

VISUAL PERCEPTION OF MOVEMENT

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8 April 1963.

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Summary of work accomplished.

1. We have developed a number of new experimental techniques for investigating perception during relative movement of the observer and the display. In doing this we have built apparatus in which either the display, the observer, or both can be moved at will while the display is arranged to change in size or shape in a pre-set related manner. This allows us to use Null methods for estimating constancy scaling in the perceptual system during movement - information as to the observer's or display's movements being controlled. The major apparatus has taken two forms: (1) an electrically driven carriage on rails (2) a large swing. Several methods for varying the display shape or size have been built and tested, these falling under the categories: (i) mechanical, principally using linked iris diaphragms, (ii) optical, principally using a shadow technique described in a paper published in Nature, (iii) electronic techniques, principally using Lissajou figures on a cathode ray screen, with electrical pick off from the swing or railway to vary the size or shape of the Lissajou figure, itself generated by oscillators with suitable phase shift between the X and Y plates of the 'scope.

We have found that the methods (ii) and (iii) are by far the most satisfactory, and they seem to be entirely appropriate as the basis of techniques for investigating the problems we are concerned with. Apparatus using these techniques is built and in use.

We have established (and we believe this to be a new finding) that size constancy during movement of the observer is greater during forward than backward movement. The asymmetry could be significant in the aircraft landing situation, and probably arises from the fact that in normal conditions movement is toward rather than away from perceived objects.

We also find that proprioceptive information of body movements through the limbs increases perceptual constancy. These results are not yet published, and work on the second continues.

We have designed an experimental technique (this will be described as a possible subject for a patent under the appropriate heading) for presenting visual displays perceptually in depth but in fact flat, so that motion parallax is avoided. It is possible to control independently the disparity between the retinal images of the two eyes so that the perceived object may be placed perceptually at infinity (or beyond infinity) or any nearer distance, and it may be viewed during movement of the observer, which can be either normal walking or passive movement, when he is carried on the swing or the railway. We have so arranged it that when he is carried on the railway the tracking angle of his eyes is controlled by the experimenter and can be set for any effective distance of the perceived object, and this can be varied independently of the disparity. It is thus possible to separate: (a) apparent distance of the perceived object, (b) apparent depth of the object (i.e. relative distance of the nearer and further parts of the object given by the

disparity gradient, which itself is independently variable from the total disparity) (c) the angle through which the eyes have to turn in order to keep the objects fixated for a given movement of the observer. This means that we can vary separately all the sources of information giving distance and velocity information to the perceptual system, and this seems to be a pre-requisite for satisfactory experiments on the problem of perceived movement and constancy during movement. In addition, by using photographic stereo techniques, we can introduce appropriate or inappropriate geometrical and texture depth information (c.f. J.J.Gibson, The Visual World, 1950).

We find that when the variables are so arranged that they are incompatible with perception of the normal world, the subject experiences nausea. This occurs quite apart from vestibula stimulation, for we find that nausea occurs under conditions when the subject is moved at constant velocity and slow speed, on the railway. This should have some significance to the general problem of motion sickness, and suggests that we should expect nausea under some unusual conditions where apparent distance and velocity do not agree with normal conditions. We submit that this is worth consideration, where one or more sensory systems have become adapted as during prolonged continuous movement, and in unusual flying conditions such as mist where perceived distance changes, or in space flight. As a preliminary finding, we are inclined to think that nausea occurs primarily when visual and proprioceptive movement information disagree, and less so when the disagreement is between different visual features. If this generalisation holds up it will minimise

the probability of nausea under the conditions cited immediately above, but the possibility should still be considered.

