Recent developments in vision science and their relationship to semiotics as seen through design practice

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1 Introduction

At its most fundamental level, semiotics helps us to understand how we assemble in our minds eye, a picture of what we imagine to be 'the real world'. *'Studying semiotics can assist us to become more aware of reality as a construction and of the roles played by ourselves and others in constructing it'* (Chandler, 2006). In trying to understand that reality, semiotics draws on many fields, including principles of visual perception. Many respected authors have provided insights into the semiotics of perception from a combination of psychological, aesthetic or cultural viewpoints. However, some of that analysis presupposes that we are all physically seeing the same thing. This paper sets out facts about some aspects of what we really see – effectively a precursor to the interpretation of signs, codes and meanings arising from sight. Ultimately, the paper makes this analysis for the purpose of understanding how the meaning within design work can be better controlled, and we will refer to this as design semiotics.

A great deal is already known about how the human brain tries to make sense of signals it receives from the eye, and it is increasingly clear that what we see as 'reality' is not necessarily an accurate picture of the physical world, but rather an interpretation based on our own internal codes and experiences. 'We think that it is the world itself we see in our "mind's eye", rather than a coded picture of it' (Nicholls, 1981).

Zeki offers the view that 'the brain is no mere chronicler of the external world but is an active participant in generating visual images according to its own rules and programmes' (Zeki, 1999). This clearly has implications in design semiotics where the way images are 'read', depends very much on the way the visual system is 'wired' in the brain. Understandings about that 'visual circuitry' can help designers to use form and composition to better control interest and meaning.

An example of this can be seen in the Playstation advert (fig.1) where the viewer is presented with a visual puzzle. Close up, the symbols clearly signify individual
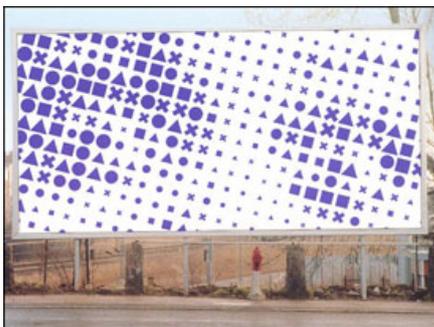

Fig. 1 Playstation advert

playstation controls. However, from further away, our brain is programmed to see the symbols as a collective grouping, forming contours of shadow and light, so that we see an excited facial expression instead. The image remains the same, but the way we construct its reality has changed with distance. In this example, the brain is 'wired' in such a way that we feel the need to distinguish a dominant shape. The gestalt psychologists Koffka, Wertheimer, Kohler, et al thought of this as figure and background, and distinguishing this appears to be a universal property of our visual system.

fig. 2 Rubin's vase

The added input of design in this example means that the ambiguous figure ground relationship here is operating at a more subtle level than the famous example of 'Rubin's Vase'. In that example, the two interpretations (vase or two faces) were unrelated. Here however, the designers have used knowledge of perceptual organisation, to make sure that the two possible meanings of the image, subliminally connect the ideas of 'playstation' and 'excitement' in our minds – an obvious selling point.

The application of scientific understanding to image design is nothing new. Another example can be found in De Carlo and Santella's research on perceptual effort reduction. This is based on an understanding of how the variable resolution of the

Fig. 3a: photo before transform

Fig. 3b: photo after transform

eye influences how we take in images, and how central and peripheral vision play important, but separate roles in determining detail, spatial organisation, recognition, and differentiation of subject and background. De Carlo and Santella combined perceptual knowledge and eye tracking technology to demonstrate that images can be simplified whilst increasing the effectiveness of their visual communication (Santella, A. DeCarlo, D. 2002).

In the above example (fig 3a and fig 3b), the reduction of the photographic image to a painterly representation of it, is based on the idea that removing unnecessary detail will help the image to communicate its essential meaning more quickly and effectively. This could have been done by reducing the whole image just to its basic contours. However Santella and De Carlo found that the communication was much improved when they used eye tracking technology to identify levels of interest in the image and to adjust image detail accordingly. Thus areas of least interest are reduced to 'suggestive contours' that provide visual cues for the brain to extrapolate image details, based on the mere suggestion of them. At the same time, the unnecessary detail is eliminated, which means that the effort needed to understand the image as a whole is reduced, and the communication enhanced.

