Geraint Griffiths BScOptom, MSc, MCOptom, BSc, Mech. Eng.

# Visual performance in yachting

## SVA testing for the Olympics

**Great Britain is the most successful sailing nation in the world and sailing is its most successful Olympic sport. The dedication of our Olympic team is a reflection of the pleasure the sport has given this ancient seafaring nation for thousands of years.**

The Olympic team comes under the jurisdiction of the Royal Yachting Association – a training organisation with 100,000 members. It is made up of 162 class associations (clubs which sail a particular class of boat) **(Table 1)**, 10,462 clubs (111 overseas) and its Southampton headquarters has 100 staff.

Britain was the top nation at the Sydney Olympics and Ben Ainslie is our most successful sailor, winning Silver at the Atlanta Olympics and Gold at the Sydney Games. He has also been world champion for three successive years. Ainslie, who is a member of the current Olympic squad, was tested by the Sports Vision Association prior to the Atlanta Olympics in 1996. This report is a detailed examination of the visual performance in yachting based on the Atlanta team.

### Visual requirements

It is generally held that sailors need to 'see' the wind. Critical attention is paid to the leading edge of the sail (the luff) as it fills and empties. Patterns of the wind on the water provide clues to its direction and intensity and even the feel of the wind across the face and eyes will be used to make tactical decisions in a race. At the same time, the direction of the boat is judged in relation to the bow and the pattern of the water about one or two boat lengths ahead. The general direction comes from a marker buoy, often at great distances.

Fine judgment, of relative speed and distance, is needed when dipping behind other boats and there are constant changes of gaze and vergence. The information ahead is so critical that there is no time to look directly at a competitor's boat, whose progress is judged entirely by peripheral vision.

Even before the race begins, visual decisions must be made to time the run in to the gun. If the starting line is crossed before the gun is fired, it means instant disqualification and possibly years of planning and financial hardship wasted.

### Environmental conditions

The visual demands of sailing are exacting, but the environmental conditions make sailing arguably the most visually demanding sport of all. The movement of the boat and the sailor within, both of which can be violent, compounds the movement of objects of regard. Wind, spray and salt cause stinging, conjunctival injection and epiphora, and the normal optical integrity of the tear layer is compromised.

British Champion, Ben Ainslie, who will compete in this Summer's Olympic Games in Athens

### Visual correction

There is now compelling evidence that optical correction is directly related to sporting performance[1]. If a visual correction is required then losing it overboard is probably the least of the sailor's problems.

#### Contact lenses

Ideally, contact lenses are the correction of choice in sport **(Table 2)** but in the exposed conditions of sailing, they provide

*Table 1*
Class divisions of the Royal Yachting Association

| | |
|---|---|
| 1. **Men's sail board** | Windsurfing |
| 2. **Women's sail board** | Windsurfing |
| 3. **Europe** | 11-ft, women's single-handed |
| 4. **Laser** | 14-ft, men's single-handed |
| 5. **Finn** | 15-ft, the heaviest and biggest men's single-hander |
| 6. **4.70m** | Class for men and women, two-person dingy with trapeze (the device which allows yachtsmen to hang over to balance the boat at speed) |
| 7. **Tornado** | Catamaran for two people, the fastest class |
| 8. **Star** | 22-ft, two-man keel boat |
| 9. **Soling** | 26-ft, three-man keel boat |

**Table 2**
Advantages of contact lenses in sport – optometric and dispensing

**Optometric**
- No differential prismatic effect in different positions of gaze
- Correction of astigmatism and other eye aberrations
- Correction of muscle balance problems, vertical and due to the prescription (e.g. decompensated esophoria related to hyperopia, affecting depth judgement and timing)
- Correction of monocular problems which affect depth perception
- Correction of small amounts of astigmatism with aspherics or GP lenses to improve contrast sensitivity
- Correction of low levels of myopia down to -0.25 (equivalent to -0.75 under-correction based on the modal value for athletic groups), which can be highly symptomatic
- Correction of hyperopia in young athletes leading to decompensated esophoria
  - Lens looks where the eye looks