When viewing our perceptually three dimensional display which is in fact flat, we find that during movement of the observer the display perceptually follows every movement of the observer; and it rotates so that it, as it were, remains aimed at him as he moves. This is the basic result of removing motion parallax, which under normal conditions causes objects lying at different distances to rotate round the point of fixation against his movement (c.f. Gibson, op.cit.) The normal counter rotation results from the geometry of the situation. Our finding that the visual world follows his movements when motion parallax is absent but objects are still seen in depth, should not be too surprising in itself, for the retinal images on the eyes remain constant under these conditions although the observer is moving and normally this only happens when the perceived objects follow him. An example is if someone aims a rifle at him, when he sees the rifle swinging round although his retinal images remain constant. When we now set the gradient of disparity on our apparatus so that it is incompatible with apparent distance on other information provided, we find some very odd effects which allow us to gain some insight into the neural system normally mediating depth and velocity perception. If disparity is set to correspond to a very near object though the eye tracking angle is appropriate to a distant object, then the entire display perceptually moves with the subject, and does not rotate as before. This effect is best visualised by

considering the case of looking at one's own face in a mirror and then moving, when one of course sees one's head moving across the mirror. The effect is similar here, though the cause is entirely different. It is generally accompanied by nausea, the onset of which may occur within one minute.

There is considerable individual variation in what is perceived when these various sources of information are made incompatible. Some subjects lose their perception of depth as soon as movement commences: observers are presented with a paradox which these observers resolve by rejecting depth information from retinal disparity. Most subjects do not reject this information however, but perceive the rotations and other movements of the display described above, (although the displays are physically stationary) and it is these observers who experience the nausea. We think it likely that the observers who reject the disparity information are those with a history of myopia or other optical defects tending to give poor depth information by disparity under normal conditions. It would be interesting to follow this suggestion up by systematically studying cases where optical correction has been provided at various ages in childhood, for this could provide some information bearing on the problem of perceptual learning, about which we know very little indeed at the present time.

2. The theory of the geometrical illusions which we have been working on since the start of this grant - the idea being that they are due to constancy scaling being inappropriately

applied by perspective features of certain flat figures - is still being developed. This has involved a large number of exploratory experiments, and some of these we do not intend to publish as, although they were useful in clarifying our ideas, some turned out to have various inherent difficulties which made them unsatisfactory as final experiments to show conclusively that there are two essentially different mechanisms for producing constancy scaling. (I prefer the term "constancy scaling" to the usual "constancy", because I wish to refer to an active process in the nervous system, the end result of which is constancy. The terminology in the literature is in my view extremely confusing and should be changed as soon as possible). It is essential for the theory that there should be two scaling mechanisms being mediated by (1) perspective or other features generally indicating depth although depth is not perceived. (2) as a direct result of perceived depth even in the absence of any sensory information. (as an example of an object having an apparent distance and a given constancy scaling in the absence of any sensory information we may cite the moon). It is essential to postulate these two mechanisms because the distortions of perceptual space we are considering occur in figures flat and seen as flat, and yet we are supposing that it is the constancy scaling mechanism which is normally set by the distance of objects which is producing the distortion.

Among other illusions, we have studied perceptual changes in self-luminous three dimensional skeleton shapes such as cubes. Shape changes evidently due to misplaced constancy occur when they perceptually reverse in depth. A study of the relation of visual reversal with simultaneous touch information of their true position in space has been completed, and is in the press (Shopland and Gregory, Quarterly Journal of Experimental Psychology). I will submit a manuscript copy of this paper.

3. We have carried out an experiment (Ross and Gregory, Quarterly Journal of Experimental Psychology, in the press) apparently establishing that the differential sensitivity to weight is not simply a function of scale weight, but may be affected by apparent weight. This we have done by determining differential thresholds for weights of various sizes. It is well known that large weights are judged lighter than small objects of the same scale weight: We have shown that the large (apparently lighter) objects give a lower differential threshold than the small (apparently heavy) objects. Pre-prints have been submitted.

4. Experiments on the well known autokinetic illusion (the apparent motion of a fixed dim light viewed in darkness) have been performed and an explanation given. The experiments and theory with a historical section, is in the press (Gregory and Zangwill, Quarterly Journal of Experimental Psychology.)

