1 The Basic Problem of Acquisition

Of man's 5 senses vision is claimed to provide some 75% of the total input to the brain about his environment. This means both that the amount of data being received through two small optical sensors is truly enormous and that it is important to know how this information is received and processed. Not surprisingly a very great deal of research effort has gone into discovering more about man's visual system over many, many years. Researchers are hampered, however, by the fact that the visual receiver – the retina at the back of the eye – has numerous individual detectors implanted in it which are known to couple through a very complicated array of neural networks to the cortex.[1] It is hardly practical to probe deep into these networks with living subjects and, although some work has been carried out on eyes bequeathed to medical research by deceased persons, there is a severe limit on what can be learnt from such studies. This has led many scientists to carrry out extensive studies on various forms of lower animals, from which a great deal has been learnt as to what *might* be facets of human vision. However, in the author's opinion care should always be taken in drawing too close parallels between the established behavioural characteristics of the visual systems of lower animals and that of man. It seems highly probable that evolutionary processes will have been largely responsible for roughly optimising a given animal's visual system for its environment. Having said this, it is difficult to justify an assumption that, say, a cat's visual system is the same as man's, except perhaps in spectral sensitivity (which might be expected in most animals to be optimised about the peak emission of the sun). The foregoing comments are not intended to imply that research on animals is of no use. Far from it – a lot of very valuable data has come out of such studies. All that must be stressed is that it is not *enough* – it must be supplemented by data obtained about man by whatever method possible.

Much has been written on the anatomy and neurophysiology of the eye. The reader wishing to study these in depth is referred, for instance, to Pirenne[1] and Brindley.[2] It is not the purpose of this book to go into these subjects in any more detail than necessary to develop the subject of the title – Vision and Acquisition. Instead the emphasis will be on a *general* consideration of everything, both external and internal to the eye, which goes towards the ability of man to see things in practice. An attempt will be made to show that at the present time, whilst there are still a lot of unanswered questions, a real possibility exists of estimating when many classes of visual stimuli can be 'acquired'.

1.1 THE MEANING OF ACQUISITION

Before going further let us define what we mean by acquisition. The word has to many people a military flavour – and indeed our involvement in visual research was predominently centred for a long time around the ability of man to see military targets. As we have delved deeper into the subject, however, we have come to look upon this word *acquisition* in a very much broader sense. We now prefer to consider it to relate to any object which we are interested in looking at.

The word *acquisition* does not only cover one specific visual process, but rather a series of processes, which range from the first awareness of some local difference in energy at a specific point in the visual field through a progressive awareness of the detail structure of an object. The various stages of this progressive process of acquisition are variously defined by groups of workers. For the purposes of this book we shall choose to define three specific facets. Firstly the awareness of existence of local difference energy we shall refer to as *detection*. Secondly we shall refer to awareness that an object is of a particular class – for instance a vehicle rather than a bush – as *recognition*. Finally the ability to specify that an object is a particular one of a class – for instance a particular model of car – we shall term *identification*. It will be seen as we proceed to study the subject that there are no watertight compartments of detection, recognition and identification, but rather a continuum. Even so, it is believed that the three definitions can be related to different aspects of the acquisition process.

Detection, which is usually defined as the ability to detect the presence of something (unknown) in an otherwise uniformly illuminated field, is frequently associated with military situations (although, of course, it is equally applicable to other fields such as astronomy). However, recognition, which, in a military sense, is the next stage in the acquisition process, and involves the detection of the presence of some characteristic structure (or movement perhaps), is really a word which can be applied to each and every visual task we carry out, and for whatever purpose. Looked at in this way the whole of the understanding of the visual process is tied up with an understanding of ability to *detect* details (without at this stage defining what we mean by 'details'). It is for this reason that we feel justified in spending a large amount of time in this book discussing the process of visual detection, and what might appear to be relatively little time discussing other facets of acquisition.

1.2 FACTORS AFFECTING 'SEEING'

With this preamble let us look a little further into the factors which potentially affect our ability to see.

1.2.1 Available energy

Firstly, there must be sufficient of the right form of energy available. The human visual system is only sensitive to a very small portion of the electromagnetic spectrum – wavelengths from about 0.4 μm to 0.7 μm with a predominent peak sensitivity at around 0.55 μm. In terms of evolutionary optimisation it is interesting to note that the band of visual sensitivity coincides very roughly with the peak of radiation from the sun (around 0.5 μm), thus tending to optimise the efficiency of the visual system to natural illumination. Because of the above it is no use trying to see an an object which only emits radiation around 0.3 μm (ultraviolet) or, perhaps, at 10 μm (well out into the infra-red) without first transducing the energy by some means. It is perhaps unfortunate that until very recently it has not been possible to visualise radiation at 10 μm, since this is a valuable spectral region for viewing through the atmosphere (due to relative freedom from atmospheric attenuation coupled with the fact that it coincides with the peak thermal radiation from objects at ambient temperature[3,4]). Recent advances in electro-optics seem likely to make such a visualisation become much more common in the not too far distant future.[5,6,7]