**Dispensing**
- Tinted lenses to control UV and visible glare
- Protection from non-ionising radiation
- Do not steam up
- Reduced risk of facial trauma due to lens fragments or frame edges
- No disturbing movement when jogging
- No problems with poor fit or frame slipping
- Cosmesis
- Full wrap protection from plano sunglasses over contact lenses
- Increased peripheral awareness, wider field of view; no blind areas in field and by frame
- Reduced magnification effect
- Reduced spatial distortion
- Good vision in the rain

little protection for the globe and its adnexa from trauma and non-ionising radiation[2]. Contact lenses float off easily in salt water due to the osmotic effect off hypertonic saline[3] (they stick to the cornea in fresh water). The consequences of a face full of salty spray and rapid wiping of the eyes with the back of the hand are obvious. As a whole, the profession and manufacturing industry do not seem to be aware of the potential of tinted (not cosmetic) contact lenses in sport. These lenses can give relief and longevity to the ocular media and the macular, especially when the light sensitivity of the eye is clinically significant[4,5].

## Other optical appliances

Corrective and non corrective sports appliances have many advantages,

**Table 3**
Advantages of optical and non-optical sports appliances in yachting

- Protection from:
  - Blunt and penetrating trauma
  - Hypertonic saline (sea water)
  - Non-ionising radiation
- Protection of the ocular adnexa
- Complete range (hue and transmission) of contrast enhancing and protective tints available
- Hydrophobic materials
- Ventilated appliances
- Light weight
- Low cost maintenance
- Wide angle peripheral vision achievable up to ±4.00 up (to 2.00 cyl)
- Important small and monocular corrections easily achievable
- No adverse effects on corneal integrity
- Plano or correction lenses can be worn over contact lenses
- Easily applied in adverse conditions (if spare is washed overboard)
- Cosmesis
- Convenience

including protection from trauma, and modern technology allows many of the disadvantages, including steaming up, weight, movement and peripheral awareness, to be ameliorated **(Table 3)**. The needs of the elite athlete, however, have to be understood. Sun protection in the heat of race, for example, is a barrier to the appreciation of the direction of the wind as it passes over the face and eyes. The long-term consideration of ocular health may be secondary to the athletes' urge to win.

## Non-ionising radiation

The short-term effects of sunlight (corneal oedema, glare, reduced dark adaptation, reduced contrast sensitivity, epiphora, 'squinting' and headaches) are all critical to sporting performance, because of their effects on vision and visual acuity.

The long-term effects of non-ionising radiation are well known[6] and have profound and permanent effects on visual acuity. The nature of the source of this radiation has particular significance in sailing. Light comes directly from the sun, it is reflected off the deck of predominantly white boats, and water reflects 20% of sunlight[7]. On overcast days, cloud cover does not stop ultraviolet radiation (UVR) reaching sea level.

## Psychology/physiology

When the visual demands of sailing are superimposed onto the problems of glare, wind, spray, mist, poor light and, sometimes, violent movement, the sport becomes very difficult. But that is the attraction of competitive yachting – dealing with the physical and visual challenges and still having enough mental energy left to plan a race tactically and cope with the unexpected movements of competitors.

The problems of retinal fade and tension due to over-concentration on central fixation are unlikely to occur in such a dramatically changing visual environment. Physical activity must also help in this sense, but the visual effect of fatigue (intra-muscular lactic acid build-up), hypoxia (retinal fade), hypoglycaemia (reduced binocular control[8]) and dehydration (decreased oxygen perfusion) need to be taken into account. A fluid loss of only 2% of body weight can reduce muscular efficiency by up to 20%. In a relatively less energetic sport like archery, between one and two and a half litres are lost per hour – in yachting this must be much higher.

It is likely that the muscular efficiency of the eye muscles will be affected in the same way as the other skeletal muscles. Hydration is also important in maintaining the tear film of the eye, which is critical to clear vision and comfortable contact lens wear.

## Tear film

Contrast sensitivity and depth perception, where both eyes are working properly together, depends on the health of the cornea and the integrity of the tear film. Infra-red radiation (heat) will tend to dry the cornea and diminish its optical properties, the eye may then over-react and produce excess tearing. Painful inflammation of the eye (ultraviolet keratitis) can be caused by exposure to the sun; this is often not felt until a few hours after the initial exposure, during which time even more damage can be done.