5. Stuart Anstis has conducted a number of experiments primarily concerned with after effects of prolonged viewing of moving objects. He has been particularly concerned with trying to locate the resulting neural adaptation to the retina or to more central parts of the perceptual system, and has devised some new techniques to this end. He has established some new facts. He has found a new after effect, namely that upon viewing an evenly illuminated field varying in intensity with a saw tooth wave form at a rate of about 5 ramps per sec., a constant illuminated field then appears to grow brighter or dimmer, this effect lasting for about 10 seconds. The direction of this after effect is such that there is an increase in apparent brightness following a falling ramp on the stimulus wave form and vice versa. He is at present investigating sharpening of contours during shift of images across the retina, using experimental techniques he has devised himself.

6. Investigation of a primitive eye apparently functioning by Scanning.

Exner, in 1891, described a most curious eye - that of a Copepod, *Copilia*, which he found in the Bay of Naples, while on the staff of the Marine Station. He reported this eye as telescopic, having two lenses, the second lens being in the middle of the animal, and continually oscillating across the image plane of the primary lens. This suggests that there may be in nature an eye working on a quite different principle from known eyes which, of course, rely on a spatial mosaic provided by the retina, information being fed to the brain along many parallel channels. Exner's description of *Copilia* suggested that we may here have an eye which works on the other known engineering principle for transmitting spatial information - from a scan, as in television. We determined to look for this animal, having searched the literature and found no more recent account of it, and with Dr. Neville Moray of Sheffield University (who knows more Zoology than I do) we went to the Naples Marine Biology Station and were fortunate enough to find eight specimens of *Copilia*, at a depth of 450 feet.

We established the essential correctness of Exner's description, and we obtained photomicrographs of the living animal and cinerecords of the scan.

We attempted some behaviour studies but these were unsatisfactory in the time available. It should be mentioned that the creature appears to be rare, for we found it necessary to search through gallons of water after dragging miles of sea with fine nets for each specimen we found, and as this involved

examining the water drop by drop with a microscope we regard ourselves as lucky in finding any specimens. We can however now recognise them with the naked eye in favourable lighting conditions: Their naked eye visual characteristic is extreme transparency. None of the structure ^{is} visible to the naked eye, but is very readily seen with about X 100 magnification. There is no retina; a single ^{receptor and one} optic nerve fibre goes to the central brain. This fibre is quite long and we think it might be possible to record from it with a micro-electrode, though there certainly are technical difficulties which would have to be overcome, especially as the animal has a tough though transparent cuticle.

Consideration of this animal has suggested some ideas as to how the evolution of the compound eye might have occurred. I think it likely that very primitive compound eyes had one or very few ommatidia, and that they worked by scanning. This would be a reasonable development from movement perception, which is almost certainly primary in evolutionary development. The transmission of information down a single nerve fibre would be limited by the band width of a neurone, and this would be under 1,000 c/s. Given that the rate of firing of neurones could not be increased (and this is presumably limited by the basic physics of nervous conduction) the only development possible would be increase in the number of channels. Scanning would still be necessary until the number of channels was quite large, several hundred ommatidia at least, after which a static spatial mosaic would transmit more information. I thus predict that eyes having out a few ommatidia should employ some scanning. The well known Daphnia has about twenty ommatidia, and it is very easy to

see that this eye is in continual oscillation around its optical axis. Very large compound eyes (the eye of the bee or the dragon fly for example) are static except for movement of the whole animal, which may or may not be important. I propose to survey simple compound eyes and establish whether oscillations are present in all eyes having only a few ommatidia. I would also like to attempt recording from the optic nerve of certain chosen eyes, including Copilia. So far as I know this is an entirely new research project.

Difficulties encountered.

Under this heading in our previous report for 1st April 1961 - 31 March 1962 we stated that there was a delay in the completion of Stuart Anstis' Ph.D. thesis and its submission for examination. He has now completed this work, and has received the degree of Ph.D. from this University.

