Visual illusions classified

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Visual illusions provide evidence of perceptual processes, especially the use of knowledge about objects and the working rules for seeing. The classification of phenomena is necessary for any science because it facilitates induction and deduction. The phenomena of illusions are no exception. It is hoped that the tentative classification presented here may stimulate further research and raise new questions by revealing gaps in the conceptual structure of how perception proceeds. Finally, a speculation is offered for the functional use of sensations, the qualia of consciousness.

Following Helmholtz's lead we may say that knowledge is essential for vision because retinal images are inherently ambiguous[1] (for example, the size, shape and distance of objects) and because many vitally important object characteristics are not represented by images in the eyes (such as hardness, weight, hot or cold, edible or poisonous). For Helmholtz, ambiguities are usually resolved and non-visual object properties inferred, from knowledge or assumptions by unconscious inductive inference. It is a small step to say that perceptions are hypotheses[2–4] predicting unsensed characteristics of objects and the immediate future[5].

That vision is but indirectly related to objects and stimuli was appreciated by Helmholtz[6] as following from the Law of Specific Energies (perhaps better named the Law of Specific Qualities), proposed by his teacher Johannes Muller, which says: 'any afferent nerve signals the same quality or sensation whatever stimulates it'. Thus, of course, we see colours not only from light but also when the eyes are mechanically pressed or are stimulated electrically. We may regard eyes and the other sense organs as being designed by natural selection to convey different stimulus characteristics by the same neural signals, action potentials, which are routed to different brain regions for the different sensations of colour, touch, sound and so on. Sensations such as colours are generated by specialized brain 'modules' (Ref. 7). It was clear to Newton[8] that it is strictly incorrect to say that light is coloured. Light elicits sensations of colours in suitable eyes and brains, as we now say, psychologically projected into external space to be seen as surfaces of objects. Thus, perceptions are projections of brain-hypotheses, which may or may not match physical reality.

Perception requires assumptions, which when not appropriate can generate cognitive illusions. A striking example is the 'hollow face'. The visual bias that favours seeing a hollow mask as a normal convex face may be accepted as evidence of a powerful 'top-down' object knowledge process[9]. This bias is so strong that it counters the competing monocular depth cues, such as shading and shadows of the considerable stereo information signalling that the image is truly hollow (see Fig. 1).

It is significant that this, and very many other illusions, are experienced perceptually even though the observer knows conceptually that they are illusory. This does not show that knowledge has no part to play in vision; rather it shows that conceptual and perceptual knowledge are largely separate, with the visual system being almost 'stand-alone'. This is not altogether surprising, for perception must work extremely fast to be useful for survival, while conceptual decisions may take minutes or even years. Furthermore, perceptions are of particulars rather than the generalities of conceptions.

For visual illusions to reveal brain or mind processes they must be explained, and preferably placed in explanatory categories. Here it may be noted that for perception itself, sensory data must, at least implicitly, be classified for inductive generalizations to be possible. They must be classified explicitly for deductive inferences. Classification by the visual system is implicit, allowing Helmholtzian unconscious inferences; but for us to relate the phenomena to theory, we need explicit classes of phenomena to consider. There are two basically different kinds of illusory phenomena: those having a physical or physiological cause, and cognitive illusions due to misapplications of knowledge.

Visual illusions due to disturbance of light between objects and the retina are different from those due to disturbances of neural signals, but both might be called 'physical'. Extremely different from these are cognitive illusions due to misapplied knowledge or misapplied rules. The hollow face effect seems to be a clear example of the power of misplaced knowledge about a particular class of objects, namely, faces. Organizing rules, such as the Gestalt Laws[10] of 'closure', proximity', 'continuity' and the 'common fate' of movements of parts of an object (such as leaves on a tree blown by the wind) are very generally applied, although not always appropriately, to objects or situations. When object knowledge or the organizing rules are inappropriate, illusion can result even though there is no fault in the physiology. So these (cognitive) explanations are not 'physiological', although, of course, physiology is always involved in perception. We know a great deal about 'bottom-up' processing of visual signals (especially from physiological recording from the striate area of the brain)[11], which may introduce physiological signal errors; but this will hardly be considered here.

We may distinguish between: bottom-up signals, top-down specific object knowledge, and what we may call

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'side-ways' general rules. The knowledge and rules for perception may be compared with semantics and syntax of language. Perceptions are regarded as hypotheses of objects and situations (richer than available sensory data and indirectly related to the external world). Perceptions are also predictive, so that behaviour is appropriate to non-sensed characteristics of objects, and anticipates events, to reduce or abolish physiological reaction-time. These considerations may suggest something like the 'ins-and-outs of vision' of the functional scheme shown in Fig. 2.