It could be argued that a non-technological forerunner to this approach can be found in the work of prolific graphic designer Abram Games more than half a century earlier. His famous guiding principle 'Maximum meaning, minimum means' is not that dissimilar to what Santella and De Carlo are trying to achieve.
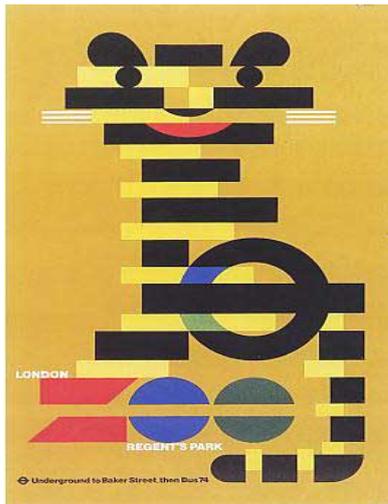
Fig. 4: Abram Games poster

For example, his poster advertising London Zoo (fig. 4) uses very simple elements of form (basic colours and shapes), to convey subject matter and meaning (the idea of visiting London Zoo by underground). However, the smiling, colourful and playful arrangement of the shapes also conveys another powerful message at a more subliminal level, to do with enjoyment and fun which is actually essential to that communication.

2. Towards a Visual Grammar

Visual awareness amongst designers is often based on experience and intuition. However, the concept of a 'visual grammar' based on the 'rules and programmes' of the human visual system, has the appeal of being more objective. The concept of a mental framework that unconsciously guides how an image is 'read' has been the subject of considerable interest and debate. Kress G. and Van Leuwen defined it in the context of compositional structures as 'the way people, places and things are placed into a meaningful whole'. Zeki saw it as the visual brain's quest for essential detail and knowledge of the world and the 'rules and programmes' it applies. Ramachandran proposed a neurobiological hypothesis of 'visual grammar', seeing responses to imagery as 'hard wired' into the brain's circuitry. However, although the term is widely accepted, it is often used loosely so that many designers would be hard pressed to explain what is meant by it. In the context of this paper, it is used in the sense implied by Zeki, that the visual brain seeks out 'essential' detail and discards much else. The mental mechanisms involved in this may be thought of as visual grammar which may thus be seen as a precursor to design semiotics, in that it can be used proactively in design to influence the interpretation of subject and meaning.

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3 Visual science understanding and its applicability to design

Vision science research is by its nature a slow and methodical process that, 'provides a neat, well defined but rather narrow beam of data in the light of which one attempts to explain much broader aspect of human behavior' ([Deregowski](#)). How does this relate to the processes of design? Starting with Zeki's view of visual grammar, the authors set out to compare the ways designers use design 'principles', with the scientific levels of visual understanding behind them. Fig. 5 illustrates how the use of visual grammar by designers can vary. Of course, understanding of vision is only one of a number of factors that would normally be brought to bear on design problems.

