, Hyperbaric and Tropical Medicine to be held in June 2009 in Gdynia, or sending a contribution to the next issue of our IMH journal.