## Glare

Vision is such an important sense in sailing that visual stress due to glare could have a marked effect on physical performance. If the brain is using all its spare capacity to interpret a degraded retinal image, there will be less energy left to deal with tactics and anticipation.

## Endurance

Yachting is an extremely demanding sport, both physically and visually. In the sail board class, competitors have up to three races a day of 40 minutes duration, in an eight-race programme. The sail has to be actively pumped throughout the race to help propel the board through the water. The physical stresses on the athletes are like combining Olympic rowing and 800m running. In all classes, great strength and agility are required, a delayed or miss-timed manoeuvre can lose a race. This physical demand comes on top of probably the most visually demanding sport there is.

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*Table 4*
Demographics (N = 13, average age 26.9 years)

| Question | Answer (%) |
|---|---|
| Have you had a previous eye examination? | 69.23% yes |
| Do you wear spectacles for sport? | 7.7% (1) yes |
| Do you wear contact lenses? | 7.7% yes |
| Is your eye colour light blue/green or dark hazel/brown? | 69.2% and 30.8% yes respectively |
| Have you had a previous injury (N=14 with coach) – to your eye? Or head? | 21.4% (3) and 7.7% yes respectively |
| Do you have visual difficulties including with night driving, the sun/tired/sore, deterioration? | 23.1% yes |

*Table 5*
High and low contrast vision

| Elite Sport[8] | LogMAR vision | | | |
|---|---|---|---|---|
| | 90% | | 10% | |
| | Right | Left | Right | Left |
| Yachting | -0.20 | -0.17 | 0.05 | 0.05 |
| Cricket | -0.04 | -0.05 | 0.25 | 0.22 |
| Football | 0.03 | 0.10 | 0.30 | 0.32 |
| Excluded data (yachting) | 0.7<br>0.6 | | 0.8<br>0.8 | |

| Levels of logMAR vision and their equivalent Snellen | | | | | | |
|---|---|---|---|---|---|---|
| LogMar | -0.2 | -0.1 | 0.0 | 0.1 | 0.2 | 0.3 |
| Snellen | 6/3.8 | 6/4.8 | 6/6 | 6/7.5 | 6/9.5 | 6/12 |
| LogMar | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | |
| Snellen | 6/15 | 6/19 | 6/24 | 6/30 | 6/38 | |

## Demographics

Each team member was asked to fill in a questionnaire. The sailors rated the importance of their sight higher (on a scale of 1 to 5, 100% grade 5) than any of the sports the Sports Vision Association[9] had assessed, including archery. Nearly 70% had had a previous eye examination, despite only one of the group needing spectacles for sport and one wearing contact lenses **(Table 4)**. This compares with only 42% of British Olympic athletes in their pre-Atlanta training camp in Tallahassee, and a league soccer club where 88.3% had a previous eye examination. There was also a history of three (including a coach) eye injuries (21.4%) and one head injury. In this small population, the incidence of reported eye injuries is a concern.

### Blue eyes

In two sports, which require the highest visual ability, the majority of competitors have green or blue eyes (archery 68% and yachting 69.2%) It begs the question – is there some inherent advantage in having light coloured eyes? Unfortunately, blue eyes are also more susceptible to macular damage because of the lack of absorbing brown pigment in the iris and fundus. An additional hazard for brown eyes is that the iris acts as a heat sink and tends to 'cook' the lens underneath[12]; the protective effect of the brunescent cataract[13] is probably not a comfort.

## Tests and results

### Retinoscopy

Only two of the group had any significant refractive error and they were both anisometropic (one hyperopic and one myopic) with the good eye of the myope only slightly short-sighted. All the others were in the range of plano to +0.75 in both eyes.

### Vision

High and low contrast LogMAR charts **(Figure 1)** were used to measure vision as the athlete competes. These give an idea of the subjects' ability to see small differences in poor visibility between an object and its background; this is critical in sailing when subtle differences in contrast can help to distinguish between waves and different types of sea.

With the results of the two anisometropes eliminated (the right eye in both) the mean vision in both eyes was consistently better than other groups at high and low contrast **(Table 5)**. All were measured indoors, but ambient light levels were not recorded.

