VISUAL ACUITY OF THE HARBOUR SEAL AND THE STELLER SEA LION UNDER WATER

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Visual Acuity of the Harbour Seal and the Steller Sea Lion under Water

SOME investigators have suggested that seals and sea lions rely primarily on sight when catching food under water[1–4]. Earlier experiments on the visual acuity of pinnipeds under water[2] were largely unsuccessful in keeping animals at a minimum distance from the stimuli so that accurate visual angles could be calculated, and in using stimulus configurations in which visual resolving power could be measured uncontaminated by intensity discriminations[5]. This report describes experiments which have corrected these deficiences.

The animals tested were a four-year-old male Steller sea lion (*Eumetopias jubata*) and a five-year-old male harbour seal (*Phoca vitulina*). Although the seal's eyes were normal, the corneas of the sea lion were slightly "milky" throughout the study. Previously both animals had received extensive experience with pattern discriminations[2].

The tests were carried out in an oval tank outdoors between 0800 and 1200 h. Animals were not fed for 20 h before a test. The tank was constructed of redwood, painted white, and measured 4·6 × 9·1 × 1·8 m. Details of the method and apparatus have been published[1,2]. Acuity targets were produced from 12·7 cm² photos of Ronchi rulings, with black and white stripes of equal width to within a tolerance of better than 0·001 of an inch. The standard grating consisted of 300 lines per inch (0·05 mm in width). The lines were invisible to the human eye without the aid of a lens and appeared as a flat grey. Variable gratings consisted of lines varying in width from 25·4 mm to 0·96 mm. When compared with the standard at distances preventing resolution of the lines, three human observers reported that the variable gratings were indistinguishable from the standard grating. Photos of the horizontal striations were centrally fixed and laminated within a 22·8 cm² clear plexiglass, 0·4 cm thick. A black frame surrounded the acuity grating. These plexiglass squares could be slipped into a 26·7 cm² aluminium frame, 3·2 cm thick, with a 20·7 cm square cut in the front. The frame was painted flat black on the outside and flat white on the inside, with the back side attached to an 89 cm long rod. Thus the animals saw a 12·7 cm² acuity grating with a large black border, 7 cm wide, surrounding it. Ambient light measurements around the stimulus display area were taken with an SEI photometer from behind the back window of the tank when it was filled with water and yielded readings of 130 mL on clear days and 85 mL on completely overcast days.

When the targets were lowered into the water, the animal's task was to swim in from 6 m away and push the target with the variable grating (correct response) in order to obtain a piece of herring. The position of the standard and variable gratings was randomly determined. Care was taken between presentations to avoid differential auditory, visual or temporal cues, and variable and standard gratings were changed from one target holder to the other to eliminate cues associated with the target holders. If, after an animal swam toward the targets, its head extended beyond the outer point of a 68·6 cm long stimulus divider on the side of the standard grating, it was forced either to press the target on that side or to swim back to its starting position, and the response was counted as an "error". Thus the minimum distance between the gratings and the animal was taken as 68·6 cm (27 inches) and visual acuity, which has been defined as the spatial resolving capacity of the visual system[6], could be specified in terms of the angular width of the stripes of the finest grating that could be resolved[5].

The study consisted of three phases. First, subjects were trained to respond to a variable target with striations 25·4 cm wide. Stimulus control was then gradually shifted to finer striations. Next, a modified method of limits was used to obtain a range of acuity targets for estimating thresholds. There were sixty-two sessions for *Eumetopias* and fifty sessions for *Phoca*, with performances stabilizing during the last ten to twenty sessions. Threshold estimates were bracketed at between 5·5′ and 8·5′ of visual angle. Finally, thresholds were obtained by the method of constant stimuli. After a warm-up period of ten trials with a suprathreshold target, each of six variable gratings with line widths, as listed on the top abscissa of Fig. 1, was paired randomly with the standard for ten consecutive trials. Fifteen such sessions were run.

