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Guest editorial essay

Stimuli, information, and the concept of illusion

The question of what constitutes the 'input' or 'stimulus' for visual perception is brought into sharp focus when we consider situations like the Ames Room (Ames 1951; Runeson 1988). If we forget about the people in the room for a moment, should the 'input' to the perceptual system be described in terms of the room's real world characteristics—its trapezoidal shape—or its informational content—ie it is constructed so that the perspective information reaching the eye is identical to that produced by a normal rectangular room? Another way of asking the same question is—"does it matter how the pattern of light reaching the eye is created?" If the pattern of light is identical ("projectively equivalent"—Howard and Rogers 2002), over both space and time, then it must be true that no seeing machine, biological or man-made, could ever tell the difference. Richard Gregory (1966) made this point over forty years ago when he described the Ames room in the following way: "it *must* look like a normal room if constructed according to strict perspective, and viewed from the right position, because the image it gives is the same as for an ordinary room". As a consequence, it makes no sense to ask the question "why don't we see the room as trapezoidal?" because, if it is built with sufficient care, there is no visual information for its true, trapezoidal shape[1] (Rogers 2004). Talking about its 'true' shape only introduces confusion. The more appropriate question to ask is why a normal rectangular room looks rectangular and this then leads us to consider the nature of perspective information as well as to investigate human observers' sensitivity to that information.[2]

A similar point can be made about the viewing of two flat pictures in a stereoscope or the transforming patterns of motion (KDE) on a flat computer screen. If the patterns of light reaching the two eyes are identical to those that would be produced when viewing a real 3-D scene, then it is not surprising that what we see corresponds to what is seen with the real 3-D scene—no seeing machine could ever tell the difference. Likewise, if the transforming pattern of motion on the computer screen is identical to that produced by an actually rotating 3-D structure, how could we see anything else? Constructing either a stereogram or a transforming flow pattern should be seen simply as a convenient way to *manipulate the information* provided to the visual system, but the way the particular pattern of light is created is surely totally irrelevant to understanding the perceptual system. Moreover, describing the input in terms of how the pattern of light was created (rather than the real-world situation it is mimicking)—"*two-dimensional* stereo images" or the "*flat* computer screen" or the "*trapezoidal* shape of the Ames room" has the potential to cause much confusion.

If we accept the preceding argument that it does not matter how the particular patterns of light reaching the eyes are created, this raises a further point about what

[1] The opposite corners of the room may require slightly different accommodation.

[2] The same arguments apply with respect to the notion of 'equivalent configurations': that there can be an infinite number of real world situations that can produce the same pattern of light at the eye (Ittelson 1960). However, the existence of 'equivalent configurations' has been used to support the idea that perspective and other sources of 3-D information are inherently ambiguous but the argument is surely flawed. Ambiguity of a depth cue (or the lack of ambiguity) depends on (i) how the source of information is defined and (ii) the characteristics of the particular mechanism used to extract the information, not on how the pattern of light was created.

constitutes an 'illusion'.[3] Is it appropriate to talk about the impression of depth in a stereoscope as illusory just because the pictures themselves are flat? Is the perception of the Ames room as rectangular an illusion because the room is actually trapezoidal? I would argue that it makes no sense to call our perception 'veridical' if it corresponds to the actual characteristics of the world that surrounds us and 'illusory' when the identical pattern of light reaching our eyes has been created by some other means. Barbara Gillam (1998) made a very similar point when she wrote that the term illusion is not used in the case of pictures and other situations where "the origin of the impression in mimicry of the stimulus conditions produced by the 3-D world is obvious". Note that this argument does not just apply to situations involving 3-D perception. We can imagine a device (a spectrometer display?) that creates the same pattern and distribution of wavelengths as those created by a real scene, but it would not make sense to speak of the perceived colours as being illusory just because they are not the product of the reflections from real surfaces. If you like, we could call all these situations 'facsimiles' because the pattern of light reaching our eyes is a facsimile of the pattern of light created by a real scene but just because the stimulus situation is a facsimile doesn't make our perception illusory.