There are no special difficulties, except for lack of time due to other commitments.

Inventions.

The following techniques for presenting objects perceptually in depth but in fact flat, might form the basis of a patent, though it is closely related to stereoscopic photography, using polarised light.

We use two point sources of light placed close together, (for instance separated by $2\frac{1}{2}$ inches, the average inter-ocular distance) the imaginary line between them being horizontal. These lights are arranged to throw a pair of shadows from an object placed in front of them on to a screen. The light sources are fitted with crossed polaroid filters, and the screen is of a material which will not depolarise the light. (It is either aluminium paint, for front projection, or ground glass for back projection.) The observer wears crossed polaroid glasses, so that he sees the shadow cast by one of the point sources with one eye and the shadow cast by the other point source with the other eye. He then experiences a black object lying in 3-D space, either in front of the screen or behind it depending upon which eye sees which shadow, this being changed at will by switching the polaroid filters. This is a perceptually interesting situation, for by varying the distance between the point sources we can control the effective interocular distance of the observer's eyes, and by changing the distance of the point sources from the object producing the shadows we can change the effective distance of the observer from his perceived object. We have found it useful as the basis of an experimental technique for investigating depth

and velocity perception, but it might also be used in an instrument for presenting three dimensional information. It might possibly be used in some form of visual landing display or simulator, or it might be used for demonstrating or investigating scale changes in models for example of mathematical functions.

Research plans for next period.

(1) I regard the problem of the autokinetic effect as essentially solved, and at this time I see no reason to conduct further experiments on this topic.

(2) I regard the problem of the Distortions of visual space, typified by the so-called geometrical illusions, as also essentially solved, but the experiments can be developed and about two years' work remains in completing them and tidying up the details. I propose to do this over the period of the new grant.

(3) The work on estimating constancy during observer movement has got to the stage where we have worked out appropriate experimental techniques and built the apparatus (though some ancillary equipment is still required for the railway) A lot of work remains to be done but I believe that in outline we are beginning to understand the kind of perceptual systems involved. A great deal of systematic testing of observers under various conditions is required. There are still difficulties in getting quantitative results of some of the effects and I do not imagine that we will solve all the problems. We are dealing with an extremely complex problem, but I regard it as central to an adequate account of perception, and as having some practical importance in any situation where judgements of velocity and distance are required from a moving observer.

(4) A rather different kind of experiment is envisaged for the railway. By optical means (magnifying or reducing lenses) the apparent length of the corridor along which the railway runs may be varied, and so it is possible to investigate the effect

of changing apparent distance while maintaining velocity and time constant. This raises some interesting possibilities as to just how velocity/^{time}and distance judgements are made, and we hope to work along these lines, but at this time I have not thought of a way of quantifying the results.

We would like to continue the investigation on the scanning eye of Copilia and other simple eyes. The purpose would be (1) to try to gain understanding of the evolutionary sequence of primitive eyes, and (2) to establish whether scanning is used for pattern recognition in any present or past eyes, and if so how efficient it can be in nature. I am doubtful whether we could undertake this without extra support.

Personnel and administration.

There has been no change in personnel over this period. Stuart Anstis has now obtained his Ph.D. Helen Ross is seriously considering applying for a place to work for a Ph.D. which would involve her resigning her present post on this grant. This is under consideration at the present time.

Travel.

Visited Naples Zoological Station (August/September 1962) for the purpose of looking for the Copepod *Copilia*. This visit was made with Helen Ross and Dr. Neville Moray of the University of Sheffield, who received no financial support from us, but received some support from his own university. The equipment I used was not obtained especially for this expedition. The Exacta was bought previously on this grant, the microscopes were bought by me on other monies, and the cine camera used was loaned from Professor J.Z. Young. If we are to continue work on this project some extra equipment would be required, especially if electro-physiological recording is to be undertaken.

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