As with any detector system, the more energy that is available to the visual system the less serious the internal system noise is, and the more sensitive and reliable the detector becomes. That this is so for the visual system can be readily appreciated when one realises how relatively poor visual performance is at night compared to that in good daylight. In order to cope with the tremendous range of luminance levels met with in natural viewing (from about 5000 cd/m^2 down to 10^{-6} cd/m^2) whilst retaining a high sensitivity, the human visual system has developed two distinct forms of receptors – the cones and the rods.[1] The cones, of which there are several types with different spectral sensitivities, look after our colour vision and, it is believed, have individual connections directly to the brain. They are most concentrated in a tiny area of the retina known as the fovea, which covers a circular portion of the visual field subtending between 10 and 20 mrad diameter. As we move further and further from the fovea into the peripheral regions of the retina the cone density falls off sharply.[8] This means that colour vision, which is very acute in the fovea, becomes progressively less acute at angles away from the fovea. In contrast the rods, which have predominently blue sensitivity and appear to be grouped together in the primary neural networks, are completely absent in the fovea and progressively increase in number as one moves to the periphery. These rods are primarily responsible for night vision at luminance levels where the cones are inoperative. Night vision is thus 'colour blind', and with a maximum sharpness at a position several degrees from the fovea.[1] The above properties of the eye will be covered in rather more detail in Chapter 2.

1.2.2 Stimulus characteristics

Other factors which must be considered in discussing visual performance are several associated with the object being viewed (which we shall refer to as the stimulus). Some of them may appear obvious in general terms but can be difficult to define in absolute terms. For the moment suffice it to say that size, shape and form, contrast against surroundings, texture, edge sharpness and interaction with surroundings are all stimulus parameters which may affect ability to see. In this book contrast will always be assumed to be defined as the psychometric contrast $(B/B' - 1)$ where B and B' are the luminances of the stimulus and immediate background respectively. In many structured situations it will be found that such a concept cannot be used. In such cases local luminance structure will be described in terms of local luminance differences (ΔB). Some of the many effects due to stimulus and background will be discussed in detail in Chapters 4, 5, 11, 12 and 13.

1.2.3 Other factors

In addition to the available energy and the stimulus characteristics, other factors which may affect visual performance are effective exposure time, any search requirements, stimulus motion, atmospheric effects and scene structure. Let us take these in order.

The effective exposure time is the total time available for inspection of any particular part of a stimulus. It may be limited by physical constraints external to the eye, or may be an implied limit due to visual search. Search itself may be present due to uncertainty as to where a stimulus is in the visual field – as for instance when searching the sky for an aircraft – or it may be an imposed detail search within a local area of a visual scene, or even within local parts of a complex stimulus. In each case the search strategy will yield progressive bits of data on which to build a brain 'picture' of the fine details of the scene being studied, but at the expense of available time to study any one elemental area. If a stimulus to be studied has relative motion with respect to the observer then the effect on the ability to see it, or detail within it, depends very much on the rate of motion, its size and contrast and the position within the visual field at which it is viewed. These various facets of the presentation situations are covered in detail in Chapters 4, 5, 8 and 13.

If there is any significant distance between the observer and the stimulus it may be necessary to consider the effects of the atmosphere on the appearance of the stimulus. The main atmospheric effects are of two kinds. Firstly, and usually most important, there are the effects due to the significant scattering properties of most real atmospheres. These properties are the predominent cause of mists and fogs, and result in the light from parts of a scene being attenuated (extinction) at the same time as additional veiling light is added into the viewing path from elsewhere (air-light). The second effect, most usually seen as shimmer from hot surfaces, is atmospheric turbulence. This is the result of eddying of air due to thermal effects, is a refraction phenomenon, and usually leads to time variant detail image motion or blurring, dependent on the viewing conditions. The above facets of atmospheric optics will be considered in detail in Chapters 15 and 16.

Finally, in this list of factors which can affect visual performance we come to scene structure. This can have several effects on performance, most of them ill-defined at present. It may include similar objects to the stimulus studied, thus producing conflicting input data. It may upset the adaptation level at which the local visual inspection is taking place. It may introduce local veiling glare effects which detract from visual performance. These are considered in more detail in Chapter 13.

1.3 AIDED VISION

In order to improve viewing conditions, it is often the practice to employ one of a number of forms of visual aid. For instance a microscope, telescope or binoculars may be used to produce a magnified image of the stimulus to be studied. Alternatively television may be used to translate an image to a more accessible spot, or to give enhancement of luminance in difficult lighting situations. Then again, photographic processes are frequently used to record visual data for later study. Finally, for very low luminance situations, image intensifiers are becoming fairly common instrumental visual aids.

If these visual aids were perfect the appraisal of their effects on visual performance would be easy, but unfortunately they each have quality limitations which must cause complex interactions with the structure of the visual system itself. Because of the importance of this aspect of vision, and the number of difficulties associated with it, the whole of Chapters 9 and 10 are devoted specifically to the problems of aided vision.

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