This is a functional rather than an anatomical scheme, but it must be consistent with brain neuroanatomy. It has been confirmed that there is a greater richness of fibres downwards from the cortex, especially to the lateral geniculate nucleus (LGN), than upwards from the eyes[12–16]. In addition, in the primate brain modulation of cortical processing by attention can occur[17].

The separation of conceptual and perceptual knowledge is based on behavioural and phenomenal evidence, for example: perception must work within a fraction of a second to be useful but conceptual decisions may take minutes or even years. Furthermore, perceptions are specific but conceptions may be general and abstract. Indeed, we experience an illusion although we know it is an illusion, and even why it occurs. This separation is quite disturbing, as perception and understanding can disagree.

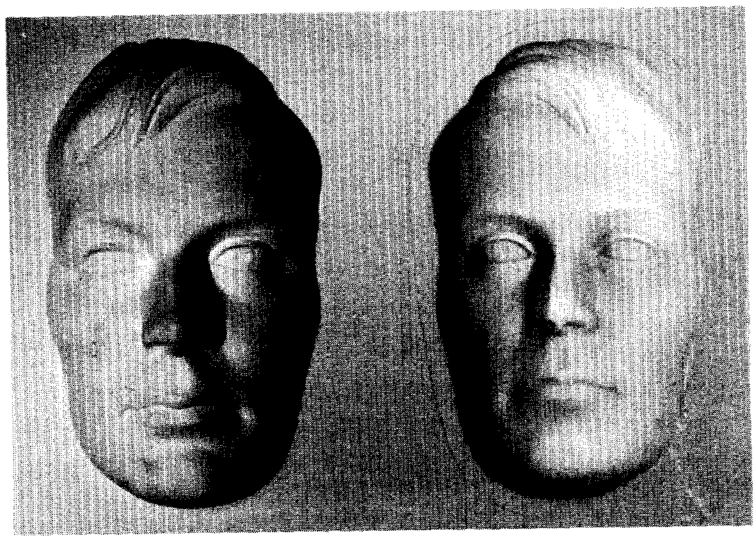


Fig. 1 The 'hollow face'. The left-hand face is normal, the right-hand face is hollow. Viewing the actual hollow mask with both eyes, it appears convex, until viewed from as close as a metre or so. Here 'top-down' knowledge of faces is pitted against 'bottom-up' information from the eyes.

Classes of illusions

I will attempt to classify the phenomena of illusions, in terms of appearances and causes (see Ref. 18 for a useful source of illusions and their histories). Visual illusions can be classified into four classes based on appearance, which can be named quite naturally from errors of language: ambiguities, distortions, paradoxes and fictions (see Fig. 3). It is possible that language grew from pre-human perceptual classifications of objects and actions[19]. This may explain why language developed suddenly in biological time.

The causes of many illusory phenomena have not yet been explained satisfactorily, but classification may suggest where to search for answers. We may suppose four principle causes, the first two lying broadly within physics; the last two are associated with knowledge, and so are cognitive. The first (physical) is the result of an optical disturbance intervening between the object and the retina; the second (physical) is due to disturbed physiological signals in the eyes or the brain; the third (cognitive) is the application of misleading knowledge of objects; the fourth (cognitive) is the application of misleading general rules. Applying the appearances (named from errors of language, see Fig. 3), we arrive at Table 1.