fig. 5: The ways designers use visual grammar

by chance   trial and error   intuition   experience   knowledge
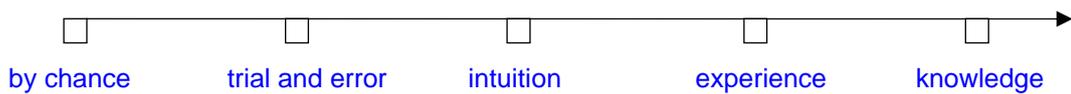
Similarly, there are different levels of scientific understanding of the various aspects of how visual grammar works (fig 6). In some cases this can be quite low or even non existent whilst in others it can be at a much higher level. By way of example, it has long been thought that the 'rule of thirds' (which is a compositional design principle), can improve visual aesthetics. However, this cannot readily be explained scientifically, whereas the rules of perspective are clear and can be rigorously applied.
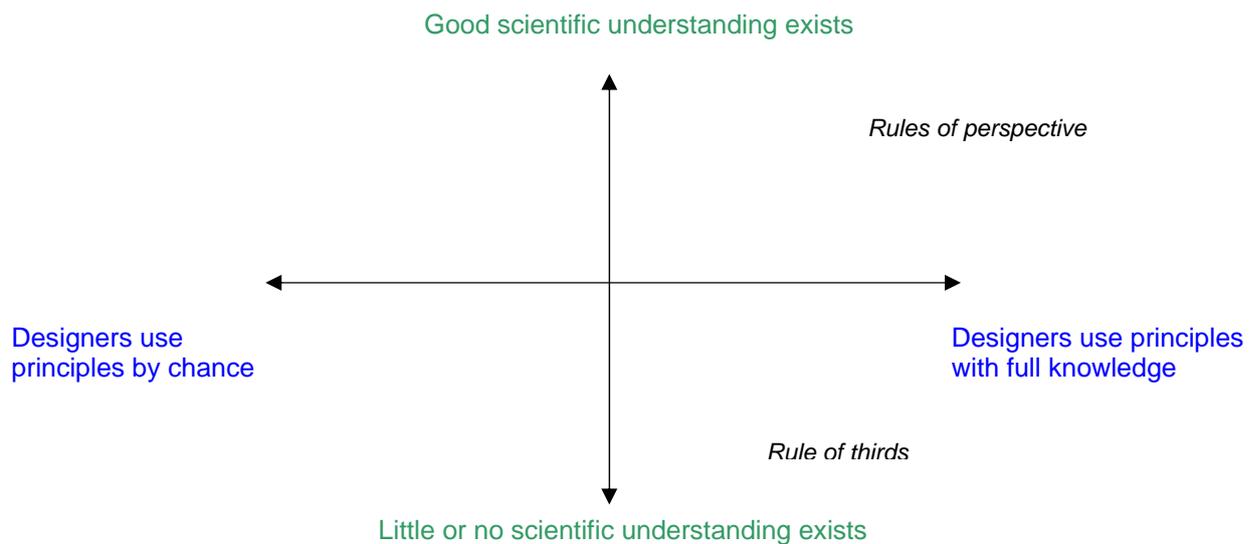.

fig. 6: Scientific understanding of design approaches

none   hypothesis   outline   partial   full

When these two approaches are put together (fig. 7) the applicability and relevance of visual science to design practice becomes clearer. There are many design principles that have a scientific basis and these might in theory,

be plotted on this chart to show the current relationship between knowledge and use - two such principles, the 'rule of thirds' and the 'rules of perspective are shown plotted on fig. 7, by way of example.

fig. 7: positioning design practices with scientific understanding

Good scientific understanding exists

Rules of perspective

Designers use
principles by chance

Designers use principles
with full knowledge

Rule of thirds

Little or no scientific understanding exists

The difficulty of accurately locating these and other design principles such as contrast, perceptual balance, alignment, grouping, perspective, etc is immediately apparent. However, this is not the purpose of the chart which is to show theoretically the potential of visual science to design semiotics. The quadrant diagram has its limitations, but the process provides us with a very wide range of topics covering vision science and design which we believe are related in many ways. In order to better understand how the two fields link together, we need to organise those topics into a taxonomy which classifies where each area of knowledge is operating.

4   A proposed taxonomy to link the stages of perception and cognition with design practice and visual science knowledge

4.1 About the framework

A framework is proposed in table 1, to link the various stages of perception and cognition, to design practice and vision science knowledge, making