### Stereopsis

Stereopsis was measured with the TNO (?). Ten subjects were measured (two anisometropes excluded). All results were in the range of 15 to 60 seconds of arc (modal value 30 seconds of arc, seven subjects) The longest perception time was eight seconds, and the shortest one second.

### Dominant eye

Eye dominance was measured using the standard SVA test **(Figure 2)**. All subjects except one were very strongly left or right eye dominant. The mix of eye dominance was against the population norm of

*Figure 1*
LogMAR high and low contrast visual acuity charts


*Figure 2*
Performing the eye dominance test

**Table 6**
Incidence of eye dominance in elite sport (%)

| | Yachting | Cricket Scottish | Archery | Archery | Football | Rifle |
|---|---|---|---|---|---|---|
| **Dominant eye** | N = 14 (including coach) | National N = 15 | Internationals N = 16 | Coaches N =70 | Leyton Orient N = 18 | GB Junior N = 32 |
| Right | 42.9 | 53.3 | 68.75 | 87.15 | 72.2 | 87.5 |
| Left | 57.1 | 46.6 | 31.25 | 12.85 | 27.7 | 12.5 |

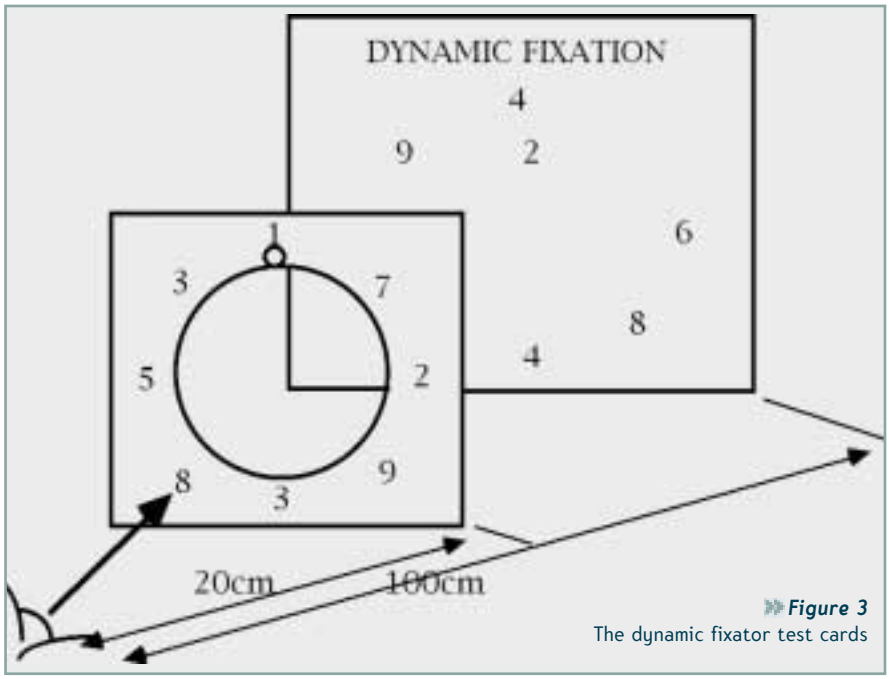


**Figure 3**
The dynamic fixator test cards

around 68% right eye dominant[13] and differs from other sports **(Table 6)**. This data excludes information about handedness, which was not recorded for the sailors, but which is needed to properly interpret the significance of eye dominance[8].

## Eye speed

Eye speed was measured using the dynamic fixation test (DFT)[14] **(Figures 3 and 4)**. This test consists of two cards. The subject holds the near card while the distance card is suspended on a wall at eye level one metre away. The subject reads from the near card through the hole to the distance card, reading out the numbers in a clockwise direction, alternating between near and distance cards. Three circuits of the cards are timed.

Speed of eye movement, endurance, consistency and mental strategy are all indicated by the results of this test. It gives an indication of how quick or controlled the eyes are, and the mental balance between control and explosion. Speed of eye movement may also correlate with leg speed, and general speed of body co-ordination[14].

The average time for the third reading (14.52), which has been found to be the most significant, confirms that yachting is more an 'explosive' event than an overtly controlled one. In other words, yachtsmen seem to have the muscle speed of international athletes (14.88) rather than the control of archers (17.41) or elite soccer players (20.87). A norm for the general population might be around 17.48[14]. This would tie in with the reactive nature of sailing, where speed is essential.