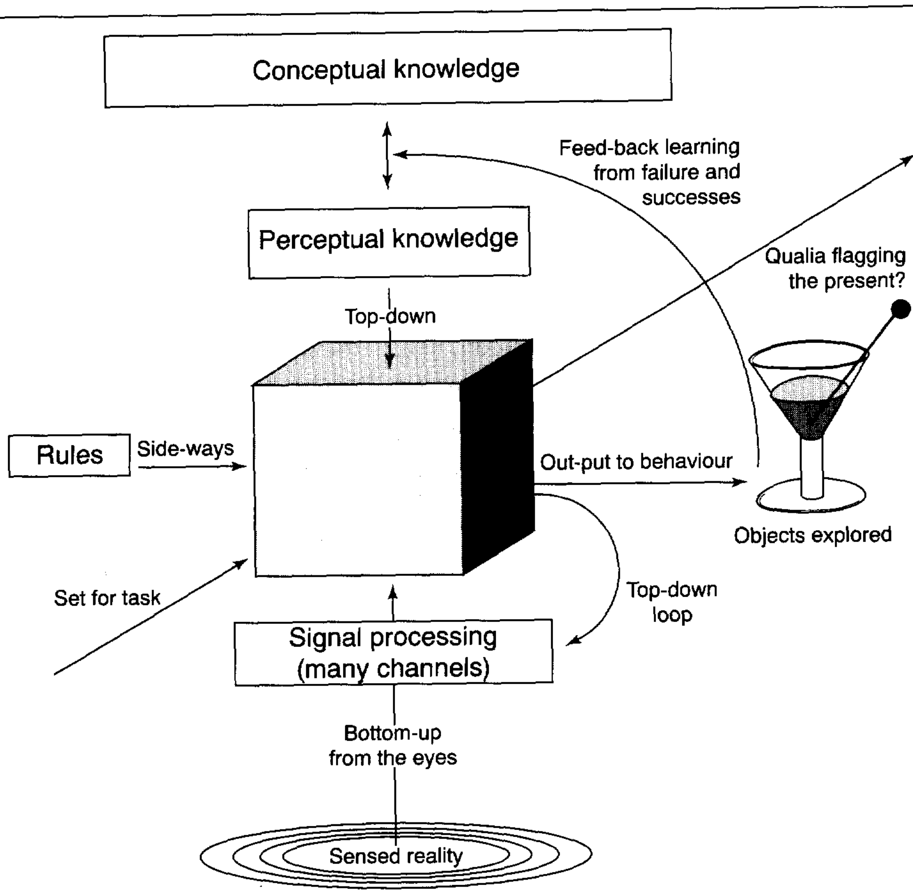


Fig. 2 Ins-and-outs of vision. The 'hypothesis generator' is fed 'bottom-up' by sensory data, and 'top-down' by stored knowledge. These are shown in two largely separate boxes: conceptual knowledge is mainly abstract and general; perceptual knowledge of objects is specific, and is used for interpreting or 'reading' sensory signals, making them useful real-time data for object perception. General rules (such as the Gestalt Laws of perceptual organization, and rules of perspective) are introduced as 'side-ways'. Learning from the results of actions by feed-back is very important, although some object knowledge and rules are innate, inherited from ancestral disasters. There may be some selection of knowledge and rules for the current task. The prevailing perceptual hypothesis (perception) may affect initial signal processing, 'downwards'. (The evidence for this is from 'flipping' ambiguous figures such as the Mach corner). It is speculated that qualia of consciousness may serve to flag the present, normally to avoid confusion with memory and imagination.

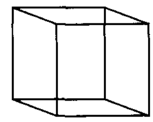
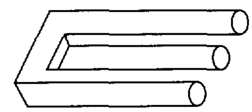
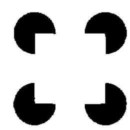
	Language errors	Visual illusions	
Ambiguities	*People like us*	Necker cube	
Distortions	*He's miles taller*	Ponzo figure	
Paradoxes	*Dark haired blonde*	Tri-bar impossible figure	
Fictions	*They live in a mirror*	Kanizsa square	

Fig. 3 Phenomena of illusions and errors of language. Visual illusions can be classified into classes: ambiguities, distortions, paradoxes and fictions, which can be derived from errors of language

Status of the classes

These classes are assigned tentatively, on the basis that perception is the active generation of hypotheses (perceptions being best-bet predictive hypotheses of the object world) that are indirectly related to objects. The eyes' signals may be erroneous, and they may be misinterpreted, giving the most general classes: 'physical' and 'cognitive' (roughly, 'hardware' and 'software').

Illusory phenomena are assigned to particular categories according to various criteria. Explicit 'litmus tests' are required to test the classification scheme. There are many examples of litmus tests, for example, the loss of distortion with colour but no brightness contrast indicates retinal signal errors, for example the 'cafe-wall' distortion[20]. Loss of distortions with seen depth indicates a cognitive explanation in terms of size scaling, as for the Ponzo, Muller–Lyer and Poggendorff distortions[22]. Changes of object as seen with changes of orientation suggest the importance of 'object knowledge', as for the inversions of Scott Kim[25] and the hollow face[9]. There are many other litmus tests but unfortunately they are rarely, if ever, made explicit in the literature of perception and illusion. This is an important area for future research.