	Stages of perception	Aspects of perception and cognition relevant to design	Areas of visual science research relevant to design *	
1	Input to the eye	Taking in an image is initially concerned with spatial organisation, recognition, differentiation of subject and background, and in determining what is to be looked at in detail.	• figure ground • alignment; • perceptual effort; • eye tracking; • less is more; • connection;	• spatial imprecision • visualising acuity • acuity effects • metameric images
2	Discerning the building blocks of the image	The essential detail of an image is emphasised by the elements of form. These are the building blocks of vision that register strongly in early image processing and can be used powerfully in composition.	• Colour; • line; • value;	• texture; • shape: • Colour and luminance analysis tools
3	Seeing meaningful relationships between components	Structure and organisation in an image is sought out by the visual system in order to make sense and add meaning. This can be used purposefully in design.	• grouping, • symmetry, • continuation, • orientation sensitivity, connectedness • figure ground	• Proximity • Scale • common fate • Closure • Law of pragnanz
4	Interpreting visual clues	The brain looks for visual clues to help facilitate recognition and identify properties. Many of the rules and codes for this (eg. depth perception) are effectively are 'hard wired' into the visual system and can be manipulated to enhance effects.	• perspective, • occlusion • relative motion • colour values • steriopsis, • top down lighting bias	• shading, • haze, • texture • reflectivity • horizon • chromosteriopsis
5	Locating the important detail	The eye scans for detail and the visual system can be influenced as to where the centre of gaze is driven. For example, organisation in an image can be designed to direct the viewer's attention to the relevant content and to influence perception of it.	• Alignment, • Connectedness • Grouping • Use of space • Visibility	• Colour • Hierarchy • Emphasis • Scale • Perspective • Eye tracking studies
6	Extracting meaning from the visual data	Form and organisation determine how the content or message in an image is communicated to the viewer.	• Orientation sensitivity • Law of pragnanz • Perceptual effort • Emphasis	• Visibility • Icons • Colour • Others
7	Responding to the Expressive content	Whilst Image appeal is strongly linked to subject and presentational style, aesthetic response is also influenced by the use of form and composition.	• Rule of thirds • Use of ratios • Fibonacci series • Symmetry, • Alignment, • Aesthetic illusion • Balance	• Colour • Signal to noise ratios • Top down lighting bias • Visual problem solving • Golden ratio toolset • Colour balance

Table 1: * Note that the areas of vision science understanding listed in column 3 are all linked to multimedia examples, demos or tools
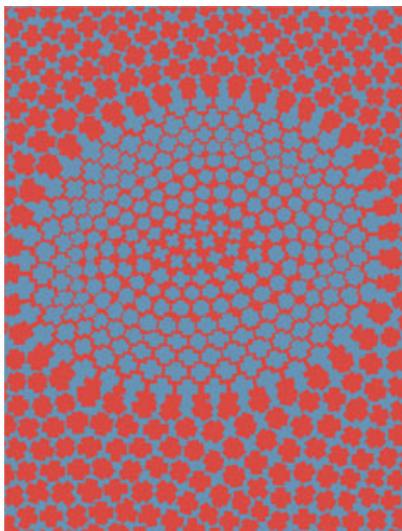
clearer the areas of research that connect them. It is important to note that these areas of research include knowledge that is well established, but also new knowledge and areas of technology that have potential for exploitation in design.

The table is necessarily simplified in order to present a coherent picture representing an otherwise huge amount of information and data. For each stage of perception, we list the main areas of design and vision science that the stage relates to. The detail is provided in a range of interactive multimedia examples, demonstrations and toolsets hyperlinked to the headings in the right hand column. The movies explain, show or analyse different aspects of visual grammar in action.

In practice, the multimedia movies (each of which contains considerable visual information and reference material), would be accessed by clicking directly on a heading in the table or from an accompanying DVD. Two examples have been provided on the web to demonstrate how the table works. If you are reading an electronic version of this text, then click on 'Depth cues' or 'Orientation sensitivity' to see some example movies.

5 A case study approach

One of the purposes of the taxonomy was to show ways of linking vision based understanding more clearly with objective design. We felt it was important to take this further with some more detailed case studies representing each of the vision stages, showing how 'visual grammar' has actually been used in practice, and how the stream of new findings about vision (combined with new technologies such as eye tracking), could guide objective creativity. The approach taken has resulted in a series of case studies that explain how both

Fig. 8: Anuselki's Plus Reverse

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established and new knowledge about vision relate to design semiotics.

The case studies are too detailed and numerous to describe here but fig. 8 and fig. 9 highlight two interesting examples of linkage between science and design.