Threshold curves are shown in Fig. 1. Threshold estimates measured in minutes of visual angle over fifteen test sessions were 7·1 for *Eumetopias* and 8·3 for *Phoca*. *Eumetopias*, in spite of its slightly "milky" eyes, performed significantly better than chance ($P < 0{\cdot}01$) with stripes which subtended a visual angle of 6·4′ of arc, while a significantly better-than-chance performance by *Phoca* was not achieved until tested with broader stripes subtending a visual angle of 7·5′. Threshold values during the first eight and last seven test days were 7·5′ and 6·5′ for *Eumetopias* and 8·6′ and 8·1′ for *Phoca*.

Anatomical evidence suggests that pinnipeds have a large spherical lens providing enough accommodation to

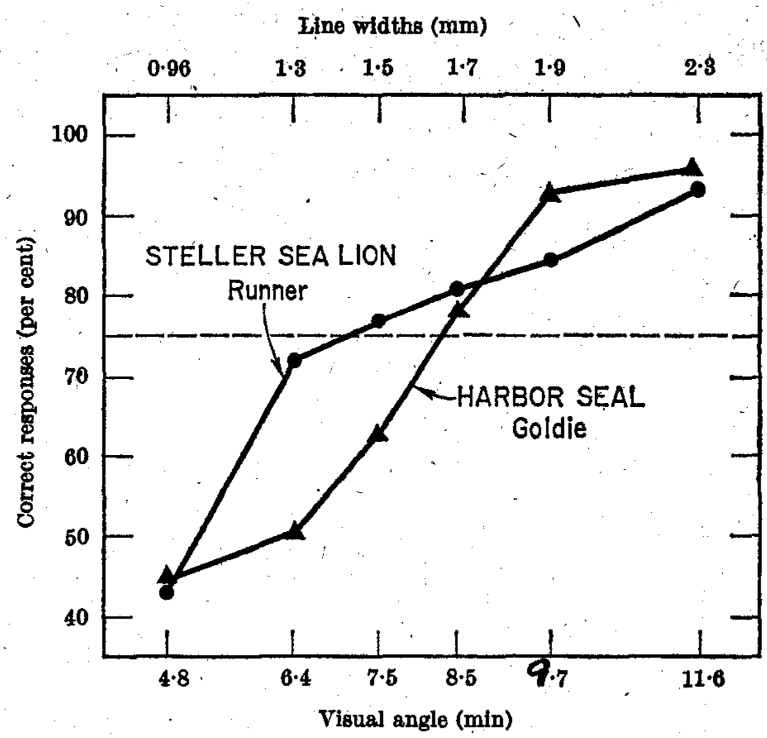

Fig. 1. Correct responses as a function of visual angle calculated at a distance of 68·6 cm.

focus a reasonably well defined image on the retina and thus compensating for the "loss" of the refractive power of the cornea under water[7–9]. Our results are consistent with such a structural adaptation. Other acuity functions[10] indicate that these pinnipeds compare favourably with species of land mammals reputed to have sharp aerial vision, such as the elephant, antelope and cat, and their vision seems suitable for detecting even relatively small prey. Degree of water turbidity, however, may place limitations on the visually guided feeding behaviour of these pinnipeds. This may be especially true for *Phoca*, which sometimes lives and presumably feeds in rather muddy bays and estuaries[11].

Discussing test patterns for measuring visual acuity, Riggs[5] states that resolution of only two fine lines depends on the dimensions of the lines. Broadening the lines tends to lower the minimum discriminable threshold and acuity measured in this way probably involves a brightness discrimination. In view of these considerations and in the light of our results, it seems likely that earlier work with pinnipeds over-estimated their visual resolving power. Perhaps a similar criticism may be levelled at experiments on the visual acuity of cetaceans (P. Spong, abstract of paper presented at the Western Conference of Experimental Psychology, Neurophysiology and Brain Research, Lake Tahoe, California, 1968; P. Spong and D. White, abstract of paper presented at the Sixth Annual Conference on Bio-Sonar and Diving Mammals, Stanford Research Institute, Menlo Park, California, 1969).

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