Qualia

The most mysterious features of perception are the qualia of consciousness: experiences of red, green, pain and so on. Perhaps the most striking yet least considered visual experiment is the following: look carefully at an object, or scene, for several seconds; then close the eyes and 'see' the immediate memory. Surely, the vivid qualia of vision have disappeared. Reversing the situation, compare the memory with the visual experience when the eyes are opened. There is a shocking difference. It seems that normally qualia only occur in real-time perception.

We neither know how qualia are produced by brain processes nor what, if anything, they do. I would like to speculate that qualia serve to flag the present moment and normally prevent confusion with the remembered past, the anticipated future, or more generally, with imagination. The present moment must be clearly identified for behaviour to be appropriate to the present situation, and this is essential for survival. As top-down knowledge derived from the past is perhaps the major contributor to human perception, real-time sensory inputs must not be ignored when signalling the present.

On the Helmholtzian view of perception taken here, vision is given mainly by inferences from limited sensed data and from (not always appropriate) object knowledge and organizing rules. As pointed out by David Marr[26], the eyes receive only an observer-centred view of the world; but for interactive behaviour with objects, perception must take into account currently invisible aspects, and non-sensed properties such as hardness and weight. Clearly these are inferred; but this is an extension of the immense role of inference in all object perception. It seems that the qualia of consciousness are limited mainly to what is sensed locally in real-time; this being but part of perception, which is far more general and largely non-conscious.

Visual time-confusion can occur in rare individuals having exceptionally vivid memory and imagination. A striking case is 'Mr M', described by the Russian neuropsychologist

Table 1. Illusions classified

	(Physical)		(Cognitive)	
Classes	**Optics**	**Signals**	**Rules**	**Objects**
Ambiguity	Cataract, mist, fog, (any loss of image quality)	Retinal rivalry, aberrant stimulation (e.g. pressure on eye)	Figure-ground (usually set by Gestalt Laws of closure, etc.)	Necker cube, face–vase, Schroder staircase, Mach corner, hollow face
Distortion	Astigmatism, spoon-in-water, lateral inhibition effects (such as brightness and colour contrast)	Fraser spiral, café wall, Pulfrich pendulum (stereo-depth)	Ponzo, Müller–Lyer, Poggendorff, Hering, vertical–horizontal (?), moon-illusion (?) (perception-depth)	Size–weight (small object feeling heavier than larger object of same weight)
Paradox	Looking-glass (one's image in wrong place, self in two places at once)	Rotating spiral after-effect (expanding or contracting, yet staying same size)	Tri-bar, Penrose triangle, Escher's 'Belvedere', 'Waterfall', etc.	Magritte mirror (back of head seen reflected, instead of face)
Fiction	Rainbows, moiré patterns	After-images, Mach's bands, Benham's disk (colour)	Kanizsa triangle, Schumann (illusory contours and surfaces)	Faces-in-the-fire, man-in-the-moon, galleons in clouds, ink blots

The Necker cube is the best known example of visual ambiguity (see Ref. 9). The 'hollow face' illustrates resolving of ambiguity according to probabilities. The 'cafe wall' Illusion (long distorted wedges, seen in a chess board-like pattern, with alternate rows displaced by half a cycle) depends on luminance but not on colour contrast[20]. The rotating spiral gives expansion (or contraction) without change of size. The Ponzo, the Muller–Lyer and other perspective distortions are attributed to misplaced 'constancy scaling' (Refs 21, 22). The 'tri-bar, impossible triangle' (Ref. 23) and many more impossible figures can ppear to be 'impossible' objects when viewed from a critical position. The 'size-weight' illusion is when smaller objects feel heavier than larger objects of the same scale weight. The Magritte mirror is a painting of the back of a man's head with a mirror impossibly reflecting the back of his head instead of his face; our knowledge of mirrors, and the assumption that it is a mirror in the picture, makes this appear impossible. (Paradoxes and puzzles of looking-glass images are discussed in Ref. 24.)

Alexandre Luria, whose memory and imagination were so vivid that he did have these problems of confusing the memory, for example of traffic lights, with actually seeing them[27]. A more common exception to the usual lack of vivid qualia in memory is emotional memories, such as memories of guilt producing blushing. Perhaps this is qualia-rich because there are afferent inputs from the body evoked by memories of embarrassment[28]. Further exceptions are dreams and the hallucinations produced by schizophrenia or hallucinogenic drugs – qualia that appear when the system is not functioning normally and is isolated from sensory inputs or is stimulated abnormally by drugs.