However, because of complicated manoeuvres, which have to be carried out at speed, control is also important. All three times (three subjects excepted who had difficulty with the first reading) were very consistent. This consistency is given by the standard deviation or spread of the three times, which equates to control. A mental strategy of not trying too hard, encourages an element of relaxation, which allows quick reaction and prevents muscle groups fighting each other. This applies to the DFT test and in the sport itself. If the three subjects who had initial difficulty with the test are excluded, the results make an interesting comparison with other sports.

**Table 7** shows that the fast times of the sailors were also very well controlled with no tripping over of numbers in the haste to say them. It is likely that the yachtsmen and women represent the optimum combination of control and speed.

**Figure 4**
Performing the dynamic fixation test

**Table 7**
Dynamic fixation times

| Sport | Third reading | Standard deviation |
|---|---|---|
| Yachting N = 11 | 14.52 | 0.86 |
| Athletics N = 16 | 14.88 | 1.23 |
| Archery N = 13 | 17.95 | 1.09 |
| Control N = 18 | 18.27 | 1.59 |

## Vergence facility

This was measured with a two base-out right and left prism flipper **(Figure 5)** and the number of cycles achieved in a minute recorded. The mean for the group, 25.85, was above the normal and equated with the fast eye speed. Where low scores occurred, convergence weakness, for example, could have become a problem in the later stages of the race.

## Accommodation facility

Again, this was measured with flippers, this time minus two spheres right and left, which the subject had to focus with and without over a period of a minute on a six metre distance chart. There were many good scores in this test with two or three exceptions; these athletes could have benefited from a full eye examination to see if there was an easy explanation (latent hyperopia, accommodative insufficiency, early presbyopia).

**Figure 5**
Paul Wallis carrying out the vergence facility test on Olympic Gold Medallist (Seoul), Mike McIntyre

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**Table 8**
Muscle balance data (x = no reading)

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cover test | Distance | 0 | 0 | x | 0 | 0 | 0 | x | 0 | 0 | 0 | 0 | 0 | 0 | x |
| | Near | -2 | 0 | x | 0 | 0 | -4 | x | -8 | -8 | 0 | 0 | -4 | 0 | x |
| Maddox wing (near) | | 0 | x | -5 | 0 | -2 | -3 | -3 | -9 | -9 | 0 | 0 | -6 | 4 | 2 |

(x = no reading)

## Cover test

Muscle balance was measured at distance and near viewing, where any observable movement could be significant. The quality of recovery was also important. Certain types of movement could be related to visual correction. Uncorrected long sight can sometimes lead to muscle balance problems which, in turn, can affect binocular vision and distance judgement. Muscle balance problems can be worse if an athlete is fatigued.

## Maddox wing

The Maddox wing, which is a more objective test than the cover test, was also used to check near muscle balance. A minus measurement indicates exophoria, a tendency for the eyes to drift out, and a plus measurement, a tendency to move in. Excesses in each direction create different types of problem, each with its own solution. The problems are likely to be worse when the subject is fatigued **(Table 8)**.

Most of the exophorias were spotted with the cover test and fairly assessed quantitatively, but the need for an objective measure of muscle balance was indicated. In subsequent screenings, the Howell Phoria chart has been found useful for distance and near **(Figure 6)**.

## Visualisation

Visualisation is widely used by elite hockey players (89.5%) and, surprisingly, less so by the soccer players (41.67%). It is a powerful way of rehearsing skills and competitive strategies; 76.92% of the team use this technique. Visualisation is an extension of visual memory without which, quick decisions depending on so many different pieces of stored visual information, could not be made,

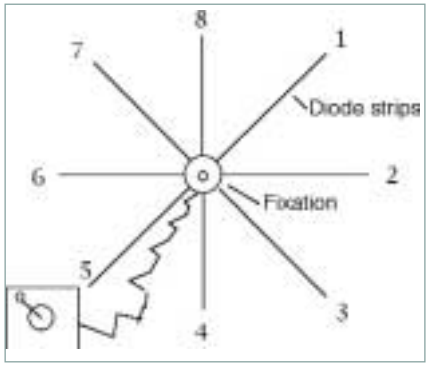
**Figure 6**
The Howell phoria test

## Peripheral awareness

This was measured with the peripheral awareness test **(Figures 7a and 7b)**. With this test, the subject stands at a distance of 40cm, in front of a central fixation light from which radiate eight strips with a light emitting diodes at the end of each one. Every time a peripheral stimulus appears, the joystick is moved as fast as possible in the direction of the stimulus. Peripheral reaction time is recorded for each of the eight positions.