In *Eye and Brain* Richard Gregory argues that the Ames room becomes interesting when people are added into the room because it shows that the "perceptual interpretation involves betting on the odds". I agree. There are two conflicting sources of information—the perspective information from the room indicating that it is rectangular and the size-of-a-familiar-object information suggesting that the two people must be at different distances since their angular sizes are different.[4] But note that putting these two sources of information into conflict has nothing to do with the fact that the Ames room is trapezoidal. The experiment could just as well have been done in a normal, rectangular room and superimposing two different-sized images of the same person in the two corners (figure 1). The Ames room is just a convenient way of manipulating the two sources of information at a time when more sophisticated techniques were not available.[5]

The preceding discussion suggests that, for the purposes of understanding perception, we should forget about which particular device was used to create the input to the visual system and consider instead the available information. But how do we know what constitutes 'information'? This is the "computational theory" question that Marr (1982) argued could be answered using the tools of mathematics and geometry. For example, Mayhew and Longuet-Higgins (1982) and Gillam and Lawergren (1983) both showed mathematically that there is information in the gradient of vertical disparities between the eyes to specify the absolute distance of points and surfaces. But note that identifying the available information is quite separate from the question of whether we are able to use that information and, in this case, it was another ten years before we had empirical evidence that the human visual system is able to use those vertical disparity gradients (Rogers and Bradshaw 1993).

[3] Gillam (1998) has proposed that "the term *illusion* typically refers to a discrepancy between perceived reality and objective or physical reality". Gregory (2004) has defined illusions as "discrepancies from truth". A comprehensive history of illusions and discussion of the concept itself can be found in Wade (2005) who points out that illusions require "a yardstick or reference relative to which (the illusion) can be assessed".

[4] Note that, the size-of-familiar-object information does not actually contradict the perspective information about the *shape* of the Ames room—it only indicates that the people are at different distances.

[5] Situations like the Ames room where two or more sources of information (including tactile cues) are put into conflict can be useful because they allow us to investigate which source(s) of information has the greater influence on what we see. It is not clear, however, that our perception should therefore be labelled as 'illusory', whatever the outcome.

Figure 1. [In colour online.] A trapezoidal Ames room with twins standing in the two corners?

If the input to the perceptual system should be specified in terms of information, then this suggests an alternative definition of the term 'illusion' which would be something like "what we perceive does not correspond to the available information". This sounds like an improvement because the Ames room and depth-from-stereograms would no longer be classified as illusions, since what we perceive corresponds to the perspective or disparity information provided. There are other situations, however, where the identification of 'information' is not so straightforward. For example, what constitutes the information for the colour of surfaces or the motion of an object? Clearly it has something to do with the spatial patterning of wavelengths in the first case and the displacements of contours over time in the second case, but the exact specification of the information is intimately bound up with the characteristics of the mechanisms used to extract that information. Colour information for a trichromatic visual system is necessarily different from colour information for a dichromatic or tetrachromatic visual system. Our susceptibility to the phi phenomenon and stroboscopic motion means that the information for motion has to include those situations where the displacements of contours are in discrete steps rather than being continuous.

It is tempting to regard colour metamers (red plus green that is seen as yellow) and the phi phenomenon as illusions, but a moment's thought makes it clear that every aspect of our perception, including thresholds and nonlinearities, is dependent on the particular ways our perceptual systems work. Metameric yellow should not be regarded as an 'illusory' colour but rather the consequence of a trichromatic visual system[(6)], and the phi phenomenon can be seen as a consequence of the tolerance of the motion detectors (Gregory 1966). Even the question of how we determine the straightness of straight lines seen in peripheral vision depends on how we define straightness (Rogers and Rogers 2009). In other words, the concept of information (which seemed to be a convenient way of dealing with the problem of 'facsimiles'), is intimately bound up with our knowledge and assumptions about how our perceptual mechanisms work.

[(6)] Note that, since all perceived colours have metamers, all colour perception would have to be regarded as illusory and not just metameric yellow, as Charles Wheatstone pointed out a hundred and fifty years ago.

How we define information implies a particular sort of mechanism used to detect it and, conversely, specifying the properties of the mechanisms leads to a particular definition of the available information. The interdependence of information and mechanism leads to the conclusion that, if we fully understand how our perceptual systems work, there would be no illusions—there would only be descriptions of the characteristics and limitations of our particular perceptual mechanisms. At present, it seems appropriate to classify the Müller-Lyer figure as an illusion because we don't fully understand how the visual system measures length or spatial separation (but see Morgan et al 1990), but we must assume that, when we do understand how this is done, we will see the Müller-Lyer 'illusion' as no different from the phenomenon of metamerism in colour vision—it is just the way the visual system 'measures' length. As a consequence, we have to consider either that all perception is an illusion or that there are no illusions! This does not mean that the study of those things that we traditionally regard as 'illusions' is worthless. Whether we measure thresholds, cue conflicts, nonlinearities or distortions in appearance, these all provide insights into how our perceptual systems work. As Purkinje (1823) remarked: "illusions reveal visual truth", but we might have to acknowledge that there may be no meaningful way to distinguish between those perceptions that should be classified as 'veridical' and those that should be classified as 'illusory'.

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