'Plus reverse' is a visually unstable design where the image appears jittery and floats around. The explanation for this by Livingston lies in its use of colour values that are equiluminant. This causes specific problems in the areas of the visual system that interpret spatial location, and that's what gives rise to the effect. The authors have taken this equiluminance aspect of vision science knowledge much further into the creative domain through a range of analysis and design tools.

fig. 9: Swan Vestas advert

Our case studies made full use of technology such as eye-trackers to see how past designs worked visually. For example, this simple advert for Swan Vestas matches is known to have been very effective in its time. Designers understand the power of a simple colour to attract the viewer's attention, especially when it's surrounded by a grayscale image. Vision scientists would probably explain it as an aspect of orientation sensitivity. However, the eye tracker image of the advert (fig 9) shows very visually how the image attracts the viewers gaze in practice, and this in itself can lead to new insights.

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6   Making more complex concepts accessible to designers

Some new vision science findings can be readily understood in terms of their connection to design semiotics, and for these we have created multimedia examples and demonstrations of principles to illustrate the point. Others

however, require some analysis to show the connections more clearly (for example, whether geometric ratios have been used in design, or how visual acuity works). In these more complex cases, our approach has been to design digital tools that act as an interface and make the science accessible to designers. An example described here is concerned with visual acuity, where the resolution of what we see coarsens away from the centre of gaze and towards the periphery of vision.

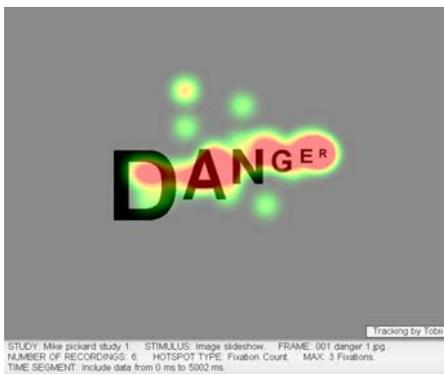For visual acuity, we have designed a number of tools. One of these allows a designer to dynamically view the effect of acuity on what is seen and determine the loss of detail away from the centre of gaze (or points of interest). Another tool can be used in creative mode which is based on research by Stewart Anstis (picturing peripheral acuity). It allows a user to create text or simple designs that are metameric, meaning that when the gaze is focussed on a certain position, all objects in the image are equally legible. The tool is

fig.10: Metameric text (via eye-tracking)

programmed to compensate for loss of retinal resolution by increasing size proportionately away from the centre of gaze. This multimedia tool has been designed in accordance with accurate data on retinal resolution provided from the Anstis research. Fig. 10 shows it in use. In this example, when the eye is fixated on the letter 'r' of the word 'danger', then within limits, all letters are equally legible. Equi-legible text and imagery may have some special uses in design where eye movement needs to be minimised whilst information intake is maximised.

7 Some conclusions

Artists and designers have always had an intuitive way of seeing things which they've used to good effect in communicating ideas through images. Vision scientists have understood this, and so historically have used examples of

artwork and design for study in order to better understand the processes of vision.

However, since much more is now known about perception and cognition the time has now arrived when it is possible to regard such knowledge more positively and see it as a potential source of creativity and a means of achieving design objectives more easily. In this paper, we have described an approach to this that more closely links how people seen and make sense images with areas of scientific understanding and design practice (and have shown some of the advantages of multimedia in setting about this). We have also provided examples of visual grammar in action and of new developments in scientific developments and understandings relevant to design.

We have highlighted some of the difficulties in linking more complex aspects of vision understanding to practice and ways round this through the creation of software to act as an interface. The example of equiluminant colour effects was briefly described where software could help designers create suitable colour palettes for use in their own work. In fact the authors have developed tools for this as with other areas, as part of this research.

Our studies have indicated that as vision science understanding increases it's potential for use in objective design will also increase. From a designer's perspective, the intuitive approach may no longer be suffice and so it is therefore important that a number of things happen.

Firstly we need to build on the framework and related multimedia for seeing where and how the science connects to design semiotics, so that design professionals can position their own work in relation to it.

Secondly, we need to continue developing software tools to enable their use and to share ideas so that an increasing number of applications can be found for the new knowledge.

Thirdly, we need to begin introducing into design schools, formal tuition about the areas where vision science and design overlap. Vision science should not be seen as something separate to creative endeavour, but rather something that can potentially enhance it. In future, communicating ideas more effectively through images by having a better understanding of the science that makes them work, should mean more effective design.

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