A deficiency in peripheral awareness in yachting would have a profound effect on competition since so much of the event depends on it. In the absence of pathology, this will be maximised by reducing visual stress with a full correction and protection from glare, aiming at the least possible restriction of peripheral vision in the chosen mode of correction. Motility problems might be amenable to orthoptic training.

**Figures 7a and 7b**
The peripheral awareness test




The times on the test have been shown in previous screenings to equate to hand-eye reaction time as measured by the saccadic fixator. The overall average for the group was 0.48 seconds, but deficiencies would be looked for in the individual readings.

## Colour preference and light sensitivity

A formal test for light sensitivity and colour preference had not been developed at the time of the Altanta screening. In outdoor sport, protection from the sun is essential and the choice and use of filter depends on colour preference and light sensitivity. The Eye Bright Test[6,7] developed since 1996, is now used routinely in all sports vision screenings **(Figure 8)**.

**Figure 8**
Eye Bright Test lenses

## Discussion

One of the striking features of the data was the consistently excellent vision of the team; discrepancies in some athletes only began to show up monocularly and on the low contrast chart.

Sailing is interesting visually. The environment and visual demands are likely to favour low hyperopes at the highest level of competition, who need no visual correction. There also seems to be some self-selection amongst athletes who have a tendency to left dominance. Certainly, the incidence of left eye dominance is against the trend in the normal population and in many sports. Had the corresponding hand and foot dominance been recorded, it might have shown a high incidence of cross dominance. This would correlate with the need to be able to sail the boat from both sides.

Dynamic fixation is also another indication of the peak of visual performance required, where great eye speed is matched by great control. There is a need to move very quickly within the boat, but the movement has to be precise and very well controlled.

The sport is so visually dependant, that every thing should be done to make the eyes comfortable, and to make sure contrast sensitivity is maximised. If a correction is needed, the method of choice is probably contact lenses with polycarbonate UV sunglasses, or for lower prescriptions, a high base curve sports lens, in a protective sports appliance.

### Contact lenses

Corrections of small amounts of short sight in one or both eyes, and proper maintenance of contact lenses, will keep the eyes sensitive to contrast differences and depth perception. Regular disposal makes sure that there is no build up of protein on the lenses and that there are always plenty of spares. Given the problems of wearing sunglasses in competition, a possible compromise would be tinted UV contact lenses.

Two team members had an amblyopic eye, but this had been present from birth, and the visual system had adapted well, as their achievement at this level of competition confirms. Acquired defects are of greater concern in terms of sporting performance.

## Conclusion

Optometric colleagues might say to an Olympic sailor, "Sunlight can cause cataract and macular degeneration, do you think this brief period is worth putting at risk the rest of your life given the profound effect that visual deprivation can have on lifestyle and behaviour?" The response would probably be respectful incomprehension. This period of life is their whole life and nothing must interfere with the ability to win. Unless the argument is presented in terms of visual and sporting performance, such suggestions will probably fall on deaf ears.

There is now compelling evidence that visual performance is directly related to sporting performance, and it is up to the profession to make sure that the mode of correction or protection also helps to prevent long-term ocular disease.

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## About the author

Geraint Griffiths is a Founder Committee Member and Vice Chairman of the Sports Vision Association and Editor of the SVA journal. He is a College of Optometrists Examiner and Assessor and Clinical Director of the Sports Vision Group. He is a former British International high jumper and Welsh record holder, and currently holds the British Masters high jump record.

## Contact information

- Sports Vision Association 01903-218781
- Sportsfair 04, November, www.sportvisionservices.co.uk
- Royal Yachting Association, www.rya.org.uk

## References

For a full set of references, email nicky@optometry.co.uk.