The speculation is that normally for higher (cognitive) species, and especially humans, real-time sensory signals evoke vivid qualia of consciousness to avoid confusion with memory and imagination (which use much the same brain regions)[29] as an aid to survival into the future, by flagging the dangerous present.

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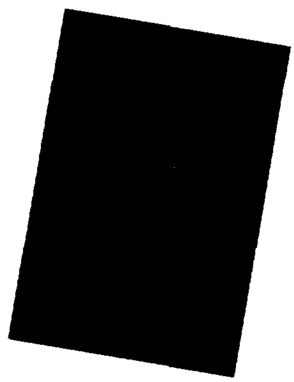
The Mind–Brain Continuum



edited by Rodolfo Llinas and Patricia S. Churchland, MIT Press, 1996. £42.50 (xi + 315 pages) ISBN 0 262 12198 0

The academic mind is addicted to problems and averse to solutions, since a problem is a nice little earner but a solution requires the unfortunate solver to find a new justification for the continuation of funding. The mind–body problem has been, and continues to be, one of the nicest little earners of all time. We learn in the introduction that the title of the present volume refers not to the idea that the mind and brain are parts of a continuum, like the colours of the rainbow perhaps (which would be an odd notion) but rather to the denial of: 'the traditional Cartesian posit of a radical discontinuity between the mental and the neural' (p. ix). In its place the editors suggest cautiously that: 'Mental activity, it appears, is brain activity' – caution being a natural side-effect of an aversion to solutions. So the continuum in the title is, according to this view, a continuum between two things that are actually one and the same thing. Again, an odd kind of continuum, and hardly an improvement on the more familiar formulation of this position as one of mind–brain identity.

However that may be, the contributors happily steer away from the deep waters of the introduction and there follows a haphazard mix of reviews in various areas of cognitive neuroscience, none of the contributors making any reference whatsoever to the supposed theme put forward by the editors. An elegant and impressive chapter by J.A. Simmons on images in bat sonar is, unfortunately, not likely to be comprehensible to any philosopher who wants to find out how it feels to be a bat. The most exciting chapter is by Logothetis and Sheinberg and it deals with the visual recognition of objects in rotated views. They conclude, from a wide survey of psychophysical and electrophysiological findings, that object constancy depends on a memory-based, viewer-centred recognition system rather than on an object-centred representation. The book ends with a chapter by Churchland that finally does address the issues raised in the introduction. The mind–brain identity position is defended in a vivid and informal style: 'volcanoes, atoms and ferns are just out of luck as far as consciousness is concerned' (p. 290). On page 295 the misprint celebrates its ability to outwit the spell-check and the grammar-check by castigating Dennett for his belief that: 'chimpanzees and oranges are not conscious'. Now that the unconsciousness of oranges has been publicly brought into question the founding of People for the Ethical Treatment of Fruit cannot long be delayed, to be followed by liberation movements for ferns and volcanoes.

Clearly then, any reader who goes to this volume in search of a rounded presentation of the mind–brain identity position, including objections to it, will be disappointed. The idea that mental activity is brain activity has retarded research in neuroscience. We have gone into the brain expecting to find such things as memories and percepts waiting there to be discovered, and systems for attention, action, and so on – all corresponding to traditional mental events or faculties. The better we understand any of the brain processes we study, however, the clearer it becomes that they do not correspond in any sense to mental activities in folk psychology. According to Duncan[1], for example, the concept of 'attention' for a neuroscientist is, at best, an intuitive label for a set of questions whose answers in the end are given by reference to a general account of cortical competition, an account that goes far beyond the topic of attention. The search for an attention system or an attentional mechanism in the brain has hindered, not helped the finding of these answers. Similarly, the search for memory systems in the brain, and the idea that cortical plasticity will instantiate the associationism of folk psychology, have hindered progress[2]. This hardly seems surprising if one considers that the claim to remember an event is not a description of one's brain, but rather a move in a rule-governed social game carrying, for example, the implied promise that one can supply further details about the event if requested. So I am sceptical about the idea, presented in Churchland's chapter, that neuroscience is simply an improved version of folk psychology and that folk psychology is nothing more than neuroscience-in-waiting. Rather, the two are parallel activities with different aims, a situation that one could tendentiously describe as: 'the posit of a radical discontinuity between the mental and the neural' but more properly is described as common sense. I suppose most practising neuroscientists would agree with me, and would not consider the relation between mind and brain as problematic, but in consideration of their colleagues' addictions and aversions they would forbear to say such a thing.

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